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2024.gada 27.-28.jūnijs

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I

ENVIRONMENT AND RESOURCES

SATURS
CONTENTS

Environment and Resources

The Effect of Digestate and Wood Ash Mixtures on the Productivity and Yield Quality of Maize

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Abstract. **Maize (Zea mays L.) is one of the world's most productive and prevailing crops. It is widely grown as human food and animal feed, as biofuel, and as a raw material for industry. Digestate and wood ash are the byproducts of cogeneration plants. Digestate is rich in nutrients, can provide plants with many nutrients required by the plant during its growing season, as well as improves the soil structure. The aim of the study was to determine the effect of the rates of digestate and wood ash mixture fertilizer on maize productivity and crop quality. In 2020, 2021 and 2022, in field trials with maize, the variety 'Hulk', FAO250, was used; the soil – sod-calcareous, medium-heavy sandy loam. Different variants of the mixture of cattle manure digestate and wood ash were used as a fertilizer on corn plantations. The ratios of digestate and wood ash was 1:0, 1:1, 2:1, and 3:1; fertilizer rates were 15 and 30 t ha^{-1}. In the trial, different types of fertilizers demonstrated different effects on the yield and quality of maize. The use of the new fertilizers produced on average 36.93–38.33 t ha^{-1} of high-quality maize green mass in three years without using mineral fertilizers.**

Keywords: digestate, fertilizer, mixtures maize, wood ash.

I. INTRODUCTION

Agricultural production must be carried out in accordance with environmental protection requirements. It is important to maintain the safe use of fertilizers, especially nitrogen fertilizers, in the agricultural environment. About 180 million tons of anaerobic digestion digestate is produced in the European Union annually, most of which is used as organic fertilizer [1]. Anaerobic digestion residues are products from various sources of organic raw materials, which include sewage treatment, plant sludge, agri-food industry waste (a part of household solid waste, including fruit and vegetable by-products, canteen waste, kitchen waste), green waste (agricultural and horticultural waste), animal waste (pig, cattle, etc., manure), and food waste (animal fat, used cooking oil, degreasing waste from restaurant tanks) [2].

The nutrients present in the digestate are in a form that is easily utilised by plants. Also, digestate is a plant fertilizer competitive to mineral fertilizers. The organic substances present in digestate have a positive effect on the physical and chemical properties of soil and on the soil fertility in general [3].

Digestate performs several functions and plays a beneficial role in both improving the soil properties and promoting the plant growth. First of all, digestate contains nutrients necessary for plant growth and serves as a fertilizer that improves plant productivity. Secondly, digestate significantly affects the overall soil fertility and other important soil parameters. Digestate plays an important role in improving soil efficiency by ensuring the cycle of nutrients in the soil, carbon transformation, and maintenance of soil structure [4]. Field application of digestate could have less short-term results due to the slow mineralization or microbial activity [5].

In order to use digestate as an organic fertilizer, it is usually divided into a solid (dry) and a liquid fraction. They differ in dry matter content and chemical composition, which in turn can affect biomass production differently [6].

In agricultural practice, digestate is often used as a fertilizer for crops grown for biomass production, especially for the production of biogas, as digestate is rich in nutrients. Maize is one of the most important biomass crops in Europe [7]. However, practice shows that maize cultivation is very sensitive to nitrogen losses (through leaching and gaseous emissions) and soil erosion [8].

In Germany, researches were carried out on the use of digestate's solid and liquid fractions in maize fertilization. Different digestate application variants were compared with the mineral fertilizer application variant. In all variants, the applied ratio and amount of fertilizer was calculated so that the annual fertilizer rate makes N 150 kg ha^{-1}. The researches showed that the use of mineral fertilizer gave the highest maize dry matter yields, but the use of solid digestate fraction in fertilizer produced the

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lowest dry matter yields. The use of mineral fertilizer proved to be most efficient when maize was grown in unfavourable years, i.e., when spring was cold or summer was dry [9].

Other trials in Germany investigated the effect of the application of mineral fertilizers and digestate on the yield of maize at different nitrogen rates (from N0 to N180). Certainly, the lowest average maize dry matter yield (13.4 t ha^{-1}) was obtained in the N0 variant. In the digestate fertilization variant, significantly higher corn dry matter yields (19.3 t ha^{-1}) were obtained when the nitrogen rate of 96 kg ha^{-1} was used. Significantly higher nitrogen rates (150 kg ha-1) had to be applied to obtain the same amount (19.1 t ha^{-1}) of maize dry matter yield using mineral fertilizers [10].

According to Gatenby [11], the analysed crude protein contained nutrients supporting ruminant production, i.e., 8–11%, which is recommended for the growing of ruminants. Accordingly, this amount of protein is sufficient to meet the protein needs of growing ruminants, generating significant levels of ammonia in the rumen to guarantee an effective digestion process [12]. The analysed crude protein content in maize exceeded its critical limit (7%), below which the forage intake by ruminants and rumen microbial activity would be antagonistically influenced [13].

II. Materials and methods

Field trials (2021–2022) with maize were established in sod-calcareous, medium-heavy sandy loam soil: pH KCl 6.6-6.8; phosphorus (P_2O_5) content – 50–54 mg kg-1; potassium (K_2O) content – 182–206 mg kg-1. Maize trials were carried out using fertilizer mixtures consisting of cattle manure digestate (from JSC “Ziedi JP”) and of wood ash (from LLC “Gren Jelgava”) at different digestate: wood ash ratios – 1:0, 1:1, 2:1, and 3:1. The rates of the innovative mixed fertilizer with cattle manure digestate for maize were 15 and 30 t ha-1. The nutrient content of the digestate and wood ash mixtures are given in Table 1.

TABLE 1 NUTRIENT CONTENT OF THE DIGESTATE AND WOOD ASH MIXTURES

Nutrients	Nutrient content in dry matter, %			
	D+P 1:0	*D+P 1:1*	*D+P 2:1*	*D+P 3:1*
Nitrogen in a natural sample (N)	0.29	0.27	0.30	0.51
Ammonium nitrogen (N/NH4), g kg^{-1}	1.20	0.43	0.40	0.76
Phosphorus (P)	0.74	0.90	0.89	0.83
Potassium (K)	1.70	2.90	2.92	2.73
Calcium (Ca)	2.41	13.44	13.55	10.48
pH	9.27	12.19	11.84	11.22

D – cattle manure digestate; P – wood ash

For field trials, maize variety 'Hulk', FAO 250, was sown in 2020 and 2021, and the variety 'Vitaly', FAO 220, was sown in 2022; sowing rate – 80 000 germinating seeds per ha; sowing depth – 5 cm; row width – 70 cm; sowing date – May 10 and 5, respectively; precrop – winter wheat; direct seeding technology. Study areas for each variant and replication were arranged before fertilizer application. Research experimental plots was 100×12 m or 0.12 ha in each replication. All research variants were set up in triplicate. For weed control, the herbicides Maister Power and Estets were applied; rate – 1.0 L ha^{-1} and 0.4 L ha^{-1}, respectively. Herbicides were sprayed only once per season, when maize had four leaves.

Qualitative indicators were determined at the Biotechnology Scientific Laboratory (BSL) of the Latvia University of Life Sciences and Technologies (LBTU): the content of dry matter (DM), fat and ash were determined by gravimetric analysis, the crude protein (CP) content of DM yield was determined by modified Kjeldahl; mineral elements P, K and Ca were analysed by atomic adsorption spectrometry.

Data processing was performed using a three-way analysis of variance (ANOVA) "Microsoft Excel" computer program.

III. Results and discusion

Maize (*Zea mays* L.) is one of the most important crops for both human food and livestock feed. The primary goal of its cultivation is to maximize the productivity and yield while maintaining crop quality.

On average, 36.93–38.33 t ha^{-1} of maize green mass were obtained using the new fertilizer in three trial years (Table 2). The increase in the rate of fertilizer had a negative effect on maize yield. Significantly ($p<0.05$) higher maize yields in 2022 were obtained using lower (15 t ha^{-1}) fertilizer rates. Also, in 2020 and 2021, it was observed that maize yield tended to increase at lower fertilizer rates; however, the yield difference was not significant, but the yield difference was not significant (Table 2). The decrease in maize yields at a doubled fertilizer rate can be partially explained by the high pH (>11) of the new fertilizer (Table 1), which could have increased the soil acidity and affected the plant growth.

The trial demonstrated that the effects of the different digestate-to-ash ratios in fertilizer mixture on maize yield had no significant differences in 2020 and 2021.Only in 2022, significantly higher maize yields were obtained in fertilizer variants with prevailing amounts of digestate (digestate: ash – 1:0; 2:1, and 3:1), compared to the variant with equal amounts of digestate and ash (1:1).

Increasing the fertilizer rate from 15 t ha^{-1} to 30 t ha^{-1} significantly ($p<0.05$) reduced the average three-year yield of maize. No significant effect of the digestate-to-ash ratio on the average maize yield was found in the three trial years.

When applying lower rates of fertilizer (15 t ha^{-1}), a tendency was observed to obtain higher maize yields in variants with greater amounts of digestate (digestate:ash – 1:0, 2:1, and 3:1), compared to the variant with equal amounts of digestate and ash (1:1) in the fertilizer.

The applied rate of fertilizer, as well as the ratio of digestate to ash in the fertilizer did not have a significantly different effect on the quality indicators of maize dry matter in 2020. High-quality maize yield was obtained in all research variants. The rate of fertilizer used in 2021, as well as the ratio of digestate and ash in fertilizer did not have significantly different effects on the quality indicators of maize forage. Similar results were obtained also in 2022. The rate of applied fertilizer, as well as the digestate-to-ash ratio in the fertilizer had an insignificant effect on maize dry matter quality indicators maize. The applied fertilizer rate did not have a significant effect on the quality indicators of maize forage in 2022. The ratio of digestate and ash in fertilizer had a significant ($p<0.05$) effect only on digestibility. The application of both fertilizer rates (15 and 30 t ha^{-1}) gave higher digestibility indicators.

TABLE 2 THE EFFECT OF DIDDERENT DIGESTATE AND WOOD ASH MIXTURES ON MAIZE MASS YIELD, T HA^{-1}

Fertilizer rate, t ha^{-1} (F_A)	**Digestate and wood ash ratio in the mixture, (F_B)**	**Trial year**			**On average in three trial years**
		2020	***2021***	***2022***	
15	1 : 0	36.08	39.38	40.52	38.66
	1 : 1	34.98	38.87	39.51	37.79
	2 : 1	34.74	37.11	40.77	37.54
	3 : 1	36.39	41.01	40.63	39.35
	On average	**35.55**	**39.09**	**40.36**	**38.33**
30	1 : 0	33.74	38.24	40.06	37.35
	1 : 1	33.84	37.71	38.58	36.71
	2 : 1	34.53	37.01	40.02	37.18
	3 : 1	33.86	36.19	39.33	36.46
	On average	**33.99**	**37.29**	**39.50**	**36.93**
$LSD_{0.05}$ A		1.63	2.17	**0.60**	**1.13**
$LSD_{0.05}$ B		2.31	3.07	**0.84**	1.59
$LSD_{0.05}$ AB		3.27	4.34	1.19	2.25

Although dry matter yield level is very important for the production of forage, the yield quality is more important. Due to the cool climatic conditions in Latvia, the main maize yield quality indicator in this country is dry matter content at harvest. The dry matter content in maize reached on average 31.2–33.4% in two trial years, which is very good for obtaining high-quality silage, and it varied slightly depending on fertilizer rate and the digestate-to-wood ash ratio in the fertilizer mixture (Table 3).

Maize yield and total crude protein content are closely related to maize growing conditions. As it is seen in Table 3, crude protein content varied between 8.67% and 10.48% of maize dry matter. The crude protein content in maize yield increased with the increase in fertilizer rates. This is also confirmed by other research results of scientists.

Ash content represents the total mineral content in forage or diet. The normal ash content in maize silage makes approximately 5.0% of dry matter. However, in our study, there were maize silage samples containing up to 10.0% of ash. It is important to understand what is a normal ash content in feed and what is an abnormal ash content. If the ash content in feed is too high, there is a high probability that the feed is contaminated with soil, which is not desirable.

Minerals in feed can be divided into two general categories – endogenous and exogenous. Endogenous minerals can be defined as minerals the plants usually contain, for example, calcium, phosphorus, potassium, magnesium, etc. Many endogenous minerals are of nutritional value for lactating dairy cows; therefore, it is recommended that it is high, especially the content of calcium, in order to reduce supplementation costs.

Exogenous minerals can be defined as minerals not found directly in plants. Exogenous minerals (such as silica) are primarily associated with soil, and forages and rations should contain as little soil contamination as possible [14].

It was found that the ratio of digestate and ash in the fertilizer did not have a significant effect on maize quality indicators in 2020. The applied fertilizer rate had a significant ($p<0.05$) effect only on the calcium content in maize dry matter yield. A higher calcium content in dry matter was obtained by applying a 30 t ha^{-1} fertilizer rate. The application of the innovative fertilizer in maize crops ensured the production of high-quality green mass and silage (Table 3).

TABLE 3 THE EFFECT OF DIFFERENT DIGESTATE AND WOOD ASH MIXTURES ON MAIZE GREEN MASS QUALITY (ON AVERAGE IN 2020 AND 2021)

Fertilizer rate, t ha^{-1} (F_A)	**The digestate and wood ash ratio in the fertilizer mixture (F_B)**	**Dry matter content, %**	**Content in DM, %**				
			Crude protein (CP)	**Crude fibre (CF)**	***Ash***	***Ca***	***P***
15	1 : 0	31.24	9.90	16.30	3.39	0.18	0.26
	1 : 1	32.91	8.73	15.20	3.50	0.23	0.28
	2 : 1	29.42	8.80	24.55	4.65	0.26	0.26
	3 : 1	31.19	8.67	16.48	3.45	0.23	0.25
	On average	**31.19**	**9.03**	**18.13**	**3.75**	**0.23**	**0.26**
30	1 : 0	33.98	9.92	16.69	4.57	0.26	0.28
	1 : 1	33.78	10.48	19.95	4.29	0.46	0.25
	2 : 1	33.61	9.70	17.45	3.89	0.33	0.24
	3 : 1	32.19	10.31	18.14	4.13	0.33	0.26
	On average	**33.39**	**10.10**	**18.06**	**4.22**	**0.35**	**0.26**
$LSD_{0.05}$ A		2.51	1.27	2.96	1.35	**0.12**	0.04
$LSD_{0.05}$ B		3.55	1.80	4.18	1.91	0.17	0.05

Ca – calcium; P – phosphorus

Calcium and phosphorus are particularly important for animal health. Calcium and phosphorus should be analyzed together because the dietary levels of Ca and P should be balanced to increase their availability and utilization [15]. Some studies suggest that the Ca:P ratio in animal feed should range from 1:1 to 2:1 [16]; whereas, according to some authors, the optimal Ca:P ratio is 2:1 [17,18]. Diets with a Ca:P ratio higher than 2 can have a detrimental effect on animal health [19]. Grzegorczyk et al. [20] have indicated that an insufficient Ca:P ratio can lower the availability, absorption and utilization of these elements.

IV. Conclusions

The mixtures of digestate and wood ash are an innovative way for improving the soil fertility. The use of innovative fertilizers favoured to the nutritional qualities of maize yield without using mineral fertilizers.

The application of the analyzed innovative fertilizer mixture is recommended because it increases soil fertility, which eventually improves the nutritional qualities of maize plants.

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Literature Review on Management Consulting Collaboration with Companies While Crafting Strategy

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Abstract. The literature review aims to explore how companies collaborate with management consulting service providers. Also, the review identifies collaboration impact on company's strategy and encompasses relevant theories and research results performed and developed in the field of management consulting, strategy and its development over decades as a supportive service for companies.

Literature review results are obtained with qualitative methods - by exploring insight from diverse selection of works covering management consulting and competitive strategy. Insights are analyzed by revealing patterns of how management consulting providers use their expertise to help their clients - various size companies in their path to craft the strategy or solve business related problems. Also, how management consulting firms identify their strategy-as-practice niche and create perception of value creation ability for clients.

Research results indicate a connection between management consulting services and strategy as a service and practice and need for external knowledge and experience-based expertise. Findings indicate that for small and medium-sized companies it is often hard to craft and implement a competitive strategy with limited resources and inner management solution generating and executing capacity. Struggles that companies will face on the transformative path are decision taking in solving problems, change of a business model and setting up overall strategic direction and goals.

Research limitations relate to companies that experience struggle of how to craft strategies in collaboration with management consulting services that are provided by professionals that work with various size companies and industries.

The value of this paper is a literature review that covers up-to-date knowledge of what is known and what should be more deeply explored. Review includes the indication and collaboration opportunity direction of how to create a competitive strategy for various and especially small and medium-sized enterprises in modern business world. Paper can be used further for creating a theoretical model of how and when to efficiently use the management consulting services globally and is their actual impact.

Keywords: Management Consulting, Strategy, Competitive Strategy, Strategy as practice, Strategy-as-practice, Strategic Management.

I. INTRODUCTION

Over decades in 20th and 21st centuries Management Consulting (MC in further) services and consultants were and still are one of the most powerful tools across multiple economic sectors [1] - [2] but there is lack of research performed on collaboration issues while crafting the strategy [3] - [4].

Commercial wisdom and know-how passed over the generations within family were apprentices, employees, and management were crucial for companies to exist and perform well [5] - [7]. In the emerging digital age, it is both important for MC and their clients to stay competitive by digitizing processes and leading digital transformation advisory that goes together with strategy implementation and renewal [4], [7] - [10] While operating with limited knowledge, execution capability and resource capacity – especially the small sized companies lack experience and confidence – should they use some external help while setting their competitiveness [9], [11] - [13]. Important questions to ask and explore are about what the balance and appropriate way of is how to use the services wisely and get overall effectiveness for the company at uncertain times with different problems but similar approaches. That can be followed up in more than over the century long publications of business strategy, company cases and MC service development history in business world globally [2], [13] - [14].

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II. MATERIALS AND METHODS

Literature review was performed through structured search process that included selection and qualitative analysis. Search of literature and its systematization was performed following methods suggested from Webster and Watson [15]. Search was performed in SCOPUS (Scopus in further) and Web of Science (WoS in further) databases by using indexed keyword combination "Management consulting" and "Strategy". Additional filtering options were set as criteria:

a) Subject area limited to "Business, Management and Accounting" (Scopus) "Business" and "Management" (WoS) with document type: article that is published in English language.

b) A year range of publications was limited to the most articles published within the scope of a literature review research: 1979-2024 (see Fig. 1.).

c) No exclusion of authors, source title, affiliations, country/territory, and other related keywords in the article.

After deleting the duplicating articles – altogether 110 fitted the criteria. Initially selected literature was re-filtered in three steps:

1. Reading the titles and checking the keywords
2. Reading the abstracts.
3. Examining full article content.

Articles out of literature review scope and aim of research were de-selected. Primary research was chosen over secondary level and general relevance of the papers. Articles of strategy for MC service providing firms and their own performance and inner managerial issues were also excluded. Finally – 34 articles were chosen for literature review on the cut-off date of February 25, 2024.

III. RESULTS AND DISCUSSION

A. Descriptive statistics

As seen in Fig. 1. – most of the articles were published starting from the year 2000 with an up–keeping trendline with no particular concentration of the final version appearance.

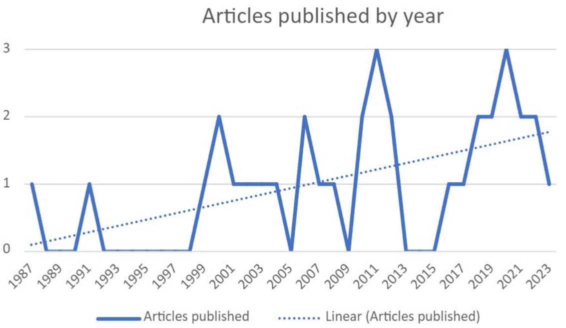

Fig. 1. Articles published by year. Source: Created by authors by combining information from Scopus and WoS.

After analyzing journals and sources where the most articles were published – 33 of 34 were rooted in the field of management and business. Three journals stood out as repetitive (2 articles each):

- "Management Decision" [12], [16].
- "International Journal of Learning and Intellectual Capital" [24], [27].
- "Strategic Management" [4], [8].

When analyzing articles by country (Fig. 2.) – most published are United Kingdom, Portugal, United States and Australia. It means that MC is relevant and practiced internationally and there are few specific articles that focus on country or territory related cases and research [4], [13], [16] - [17].

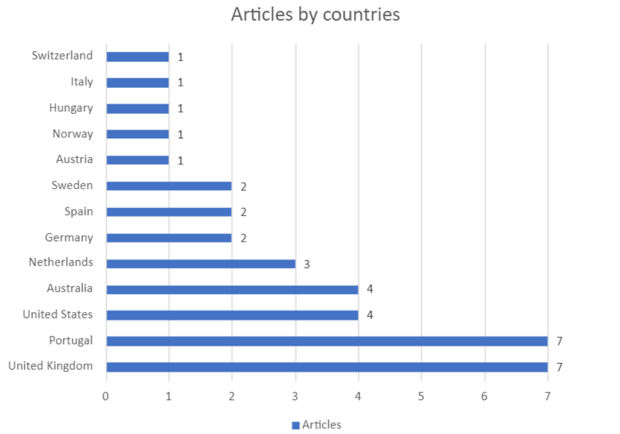

Fig. 2. Articles by country. Source: Created by authors by combining information from Scopus and WoS.

Leading authors in the field within the scope of literature review are seen in Fig. 3. With equal role of contribution to the knowledge in the field.

Authors with publication count of 3-5 were published in in the range of 2019-2023 years and are not yet cited more than 10 times each [1], [18].

Fig. 3. Articles by author. Source: Created by authors by combining information from Scopus and WoS.

Most cited publications are from authors M.T. Hansen N. Nohria, T. Tierney (2912 times in Scopus) [5] and S.E. Sampson, C.M. Froehle (502 times in Scopus) [19].

B. What we understand with management consulting?

MC as a service was discussed and widely used as a practice from 1980's and up to today [13], [20] – [21]. Strong evidence and often reference from articles published comes to 20th century – P.F. Drucker's article "Why management consultants?" that was published in 1979 [32] where author emphasizes that MC is a practice rather than science or art and it is becoming influential on institutions (especially commercial organizations) [2], [13], [18].

The first appearance and historical affiliation to business strategy and the concept plus actual terminology of the modern management consulting comes from contributing author McKenna C to whom many articles reference. The author dates the starting point decade already from the year 1910. More significant growth was spotted in the 1930 and up [2], [13], [20] where MC are in a business to give advice for a firm to operate.

MC are often referred as consultants, business consultants and advisors. Original intension was aimed towards executive-level advice to strengthen corporate strategies but there was also a focus on single shop and small business issues [4], [13], [21]. MC is a process where a firm as a client is assisted by a consultant [1], [17] because of the independent knowledge-expert status and ability to help solve a problem [3], [16], [22].

Individual consultant experiences can accumulate knowledge that can be systematized and delivered as strategy implementation projects [8], [10], [23] - [24]. Therefore, a clear benefit from MC is indicated as a better price and faster solutions because dealing with similar problems and cases that repeat for many clients.

Authors indicate that knowledge management as way how to store and access exclusive knowledge develop after especially after 1990 and was widely used by MC companies with intention to aim for competitive strategy which is desirable outcome for clients [1], [3], [14], [24] - [25]. Collaboration with companies was discussed and explored in any other further decade from various perspectives. Similar meaning of client as a company was enterprise and firm [20], [24].

MC in literature is often referred to or directly used as other similar meaning term. Various terms used by authors also explain the same or sometimes similar operations and services. Widely used are terms as PSF Professional Service Firms, KIF Knowledge Intensive Firms, KIBS Knowledge-Intensive Business [9], [14], [26] - [28] and some other less common slight variations when involved in system building, strategy rafting and project-based collaboration forms [7], [22] - [23], [29] In few sources MC service company are indicated as Management Consulting Firm (MCF) which can clearly be used as a synonym because of external interaction [3], [7].

To sum up the findings from articles – authors created content analysis (TABLE 1) for providing visualization which demonstrates aspect criteria within 34 main subject articles.

TABLE 1 ARTICLE CONTENT ANALYSIS

No. of criteria	Article content (34 = 100%)		
	Management consulting explained as a service across the selected articles	***Number of articles, count out of 34***	***Number of articles, percent out of 100%***
1.	Consultant role as important factor in solving a problem	9	26%
2.	Management consulting explained as a service	18	56%
3.	Specific aspects of management consulting services and cases related to territory or country	8	24%
4.	Consultant role in crafting strategy (in general)	9	26%
5.	MC collaboration with SME (in general)	8	24%
6.	MC collaboration with SME for strategy creation purpose	6	18%
7.	Challenges related with buying and using MC services	5	15%
8.	Result measurement of a company on service performance while collaborating with MC	3	9%
9.	Knowledge management explaned	7	21%

Source: Created by authors based on analysis of selected 34 articles from Scopus and WoS.

Articles explain the essence of MC consulting services and indicate the important role of a consultant in business. Little less explored (15% - 24%) is collaboration of MC services with small and medium sized companies while in general 26% of the content confirms contribution to strategy when used.

Phenomena of MC lacks studies that explore relations of managers and consultants in their daily interactions and effectiveness what a service can bring for a company [1], [3], [17] – especially for SME sectors. [18], [24].

C. Strategy as a service and practice

Authors in articles agree that strategy creation is and can be strongly associated with MC services [2], [20], [29] - [30]. Capabilities and core competencies as a skill to perform activities are crucial in strategy crafting process and is identified as consulting success [12] - [13], [16], [31]. Support can be given for a company in local territory or operating worldwide and by also using same consulting company experiences in global markets with offering wide services within a field of business [6], [8] - [9], [21]. Main unified criteria of success in collaborating with MC are mentioned success which is in general understood with profitability, growth, value creation and long-term balanced goal reach [3], [13], [16], [19], [21], [26]. SMEs while collaborating with MC services provider indicates them being as reactive rather than proactive [9], [17] - which means that push and support from a MC can often lead to growth.

Authors describe that "Strategy-as-practice" gained the attention to consulting field in period from 2007 and there is little exploration made especially in relations with Small and Medium sized enterprises [1] - [3], [17], [22], [24] - [25], [30] - [31]. Most relation in keywords "Management consulting" and "Strategy-as-practice" within this research are published by R.L. da Costa et al.

which explores and describes consultant roles [2] – [3], [17] - [18], [24] - [25] with publications issued from 2019-2023 and being one of few recent studies of MC collaboration with SMEs in strategy crafting and role identification.

Retention of capacity and human capital was stressed out in a well cited article from Vaiman V. (20 times cited in Scopus) [27] and Pemer. F, Werr. A (52 in Scopus) [33]. High level importance for strategic purposes is to keep the knowledge within the firm and is challenging for MC – because of high performer demand in knowledge-intensive industries and is a reason for insufficient skills and expertise within a company [14], [22], [28]. Quantitative research on small and medium sized enterprise performance while collaborating with MC services are identified in several articles [3] – [4], [6], [9], [13], [16] - [18], [24], [29], [34]. Results indicate positive role relation of an input from consultants either adding value, solving problem, or helping to strengthen an overall direction and strategy.

In the articles most relevant theories mentioned were Unified Services Theory practice is noticeably cited (502 Scopus) and explains MC service characteristics that should be considered by consultants [6], [19], [33] and explains MC and other similar services from a perspective of value creation. Also, appearance of Ambidexterity theory, Capacity and capabilities [28] and Information-based imitation theory [34].

Porter's five forces model [35] is frequently mentioned because the newly discussed concept in 1980's of entry barriers is also addressed to consulting business as similar group of competitors or substitutes who can offer MC services (for example – law, accounting firms and other) [13], [16], [19].

Skills and values of successful consultants according to research were integrity, discipline, communication, and value creation ability [13], [16], [36] with tendency for a customer to choose the ones with highest reputation and recognition [6], [22], [31], [33].

A few articles collected evidence of opinions that MC often can be seen as challenging and sometimes even in more negative light because often selling fashion ideas or already established processes at MC service convenience [3], skepticism and power positions from existing management [7], [37]. Also, there can be confusion for an existing or potential client when MC firms gain more publicity. The MC gaining the attention can be seen more positive and seemingly because of brand recognition and credit of trust that may not be objective. When developing MC services – importance of recognition often can be a cause of imitating each other within the industry or trying to differentiate the offerings for a purpose to stand out towards meeting expectations of clients [6], [8] - [9], [34], [37].

IV. CONCLUSIONS

Management consulting services can be used as external help that supports executive level managers in taking strategic action in various company sizes and the role with actual impact while crafting and during strategy execution should be measured and well analyzed. Continuation of exploration about the today's business world situations worldwide can be a clear research direction where outcome can be a contribution from a practical perspective - in the form of guidelines or framework – how to balance the use of services and internal managing and decision taking capacity depending on size, repetitive problem or challenge-based cases and capabilities of a company.

The role of consulting companies as knowledge and know-how providers for companies is within a path of digitization that overall creates positive effects (decrease of costs, increased efficiencies).Following the article publication trendline growth it is expected to see new relevant publications and research to appear in 2024 and up.

Further research on "Strategy as Practice" should be done in combination of digital transformation. Scientific literature published in the last 5 years would show clearer insights into how the management services can and are utilized nowadays.

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Practicing Green HRM to Achieve Environmental Sustainability

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Abstract. The essential point of the ponder is to investigate and discover the affiliation between organizational natural maintainability and utilizing green HRM (green compensation, green hiring, green involvement, and green training), as well as to ascertain the role that an employee's green behavior may play in making the entire work settings green. Environmental responsibility is a crucial area of study. Manufacturing companies worldwide are calling for the advancement of their green center projects due to the growing concern for the environment and its effects on global warming and climate change. In a similar vein, it was emphasized that to gain a competitive edge, there is a constant need for the production and exchange of innovative green ideas while taking into account diverse environmental groups throughout the world. The researchers adopted a qualitative methodology. The study examines the relationship between variables, finding that environmental sustainability and staff green behavior correlate with green HRM.
Keywords: Environmental Sustainability, Green HRM, Employee green behavior, and, Green involvement.

I. Introduction

Sustainable development and environmental issues have gained relevance recently in both industrialized and developing nations. The adoption of "green practices" by businesses has become necessary as a result of serious concerns about the state of the world's climate and the creation of worldwide environmental management standards. These factors highlighted that Organizations are becoming aware of the need to integrate environmental and human resource management practices, sometimes referred to as "green HRM" tactics. Human resource management (HRM) aimed at encouraging environmental sustainability is known as "green HRM". [1].

In the future, CEOs and organizations are likely to prioritize sustainability. Environmental regulations and social pressure push organizations to develop systems and practices that successfully reinforce the economic, sociological, and environmental advantages of their goals and strategies. [2]. The a need for businesses to uphold their moral character and long-term reputation. Both stakeholders, including regulators and workers, are happy with the competitive benefit and the sustainability of capital and resources [3]. Recently, researchers have focused on the critical significance of Green HRM activities in driving employee green attachment and green behavior, as well as enhancing firms' environmental performance [4].

Corporate environmental responsibility is a major area of study. This increased concern for the environment and its impact on global warming and climate change has prompted manufacturing enterprises all over the world to assess and advance their green center activities. Similarly, it emphasized the importance of continuing to generate and exchange green innovative ideas, while taking into account diverse environmental organizations in the global market space, to gain a competitive advantage [5]. We are living in

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the digital age, it is a highly competitive environment and we have to lead things according to the environment [6, 7].

In the same way that environmental sustainability is tied to sustainability, so is green HRM. A more eco-friendly business management strategy includes "green" human resources management (Green HRM) practices. To achieve the environmental aim of sustainability, businesses must create a green atmosphere that refocuses not just their whole strategy but also their workers' beliefs, attitudes, and behavior. Given that they have an impact on employees' attitudes and behaviors toward the desired environmental results, green HRM initiatives are crucial in this reconfiguration and organizational transformation [8]. The administration of an organization's most valuable resource—its people—has evolved into the core area of management, or human resource management (HRM). It is common knowledge that HRM choices and actions influence organizational problems on a significant and exemplary level. Long-term sustainability is currently being considered for the entire HRM spectrum. To clarify, we think that the most important aspect of long-term sustainability is green HRM (GHRM) [9].

One aspect of green HRM is green recruiting. Hiring individuals with the knowledge, abilities, approaches, and attitudes that are compatible with a business's environmental management systems is known as "green recruiting." Companies that recruit people with a green bent may rapidly hire professionals who are aware of sustainable procedures and are already familiar with ideas such as reuse and preservation. Images of green jobs, paperless interactions, and suggestions for recycling and reducing waste are all beneficial to the cause [10]. One of the major Green HRM operations is compensating employees for their achievements through pay and promotions. Adding a variable pay system to the reimbursement system by connecting it to eco results. Payouts are dependent on acquiring highly developed green talents, and they have a long-term impact [11].

Green training is a further part of green HRM. HRM must focus on increasing employee environmental awareness, equipping them with fundamental environmental knowledge, and increasing the organization's overall environmental "literacy [12]. According to Pinzone, Guerci [4], To increase environmentally responsible practices at work, a training program is essential. According to social exchange theory, an environmental training program's significant effect could be a staff member's in-role green presentation. A carefully thought-out environmental exercise link is necessary because employees are typically trained in environmental activities and actively involved in such activities in their firm [13]. Finally, green compensation is a key element of green HRM. A system of financial and nonfinancial advantages known as "green remuneration" aims to draw in, keep, and motivate people to support the achievement of environmental goals. It is in line with a strategic reward management strategy. Employees claim that non-cash rewards, such as praise and recognition, may motivate them more [14].

The best strategy to increase involvement and participation is to draw businesspeople who share a commitment to social responsibility and the environment. They can alter the current financial, human, and natural capital in a way that adds value to the company's goods or services in a way that didn't happen before. Additionally, employee engagement teams in EM can assist in reducing waste (because workers are expected to have the most experience with laborious processes and commodities), handle complex jobs efficiently, and foster employee pride and devotion toward their work [15]. The term "employee green behavior" refers to actions taken by employees that are good for the environment [16].

Green actions are those that focus on using environmentally friendly practices to complete tasks in a pleasant setting. Only among the various strategies employed by organizations to increase their environmental efficacy and achieve long-term goals is the adoption of green behavior. Emotions predict subjective behaviors. Previous studies examined the connection between employee contentment and environmental action [16]. The primary aim of the study is to research to find out the association between organizational environmental sustainability and using green HRM (green compensation, green hiring, green involvement, and green training), as well as to ascertain the role that green behavior may play in making the entire work settings green

Our working environment currently requires a steady environment. There is a problem at work; if the company does not establish a green working environment, it will eventually harm the environment as a whole. Jerónimo, Henriques [11] claimed that the firms' inability to include green HR practices in their mission and vision statements is a challenge to their commitment to a green environment. They are unable to achieve environmental sustainability as a result. Pham, Thanh [17] when told that a company's environmental sustainability depends on the level of green employee involvement, employees in any company appear to be engaged in their work, but they are not engaged in the tasks at hand. As a result, this lowers employee performance and lowers total business production.

Previous studies have shown that most academics do not take into account green engagement and behavior when discussing environmental sustainability and green HRM. As a result of employees not receiving green environment training, there is an issue in the workplace where the environment is not green at all. The framework that the current study seeks to investigate has not been the subject of a single study, so to address these issues, the researchers seek to investigate the impact of green HRM and green involvement on environmental sustainability, with employee green behavior serving as a mediator between these variables. There are many gaps in the literature Lack of knowledge of GHRM and environmental sustainability, no integrated approach to analyzing GHRM and sustainability, and a lack of studies in the context of Pakistan, Latvia, and Uzbekistan. Our study focused on covering the gaps.

This study benefits human resources practitioners and managers in general by improving their ability to use the results and recommendations offered in this study to boost the effectiveness of green human resource practices. As a result, this study provides a policy formulation framework that highlights many behaviors that have a significant impact on environmental sustainability. The research findings provide additional information on the trends and direction of HRM in the twenty-first century. This determines the level of HR company rules adopted to ensure compliance with market trends. These measures have the potential to accomplish the goals of sustainable development and Vision 2030. To resolve issues concerning the organization's green culture, As a result, it is advantageous for those HR managers who are pleased with their organization's atmosphere. The study's conclusions will most likely benefit state-owned enterprise management by assisting in the implementation of green HRM to increase environmental sustainability. The knowledge assists them in making the required modifications to meet the environmental sustainability goals of Vision 2030. The findings could form the theoretical basis for future empirical studies on green HRM.

The current study fills this contextual gap by doing this research in the context of Pakistan, which is distinct from the surroundings, contexts, and countries of Uzbekistan, Latvia, and other prior investigations. The study investigates the relationship between green HRM and environmental sustainability among workers from Pakistan, Uzbekistan, and Latvia. Green HRM, environmental sustainability, and employee green behavior have all been the subject of prior study, but in independent studies. By integrating the mediating link of green employee behavior between green participation, green HRM, and environmental sustainability, this theoretical gap is filled in the study. The primary aim of the study is to research find the association between organizational environmental sustainability and using green HRM (green compensation, green hiring, green involvement, and green training), as well as to ascertain the role that an employee's green behavior may play in making the entire work settings green. The study is qualitative and states the main concept of the green HRM on environmental sustainability.

1.1 Research Questions

1. What is the key concept of green HRM?
2. What is the impact of green HRM and employee green behavior on environmental sustainability?

1.2 Research objectives

1. *To describe the relation between GHRM and environmental sustainability*
2. *To describe the relation of green compensation with GHRM*
3. *To describe the relation of green hiring with GHRM*
4. *To describe the relation of green training with GHRM*
5. *To describe the relation of green involvement with GHRM*

LITERATURE REVIEW

This section provides the guidelines about literature, the researcher used some steps to identify the literature such as formulating literature selection criteria, VOS Viewer bibliometric analysis, keywords analysis and defining “hot topics” and identifying scientific discussion in theoretical approach, methodology, impacting factors. Sources selected Web of Science (by Clarivate Analytics) keywords: “GHRM” and/ or “sustainability “and/ or “Green involvement” -> n=555. Document type -> “Articles” (proceeding papers, book chapters, editorial notes, newspaper articles – excluded) -> n=301. WOS Categories -> “Business”; “organizational behavior”; “Ethics”; “Management”-> n=180, publication year -> 2015-2022 -> n=160

1.3 Green HRM and Environmental Sustainability

Green HRM is the use of human resource policies, attitudes, and practices inside a business organization to support the sustainable use of natural assets and to avoid environmental harm. Green human resource management is described as HR actions that benefit the environment. Green HRM is crucial for businesses because it tackles the 'triple bottom line,' which combines economic, social, and environmental considerations. Green HRM is picking up ubiquity among scholastics and professionals, and it may be considered the following level of vital HRM, given the more extensive issue of natural disintegration and related risks [18].

“The systematic, planned integration of traditional human resource management activities with the organization's environmental goals” is what green HRM refers to [19].

Masri and Jaaron [20] “Green Human Resources Management (GHRM) refer to the use of HRM methods to reinforce environmentally sustainable practices and improve employee commitment to environmental sustainability issues”. Nejati, Rabiei [21] “Green HRM gives companies with ecologically mindful, devoted, and learned specialists who can offer assistance the company decreases its carbon impression by utilizing existing assets proficiently and successfully, such as media transmission hardware, a few paper printing, work sharing, and video conferencing”.

Furthermore, to meet sustainability goals, organizations must attract job applicants with pro-environmental behaviors and sensitivities since they must rely on their efforts to support ecologically safe practices to support their sustainability fallouts [8]. Such “green-collar recruitment,” [12] Put another way, facilitates competition between workers' and proprietors' ideals and distresses environmental preservation, which boosts employee morale and participation [15]. In the "talent battle", Attracting a high-quality workforce is a top priority for HR. Job seekers prefer to work for organizations that share their viewpoints. Because of rising environmental concerns, hiring firms' environmental image and reputation are becoming increasingly important in recruiting campaigns [12]. In the "battle for talent," attracting superior talent to a company is a basic human resources challenge [12]. Green recruiting [9], is a process for selecting employees who possess the abilities, qualities, attitudes, and conduct that a firm values. It is a framework that emphasizes the function of the environment and elevates it to a key position within an organization [22]

Green compensation is another part of green HRM. The incentive structure would be intended to promote, reward, and strengthen environmental accomplishments and components of training. (e.g., Jackson, Renwick [23], Govindarajulu and Daily [24], Ramus [25]. Compensation and rewards for going green come in many different forms. The rewards could be monetary (such as premiums, cash, bonuses, and incentives for staff to acquire eco-friendly goods, such as hybrid cars or bikes), non-monetary (such as sabbaticals, time off, and gift certificates), recognition-based (such as awards for excellence, annual award dinners, daily praise), or negative reinforcement or promotional-based (such as criticisms) (e.g., Renwick, Redman [12], Govindarajulu and Daily [24], Bangwal and Tiwari [26].

Green rewards are described as utilizing "the introduction of a system of monetary and nonmonetary rewards for employees who have a clear potential to contribute to environmental management" [27]. Compensation is a common motivator, and this is also true for environmental management. To promote and reward an employee's greener behaviors and performance, the remuneration process must be structured in a certain way. To put it another way, how well employees support environmental programs determines how they are evaluated and paid. Incentives are crucial for motivating staff members to engage in ecologically friendly activities, according to earlier studies [18].

An effective tool for the sustainable sustainability campaign is green training. Its strength comes from its capacity to accomplish numerous goals at numerous stages: (1) to educate staff on the company's green procedures, initiatives, and creativity, such as the mission and vision statement [28]; (2) to raise ecological consciousness [29] through educating employees on eco-friendly "best practices" such recycling, trash management, energy efficiency, and source selection, as well as reducing carbon impression Ahmad [9], Renwick, Redman [12], [24] and (3) to motivate employees by improving their aptitude for identifying environmental complications and their effects [24]. Green training, also known as environmental training, "employees with the requisite information about a company's environmental policies, procedures, and attitudes" [27]. The evaluation of green performance includes factors such as environmental obligations, environmental events, and the synchronization of environmental issues and strategies. On the other side, organizations struggle to compare environmental performance levels across industries and find operational information on workers' environmental performance [12].

However. Sustainability is frequently described as "the ability to meet current needs without jeopardizing future generations' ability to meet their needs" [30, 31]. There are several definitions of "green management" for sustainable development in the environmental literature, all of which, in general, aim to make clear the necessity of maintaining a balance between economic growth for capital creation and environmental sustainability for the advantage of upcoming generations [13]. Likewise, sustainability is demarcated as a company's capability to deliver lasting strategies that will help enhance the socioeconomic setting while continuing to provide jobs and economic riches [32].

According to Ciocirlan [33], "sustainability at the macro level begins with individual action at the workplace, implying that the quantity of independent environmental performance can be retrieved before or after the amount of organizational environmental performance" [34]. Given that environmental performance is regarded differently depending on whether the firm is given priority or a different level, Ones and Dilchert [35] argue that it is more appropriate to focus on the firm's associates and, more specifically, employees' perceptions of the performance of the commercial environment "will provide a more accurate image of corporate environmental performance" [36].

The literature describes the links between variables in various research, such as the connection between GHRM and environmental sustainability [16, 37-39]. There is a progressive and direct relationship between green recruitment and environmental sustainability.

1.4 Green Involvement and Sustainability

Personnel who take part in environmental management will have occasions to engage in eco-friendly management, which will inspire them to help with contamination control and environmental opportunities [12]. Green participation is critical for improving electrical and energy efficiency since wastes and emissions in offices are reduced and all sources are completely utilized [40]. From an incorporated viewpoint, Renwick, and Redman [12] demonstrated a variability of workers' green involvement procedures. We well-defined 5 aspects for calculating GI, following Renwick, Redman [12]: Green involvement, green learning, and various media channels. Green action. Concepts and signage known as "clear green views" encourage environmental protection and directly involve workers in environmental issues [12, 41]. Similarly, Jamal and Zahid [38] stated that employees were taking part in green efforts. Employee involvement in green initiatives stimulates and motivates them to contribute to the reduction of waste and pollution. According to a review of numerous research, employee green engagement is promoted, and GI is a key component in enhancing organizational performance (such as reducing waste, pollution, and resource utilization at work). Organizations must encourage and implore their employees to participate in environmentally friendly projects as part of implementing green practices. It's feasible by giving staff additional authority.

The more engaged and enthusiastic employees are about environmental conservation, the more they will be oriented and focused on environmental responsibility [42]. Employees will build mailing lists and problem-solving green squads and teams as a result of their engagement. It will enhance the company's environmental endeavors and impart fresh knowledge to the employees [43]. GI aspires to provide a strong development-based vision of environmental management while also fostering an atmosphere of cooperative learning for environmentally conscious action. It also allows for the creation of both ordered and unstructured (informal) communication pathways to build an environmentally friendly coordination culture. [44]. GI also permits value enhancement and problem-solving abilities on environmental-related issues due to better awareness of how environmental organizations operate and the development of an environmental conservation community [12, 45].

According to Ciocirlan [33], "sustainability at the macro level begins with individual action at the workplace, implying that the quantity of independent environmental performance can be retrieved before or after the amount of organizational environmental performance" [34]. Environmental performance has been more significant to planning and economic analysis over the past century as a result of the industrialized nations' rapid depletion of natural resources and the reputation of social accountability in the workplace to gain a marginal advantage [46]. Most practitioners and researchers should look at why companies respond to environmental difficulties; this suggests that including environmental presentation initiatives in their business processes will prompt action to improve company performance [47]. The relation of green involvement was also studied in the literature by the researchers [12, 44, 48].

1.5 Green Hrm and Employee Green Behavior

Green HRM is defined as "GHRM can be characterized as a wonder that relates to the understanding of connections between organizational exercises that influence the characteristic environment and HRM framework plan, advancement, usage, and influence." [14]. Kim, Kim [49] "Top administration communication of the natural technique, arrange, and other relevant data to staff, teaching workers to consider present-day natural hones, empowering representatives to take an interest in natural activities, and fulfilling representatives for being ecologically cognizant are all cases of GHRM". Wikhamn [50] "The implementation of HRM strategies and practices that allow the achievement of financial, social, and ecological goals with an impact within and outside the organization and over a long-term time horizon while controlling for unintended side effects and negative feedback is known as GHRM".

Environmentally friendly behavior is referred to as pro-environmental behavior. They are also known as "green" approaches. Green activity is therefore associated with environmental friendliness [51, 52]. EGB is defined as any visible separate action that contributes to the workplace's environmental sustainability [35, 53, 54]. Ones and Dilchert [35], Paillé and Boiral [55], and Norton, Parker [54] Recently, environmental sustainability academics, among others, have emphasized the significance of inspiring green behaviors in the office [56-58]. Recycling programs, environmental laws, reusing, waste reduction, energy efficiency through technical upgrades, action plans to reduce energy consumption, water usage, carbon dioxide emissions, and conducting life-cycle evaluations are examples of organizational green practices, according to Kirkwood and Walton [59]. Optimistic green behaviors are also defined as the extent to which employees engage in environmental practices outside the scope of their job duties [58, 60, 61].

The green behavior of employees was studied by [16, 62]. Employee green behavior is highly related to environmental sustainability [62].

1.6 Role of Employee Green Behavior Between GHRM and Sustainability:

As discussed before by Smith and O'Sullivan [63] Green conduct in the workplace is a notion that divides a wide range of activities into two groups based on two major features. The first distinction is between direct and indirect behavior (actions to influence others, such as signing an environmental application) and direct and indirect conduct (individual acts such as recycling). The second component contrasts local repercussions (for example, turning off the lights at work) with global implications (for example, developing new environmental management methods) [64]. Kornbluh, Crowfoot [65], May and Flannery [66], Enander and Pannullo [67], Hart [68], and Antonio Ruiz ‐ Quintanilla, Bunge [69] All emphasize the necessity of individual initiative in creating an environmentally sensitive organization. Employee participation in recycling and pollution-control programs has been found to have a major impact on an organization's environmental efficiency [48, 64, 70-73].

The HR job may act as a coworker in assessing what is required or practicable in defining company values and a long-term strategy. Human resource departments of organizations have the potential to have a significant impact on the design of their organization's community of sustainability [74]. Green management and strategies have become an essential component of forward-thinking businesses worldwide. Furloughs, part-time work, and other green HR programs help organizations find cost-cutting choices while retaining top employees. Strategic Green HRM - the incorporation of environmental management into human resource management - is becoming increasingly significant. The best method for HR professionals was to encourage employees to be more environmentally conscious in the workplace [75].

Sustainability is the practice of measuring a company's performance in terms of both economic criteria, such as revenue and investment returns, as well as environmental and social ones [76]. Sustainability entails addressing today's demands without endangering future requirements, with a focus on intergenerational equity. This directly contributes to ensuring future generations' resource security [77].

In the study of Al-Tuwaijri, and Christensen [78], Using the same management approach, it is possible to investigate the connections between environmental performance and financial presentation. This course examines the strategic strategy for green HRM as a tactical tool for better environmental communication. Additionally, critical limit circumstances include staff responses to variations in environmental performance plans and facilities as well as system improvements versus those plans and facilities. [79]. Long-term sustainability has become a top priority due to climate change, political and social pressure to promote environmental and social accountability and other factors. Corporate managers give sustainable development more of a priority and are crucial in helping many organizations achieve their strategic objectives [80].

The literature states the relationships of the variables in different studies such as the relation of green HRM and environmental sustainability [16, 37-39]. The relation of green involvement was also studied in the literature by the researchers [12, 44, 48]. The green behavior of employees was studied by [16, 62]. The umpiring role of employee green has not been studied in literature by researchers in a single study. Green employees' behavior has a mediating role between green compensation and environmental sustainability.

II. MATERIALS AND METHODS

The researcher has used a thorough methodology to perform the systematic literature evaluation, drawing from previously published SLRs, Tranfield's revolutionary research in 2003, and other SLR guideline articles written by Justine Paul. The stages below delineate the technique that we have employed (or intend to employ) in carrying out our SLR:

1.7 Formulating Research Questions:

We started by developing specific research questions to help determine the breadth of our review. These questions helped us discover relevant studies and concentrate our study. As study's main purpose is to analyze and understand the impact of GHRM.

1.8 Search Strategy Development:

The researcher created a strong search strategy based on well-established SLR standards and rules. To achieve a thorough and targeted search, appropriate databases had to be chosen, search keywords defined, and inclusion/exclusion criteria established. Key words like Environmental Sustainability, Green HRM, and Employee green behavior, and, Green involvement. The researcher used databases Scopus, Google Scholar, Science Direct, and Emeralds.

1.9 Study Selection:

We sorted the retrieved studies according to how well they addressed our research questions using a methodical process. We looked for and chose studies that fit the review's goals by evaluating titles, abstracts, and full texts as needed. Written research includes books, working papers, conference papers, scientific journals, doctoral and master's dissertations, and articles.

1.10 Data Extraction:

We used a prepared data extraction form to retrieve pertinent information from the selected research. This featured data on study characteristics, methodology, sample size, and main conclusions. The extraction procedure ensured uniformity and enabled the systematic structuring of data for further analysis.

1.11 Quality Assessment:

Using recognized assessment instruments, we evaluated the included studies' dependability and quality. This stage was to make sure that our review was supported by solid evidence by assessing each study's methodological rigor, validity, and general quality. After going over each piece in detail, the writers removed any poor research.

1.12 Data Synthesis:

A total of 160 publications were chosen for the current investigation after 10 papers were recognized for data synthesis. We identified recurring themes, patterns, and trends to summarize the findings from the chosen studies. We combined the data using a methodical and exacting technique to make significant findings and offer insightful information about the research issue.

1.13 Reporting and Documentation:

Lastly, we followed Justine Paul's SLR guideline papers and Tranfield et al. (2003) reporting requirements for documenting the outcomes of our SLR. Using tables, figures, and descriptive analyses, we clearly and systematically presented our findings to provide a thorough understanding of the results of the literature review.

III. RESULTS AND DISCUSSIONS

The primary purpose of the paper is to research and find the association between organizational environmental sustainability and using green HRM (green compensation, green hiring, green involvement, and green training), as well as to ascertain the role that green behavior may play in making the entire work settings green. The study is qualitative and presents the key concepts from the literature

It is concluded that green training has a high correlation with environmental sustainability. As a result, improving green recruiting may help any company's environmental sustainability. Simply, more green pay elevates the importance of environmental sustainability. In the literature, research with similar outcomes [11, 18, 39, 81]. Similarly, Environmental sustainability and green HRM are strongly connected. Therefore, enhancing green HRM may enhance environmental sustainability in any kind of organization. Simply said, a company's capacity to manage its human resources more sustainably increases environmental sustainability, which in turn increases the value of its customers and staff. Therefore, if someone wants to improve it, employing green HRM will enhance the perception of environmental sustainability. The studies with comparable outcomes in the literature are [81-84]

Green compensation and environmental sustainability have a strong and positive relationship. We can therefore conclude that raising green remuneration can advance environmental sustainability in every industry. Simply put, more environmentally friendly pay adds value to environmental sustainability, This increases the worth of consumers and workers to any firm. As a result, if someone wants to promote environmental sustainability, they should use green compensation. Previous research has looked into these aspects [81, 85-87]. Further, Green hiring and environmental sustainability are closely associated with one or more. It stated that boosting green recruiting can progress environmental sustainability in whichever industry. Simply put, more environmentally friendly recruiting adds value to environmental sustainability, which nurtures the value of consumers and employees for any organization. So, if somebody desires to increase environmental sustainability, they can do so by using green hiring to increase the impact of sustainability. The studies with corresponding outcomes in the literature are [85-88]

The study demonstrated a strong and advantageous association between green training and environmental sustainability. Because of this, it is important to strengthen green training to increase environmental sustainability. Therefore, using green training to increase the impact of environmental sustainability is a good idea if you want to promote environmental sustainability. The studies with equivalent outcomes in the literature are [85-87]. In light of the literature, it is shown that Environmental sustainability is significantly and favorably correlated with green involvement. Therefore, to promote environmental sustainability, it is important to improve green training. Green involvement affects environmental sustainability. Subsequently, employing green involvement will improve the influence of environmental sustainability if somebody needs to expand it. The research with related findings in the literature are [85-88]. This leads to the conclusion that improving environmental sustainability and green employee behavior can assist businesses in boosting their green compensation. The literature described the connection in the study. [37, 39, 87, 89, 90]. Moreover, increased environmental sustainability can help any organization expand its green hiring, green behavior is a mediator. The study's literature stated the relationship, increasing environmental sustainability can strengthen any company's green training, and green involvement with green employee behavior acts as the intermediary. [37, 39, 87, 89, 90]. Constructed on research,

As stated in the study, our surroundings are a big problem in today's hectic lifestyle. Green HRM and green branding are key topics in our contemporary period, as countries are experiencing increased global warming and pollution. Consumers are indisputably adopting behaviors to protect the environment for their well-being and to prevent nature. The study brings to the literature a new paradigm that can assist firms in increasing green HRM practices by implementing some easy actions. Environmental sustainability is the most pressing challenge in this age of global warming. The paper stresses the significance of environmental sustainability as well as basic methods for improving environmental sustainability. Many researchers have previously worked on green HRM and environmental sustainability [5, 11, 18, 37, 39, 62, 81, 87, 88, 90]. The present study highlights the importance of green employee behaviors and green HRM to improve the environment of our country.

The current study emphasizes the significance of green employee behaviors and green HRM in improving our country's environment. The study provides new angles to study green HRM as a mediating role of green behavior and both environment and organizational-centric performance.

The contribution of research in the area included leading the employees to achieve firm strategic goals by adopting green behaviors. The research contributions in the manufacturing sector. This study provides new insights into contemporary tools & techniques of the modern world of HRM. It teaches employers new ways to deal with employees to make the environment of the organization sustainable. The research is important for the managerial level as it provides coping strategies to deal with the problems of employees. The "need for green" has quickly shifted the focus of HR managers as well. While the transition to "green products" may appear expensive in the short run, it will ultimately prove to be advantageous for the environment and more affordable. The study helps to improve the Manufacturing sector of the country by improving the organizations that are working on green HRM. The study also helps HRM practitioners and Managers.

In practice, the fast rise in consumer knowledge of environmental concerns has altered consumer behavior and turned the market toward more environmentally friendly goods and services. The great majority of environmentally concerned customers have had a significant influence on human resource management. HR managers have therefore readily embraced the "need for green." While switching to "green products" may first seem pricey, in the long term it will look to be more cost-effective and better for the environment. There is currently a demand for those who have a favorable perception of the natural world. If a company hires people who care about the environment, then its products will also be good for the environment. and put into place laws that won't harm the environment. The study concluded that green HRM practices (green compensation, green hiring, green training, and green involvement) are good indicators of green employee behavior and environmental sustainability. This study will be focused on national-level organizations that are working in the mentioned countries. The literature that was used in the research was published from 2000 through 2022. This study cannot maintain any relationship among the variables based on time sequence.

CONCLUSION

The results of studying the literature showed that green training has a high association with environmental sustainability. As a result, improving green recruiting may help any company's environmental sustainability. Simply, more green pay elevates the importance of environmental sustainability. Similarly, Environmental sustainability and green HRM are strongly connected. Green HRM is key to achieve green organizational environment. If we talk about other factors of green HRM compensation, hiring, involvement, and employee green behavior are very important to maintain the environmental sustainability. These have influential role on environmental sustainability. The conclusion is green HRM has a noteworthy association with employee green behavior, but not with environmental sustainability. The sustainability of the environment and employee green behavior are closely intertwined.

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Aronia Melanocarpa (black chokeberry) Branches Biomass as a Source of Valuable Biologically Active Compounds with Antioxidant and Antimicrobial Potential

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Abstract.** Aronia melanocarpa is a hardy berry-producing shrub that demands low maintenance and can grow on almost any type of soil. Since the best fruits can be obtained on the branches younger than 7 years, pruning of 1/3 of the shrub is usually performed each winter or after flowering, and also to remove damaged or overgrown branches. For sustainable production of Aronia melanocarpa berries, it is necessary to find a rational use for this pruning lignocellulosic biomass. Some studies available for Aronia melanocarpa berries show that they are very rich in various biologically active substances with proven functional and pharmacological activities including anti-inflammatory, antioxidant, and antimicrobial properties. The chemical composition of Aronia melanocarpa branches is currently almost unknown. The study aimed to evaluate the composition and potential of chokeberry branches as a source of polyphenols. General chemical characterization of the biomass was carried out using the method of analytical pyrolysis. Extraction of branch biomass was carried out using aqueous alcohol solutions. Quantitative analysis of the extracts showed a large amount of oligomeric proanthocyanidins. The most suitable extractant was determined to obtain the highest yield of the dominant polyphenols in the hydrophilic extract. The antioxidant activity of the hydrophilic extracts as well as antibacterial activity against six pathogenic bacteria was evaluated. The results showed the high potential of chokeberry lignocellulosic biomass as a source of valuable biologically active compounds for the creation of preparations for the healthcare, nutrition industry, and cosmetics.

***Keywords:** Aronia melanocarpa, Black Chokeberry, polyphenols, antimicrobial activity*

I. Introduction

One of the most underestimated and little investigated fruit trees is the black chokeberry (also aronia, or black apple berry) – Aronia melanocarpa. Aronia melanocarpa is a deciduous shrub-tree of the Rosaceae family, originated from the eastern parts of North America [1], [2]. The chokeberry tree is a very unpretentious plant, frost-resistant until -35ºC, and can grow well in both wet and dry soil, with preferably acidic, but also with alkaline pH [3]. It tolerates well sandy and salty soils. Chokeberries are mostly used for making juice, jam, less often wine [4], and for producing natural food colorants

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with antioxidant properties [5]. According to the Rural Development Service (LAD – in Latvian) data, in Latvia, the black chokeberry cultivation area increased 2.4 times during the last five years, and in 2022, it was 244 ha. The biggest Latvian grower is "Sirpes" Ltd., in Lielvarde (69.8 ha) [6]. As admitted by the Latvian Institute of Horticulture scientists, *Aronia melanocarpa* berries could become an important product of homemakers-gardeners [7]. The European share of the black chokeberry growth was estimated as 33% in 2023 [8]. In a range of studies it was proven that *Aronia melanocarpa* berries are one of the richest plant sources of phenolic and polyphenolic compounds including anthocyanins, procyanidins and proanthocyanidins [2], [9], [10]. *Aronia melanocarpa* contains a lot of vitamins, and is also rich in dietary fibers – pectin and hemicellulose, and water-insoluble dietary fibers, including lignin [2], [11], which are important for the prevention and treatment of atherosclerosis, coronary heart diseases, obesity, and large intestine cancer [11]. The studies recently confirmed anti-inflammatory [12], cardioprotective [13], antidiabetic [9], [14], [15] properties of the *Aronia melanocarpa* pomace and proved it's capabilities in the prevention of degenerative diseases [2]. But *Aronia melanocarpa* needs much wider popularisation and more attention of the growers, producers and consumers. *Aronia melanocarpa* shrub-tree is easy to maintain, it has an annual berry harvest, and, which is very important, no known pest problems [10]. By adding the knowledge about it's pruning lignocellulosic biomass' characteristics and application possibilities, *Aronia melanocarpa* could become a niche export direction for Latvian and other *Aronia melanocarpa*-cultivating countries' gardeners.

The studies of the *Aronia melanocarpa* lignocellulosic biomass are largely missing. In some papers, it was shown that aronia leaves contain a variety of phenolic compounds and have high total phenolics content that confirm their therapeutic potential, including anticancer properties [1], [16], [17]. To the best of our knowledge, there are no studies about aronia branches, although it could be assumed that *Aronia melanocarpa* branches may contain a range of the valuable compounds similar to what are found in the berries and leaves. Our previous comparative study of fruit and non-fruit trees twigs showed great potential of proanthocyanidins obtained from autumn twigs of *Aronia melanocarpa*, they inhibited bacterial biofilm formation by 50% [18]. Since antimicrobial resistance against chemically synthesized antibiotics is one of the biggest problems for human health around the world [19], it is necessary to identify new natural antimicrobial agents for the treatment of infections. The aim of this study was screening of the spring and autumn *Aronia melanocarpa* branches biomass composition by analytical pyrolysis, finding the optimal conditions for the branches' extraction, and evaluation of the antioxidant and antimicrobial properties of the obtained extracts and oligomeric proanthocyanidins against a range of the most frequently detected pathogenic bacteria.

II. Materials and Methods

A. Plant Material

Black chokeberry branches were collected in spring (SP) and autumn (AU) of 2023, in order to evaluate seasonal changes, from Baldone parish, Kekava county of Latvia (DD: 56.77306/24.30162). 7 years old *Aronia melanocarpa* 'Mulatka' branches were cut after the harvesting of the berries. The branches were dried at room temperature and ground in a mill (Cutting Mill SM100, Retsch, Haan, Germany) until the particle size of 1–4 mm. The samples were stored at −8 °C.

B. Analytical Pyrolysis of Biomass

Analytical pyrolysis (Py-GC/MC/FID) of biomass samples was performed using a Frontier Lab (Fukushima, Japan) Micro Double-shot Pyrolyzer Py-3030D directly coupled with the gas chromatograph (GC) Shimadzu GC/MS/FID-QP ULTRA 2010 (Japan), as described in details in Andersone et al. [20]. In short, pyrolysis temperature was 500°C, heating rate: 600 °C s^{-1}. Capillary column RTX-1701 (Restec, Metairie, Louisiana, USA) was used. The identification of the individual compounds was performed using Library MS NIST 11 and NIST 11s. The summed molar areas of the relevant GC peaks were normalized to 100%, and the data from four repetitive pyrolysis experiments was averaged.

C. Branches Extraction

Autumn and spring *Aronia melanocarpa* branches extraction was performed by maceration with 96% EtOH and ethanol (EtOH)-distilled water solutions (50% EtOH v/v) and by distilled water, at 60 °C for 60 min. The extracts were freeze-dried using lyophilization equipment Heto Power Dry HS3000 (Thermo Fisher Scientific, Waltham, MA, USA) to yield a dry weight (DW) extract. The yield of the extracts is given as a percentage based on DW. The extracts were stored at −8 °C. Each branches sample was extracted in triplicate, and results were expressed as a percentage per dry branches sample.

D. Proanthocyanidins Separation

Separation of proanthocyanidins from the extracts was performed as described by Andersone et al. [21], using a solvent-resistant column packed with cross-linked dextran-based resin Sephadex LH-20, and sequentially 96% EtOH (v/v) and 70% (v/v) acetone/water solutions as solvents, for low-molecular-weight phenolics and proanthocyanidins, respectively.

E. Determination of Proanthocyanidins Content

To evaluate the potential of *Aronia melanocarpa* biomass for the production of proanthocyanidins, the content of proanthocyanidins in extracts was determined using the Butanol-HCl colorimetric method. The method is based on the hydrolysis of proanthocyanidins in the presence of n-butanol/HCl to the corresponding coloured anthocyanidins [18]. Amounts of 6 mL of acid butanol (5% (v/v) concentrated HCl in n-butanol) and 0.2 mL of iron reagent (w/v) ($FeNH_4(SO_4)_2 \cdot 12\ H_2O$ in 2 M HCl) were added to 1 mL of the extract aliquots while stirring the tube without heating and allowing it to be heated in a water bath at 80 °C for 50 min. After 50 min, the absorbance of the mixture was measured against a blank solution at 550 nm using UV/VIS spectrometer Lambda 650 (Perkin Elmer, Shelton, CT, USA). Each extract was analyzed in triplicate, and assay results were expressed as a percentage per dry extract.

F. Determination of Antioxidant Activity.

Extracts and purified proanthocyanidins were tested for their radical scavenging activity against the 2,2-diphenyl-1-picrylhydrazyl radical DPPH· assay), by measuring the absorbance of the different concentrations of the extracts solutions in DMSO (30 µl) mixed with DPPH· ($1\cdot10^{-4}$ mol L^{-1}, 3.0 ml) at 515 nm, using UV/VIS spectrometer Lambda 650 (Perkin Elmer, Shelton, CT, USA) as described in Dizhbite et al. [22]. Each extract and purified proanthocyanidins sample was analyzed in triplicate. The free radical scavenging activity is expressed as the concentration of antioxidant, mg L^{-1}, required for a 50% inhibition of the free radicals (IC_{50}). The lower the IC_{50} value, the higher the antioxidant activity of the sample.

G. Determination of the Antimicrobial Activity

Antimicrobial activity was performed for autumn and spring biomass, 50% and 96% hydrophilic extracts and purified poanthocyanidins, against bacteria strains *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Bacillus cereus*, *S. Pyogenes,* and *C. acnes* as described in [18]. Antimicrobial activity was studied in 96-well plates by the two-fold serial broth microdilution method, which allowed the determination of the minimum inhibitory (MIC) and minimum bactericidal concentrations (MBC). The MIC was determined as the lowest concentration of the studied sample, which showed no visible growth. From wells where growth was not detected, 4 µL of medium was seeded on an appropriate solidified medium for MBC determination.

H. Statistical Analysis

All analyses were performed in triplicate, except for analytical pyrolysis where four repetitive pyrolysis experiments were done. The results are presented as the mean value. Statistical analysis was done using Microsoft Excel 2016. Confidence intervals (CI) were calculated for a mean using a Student's T distribution at a significance level = 0.05.

III. Results and Discussion

A. Chemical Characterization of Aronia melanocarpa Biomass by Analytical Pyrolysis

Carbohydrates and phenols are the major components of organic part composition of *Aronia melanocarpa* biomass. Biomass phenol-derived pyrolysis products can be divided into phenyl and benzyl derivatives originating from the lignin and extractives (Fig. 1).

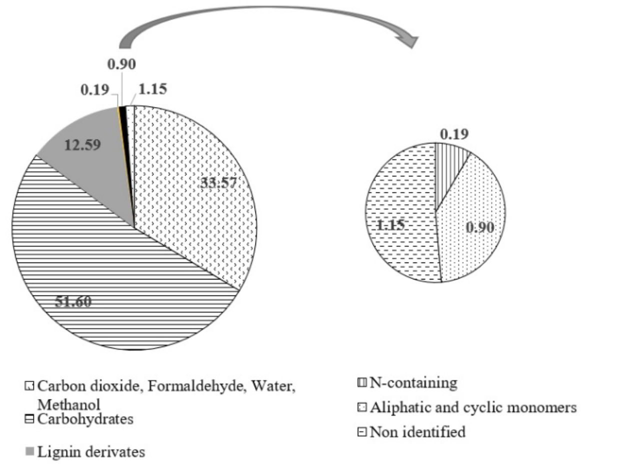

Fig. 1. Py-GC/MS/FID data of *Aronia melanocarpa* biomass-derived volatiles

B. Evaluation of the Extraction Conditions and content of Proanthocyanidins

For evaluation of the potential of *Aronia melanocarpa* as a raw material of valuable biologically active compounds, *Aronia melanocarpa* plant material after grinding and drying was subjected to extraction. The yields of hydrophilic extracts from *Aronia melanocarpa* biomass under study were different and varied from 11.7 % to 17.2 % /DM. The highest yield of hydrophilic extract was obtained by biomass extraction with 96 % (further in the text – 96% EtOH extract) and 50% EtOH (further in the text – 50% EtOH extract). The increased yield of extractives from biomass using 50% EtOH indicates that an ethanol-water solution as an extractant is required to completely isolate hydrophilic extractives. This observation was also confirmed by determining proanthocyanidins in hydrophilic extracts composition.

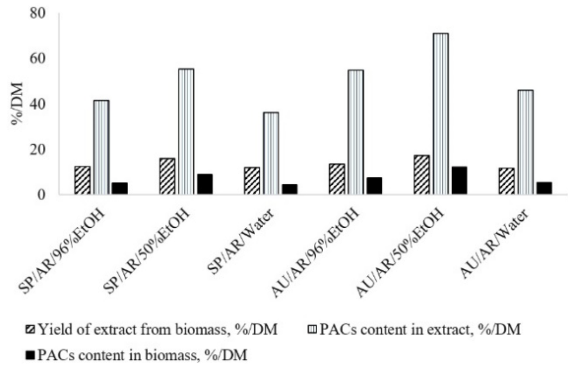

Fig. 2. Chemical characterization of *Aronia melanocarpa* biomass and hydrophilic extracts

The method is based on the hydrolysis of proanthocyanidins in the presence of n-butanol/HCl to the corresponding coloured anthocyanidins. According to the butanol method, the content of proanthocyanidins in the extracts varied from 36.2 to 71.0%/DM. The highest content of proanthocyanidins was in biomass collected in autumn (AU) and in the 50% EtOH extract of this biomass. It was shown that in the above-mentioned conditions it is possible to obtain from 8.9 to 12.2% proanthocyanidins (PACs) in purified form (Fig. 2).

C. Antioxidant Activity of the Extracts and Proanthocyanidins

In the test with DPPH·, all hydrophilic extracts showed high radical scavenging activity (IC_{50} ranged between 3.8 and 6.9 mg L^{-1}, CI≤0.2 at = 0.05). The 50% EtOH extracts have fairly high antioxidant activity against DPPH· (SP/AR/50%EtOH: IC_{50} = 4.3 mg L^{-1}; AU/AR/50%EtOH: IC_{50} = 3.8 mg L^{-1}, CI≤0.2 at = 0.05) that is higher than that of Trolox, a synthetic water-soluble analogue of vitamin E (alpha-tocopherol), a widely used antioxidant with proven strong antioxidant activity (IC_{50} = 4.7 mg L^{-1}, CI≤0.2 at = 0.05, a lower IC_{50} value corresponds to higher antioxidant activity). The IC_{50} of purified proanthocyanidins, necessary for 50% inhibition of DPPH·, was 4 times lower than for the Trolox.

D. Antimicrobial Activity of Aronia melanocarpa Extracts and Proanthocyanidins

The evaluation of the effect of hydrophilic extracts on antimicrobial activity was studied against the following pathogenic bacteria: *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Bacillus cereus*, *Streptococcus Pyogenes* and *Cutibacterium acnes*. All extracts inhibited both gram-positive and gram-negative pathogenic bacteria. The minimum inhibitory (MIC) and bactericidal concentrations (MBC) of extracts ranged from 0.2 to 3.13 mg mL^{-1} (Table 1, Table 2).

TABLE 1 THE MINIMUM INHIBITORY (MIC) AND BACTERICIDAL CONCENTRATIONS (MBC) OF EXTRACTS AND PROANTHOCYANIDINS, MG ML^{-1}

Samples	***E. coli***		***P. aeruginosa***		***S. aureus***	
	MIC	***MBC***	***MIC***	***MBC***	***MIC***	***MBC***
Proantho-cyanidins	0.08	0.16	0.16	0.31	0.04	0.31
SP/AR/ 96% EtOH	0.20	0.20	0.39	0.78	0.39	0.39
SP/AR/ 50% EtOH	0.20	0.39	0.39	0.78	0.20	0.20
AU/AR/ 96% EtOH	0.20	6.25	0.78	3.13	0.10	0.20
AU/AR/ 50% EtOH	0.10	0.10	1.56	3.13	0.10	0.10
AU/AR/ Water	0.39	0.39	0.39	0.78	0.20	0.39

Confidence interval for a mean is ≤ 0.01 at α=0.05

TABLE 2 THE MINIMUM INHIBITORY (MIC) AND BACTERICIDAL CONCENTRATIONS (MBC) OF EXTRACTS AND PROANTHOCYANIDINS, MG ML^{-1}

Samples	***B. cereus***		***S. pyogenes***		***C. acnes***	
	MIC	***MBC***	***MIC***	***MBC***	***MIC***	***MBC***
Proantho-cyanidins	0.08	0.16	0.08	0.08	2.50	2.50
SP/AR/ 96% EtOH	0.39	3.13	0.20	0.20	3.13	3.13
SP/AR/ 50% EtOH	0.20	0.20	0.39	0.39	1.56	1.56
AU/AR/ 96% EtOH	0.20	0.20	0.05	0.05	1.56	1.56
AU/AR/ 50% EtOH	0.20	0.20	0.05	0.05	0.78	0.78
AU/AR/ Water	0.20	0.39	0.20	0.20	1.56	1.56

Confidence interval for a mean is ≤ 0.01 at α=0.05.

It was reported that oligomeric proanthocyanidins play one of the major roles in the biological activity of the plants extracts [23], [24]. This statement was confirmed by the results of the present research, showing high antibacterial activity of proanthocyanidins isolated from the 50% EtOH extract of *Aronia melanocarpa* branches collected in autumn.

IV. CONCLUSIONS

In this research, *Aronia melanocarpa* collected in autumn and extracted by 50% EtOH solution showed the highest antioxidant activity among all the other *Aronia melanocarpa* extracts, and it was 1.2 times better than of Trolox, a synthetic water-soluble analogue of vitamin E. Antioxidant activity of proanthocyanidins purified from the 50% EtOH extract of *Aronia melanocarpa* branches collected in autumn, in DPPH· tests was even higher than that of extracts, and it was 4 times better than that of Trolox.

All the extracts and proanthocyanidins under study showed the ability to fully stops the bacterial growth of *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus and Bacillus cereus*, *Streptococcus Pyogenes* and *Cutibacterium acnes* (with MBC 0.05 – 6.25 mg mL^{-1}). Proanthocyanidins isolated from the 50% EtOH extract of *Aronia melanocarpa* branches collected in autumn had the smallest necessary minimal bactericidal concentration (MBC), and, therefore, the strongest ability to stop the bacterial growth of *Pseudomonas aeruginosa* (MIC/MBC=0.16/0.31 mg mL^{-1}), while the 50%EtOH extrtacts and proanthocyanidins had highest activity against *Escherichia coli* (MBC=0.10-0.16 mg mL^{-1}). Proanthocyanidins, 50% EtOH and 96% EtOH extracts had similar bactericidal concentration levels against *Bacillus cereus* and *Streptococcus Pyogenes* (MBC=0.16–0.20 and 0.05–0.08 mg mL^{-1}), while 50% EtOH extracts were the strongest against *Staphylococcus aureus* (MIC/MBC=0.10 mg mL^{-1}) and *Cutibacterium acnes* (MIC/MBC=0.78 mg mL^{-1}). Thus the results showed the possiblity to use extracts and proanthocyanidins of *Aronia melanocarpa,* or their combination, in fight with pathogenic bacteria.

The study confirmed the high potential of *Aronia melanocarpa* lignocellulosic biomass as a source of valuable biologically active compounds for the creation of antibacterial and antioxidant preparations for the healthcare, nutrition industry, and cosmetics.

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Challenges and Opportunities for Development of Organic Production in Bulgaria

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Abstract. The paper examines the development of the organic production sector in Bulgaria in recent years, particularly emphasizing the main challenges and problems and the need for close monitoring, support and re–energisation of the sector. Its potential, trends and multidimensional implications for the environment, society and local communities represent an important research subject and are the focus of the INVEST Regional Living Lab in Bulgaria, established by the University of Agribusiness and Rural Development. The Living Lab applies the quadruple helix approach to work on open innovations that fits very well the research task of identifying challenges and opportunities for the development of organic production in Bulgaria. Combining primary data, case studies and facticology from the terrain that highlight the most pressing issues for regulation and funding, the research provides a two–level view of trends on organics at EU level and the local photography. The results suggest that improving the capacity of chain operators, access to organic markets and research on fast–growing ones can expand the potential of opportunities, integrating this research with other research tasks in the INVEST Living Laboratory in Bulgaria, especially those related to alternative food networks and relationships between urban and rural territories, climate change, agriculture and tourism. Good practices, green innovations and expertise within the ecosystem to implement efficient solutions remain essential for the vision and expansion of the sector.

Keywords: Organic Production, Organic Farming, Organic Marketing, Living Labs.

I. INTRODUCTION

The Annual Report on the state and development of agriculture in Bulgaria 2023 states that organic agriculture contributes to the objectives the European Green Deal, the EU Farm to Fork strategy and the EU Biodiversity strategy 2030 because of its positive impact on the environment and climate in terms of improving carbon sequestration and soil health, protecting biodiversity and animal welfare, as well as the additional ecosystem services it provides. Organic production represent a sustainable management system that preserves elements of the natural landscape and uses energy and natural resources responsibly and operates within a strict regulatory framework. The set rate of increase in areas in organic agriculture, combined with agro–ecological measures, leads to high and multi–aspect benefits, both for achieving the goals of biodiversity protection and for mitigating the impact of climate change and for improved water and soil quality and soil biodiversity, due to the non–use of mineral fertilizers and chemical pesticides. The application of organic production practices has an indirect effect on improving or maintaining the good condition of natural habitats and Natura 2000 species.

The development of organic production in Bulgaria is favoured by the availability of quality land resources, climatic conditions, and traditions in the agrarian sector. Defining the organic farming sector is the specific method of production that maintains ecological balances and produces production covering the principles of ecological

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cycles for the continuous movement in nature by converting substances such as water, minerals, nitrogen, oxygen and carbon into different forms between living beings, water, air and soil [1].

According to the project of the National Action Program to contribute to the goals of the Farm to Fork strategy by 2030 organic production meets the objectives and priorities of the Farm to Fork strategy as the type of production with the greatest contribution to the protection of environmental components, the highest opportunities for market realization, due to the ever–increasing demand and the highest social responsibility (in terms of the safety of the manufactured products, response to the desire of consumers to eat healthy and care for the environment) [2]. The purpose of the program is to contribute to the implementation of the goals of the Farm to Fork strategy, and particularly to update and upgrade the strategic framework for the management of the agrarian sector, regulated in the National Development Program Bulgaria 2030, as outlined instruments, measures, and activities related to the implementation of specific goals and commitments contributing to the protection of climate, environment, biodiversity and natural resources. The program is aimed at promoting green investments, sustainable management of natural resources, adaptation to climate change, and mitigation of its consequences in agriculture. In addition to reducing the footprint of the food system on the environment and climate, the program also focuses on producing food in a sustainable manner that meets high standards of safety and quality, plant health, animal health, etc. The goals are in line with the policy implemented in the agricultural sector in recent years, based on environmentally friendly production and building sustainable food production systems. Their achievement is closely related to the Common Agricultural Policy (CAP) which promotes sustainable agricultural practices that are aimed at protecting the environment with appropriate interventions and schemes within the framework of the new Strategic plan for the development of agriculture and rural areas of the Republic of Bulgaria for the period 2023–2027.

Support from the European Agricultural Guarantee Fund (EAGF) and the European Agricultural Fund for Rural Development (EAFRD) aims to further improve the sustainable development of agriculture, food and rural areas and contribute to the achievement of the following general objectives [3]: 1) to promote the development of a smart, sustainable and diversified agricultural sector guaranteeing food security; 2) to support environmental care and climate action and contribute to the Union's environment and climate objectives; 3) to strengthen the socio-economic structure of rural areas. These objectives should be complemented by the cross–cutting objective of modernizing the sector by stimulating and sharing knowledge, innovation and digitalisation in agriculture and rural areas and promoting their wider use.

In that relation, the Strategic plan for the development of agriculture and rural areas for the period 2023–2027 is structured around nine specific objectives of the Common Agricultural Policy (CAP) and one EU cross–sectoral objective, which is related to the modernization of agriculture and rural areas by stimulating and sharing knowledge, innovation and digitization and promoting their use in – largely by farmers through better access to research, innovation and knowledge exchange and through training. In order to further improve the sustainable development of agriculture, food industry and rural areas, the general objectives of the CAP are aimed at the economic fabric of rural areas, the sustainability and income of agricultural holdings, the better quality of performance in the field of environment and climate and strengthened socio–economic structure of rural areas.

The transition to a more performance–oriented policy requires the establishment of a robust performance quality framework that, based on a set of common indicators, will allow the Commission to assess and monitor the quality of policy implementation. The overall quality of policy implementation will be subject to a multi-annual assessment based on impact indicators, while the annual monitoring of the quality of policy implementation will be based on the full list of result indicators. Through the output indicators each year, expenditure will be linked to the quality of performance in implementing the policy; this annual process relies heavily on a list of final product metrics.

For the current Strategic Plan for the Development of Agriculture and Rural Areas for the period 2023–2027, more than 406 million Euros have been earmarked for organic farming (compared to only 168 million Euros for the 9 years from 2014 to March 2023), of which 331 million Euros for organic crop production, 41 million Euros for organic production of ruminants, permanent pastures and fodder crops, as well as 34 million Euros for organic beekeeping. Another 40 million Euros are planned for investments in organic processing. Organic farming maintenance payments will range from €177/ha for legumes and €257 for oilseeds to €1,182/ha for fruit and berries and €1,679/ha for heated greenhouses for vegetables.

With the joint initiative of several stakeholders in the field of organic agriculture (including the Bulgarian Association of Organic Products), the Ministry of Agriculture and Food intends to support the market of organic products through a program for feeding organic products in kindergartens in the period 2023−2027. The budget provides for 30% of government subsidies for those kindergartens that have signed contracts for organic food. The number of kindergartens included in this program is expected to grow by 100 each year. Significant benefits are expected as: planned sales for producers and changing the perception of consumers that organic food is only something for the upper–class.

This is just one of several measures developed by stakeholders in the field of organic production in recent years. As part of the National Action Plan for Organic Production until 2030, one of the first activities under this plan is a Bulgarian stand of BioFach 2023.

The Action Plan for the development of organic production is directly linked to the Farm to Fork strategy and the Biodiversity strategy, with which the Commission introduces the requirement that food production be combined with environmental protection and biodiversity conservation, a key factor for which is organic farming. In this regard, the strategic goal set by the European Commission (EC) is to increase organic areas, assuming that by 2030 at least 25% of the agricultural land of the

European Union (EU) should be cultivated according to the rules of organic farming, Agriculture [4].

The European Commission emphasizes that the member states should engage all interested parties – state institutions, operators involved in organic production, relevant associations, local and regional authorities, wholesalers from the food industry sector, consumer representatives, the sector – the hotel and restaurant industry, including catering service providers and nutrition education associations, as well as citizens, to adopt, review and implement their national plans for the development of organic production to achieve the best opportunities for increasing areas and to stimulate demand for organic products.

With the adoption of the National Plan for the Development of Organic Production until 2030, the implementation of the acts of the EU institutions and their strategies will be ensured, as well as the implementation of a long–term national policy for the development of the organic production sector in the country.

The strategic goals in the National Plan for the Development of Organic Production until 2030 are: 1) Organic food and products for all: stimulating demand and ensuring consumer confidence; 2) Stimulating the transition and strengthening the entire value chain towards 2030; 3) Organic production as a role model: improving the contribution of organic farming to the sustainability of the sector.

Financial assistance is provided for interventions that contribute to achieving the specific objectives of the Strategic Plan [5]: 1) improving market orientation and increasing the competitiveness of farms in the short and long term, including a greater focus on research, technology and digitization; 2) stopping the loss of biological diversity and reversing this trend, improving ecosystem services and protecting habitats and landscapes.

II. Materials and methods

The research presented is part of the research tasks of the INVEST Regional Living Lab in Bulgaria established by University of agribusiness and rural development – Plovdiv (UARD). As part of the European University Alliance Innovations of Regional Sustainability (INVEST), UARD participates in Invest for Excellence in Regional Sustainability (INVEST4EXCELLENCE) project. Targeting the research efforts towards sustainable regional development, the INVEST Regional Living labs apply the quadruple helix approach to work on open innovations. The research is based on several case studies embracing the strategic framework for organic sector development and encouragement in Bulgaria, recent initiatives of the Ministry of Agriculture and Food, the activities of the non–governmental sector, including projects work, and the fast dynamics of recent years based on the facts according to the experience of family organic farms, as well as sharing opinions of key stakeholders in the sector, organization of events and discussions, etc.

III. Results and discussion

The development of organic farming in Bulgaria was first initiated by initiatives of academic institutions and international projects, although the relevant national legislation appeared in 2001. One of the projects led to the establishment of "Bioselena Foundation" or "Organic Farming" (1997), still functioning as one of the main drivers in the sector. The "new culture" in the attitude towards land, environment and food was difficult to develop because of various problems connected to the obstacles of the transition to a market economy in the country in this period, changes in the property, and private property in particular, access to finance and markets, lack of demand and legal protection, etc. [6]. The subsidy system has been characterized by its bureaucracy, strong control measures and too many sanctions.

The period is characterized by hesitations and uncertainties about the profits for the development of organic production in Bulgaria. In addition, there was a widespread belief that based on the specifics of organic production, techniques, certification and the realization of the product in the market, that organic operators are competitors for the limited amount of subsidy than allies in similar problems and needs.

The first National Action Plan for organic farming put the goal till 2013 to embrace 8% of agricultural land but the result was only 1,1%. Now, with the EU goal of 25% organic land, Bulgaria has only 1,7%. In the years since 2010 the organic land increases mainly because of big producers of sunflower and grain interested in the subsidy. There were evidences in which if the subsidy was not rendered in time, the producers quit organic. At the same time, essential oil plants and beekeeping were more reliable in organic sector development in the country. Although the rise in next year's reported, the decrease followed in the number of operators (after 2016), organic land (after 2018) and the number of organic apiaries (after 2019), mainly because unpredictability and uncertainty in the subsidy, as well as the systematic problems related to the low competitiveness of organic farms and enterprises, low–developed markets and non–functioning supply chains (Fig. 1) [6]. For the beginning of 2023 the country reported 4 841 certified organic operators, about 86 000 ha land, 230 000 apiaries, 10 000 cattle and 20 000 sheep.

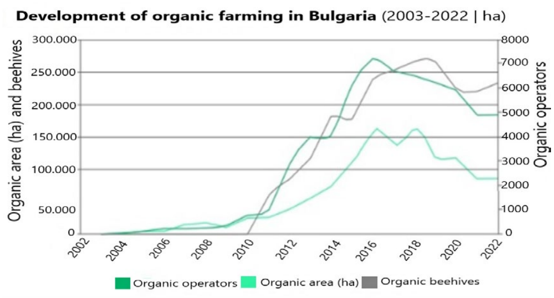

Fig. 1. Development of organic farming in Bulgaria [6].

On the other hand, it should be noted that the way of the supervision of controlling is characterized by a heavy burden on documents, administrative requirements and excessive sanctions that has led to a decrease in their number since 2016. The research also has revealed that the control system has absurdities described as: the organic certification is connected to the application for subsidy; three different systems for land identification in force with many disadvantages in functioning; shortages in the time of control requirements and risk assessment; minor omissions in documents can lead to decertification and unpaid subsidy; a very big number of checks, incl. by the ministry and the paying agency, etc. A controversial issue, however, was that the state policy in supporting organic farming is not consistent and fails to balance the vulnerable points. Experience shows that the subsidy (as an unfair public policy) is not the trigger to organic transition, but it can also turn into the biggest obstacle for the organic sector development [6].

The data presented in the project of the National Action Program to contribute to the goals of the Farm to Fork Strategy by 2030 [7], show that in the period 2013–2016 the relative share of organic crops increased and reached a maximum value of 3.2% (in 2016). After 2016, the share of areas occupied by organically grown crops began to decrease and reached the levels 1.71% (2021), i.e. after a period of expansion, a gradual shrinking of the areas of crops cultivated according to the principles of organic production is observed. During this period (2015–2021), the total number of operators covered by a control system decreased. Analogously and related to a decrease in the number of operators included in the control system with organic crop production, after 2016 a tendency to decrease the areas in the control system, including the areas in transition and the organically certified areas, was observed (Table 1).

TABLE 1. ORGANIC FARMING IN BULGARIA 2015–2021 [7]

Year	2015	2016	2017	2018	2019	2020	2021
Number of organic operators	6099	7164	6822	6478	6216	5844	4913
Areas in the control system (total, ha)	118552	160621	136617	128839	117780	116252	86310
Areas in transition (ha)	97013	124484	88164	44689	22225	19776	15887
Areas after transition (ha)	21539	36137	48453	84150	95555	96476	70423

Currently, while organic producers (+3.3%) and processors (+3.4%) are growing steadily in EU, in Europe they occupy on average about 3.43% of the total agricultural land and in the EU about 9.16% (2022), and Bulgaria is among the top European countries (Table 2.) for land use in organic agriculture with permanent crops (mainly grape) [8]. Among the main markets of organic products in Europe, Denmark is presented with the highest level of 13.0% (globally), Austria 11.3% and Switzerland reached 9.3% and with the fastest growth is ranked Germany with 22.3%.

TABLE 2. EUROPE LAND USE IN ORGANIC AGRICULTURE WITH PERMANENT CROPS – TOP 10 COUNTRIES [8]

Countries	Land use in organic agriculture, permanent crops	Countries	Land use in organic agriculture, permanent crops
Spain	662K	Portugal	66K
Italy	480K	Poland	32K
Turkey	205K	Germany	25K
France	194K	Bulgaria	25K
Greece	68K	Romania	22K

Note: Hectares (K=thousands)

While the markets and units of organic livestock production in the EU grow and become sophisticated (eg. systems of mixed plant and animal production) through new tools, policies and funding with a focus on eco–farmer and organic farming (eg. Organic Farm Knowledge – YouTube Channel), the sector of organic animal husbandry in our country is developing at a slower, but stable pace, compared to plant breeding. In 2022, the trend of weaker development of the organic livestock sector compared to organic crop production will be maintained. Bees, goats, cattle and sheep are raised organically in the country [7].

According to the Agrarian Report 2023, at the end of 2022, a total of 4,863 organic operators registered in the Ministry of Agriculture – 50 less than a year earlier, of which 4,260 are agricultural producers. There are 386 certified operators with the main and/or additional activity of processing, 693 with the activity of trade, 101 with the activity of import and 86 with the activity of export. In 2022, the number of organic operators in a control system represents 5.9% of the total registered farmers according to Ordinance No. 3 (January 29, 1999), on the creation and maintenance of a register of farmers, at 6.4% in 2021. In 2022, the trend of weaker development of the organic animal husbandry sector in Bulgaria compared to organic plant breeding will continue. Bees, goats, cattle and sheep are raised organically in the country. Compared to the previous year, there was an increase in the number of sheep, cattle and buffaloes in a control system and a decrease in the number of goats and bee colonies [1].

From Campaign 2023, the implementation of the new Common Agricultural Policy began with the introduction of interventions included in the Strategic Plan for the development of agriculture and rural areas 2023–2027 in Bulgaria, including a special intervention: Ecoscheme for organic farming (animal husbandry). Measure 11 Organic farming covers two sub–measures: 11.1 Payments for transition to organic farming and sub–measure 11.2 Payments for maintaining organic farming. Support is provided in three directions – organic crop production, organic beekeeping and organic animal husbandry. For the period 2015–2022, under measure 11 Organic farming, payments in the amount of BGN 330,180,793 were made. The funds paid out in 2022 amount to BGN 34,774,415. In 2023, financial support is planned for the interventions from the Strategic Plan for the development of agriculture and rural areas 2023–2027, including organic crop production and organic beekeeping [1].

For the academic year 2021–2022, under the “School Fruit” scheme, deliveries of fruit and vegetables were made by 111 approved applicants. Products were received by 428,268 children in 3,407 institutions in the system of preschool and school education. Apples have the highest share of fruit and vegetable supplies (over 1,600 tons, including 288 tons organically produced), followed by pears (668 tons, including 50 tons organically produced). Under the “School Milk” scheme, deliveries of milk and milk products were made by 101 approved applicants. Products were received by 428,154 children in 3,411 institutions in the system of preschool and school education. From the 2021–2022 academic year under the “School Milk” scheme, at least 4 of the supplies, but no more than 6, must be of organically produced fresh pasteurized milk and milk products. For the year 2021–2022, among the delivered organically produced dairy products, yogurt (204 tons) and fresh milk (50 tons) have the main share [1].

According to the project of the National Action Program to contribute to the goals of the Farm to Fork Strategy by 2030 [2] financial support for organic production through measure 11 within the 2014–2020 RDP plays a key role in attracting the interest of producers, including young farmers. During the implementation of measure 11 of the PRDP 2014–2020, payments were made for BGN 295,400,250.11 which is an average of BGN 42,200,029 per year and implies the presence of problems for the applicant farmers or problems from systematic errors made by farmers.

Data presented in the Agrarian Report 2023 show that the main place during 2022 was occupied by consultations under the 2014–2020 RDP – 31,444 (about 46% of all consultations). Compared to 2021, they marked a decrease of 16%. This type of consultation is mainly related to the possibilities of support under sub–measure 6.3 Start–up aid for the improvement of small farms, sub–measure 6.1 Start–up aid for young farmers, sub–measure 4.1.2 Support for investments in agricultural holdings, measure 9 Creation of producers' groups and organizations and measure 11 Organic agriculture from the 2014–2020 RDP. Specialized consultations are in second place with 16,526, and compared to the previous year, they also saw a decrease of 18%. The topics of the specialized consultations indicated in 2022 can be summarized in the main directions: agrarian economy – 5,872; crop production (including organic crop production) – 4,803; animal breeding (including organic animal breeding) – 2,968; rules for good agricultural practice (GAP) – 1,178; statutory requirements for management – 919; conditions for maintaining the land in good agricultural and ecological condition – 781; and others (agro–statistics, fisheries and aquaculture, forest management) – 5. Consult group “Direct Payment” schemes, “Market Measures and National Support” schemes numbered 8,152 in 2022. The greatest interest in this group was shown for consultations concerning: Single Area Payment Scheme; The production support linkage scheme for fruit and vegetables; National Beekeeping Program; National support schemes and state aid and payments for agricultural practices that are favourable to the climate and the environment [1].

A report to 2016 [9] states that the market for organic products in Bulgaria is relatively new and still too small, but at the same time rapidly developing. In the last few years, there has been a boom in the organic products market in the country. The number of specialized stores is increasing, as well as the number of large retail chains that are involved in the distribution of organic foods. Most of the Bulgarian organic foods and products are intended for foreign markets. Bulgaria is a traditional producer of various types of organically certified honey with excellent quality indicators, and a large part of the production is exported to the world market. Bulgarian organic fresh fruits and vegetables, milk and milk products, sweets, lyutenitsa, dried fruits and nuts, have excellent taste qualities and are highly valued on the European and European markets. Bulgaria mainly imports exotic products that are not produced in the country and raw materials used in the production of organic food, such as: cocoa, cocoa butter, various types of quinoa seeds, dates and date paste, coconut oil, coconut flour, etc. The third countries from which the country mainly imports are Peru, China, Tunisia, India, Sri Lanka, etc.

According to the project of the National Action Program to contribute to the goals of the “Farm–to– Fork” strategy by 2030 [7] most of the organic food in our country is exported, mainly to the European market. In 2022, the continued increase in the number of specialized stores for the sale of organic food, as well as the commercial establishments that are included in the distribution of organic food, is reported. The Ministry of Agriculture and Food carries out effective supervision and control in the field of organic farming which makes Bulgarian organic products legitimate on the common EU market. The development of the sector is promoted through information and explanatory activities about the benefits and advantages of organic farming.

Recently (November 7, 2023), the Ministry of Agriculture and Food launched the information campaign “Vocation: BioLogical!” [10]. The initiative was carried out jointly with the National Agricultural Advisory Service, the General Directorate of Agriculture and Regional Policy and the Regional Directorates of Agriculture. The information campaign aimed to promote organic production and attract more farmers to switch from conventional to organic production. During the events, the participants were introduced to the basic rules for organic production and the opportunities for support under the Strategic Plan for the Development of Agriculture and Rural Areas 2023–2027. Farmers were informed in detail about the differences between conventional and organic production, about its basic principles, regulations and obligations that should be observed when growing different crops and animals. During the campaign, the need for certification and the advantages it gives in the realization of production in the sector was explained, and good practices from the organic production of other countries were presented [10].

The initiative of the Ministry of agriculture and food “Vocation: BioLogical!” is becoming annual and aims to attract more new organic operators [11]. Over 500 new operators in the control system have been attracted to organic production after the information campaign of the Ministry of Agriculture and Food. We hope that during the campaign for submitting applications for support in 2024, they will be included in the implemented interventions for organic crop production, organic beekeeping and the eco–scheme for organic animal husbandry, said Deputy Minister of Agriculture and Food, Tanya Georgieva. The information campaign "Vocation: BioLogical!" of the Ministry of Agriculture and Food brought together nearly 2,500 participants. The events covered 56 settlements, half of which are in rural areas.

Despite the challenges, we expect that in 2024 we will be able to report an upward trend in organic production in Bulgaria, said Deputy Minister of Agriculture and Food Tanya Georgieva [12]. According to her, the European Commission (EC) already understands that the inflated green ambition of the EU is making it difficult for farmers, which is why the farmers' protests in many EU countries are. From 2020, when the legislative package for this policy was prepared, to the start of its implementation in 2023, the effects of the “Green Deal”, the Covid pandemic and the conflict in Ukraine should be taken into account, in terms of value and impact on the sustainable development of the sector, noted Deputy Minister Georgieva. In the negotiation processes, it was very strongly demanded by all national authorities that the Commission make a comprehensive assessment of the impact of the “Green Deal” on agriculture and food production. Also, to what extent the Common Agricultural Policy funds embedded in the EU Multiannual Financial Framework could compensate farmers and food producers so that they recognize the "green" objectives of the agricultural policy and have the motivation to contribute to their achievement, she commented. Deputy Minister Georgieva pointed out that from the standpoint of time and in the context of the Strategic Dialogue already launched by the EC, it is imperative at the European level to take into account the repeated appeals regarding whether a given ambition has been assessed fairly in the context of the new challenges.

The involvement in these initiatives of the non–profit organizations in the country working for organic production encouragement, such as the Bulgarian Association of Organic Products and “Bioselena Organic Farming” foundation, is very important. They join also efforts in projects funded by other sources.

Bioselena (2022), started the implementation of its new project “The Future of Farmers' Markets in Sofia” which is being implemented with the financial support of the Sofia Municipality – Europe 2021 Program. For 5 years, the foundation has been organizing a farmer's market “Produced on the Farm” in front of the building of the Ministry of Agriculture in Sofia. While in the process of holding the market, the facticology from the terrain, revealed that there is a great interest in such events in every location of the capital, it became clear that there are significant difficulties and problems in organizing and conducting farmers' markets. The project, aimed a dialogue between interested parties to reach an agreement regarding the conduct of farmers' markets [13].

Lastly (March, 2023), Bioselena launched a new project aimed at micro–enterprises in the food sector with the main goal – to provide opportunities for introducing energy efficiency measures and reducing food waste in them by means of: needs analysis; training and demonstration of good examples, and on –site training and mentoring in enterprises. The foundation's team will try to support enterprises through the project in increasing their capacity to implement measures for efficient use of resources. In the medium term, efforts are aimed at increasing the knowledge of managers and staff of enterprises regarding energy efficient production. In the long term, the project will aim to increase the number of enterprises implementing such innovative measures and ultimately reduce production costs and increase their profits. At least 60 micro–enterprises should be included in the project. Curricula and learning content in 2 modules will be developed: "Energy Efficiency" and "Circular Economy" with a focus on micro–enterprises from the food industry. The target is to train and inform owners and staff of micro–enterprises – a total of 80 people from 50 enterprises, as well as to provide individual support (mentoring and coaching) with at least 15 entrepreneurs starting projects to improve energy efficiency or introduce circular economy measures. Bioselena is implementing the project in partnership with the Norwegian non–governmental organization – Norges Vel [14].

The engagement of organic farmers in such initiatives and projects is very crucial. Below some examples will be presented, along with the experience of organic farmers.

The owners of the Wild Farm (where the circular economy challenge becomes a reality) are well–known to people all over Bulgaria [15]. For television viewers, they are stars of a popular reality show, and for their colleagues – an example of tireless work in the farm, processing and realization of the production. Betty and Niki Vasilievi close the circle on their farm from the meadows to the processing of the last animal bone. The farm has a processing unit and it is a successful example of integration agriculture and tourism activities [15, 16]. Wild Farm started with five or six cows (1994), with hard work and persistence today Blagovesta and Nikolay Vasilievi raise more than 1,600 cattle in an environmentally friendly way and cultivate 1,000 decares of land. Their farm is an example of energy efficiency and circular economy. The farm is organic and has Bulgaria's first certified organic slaughterhouse and plant for organic beef, where since 2018 over 45 products have been produced: raw–dried and sterilized delicacies, freshly chilled specialties and premium products without preservatives. All the raw material is used in the processing process, and finally the bones are boiled and beef stock is produced. What remains after boiling is fed to the vultures, one of the tourist attractions in the area that brings many tourists to their guest house. This is how a complete closed cycle is achieved: quality products without polluting the natural environment. Wild Farm can now say that it uses completely waste–free technologies in the production of its beef products [17].

A geographer has created a farm of the future [18]. The autonomous biodynamic farm Versol was established by a young family (2012) – a French graduate in geography, and his wife, a lawyer. Today, the family cultivates 140 decares of land, including about 3 decares of modern greenhouses and produces a wide assortment of quality organic certified fruits and vegetables: pepper, tomatoes, cucumbers, lettuce, spinach, alabash, courgettes, pumpkins, melons... They have fresh produce 10–11 months of the year. The farm supplies its produce online and also in several specialty stores. For the development of the farm, three projects under the Rural Development Program were of great importance but they were only a catalyst for its development, not a quest for subsidy. The farm has introduced significant innovations in production, such as 13 tunnel greenhouses, autonomous photovoltaic power plant, and automation of a drip irrigation system, irrigation water heating system with thermal solar panels, specialized agricultural software for management and planning of production processes (ERP system). The farm is one of the few in Bulgaria certified as biodynamic: production and work with biodynamic preparations, irrigation with structured water, treatment of plants with homeopathy, production of own compost, etc. In the farm, visitors can see innovative technologies of applying the principles of energy efficiency and the circular economy. Versol represents a completely energy independent farm. The owners of the farm are also socially engaged. Their goal is to become a social enterprise. They also deliver their produce to a home for mentally retarded children in the area [17]. Initially with the help of placing the produce at farmers' markets, today there are between 200 and 250 active customers, including people with a subscription and organic chains in the capital [18].

The idea of a group of entrepreneurs created the first trust store: Where and how it opened its doors and why no one steals the goods [19]. For the first time in Bulgaria, an organic fruit and vegetable farm opened not one, but two stores without a salesperson. And despite fears that the turnover from the cash register and the goods will not remain intact, there are no thefts. The experiment turned out to be extremely successful. Shopping at the stall is done in the following way – the customer chooses the product, writes it down in a special notebook, noting the kilograms and the value. Then he/she leaves the money in a box. If he/she is owed change, he/she takes from the money already left.

According to the representatives of the organic business, the potential for its development is high and that operators often encounter ambiguity in terms of knowledge rather than financial resources [20]. “Bulgaria can become Europe's organic oasis”, said Zdravka Smilenova, owner of an organic farm, the biohotel "Moravsko Selo" and a company for preparations and technologies Amititsa. “Interest in organic is increasing. We started doing this 18 years ago. At first only foreigners came. They gave us a great incentive, because then we felt how much this production and this food is valued. For the Bulgarians, it was something strange and foreign. Of course, the picture has already changed a lot. Many Bulgarians are coming. They appreciate nature, clean food. We have both long–standing regular customers and more and more new ones who are interested in healthy food”. According to Zdravka there are main misunderstandings “people associate organic with high prices which is not true; they say that organic is difficult to do, there are no yields, it's ugly or it's perishable and expensive... but now the science is very advanced, especially regarding biological protection of plants. Here's our chance. But much knowledge is still needed on how to apply this science in practice. Amititsa has a complete closed system. In Amititsa we have a complete product, a unique know–how – we have the production, we have knowledge, and marketing and realization – agrotourism. This is a mini version of what Bulgaria can become” – shares Zdravka. It works exclusively for the domestic market. It produces everything – spices, vegetables, fruits, etc. “Moravsko Selo” brand is very well established in retail chains. Zdravka thinks that the control issue is sick. Some things have to change. There must be people in the control bodies with the knowledge and desire to make it work. The mindset needs to change. Zdravka says: We must have knowledge, technology, and consistency in actions. All this is happening here and now, not in five years. By doing the right things, we reduce costs and thus have higher quality, lower cost output… Farmers need to be supported with knowledge to have high yields from their own production.

Despite the good examples, the organic sector is experiencing serious problems. Dr. Stoilko Apostolov, manager of Bioselena and advisor to the Minister of Agriculture and Food shared the following opinion: There are no problems with the quality of organic products in our country. Disadvantages are related to administrative burden, support, payments and reporting [21]. Apostolov says that “We persistently pretend that the European initiative Green Public Procurement does not exist…because it is not mandatory”. According to him, “Bulgaria can benefit in order to include Bulgarian food and producers in these public procurements, without violating the competition rule, but...certain interests hinders the implementation of the initiative” [22].

On its website, Bioselena tries to answer the question: can Bulgarian kindergartens, schools, hospitals and others buy organic food products from local producers [23]. For years, the version was circulated in the public space that when conducting public procurement, Bulgaria, as a member of the European Union, is obliged to ensure equal access to products produced in the Union. The other important parts are the so–called "Green Public Procurement" that the European Commission promotes. For now, they are voluntary for implementation by the member countries. Countries where politicians at national and local level are concerned about local communities have been successfully implementing the European Commission's Green Public Procurement guidelines for local food producers for years. Thus they stimulate local development, keep the regions alive and the livelihood of the local people alive.

In Brussels in translation: Bulgarian organic agriculture – running with obstacles to the European goal [24] Stoilko Apostolov shares: “The EU wants 25% organic areas, but we cannot exceed 2%”. According to him, Bulgaria's goal is to reach 5% organic areas by 2025. If this does not happen, sanctions will be imposed on our country. Our longer–term ambition is to reach 10% organic areas by 2030, which seems even more difficult against the background of trends in our country. Europe wants 25% organic areas, and we cannot exceed 2%, argued Apostolov. Even if we do not have sufficient consumption of organic products in our country, we have perfect conditions for export, believes the manager of the Bioselena foundation. According to him, there is a real danger that the 400 million Euros set aside for the support of organic production in the National Strategic Plan will not be fully utilized. In this case, this money will not be lost, but will be redirected to other directions, Apostolov pointed out.

In the comments on the project of the National plan for the development of organic production until 2030 [25], Bioselena proposes: 1) Local (Bulgarian) organic products in kindergartens, nurseries and kitchens in stages from 100 sites in 2024 (pilot testing) to 700 sites in 2030; 2) Step–by–step increase in supplies of organic dairy products, fruits, vegetables and honey under the “School Fruit” and “School Milk” schemes from 10–12 supplies for the 2023–24 school year to 40 supplies in the 2029–2030 school year. The association of controlling persons in organic production also supports these ideas.

Among the events, the annual Organic Farming Day during the International Agricultural Exhibition AGRA at the International Fair of Plovdiv organized by University of Agribusiness and Rural Development is one of the most significant annual meetings discussing the organic sector development, challenges and opportunities and possible solutions. The Organic Farming Day 2024, was organized as a workshop family business and succession in organic production in which good practices were presented but also the main obstacles in family organic farms and the most pressing problems in the organic sector in Bulgaria were discussed, particularly those connected to the financial support and the burden of the procedures [26]. The discussion concluded that organic needs no subsidy but markets.

According to Albena Simeonova, head of the Bulgaria Association of Organic Products, the main priorities in the sector are the National Action Plan, Bulgarian organic food in kindergartens, schools, hospitals, public establishments, etc, and changes in the national legislation and improvements in organic registries, etc. At the opening ceremony of the Organic Farming Day 2024 [26], Albena Simeonova said that they are “the voice” of the organic sector in Bulgaria and Europe and their protests are not on the street but on paper and in working groups at the Ministry of Agriculture and Food.

University of Agribusiness and Rural Development is working on several research tasks connected to organic production development, especially considering the opportunities of alternative food networks and integration of agricultural activities with tourism and other specialized services. In its research priorities organic production is also considered in the context of climate change mitigation [27]. Finally, the issue of the interconnections and relations between urban and rural territories are examined, particularly focusing on the social and cultural dimensions of sustainable development.

IV. CONCLUSIONS

Currently, when the increased consumer interest in healthy food with proven quality is reported, for the development of organic production in Bulgaria special attention should be paid to measures encouraging processing of raw materials (to add value) and promotion of short supply chains and organic farmers markets. While in the picture of the future, an increase in international food prices and conventional agriculture may be expected, and perhaps organic markets and prices remain uncertain, within the local–national landscape (and regionally) organic can provide multiple benefits [28] and the possibilities for the inclusion of organic products as a mandatory element of the menu of public catering facilities, state and municipal facilities, hospitals, schools, military departments, public services, etc. should be strengthened. “Greens” (eg green public procurement, etc.) promote and advance in many ways the organic ecosystem in the EU and policy neologisms (including standards and directives within Acquis) according to the Commission's methodology, should be carefully examined by the researchers of the field [29].

“Organics” should also address some of the challenges, such as (1) new and stronger community rules on organic; (2) strong competitive pressure of imported food; (3) still existing mistrust in consumers, misunderstanding; (4) incorrect labelling; (4) payments and subsidies under different financial schemes and measure with all their complexity, requirements, obligations and administrative burden; (5) growing cost for certification, control, sampling, analyses, etc. Raising awareness and capacity building and advisory services in organic production is an issue in a special focus along with consumers’ trust. Building easier access to organic products and markets is related to shortening the supply chain and direct sales, but also with the establishment of associations/cooperatives in organic production and marketing. The good practices and green innovations in the country and the developments recently launched in the EU [30] are essential for sector expansion and efficiency to challenging processes, improving knowledge and organic management methods.

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The Business Model of Alternative Food Networks in Bulgaria

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Abstract. The paper examines the alternative food networks in the agri-food sector in their variety of forms focusing on the issue of sustainable production and consumption, and particularly high quality and safety of products. Special attention is paid to the development of organic production and the potential to integrate it with some types of alternative food networks in Bulgaria. The study was implemented at the INVEST Regional Living Lab in Bulgaria under the research task of Alternative food chains and new business models. The focus on the development process of open innovations in the living lab predetermined the use of the participatory approach in the quadruple helix of research work. The opportunities of students' involvement are of special consideration, particularly emphasizing the need of new training programs and approaches oriented towards the real business and practice for capacity building in sustainable rural development. The paper presents a business model for development of an alternative food network in Bulgaria considering the main characteristics of the spatial, social and economic proximity in short production and distribution chains. The model envisages students' engagement in the main activities of an entrepreneurial initiative in University of agribusiness and rural development.

Keywords: Alternative Food Networks (AFNs), Alternative Food Chains, Organic Production, Organic Marketing, Living Labs.

I. Introduction

Retail chains are increasingly consolidating their marketing dominance. The use of classic supply chains and the ability to solve distribution problems in a complex manner gives them the opportunity to dictate the rules of the market, achieving a much lower cost per unit of product compared to their competitors located in small and micro businesses, facilitating opportunities for expansion and strong concentration on the market. The range of trade concessions they demand from their counterparties enables them to maintain long-term low, cost-oriented, price levels of final consumption goods. This increasing pressure can harm the entire chain, due to the inability of manufacturers and suppliers to be able to restructure and quickly optimize their operations to meet the new requirements [1]. The result – low prices, but more and more customers with a decreasing degree of satisfaction, refracted through the lens of shaky quality and vicious manufacturing practices. One

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possible solution to this deepening dissonance between the desires and actions of consumers and retail chains can be found in the business model of alternative food chains / networks (AFNs).

AFNs can be seen as a set of food provisioning practices that are distinct from mainstream food systems [2], operating on a production-distribution-consumption model and characterized by a minimal number of units in the supply channel, due to its spatial, economic and social proximity [3]. A study [4] defines alternative food chains as networks that include producers, consumers and other stakeholders and that are intended to create or expand a market for food that is the product of certain types of production and/or approaches to distribution. Another definition of alternative food chains was also correctly given which defines them as value chains that include direct links between producers and consumers based on the principles of fair and ecological trade [5].

Alternative food networks are seen as a response to the food crisis and as a promising basis for a new food chain based on the sustainable development paradigm [6]. Their activities are aimed at implementing a process of relocation and resocialization of production, distribution and consumption practices, with the aim of building a more ecological, socially just and economically sustainable food system. Alternative food networks encompass a variety of food supply and sale practices that differ from mainstream food systems and are based on three key concepts: accessibility (both for sale and for agricultural and food products); sustainability (in economic, social and environmental terms); quality and connections between participants [7].

The first category of short food supply chains (farm shops, agricultural markets, roadside sales, boxes, home delivery, e-mail, e-commerce) is mainly based on face-to-face interaction as a networking mechanism for producers and consumers. Consumers buy products directly from the manufacturer/processor, and authenticity and trust are built through personal interactions. This category broadly matches the narrower definition of direct sales, it can be somewhat expanded through the use of the Internet but generally remains limited to individual farms. The second category (farm store groups, consumer cooperatives, CSAs, events, restaurants, tourism businesses, institutional catering, etc.) goes beyond direct interaction and is primarily based on proximity ties. The extension of short food chains over greater distances implies the construction of more complex institutional mechanisms. Food networks are mainly based on spatial proximity, where products are sold in the region or place of production and consumers are aware of the “local” nature of the product at the point of sale. The organization of activities - events, fairs, thematic routes, etc. can contribute to the regional identity of products, attract customers and promote network development. Such networks can also be based on cultural proximity. The third category (certification marks, product codes, reputational effects) further extends the scope of short food chains to wider temporal and spatial links, where products are sold to consumers outside the area of production and who may have no personal connection and presence in this region. However, they are still considered 'short' food supply chains - what matters is not the distance the product is transported, but the fact that it has value and information that reaches the consumer, allowing the consumer to make the “connection” with the place of production, the understanding and values of the people and the production methods used. Namely, the successful transmission of information allows products to be distinguished from “anonymous” goods and to be charged a “special” price if the information in them is considered valuable to the consumer [8].

Alternative food networks are defined from the perspective of short supply chains as initiatives and practices with the potential to contribute to the sustainable development of rural areas at a time when the crisis in conventional intensive agriculture is increasingly emerging and consumer pressures are increasing the variety for food products of “different” quality [8]. As part of alternative food networks, farmers' markets are characterized as trading venues for small-volume food producers to “retain” some of the production value lost in conventional food systems [9]. Farmers' markets are described as a social phenomenon for the transition to sustainable development. They are seen as an incubator for new businesses every year that absorb the full sales value of their products by skipping middlemen. They continue to grow in number, in terms of sales volume and length of season. However, farmers' markets are much more than a place to sell food and have become essential public institutions - a place for meetings and social interactions, a well-established marketing system with great potential for sustainable development [10].

Examples of AFNs are farmers markets, community-supported agriculture (CSA), farm stores, and others where food products carry social and spatial information that differentiates them from conventional agri-food systems [11]. The common understanding of these examples is that they offer local, clean and healthy food, and can encourage holistic production methods as the organic production, in particular.

In Bulgaria, organic production is accepted as a production system that meets the objectives and priorities of the Farm to fork strategy as the type of production with the greatest contribution to the protection of environmental components, the highest opportunities for market realization, due to the ever-increasing demand and the highest social responsibility (in terms of the safety of the manufactured products, response to the desire of consumers to eat healthy and care for the environment) [12].

The purpose of the study was to make analyses of the current situation in the marketing of local food, organic in particular, and to provide a solution to the shortages and obstacles for its development based on the notion of the alternative food networks considering the contemporary trends in demand and supply based on consumers’ and producers’ behaviour and the impacts of the inspirations after a sustainable way of life.

II. Materials and methods

The study was implemented at the INVEST Regional Living Lab in Bulgaria under the research task of Alternative food chains and new business models. The focus on the development process of open innovations in the living lab predetermined the use of the participatory approach in the quadruple helix of research work engaging local stakeholders, and students in particular. The formed working group conducted a field study in line with the task of the INVEST Regional Living Lab implemented in University of agribusiness and rural development - Plovdiv. The students' involvement were of special consideration, particularly emphasizing the need of new training programs and approaches oriented towards the real business and practice for capacity building in sustainable rural development and practice-oriented training and integration to research.

III. RESULTS AND DISCUSSION

According to a study published in 2009, the consumption of organic products is low [13]. The main problem pointed out is the weak awareness of consumers regarding the advantages of these products, as well as the opportunities to distinguish organic products from possible imitations. The limited distribution of organic products could be an obstacle to consumption - the lack of specialized stores (with little exceptions in capital city and some towns in the country) and also of accessible information sources where reliable information about the distribution of products in the commercial network can be found. That year, the conclusion is that in general the organic products market in Bulgaria can be defined rather as nascent.

Understanding the strengths of the market as those characteristics of production, consumption and distribution that can be evaluated as positive, or turn into opportunities for future development of the market, the following could be outlined: the image of Bulgarian organic products is of good quality products and their competitiveness is high; price advantages of Bulgarian organic products; big variety of organic products; expanding distribution channels; regular customers; established legislation and control system, etc.

Understanding weaknesses of the market as those characteristics of production, consumption and distribution that have a negative impact, respectively can become dangers for the future development of the market: the low market share of organic products compared to conventional substitutes; insufficient awareness – both about the existence of organic products and of the ways to distinguish them of fakes and similar products with natural ingredients; the lack of popularity of organic products, mostly the society accepts "natural" products which are not always and in most cases are not organic; unjustified attitudes and expectations towards organic products, which in turn can lead to disappointment and withdrawal; the reduced consumption (relatively small number of consumers), limited distribution channels and low consumer awareness; the presence of imitations creates a feeling of mistrust in the market among some consumers and can become a prerequisite for refusal of consumption; lack of established brands and variety of brands; sophisticated market quality control system; insufficient supply in hotels and restaurants; low share of organic land in the country; insufficient subsidy and financial support to organic, etc.

Determining the market for organic products as developing means that the opportunities to expand the consumption, production and distribution of such products in the country are yet to come. Development potential can be found in the following areas: increasing the range of products offered in the commercial network; offering more organic products in other types of commercial establishments (not for sale), such as hotels and restaurants; diversification and expansion of distribution channels, incl. online (an opportunity for market development can be found in diversifying the types of commercial establishments offering organic products, as well as in the assortment they offer); stimulating demand by attracting new users; stimulating demand by increasing the awareness of current and potential users; increasing the production of organic products in order to diversify the supply; stimulating producers through a package of support measures; increasing interest in "greening" the life and environmentally friendly practices, etc.

Understanding threats to market development as all those factors that could negatively affect the development of this market in the future, both in terms of consumption and distribution and production: shrinkage in consumption due to high product prices; shrinking consumption due to the presence of many fakes and imitations; reduction in consumption due to insufficient popularity of organic products; reduction in consumption due to insufficient availability of organic products; limited distribution channels pose a risk; shrinkage of production due to insufficient subsidies; contraction of production due to unfavourable external economic factors, etc. Most of the current producers of organic products are micro-enterprises that are more dependent on the external macroeconomic environment than large ones. Therefore, the deepening of the economic crisis is one of the factors that could negatively affect Bulgarian organic producers.

Based on the analyses, the study [13] provides the following recommendations:

- Recommendations to drive demand – raising awareness, targeted information campaigns, etc., incl. though the use of Internet.
- Recommendations for diversifying the offer – orientation towards the organic "niche", information provision and motivation, integration with tourism, etc.
- Recommendations to stimulate and expand production – information, motivation, advisory and financial support.
- Recommendations for improving the regulatory framework – especially regarding the control system and labelling.

In 2016, a study came to the conclusion that the organic products market in Bulgaria is relatively new and still too small, but it is rapidly developing. The number of specialized stores and large retail chains involved in the organic products distribution is increasing. But still, most of the produce is for export [14].

In 2023, the situation is not much different. Organic produce is mostly exported [12].

The following were identified as weaknesses of organic production in Bulgaria:

- Lower average yields from organic farming compared to conventional ones;
- Underdeveloped processing sector, as well as non-promotion of short supply chains and organic farmers markets;
- Export of organic products mainly as raw material (i.e. dded value is exported);
- For part of the organic sector, an essential motive for production is the receipt of subsidies;
- Limited production of organic feed;
- Insufficiently qualified workforce in the field of organic production;
- Weak connection between science, business and the state;
- Small market for authorized plant protection products for organic production which makes them more expensive and lack of information on authorized plant protection preparations for organic production;
- Non-permanent financing for the presentation of organic products at national exhibitions and forums in order to stimulate trade and exports, including and for the expansion of the markets for Bulgarian organic products (there is a lack of certainty and predictability).

Taking advantage of the existing opportunities will contribute to the sustainable development of organic production in Bulgaria:

- Increased consumer interest in consuming food with proven healthy qualities;
- The demand for products from short chains is significant and the short supply market should be expanded, and organic products are suitable for this type of supply;
- Continuation of the implementation of interventions from the national strategies to support organic agriculture and the possibility of implementing separate measures and schemes financed with European funds;
- Approval of new channels for the sale of organic products in the commercial network;
- Growing interest in organic products on a European scale which creates conditions for better realization outside the country;
- Possibility of including organic products as a mandatory element of the menu of public catering establishments;
- Introduction of local organic products in the food offered in state and municipal facilities, hospitals, schools, military units, etc.;
- Electronic databases for certified operators, controlling persons, seed and planting material can be improved, efforts to improve the created bio-register should continue;
- Stimulation of bottom-up local economic initiatives and attitudes towards associations/cooperatives;
- Linking the environmental policies of the state with organic farming;
- Introduction of criteria with target budgets for the selection of project proposals and introduction of restrictions that ensure a fair and appropriate allocation of funds.

At the same time, organic production in Bulgaria faces and must deal with the following threats:

- Growing requirements for agricultural producers in terms of environmental protection and the new Community rules from 2022 for organic production, which make production more expensive and create difficulties for organic operators;
- Strong competitive pressure of imported foods;
- Existing mistrust among consumers due to misunderstanding and incorrect labelling of biological products;
- The same amounts of compensatory payments in organic farming for crops falling into the same group, but with different production costs;
- Growing costs for certification, control, sampling and analyses;
- Underdeveloped processing sector of biological production.

Based on the analysis of organic production in Bulgaria, it can be summarized that it is necessary to stimulate the consumption of organic products, which includes raising awareness (conducting information campaigns about the benefits of consuming organic products) and consumer confidence in the quality of Bulgarian organic products [12]. At the same time, it is imperative to encourage producers to apply organic production methods and processors to process organic raw materials into value-added products.

These actions should be supported by easier access to markets, which includes: shortening the supply chain, direct sales, associations/cooperatives of organic operators in order to create a more favourable environment for the realization of the production, carrying out information and communication campaigns about the already existing farmers markets and organic operators carrying out direct sales, as well as their public announcement in the organic register for the activity “direct sales of organic products from a producer”. Also, the development of organic production in the country requires efforts and actions to increase the knowledge and skills of organic operators for the implementation of the new rules in the sector.

When examining the emerging trends, it could be argued that the motivation of buyers to economically support local micro-businesses is growing, channelling fairly, from their point of view, the overcharge formed. For their part, they expect optimal product quality and a high degree of satisfaction. This process is fuelled equally well as by the ever-increasing Wellness idea which brings to the fore a pro-active and healthy lifestyle, as well as the increasing purchasing power or desire to consume goods with guaranteed taste, quality and origin of not a small part of the users.

These processes go hand in hand with the increasingly popular practice of more and more local producers isolating traditional supply chains by choosing to organize the sale of their produce themselves. The aim is to adapt the process in such a way as to avoid the unfair distribution of mark-ups between the numerous units in the distribution channel. Traditionally, the shorter the path of the goods from the producer to the final customer, the more serious the markup that remains with the original source. Each subsequent link in the chain increases the price of realization to a stage where it becomes unacceptable for the end user who in turn buys in the condition of continued crisis and stagnation. The current situation often causes the producer to sell around or even below cost which often leads to bankruptcy or refusal of further activity by farmers and producers.

Ultimately, the ever-expanding palette of trading methods is observed, such as the use of stationary specialized sales outlets, mobile sales outlets, automated mobile sales systems (vending machines), renting stands at temporary markets and markets, personal deliveries, web-based trade, trade through social networks, word-of-mouth trade, etc.

Of course, these relatively "exotic" commercial solutions are not a panacea. The formed working group, conducting a field study in line with one of the tasks of the INVEST Regional Living Lab implemented in University of agribusiness and rural development - Plovdiv, found the following weaknesses and/or problems in the commercial relationship thus established.

- lack of clear periodicity in the "trading sessions", as well as the too frequent change of trading places;
- insufficient predictability and quantitative discrepancies in the supply-demand system;
- insufficiently justified expenditure of time and energy on the part of users. They are often left unsatisfied by non-compliance with location, trading hours or scarcity of produce;
- lack of opportunity to build sustainable trade relations. This type of trading becomes more of a lottery than a planned choice;
- admission of unregulated commercial practices, which are more associated with the "grey" sector of the economy than with the legally established order.

As a result of the problems thus defined, the working group consolidates around one of the possible solutions and proposes the development of specialized software for commercial communication which resembles the established models for food delivery in urban conditions but is adapted for the specific purposes of encouraging organic production and sales.

The creation of a mobile application that acts as a mediator between the search for farm (particularly organic, but in separate sections also homemade food or the so-called "artisanal food" which are more popular and can attract new customers) in an established and controlled manner, produced in suburban areas and marketed in a regulated environment should counteract some of the noted weaknesses. The institutionalization of this issue should be accompanied by the adoption of an Ordinance on the trade in homemade food which is in the stage of public discussion. The state administration believes that the operational decisions resulting from this act will enable producers in rural regions to legalize their production, guaranteeing the safety of the final products - words of the Deputy Minister of Agriculture and Food Georgi Sabev [15].

Building this type of a marketing platform for trade and advertising would increase flexibility and adaptability in distribution channels after incorporating existing door-to-door delivery systems. The extreme increase in their popularity and accessibility especially increased after the negative effect that the COVID-19 crisis had on the present trade. On-line ordering with courier delivery has established itself as a preferred form, and this, together with the natural penetration of digitalization into the lives of consumers, gives reason to think about the high success rate of the presented project. This platform will make popular different events and actions, incl. trainings, good practices, etc., it will present successful real stories in organic production, will provide information and advice, etc.

Regarding the business model implemented in this platform, below the summary of the idea is presented based on the notion that "you must build something that real people with real needs will find value in and pay for" [16].

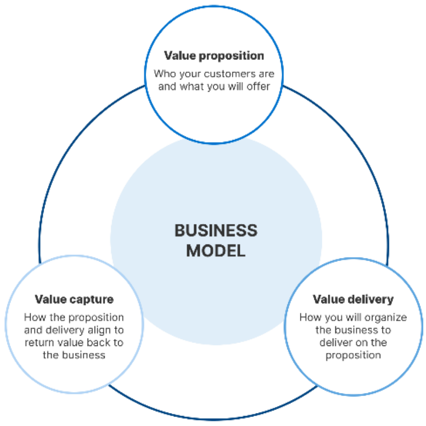

Fig. 1. Business model components [16].

In the proposed model the components (Fig. 1) are referred as follows:

Value proposition – customers interested and engaged in local development, with sustainability awareness, demanding healthy products and environmental protection, particularly organic products, not having much time / chance to go shopping on local markets / farms but preferring online trade.

Value capture – local business development and transition to environmentally friendly production systems as organic production, use of the advantages of short supply chain, information and awareness, added value through processing, etc.

Value delivery – establishing a local marketing and information platform engaging students with delivery to home.

The model proposed considers contemporary trends in increasing activity online – both of consumers and producers. It takes into account the rising use of social media (Facebook in particular) and the practices to "arrange" orders and supplies via Messenger. Usually, the delivery comes once a week at some place (not a market), unofficially. These practices try to overcome all the barriers and problems that farmers' markets experience, especially legal and organizational, but also financial and other.

Having the platform proposed is a better alternative to other initiatives. The main concept of the platform envisages the great students' engagement which will be something quite new to current practices in the country and the ways of raising the awareness and demand for local and healthy food.

IV. Conclusions

Examining the alternative food networks in the agri-food sector and their potentials for development in Bulgaria in their variety of forms, has its focus on the issue of sustainable production and consumption, and particularly high quality and safety of products. In that relation, the study presented pays a special attention to the development of organic production, particularly organic marketing, and the potential to integrate it with some types of alternative food networks in Bulgaria.

The paper presents a business model for development of an alternative food network in Bulgaria – information and marketing online platform, considering the main characteristics of the spatial, social and economic proximity in short production and distribution chains. The model envisages students' engagement in the main activities of an entrepreneurial initiative in University of agribusiness and rural development, Plovdiv, as part of their training and integration of research.

Such a model doesn't exist in the country for now. The research presented in the current paper is the first step outlining the main concept. It will be the basis for the next step of the detailed description of the platform proposed and its establishment as a functionality and a good practice.

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Theoretical and Practical Aspects of Green Entrepreneurship Development: A Study of Latvia's Experience for Ukraine's Post-war Recovery

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Abstract. The purpose of the study is to substantiate the theoretical and methodological provisions and develop practical recommendations for the development of green entrepreneurship for the post-war recovery of Ukraine based on the experience of Latvia. The scientific novelty of the study lies in solving an important scientific and applied task - further development of theoretical aspects of green entrepreneurship, substantiation of the relationship between eco-innovation, green growth strategies and environmental policy in the context of sustainable development. The study uses general scientific and special methods: scientific abstraction, deduction, analysis and synthesis, systemic and critical analysis, structural and logical, ascent from the abstract to the concrete, and statistical analysis. It is proved that the Latvian business ecosystem is adapted for highly efficient investments and innovations in the field of green technologies. The study identified guidelines for environmental policy that will promote the development of green entrepreneurship, increase the density of green infrastructure, extend the life cycle of high value-added products manufactured in the country, reduce waste and encourage recycling. The importance of studying the experience of Latvia in strengthening the strategic framework for sustainable development and green growth for the post-war recovery of Ukraine is substantiated. It is determined that improving the quality of environmental infrastructure and services, as well as investing in innovation potential, will ensure the decoupling of economic growth from resource use and environmental depletion and accelerate the transition to a closed-loop economy. The authors propose the components of a «green» post-war recovery of Ukraine in the context of its further European integration.

Keywords: «green» entrepreneurship, «green» growth strategy, «green» recovery of Ukraine, Latvian experience.

I. Introduction

Climate change, environmental degradation and unsustainable use of resources, and, as a result, the emergence of serious and complex environmental problems faced by modern society, require a transition to a more environmentally friendly future. This process is becoming increasingly relevant in the current global context, when all countries face difficulties in establishing and ensuring the effective functioning of business entities aimed at implementing green and sustainable practices. In this regard, the «trajectory» of the global economy is changing in the direction of environmental sustainable development, and emerging «green» markets are opening up new opportunities for «green» entrepreneurs to carry out activities related to the

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production and sale of innovative environmental products with high added value and the creation of new jobs, while contributing to the development of a «green» growth strategy.

To date, most researchers have used the terms «green entrepreneurship» by Berle [1], «environmental entrepreneurship» [2] – [3], «ecopreneurship» [4] to describe the relationship between the environment, sustainability and entrepreneurship, considering them interchangeable, equating them with each other and associating them with business entities seeking to reduce the negative impact on the environment.

The study of the categorical and conceptual apparatus of green entrepreneurship and the generalization of its terminology, the differences between the concept of green entrepreneurship and green growth and sustainable development, the factors that influence the development of green entrepreneurship and its stimulation are devoted to the scientific works of Blue [5], Bennett [6], Isaak [7], Farinelli [8], Thompson [9], Demirel [10], Haldar [11], Domańska [12].

However, despite the growing interest of scientists and stakeholders in the concept of «green entrepreneurship» and their identification of its foundations in the context of sustainable development, the issues of further disclosure of the theoretical essence of «green entrepreneurship» and structuring of its components, as well as substantiation of the essential and functional characteristics of the concept are relevant, which requires further scientific study.

The objective of the study is to summarize the theoretical and methodological support of the studied issues and to substantiate the importance of studying the experience of Latvia in strengthening the strategic framework for sustainable green growth strategies and environmental policy in the context of development and «green» growth for the post-war recovery of Ukraine. The research period is 2023-2024.

The scientific novelty of the study is to solve an important scientific and applied task - further development of theoretical aspects of green entrepreneurship, substantiation of the relationship between eco-innovation, sustainable development.

II. Materials and Methods

Achieving the purpose of the study and solving the tasks set was determined by the use of general scientific and special methods of scientific knowledge: scientific abstraction, deduction, analysis and synthesis (for conceptualizing «green» entrepreneurship in the context of sustainable development), systemic and critical analysis (for interpreting «green» entrepreneurship in the context of the formation and development of sustainable business ecosystems), structural and logical, ascent from the abstract to the concrete (to determine the components of «green» post-war recovery of Ukraine).

III. Results and Discussion

In the report «Climate Change 2022: Impacts, Adaptation and Vulnerability» a conclusion made that «climate change is a long-term challenge, but the need for urgent action now is clear… The cumulative scientific evidence is unequivocal: climate change is a threat to human wellbeing and planetary health. Any further delay in concerted anticipatory global action on adaptation and mitigation will miss a brief and rapidly closing window of opportunity to secure a livable and sustainable future for all» [13].

One of the ways to adapt the global economy to the devastating effects of climate change is to introduce and develop the concept of green entrepreneurship, which ensures environmental sustainability and social equality by transitioning to sustainable production and consumption, increasing resource and energy efficiency, developing renewable sources, developing eco-innovations, increasing green investment, etc.

In recent years, entrepreneurship has become increasingly interested in the formation of sustainable innovative business ecosystems that operate in accordance with environmental requirements, exploring their business opportunities that minimize environmental impact [14] – [16]. Given this approach, it is green entrepreneurship, using new technologies, that can contribute to the sustainable transition of ecosystems to sustainable development. «Green» entrepreneurship is an emerging area of interest in a world that faces the need to achieve economic growth while using natural resources sparingly and minimizing pollution [17].

Despite the fact that over the past two decades there have been many discussions among scholars and practitioners on the issues of economy, environment and social development, there is no consensus on the terminology and definition of green entrepreneurship. In the emerging green economy, research on this topic mainly focuses on the causes and consequences of the transformation of modern enterprises into more sustainable and environmentally responsible ones, as well as on identifying barriers and prerequisites related to the transition to a green lifestyle.

The results of the analysis of the scientific literature on green entrepreneurship show that, according to many authors, it emerged at the intersection of innovation and entrepreneurship, and the activities of enterprises based on the ecosystem approach meet the needs for a more environmentally friendly and environmentally friendly approach to business, offering practical and innovative solutions to social and environmental problems. The ability of enterprises to implement and benefit from eco-innovations depends on the stage of their life cycle and the stage of the industry's life cycle [18].

Accordingly, a number of definitions of «green» entrepreneurship and related terms have been proposed that reflect various aspects of environmentally oriented business activities.

For example, Haldar [11], summarizing the results of the analysis of the definitions of green entrepreneurship by different authors, proposes to classify them according to such aspects of entrepreneurship as the «organizational characteristic» of enterprises, the «process» associated with «green» entrepreneurship and the «environmental results» that entrepreneurs seek to achieve.

Anderson [19], Isaak [20], Volery [21], Walley [22], Gliedt [23], Demirel [10], Nikolaou [24], Domańska [12] consider the concept of green entrepreneurship in terms of understanding the activities of different types of green (environmental) entrepreneurs, including their motivation for it.

The OECD [25], based on the results of its study, emphasizes that the definition and terminology used to describe the concept of «green» entrepreneurship varies significantly from country to country, depending on the specific sectors of SMEs, where the integration of environmental sustainability principles into business processes can lead to a high level of commercial benefits. For example, in Canada, the term «cleantech» is used to describe the types of products and services typically developed by environmental entrepreneurs; in Germany, the concept that encompasses technologies that offer solutions to preserve the environment and meet basic human needs in a sustainable way is called «greentech»; in Israel, climate technology companies that develop technologies aimed at mitigating and adapting to climate change are called «climate tech». In Denmark, the definition of «green» entrepreneurship is not limited to any specific sectors, issues or drivers, but instead aims to encompass the many ways in which innovative actions by green entrepreneurs can address sustainability challenges.

«Green» entrepreneurship is a means of achieving the goals of green growth and sustainable development, and at a basic level, it arises from society's need to address environmental issues. On the other hand, sustainable development provides an important context for «green» growth. The OECD Green Growth Strategy [26] states that it promotes economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which the world's well-being and living standards depend. «Green» growth should be viewed as a subset of sustainable development, it is narrower in scope and creates the necessary conditions for innovation, investment and competition that can create new sources of economic growth consistent with sustainable ecosystems.

Given this theoretical background, the concept of «green» entrepreneurship, in our opinion, should be considered in the context of the formation and development of sustainable business ecosystems, which are a favorable environment for innovation to increase their value, and thus contribute to the achievement of sustainable development goals (Fig. 1).

The main prerequisites for the emergence of sustainable business ecosystems can be identified: orientation of business entities towards sustainable development; recognition of opportunities and resources for sustainable development; joint innovation on sustainable development opportunities; and the availability of a market for sustainable products.

«Green» businesses are «green» enterprises – SMEs that produce «green» products or services, or use «green» processes or technologies. As «green» businesses are classified as «green» jobs by SMEs, they take steps to ensure environmental, economic and social sustainability and provide fair employment. In addition, studies on «green» business have shown the benefits of greening in terms of cost efficiency, innovation compensation, revenue growth through product differentiation, increased transparency, reduced organizational inertia, better risk management, and improved relations with external stakeholders. As a rule, «green» technologies are more expensive and require higher start-up capital than traditional businesses. Bringing «green» technologies to market is often stalled at the proof-of-concept stage due to limited access and cost barriers associated with testing and obtaining market approval. Reducing these barriers by providing access to low-cost or subsidized testing and financial incentives, such as subsidies or tax breaks for green businesses, will help offset the higher initial investment costs. Conceptual foundations of «green» entrepreneurship. [27]. At the same time, increasing the market share of «green» technologies can have important socioeconomic benefits in terms of value added and employment [28].

It should be noted that environmentally friendly goods and services are not always competitive in the market, especially if they cost more than a conventional product. However, consumer environmental awareness, environmental labeling, perceived product performance, and cultural values can all influence the acceptance of environmental products and services [29].

The environmental goods and services sector, abbreviated as EGSS, also referred to as the green economy or eco-industries, consists of a heterogeneous set of producers of goods and services aimed at protecting the environment and managing natural resources. Environmental goods and services are products produced or services rendered with a primary purpose: preventing or minimizing pollution, degradation or depletion of natural resources; eliminating damage to air, water, waste, noise, biodiversity and landscapes; reducing, eliminating, cleaning up and managing pollution, degradation and depletion of natural resources; carrying out other activities such as measurement and monitoring, control, research and development, education, training, information and communication related to environmental protection or resource management [30].

«Green» enterprises use different approaches to producing environmental goods and services and greening their business processes. The most important approaches are as follows: development and implementation of eco-innovations; resource efficiency and cleaner production; life cycle management; cyclicality.

In recent years, eco-innovations and sustainable development-oriented innovations have become topics of growing interest in academia, organizations, and policy. Since the publication of the Brundtland report [31] in 1987, there has been a broad discussion about the introduction of eco-innovation into SMEs, i.e. the integration of environmental and social aspects into products, processes, and organizational structures.

The Background Statement for the OECD Global Forum on Environment on Eco-innovation in November 2009 declares: «Most OECD countries consider eco-innovation as an important part of the response to contemporary challenges, including climate change and energy security. In addition, many countries consider that eco-innovation could be a source of competitive advantages in the fast-growing environmental goods and services sector» [32].

Eco-innovation of products, processes, and business models aims to effectively change market structures, is closely linked to «green» growth strategies, drives each other, and requires the aggregation and interaction of technologies and resources. Some of the eco-innovation activities can add value to products at the production stage, improve the recyclability of goods after they are used, and increase the value of the product's use after it is sold. Obviously, the efficient use of resources can significantly reduce the operating costs of enterprises, and as a result, they will be able to invest more in eco-innovation. Such activities play a vital role in creating new jobs and implementing eco-efficient and sustainable growth strategies.

To assess eco-innovations, scientists propose using many indicators, but the main one related to the environment is the Global Cleantech Innovation Index, which was created in 2012. The index is calculated for 40 countries as a weighted sum of the scores of two groups of indicators: available resources and conditions for innovation (Inputs to Innovation) and achieved practical results of innovation (Outputs of Innovation). The final index is the ratio of the costs of innovation development to the effect obtained.

UNITED NATION's analytical reports and research by scientists present various conceptual approaches to environmental policy.

In our opinion, the most noteworthy are those that are consistent with the global Sustainable Development Goals.

For example, the DPPA, UNDP report [33] focuses on assessing the interaction between climate change and socio-political, economic and demographic factors that can lead to serious disruption of life, economic and political instability and insecurity at various levels. As a result, a spatial approach to data analysis is proposed to understand the spatial distribution of risks to climate security in different ecosystems, natural resource groups and livelihoods.

UNEP [34], in order to overcome the climate crisis and achieve the goals of sustainable development, has developed a science-based concept of a global environmental data strategy that outlines its principles and objectives, as well as a roadmap for its implementation and expected impact on the ground.

Marletto [35] in a scientific publication considers environmental policy as a combination of actions that can initiate, make viable and harmonize the institutional, technological and economic changes that are necessary to achieve sustainable development. In other words, the key concept in the study is the «socio-technical system» – a complex consisting of state institutions, technologies, markets and actors that evolve and meet common social needs.

That is, environmental policy should promote the development of green entrepreneurship and play a crucial role in global efforts to mitigate climate change. The process of its formation is influenced by political and economic factors, the level of development of society and its attitude to eco-innovations, the legislative and regulatory framework, and the degree of pressure of human activity on the environment.

Over the past few years, the global economy has experienced a series of profound shocks that have had a significant impact on SMEs. Following Russia's unprovoked aggression against Ukraine, new threats have emerged that complicate the economic environment, including rising geopolitical tensions and global financial risks, the energy crisis, high inflation, tighter monetary and fiscal policies, tensions in the financial sector, labor shortages, trade barriers, and slower integration into global value chains. As a result, the OECD's March interim economic forecast indicated that global GDP growth will slow to 2,7 % in 2023 from 3,3 % in 2022, and then accelerate slightly to 2,9% in 2024 [36]. However, given that SMEs activities have significant environmental impacts in aggregate, environmental urgency requires the use of all possible areas of improvement, including the further development of «green» entrepreneurship.

«Today, Ukraine-EU cooperation in the field of environmental protection is regulated by the Association Agreement between Ukraine and the European Union, the European Atomic Energy Community and their Member States. In particular, Chapter 6 «Environment» of the section «Economic and Industrial Cooperation» of this Agreement provides that the parties shall develop and strengthen cooperation on environmental issues and thus contribute to the realization of the long-term goals of sustainable development and the green economy» [40].

In this regard, «green» recovery, which is the basis of the future «green» strategy for Ukraine's post-war recovery, should be linked to full development and integration into the European Community on the principles of sustainable development, taking into account the European Green Deal, which is also a guarantee of achieving the Copenhagen criteria for EU accession.

This makes it important to study Latvia's experience in strengthening the strategic framework for sustainable development and green growth for Ukraine's post-war recovery.

Latvia has a well-developed and comprehensive framework for sustainable development, which is defined by the Sustainable Development Strategy 2030 (Latvia 2030), other legislative and regulatory documents of the country and the EU, and includes long-term priorities, goals and action areas aligned with the SDGs.

As one of the greenest countries in Europe, Latvia has a diverse natural capital that is a resource for business and job creation. The level of «green» infrastructure, which includes «green» areas (or «blue» in the case of aquatic ecosystems) and other physical facilities in land (including coastal) and marine areas, as well as rural and urban areas, is relatively high and will continue to grow.

Latvia has accumulated extensive experience in the production of electricity from renewable sources, it provides a favorable environment for innovative «green» energy projects and is a leading exporter of environmental technologies and resources to the EU. Hydropower accounts for 97 % of the country's total production, with wind and biomass accounting for the remaining 3 %. In addition, 40,4 % of annual energy consumption in the domestic market is provided by renewable sources. The prerequisites for the expansion of this sector are: easy access to raw materials due to the favorable geographical location; developed logistics infrastructure; high competitiveness in the production of high value-added products, transition to more high-tech industries [37].

Although Latvia's waste recycling rates have been lower than the EU average for ten years, the introduction of eco-innovations has intensified activities in the production and management of waste, namely biodegradable materials, wood waste, construction materials, etc.

Promising key industries that are pioneering «green» innovations and overlap with Latvia's Smart Specialization Strategy for Research and Innovation (RIS3) include knowledge-intensive bioeconomy, biomedicine, medical technologies and biopharmaceuticals, smart materials, technologies and engineering systems, smart energy, and information and communication technologies. It should be noted that the state budget and EU funds are the main sources of funding for environmental research. Latvia spends 9,5 % of the state budget on R&D and research related to the environment and energy. The environmental goods and services (EGS) sector in Latvia is growing moderately, but is less developed than in most EU countries: about 20 % of the country's SMEs offer environmentally friendly products and services, compared to the EU average of 24 % [39]. The main reasons for this indicator are low demand for these goods and services due to lower incomes and lack of awareness of sustainable consumption and production. This necessitates the development of a set of measures by entrepreneurs to stimulate demand for more expensive environmental products and services through green public procurement, environmental labeling, market incentives, awareness raising, and better enforcement.

The current guidelines of Latvia's environmental policy for 2021-2027 provide for [38]:

achieving the goal of reducing greenhouse gas emissions by 2030 and achieving climate neutrality by 2050; improving adaptability, strengthening resilience and reducing vulnerability to climate change; moving towards a renewable growth model by decoupling economic growth from resource use and environmental depletion and accelerating the transition to a circular economy; striving for a zero pollution environment free of toxic substances, including air, water and soil, and thus also protecting the health and well-being of Europeans; protecting, conserving and restoring biodiversity and enhancing natural capital, including air, water, soil, forests, fresh water, wetlands and marine ecosystems; promoting environmental sustainability and reducing the pressure on the environment and climate associated with production and consumption, in particular in the areas of energy, industrial development, buildings and infrastructure, mobility and food systems. Latvia's environmental policy guidelines, in cooperation with the new European policy, will increase the density of green infrastructure, continue to develop environmental innovations, extend the life cycle of green products produced in the country, reduce waste and encourage recycling. Based on the results of the study of Latvia's «green» experience, we can conclude that the main principle of Ukraine's «green» post-war recovery is compliance with European environmental planning instruments. In this regard, we propose the components of Ukraine's «green» post-war recovery aimed at balancing the interests of society, business and the environment. Components of Ukraine's «green» post-war recovery: Strengthening the strategic framework for sustainable development and green growth; compliance with the European Green Deal, EUR and Ukrainian environmental and climate legislation; international and public investment in lo-carbon infrastructure; promoting eco-innovation and green markets; stimulating the development of the EGS sector; Development of grant programs, competitions and other opportunities. [39]

Thus, Ukraine's «green» strategy is a strategy for the country's development based on the principles of sustainability, taking into account the requirements of European and Euro-Atlantic integration, international partnership, and current challenges. Implementation of the «green» model of Ukraine's post-war recovery requires unconditional support from international partners, especially the EU, and a fundamental change in their vision of Ukraine's role
and place in the future European and global economy and trade.

CONCLUSIONS

The documents of the UNITED NATIONS and its specialized bodies and organizations, the decisions of the G20 and G7, and the Global Risks Report show that the natural resources available to mankind are limited and rapidly depleting due to uncontrolled and irrational use, and the rapid growth of global production has led to global climate change, pollution and degradation of nature, and, as a result, serious environmental problems. The transformation of the economy towards ecology has laid the foundation for the concept of sustainable development and the creation of a green business model that ensures environmental sustainability and social equality through the transition to sustainable production and consumption, increased resource and energy efficiency, development of renewable sources, development of eco-innovations, and increased green investment.

The systematization and analysis of theoretical studies of various aspects of environmentally oriented

entrepreneurial activity has led to the conclusion that there is no consensus on the terminology and definition of green entrepreneurship, and the activities of enterprises based on the ecosystem approach meet the needs for a more environmentally friendly and environmentally friendly approach to business, offering practical and innovative solutions to social and environmental problems. Given that «green» entrepreneurship is a means of achieving the goals of «green» growth and sustainable development, we propose to consider its concept in the context of the formation and development of sustainable business ecosystems, which are a favorable environment for innovation to increase their value. It is proved that environmentally oriented enterprises can benefit from the creation of a developed sustainable ecosystem and a favorable business environment to a greater extent than ordinary enterprises, using eco-innovations and «green» technologies to produce «green» products.

To support the introduction, development, stimulation and dissemination of eco-innovations, a special public policy is required, namely, an environmental policy aimed at integrating and implementing a green growth strategy at all levels: global, regional, national and subnational. The process of its formation is influenced by political and economic factors, the level of development of society and its attitude to eco-innovations, the legislative and regulatory framework, and the degree of pressure of human activity on the environment. The study substantiates the importance of studying Latvia's experience in strengthening the strategic framework for sustainable development and "green" growth for the post-war recovery of Ukraine and proposes its components aimed at balancing the interests of society, business and the environment.

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WinFOLIA flag leaf analysis of winter wheat (Triticum aestivum L.) and evaluation of grain quality indicators

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Abstract. Winter wheat (*Triticum aestivum *L.) is one of the most widespread and economically beneficial crops in Latvia. Wheat grain yield and quality are strongly related to the growing conditions of crop that are possible to improve agronomically by carrying out an appropriate soil tillage and growing it in a well-planned crop sequence. The aim of the study to determine soil tillage system and precrop influence to winter wheat flag leaf parameters and grain yield quality indicators. A two-factor field trials was set up in the Latvia University of Life Sciences and Technologies training and research farm "Peterlauki" in 2022/2023: 1. soil tillage system and 2. precrop. The basic indicators of flag leaf length, width (cm) and flag leaf area (cm2) of a winter wheat were detected using a scanner STD4800 and the specialized computer program WinFOLIA Regent Instruments Software were determined from 10 plants in each variant. Three samples from each variant were taken for yield determination and structural elements of crops. Winter wheat 1000 grain weight and grain quality indicators were determined in Grain and Seed study and research laboratory of LBTU. Winter wheat precrop did not significantly affect (p>0.05) grain yield in the trial year, but the lowest yield was obtained in the conventional soil tillage system where wheat was grown in repeated sowings (5.1 t ha-1), and the highest yield in the minimal soil tillage system where precrop was field beans (7.0 t ha-1). The larger winter wheat flag leaf area was determined in both soil tillage systems, if the winter wheat precrop was field beans, the relationships are not significant (p>0.05).

Keywords: grain quality, precrop, soil tillage, WinFOLIA, winter wheat, yield.

I. Introduction

Wheat belongs to the family *Poaceae* and is an important cereal crop for the vast majority of people around the world [1] and it is also an annual staple food crop, with an average planting area of more than 23 million hectares in the European Union, with an average yield of 5.5 t ha^{-1} dry weight [2]. Literature also indicates that the main bread wheat is grown in various parts of the world, including Europe and Latvia [3], [4]. Research in scientific articles shows that wheat contains rich ingredients such as carbohydrates, vitamins (especially B vitamins), gluten proteins and phytochemicals that are essential for human health. In fact, the unique properties of the gluten protein fraction allow the processing of wheat into bread, pasta, pastries, noodles and the production of a wide range of functional ingredients [5], [6], [7], supplying a fifth of global food calories and protein [8], [9]. Furthermore, scientists from Uman National University of Horticulture, Ukraine Hospodarenko and Liubych [7] reported crop productivity is the most variable and significant indicator of their vitality, this increases their genetic potential, soil fertility, weather and aspects of the cultivation method. According to research findings from Latvia, the process of cereals' maturation and harvesting is possible during the rainy season, this is often attributed to a low quality of the grain and even grain sprouting in ears [10]. Indeed, just a few studies have noted that the sudden weather changes, floods, strong winds, heavy rains and storms, hail,

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droughts, which lead to significant environmental and economic damage around the world and affect the yield of most crops, especially cereals [11], is anticipated to have a marked negative impact on crop production [12].

Scientist from Kalam Technical University Lucknow, India [13] evaluated the most recent scientific studies that have been published, and concluded that the leaf is a reflection of the plant's health and the area of the leaf is one of the most important parameters in tracking the plant's growth. As a result, the greater amount of data is available to get about the leaf – the better quality of decision making is expected. Researchers Pandey and Singh [14] has accepted that the area of the leaf is estimated in studies of plant nutrition, competition, water relations, protection, respiration, light reflectance, and heat transfer in plants. Because of this, it's an important component of the understanding of photosynthesis, light interception, water and nutrient utilization, and the potential for crop growth and yield. In turn by University of Göttingen, Germany scientists study leaf traits are among the most important traits as they describe key dimensions of a plant's life history strategy. Further they emphasizes that leaf area is a key parameter with relevance for other traits such as specific leaf area, which in turn correlates with leaf chemical composition, photosynthetic rate, leaf longevity, and carbon investment. Measuring leaf area usually involves the use of scanners and commercial software and can be difficult under field conditions [15]. Scientists have proven in their research that the measuring leaf area can be difficult under field conditions as standard protocols require a scanner, computer, and digital image processing by sophisticated and often expensive software to obtain accurate and reliable results, e.g., WinFOLIA (Regent Instruments Canada Inc.), [15]. WinFOLIA is a computer image analysis system that accurately do morphological measurements on broad leaves. It comprises hardware for image acquisition (scanner or digital camera and accessories) and a computer program, WinFOLIA, specifically designed for leaf analysis (area, morphology and disease analysis) [16]. Studies revealed that knowledge of leaf parameters is necessary for numerous calculations in agronomy. It is critical for an understanding of crop production, crop growth, weed control, crop–weed competition as a area of leaves impacted by plant diseases and pests [17], [18].

The aim of the study to determine soil tillage system and precrop influence to winter wheat flag leaf parameters and grain yield quality indicators.

II. Materials and Methods

Study fields. A two-factor field trials with winter wheat cultivar 'Zeppelin' (Latvia) was set up in the Latvia University of Life Sciences and Technologies training and research farm "Peterlauki" (56°30.658′ N and 23°41.580′ E) in 2022/2023: 1. soil tillage system and 2. precrop. Latvian Seed Breeder's Association 'Zeppelin' describes: type of use for food grain production, an early, winter-hardy winter wheat variety that stands out with stable, high yields (https://www.syngenta.lv/product/seed/zeppelin). Soil tillage systems were applied for each precrop: a conventional soil tillage system with ploughing at a depth of 22 to 23 cm and minimal soil tillage system with disc harrowing at a depth to 10 to 12 cm. The field trial was arranged in split-plot design two blocks. Each blocks was split forming six field trials (0.25 ha each) with different precrop.

Three different variants of precrop were examined: wheat after field beans (W–FB); wheat after wheat (W–W); wheat in repeated sowings (W–W–W). The field trial was arranged in a two-factorial split–plot design in two blocks.

Winter wheat was sown in 25 September 2022, seeding rate from winter wheat variety was 420 seeds per m^{-2}, start of vegetation period in 12 April 2023. Winter wheat was harvested on 15 August. Harvesting, three sample sheaf's (each from 0.1 m^2) were taken from every plot, which was later used to calculate the grain yield, by uprooting the plant.

The basic indicators of flag leaf length, width (cm) and flag leaf area (cm^2) at wheat tillering growth stage BBCH 44 of a winter wheat were detected using a scanner STD4800 and the specialized computer program WinFOLIA Regent Instruments Software (Figure 1). The winter wheat flag leaves were taken in each field places, in each place in 10 repetitions according to the principle of randomization.

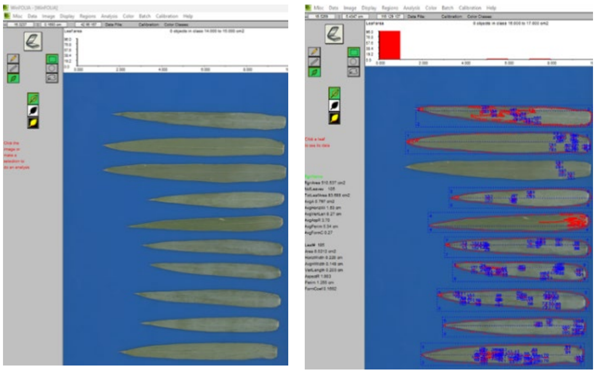


Fig. 1. Winter wheat flags leaves placed in the scanner (A) and the analysis process (B).

Sample sheafs for winter wheat were taken before the yield harvesting at BBCH 87 for analysis of crop yield components from 0.1 m^{-2} area at three locations randomly selected in each replication. The following yield components were detected: number of ears per m^{-2}, grain number per ear, 1000 grain weight (g). After harvesting the whole plots, yield's data was calculated to standard moisture (14%) and 100% purity [19].

The evaluated yield structural elements were: number of winter wheat spikes, pcs. per m^{-2} (counted from (20×50 cm) 0.1 m^2 frame (sample sheaf) and recalculated per m^{-2}), root mass, kg; number of productive stems, pcs.; mass of spikes, kg; mass of straw, kg; grain weight of sample sheaf, kg.

Wheat grain qualities. The winter wheat grains analysed at the Latvia University of Life Sciences and Technologies in Grain and Seeds research laboratory.

The plots were combine-harvested at grain ripeness BBCH 89. Winter wheat grain quality indicators – *crude protein content* (CP, %); *starch content* (SC, %); *gluten content* (GC, %) and *Zeleny index* (ZI, %) were detected by the Near Infrared Spectroscopy (NIRS) method (analyser InfratecTM NOVA (FOSS, Hillerød, Denmark)). *The thousand grain weight* (TGW, g) was determined according to the standard ISO 520:2010.

Meteorological conditions according to Latvian Environment, Geology and Meteorology data. April 2023 with an average air temperature of +7.4 °C (1.3 °C above normal). May was cooler than normal, with an average air temperature of +11.3 °C (0.1 °C below normal), which influenced plant growth and development. June as a whole, with an average air temperature of +16.6 °C (1.4 °C warmer than the monthly norm). On August 15, a week-long heat wave of +34.4 °C began, and until the end of August, daily average air temperatures remained above normal. The summer started with a great drought. In June, the total amount of precipitation was 22.9 mm, which is 67% below the monthly norm (70.1 mm). In contrast to a dry June, August became the 4th wettest on record, with a total of 144.7 mm of precipitation, 88% above the monthly normal (76.8 mm). The data sets generated during and analyzed during the current study are available in the repository of LEGMC Latvian Environment, Geology and Meteorology Centre, *https://www.meteo.lv/meteorologija.*

Statistical analysis. Analyse of variance were used for data statistical processing, whereas the significance of differences between mean values was evaluated with p-value.

III. RESULTS AND DISCUSSION

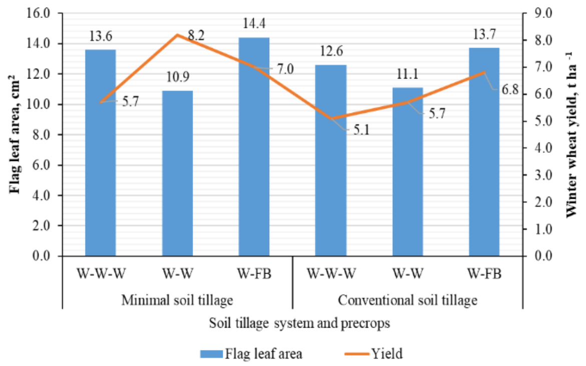
Article summarizes the research findings on the soil tillage system and precrop influence to winter wheat flag leaf parameters and grain yield quality indicators. Literature from different scientific journals all around the world has been used. It includes information from studies conducted in Latvia, Poland, Bulgaria, Switzerland, Ukraine, Uzbekistan and other countries.

The flag leaf area, are the main source of carbohydrates production. At least 50% of photosynthetic products for grain are provided by flag leaf, the most important organ for photosynthesis. Some traits, such as size and shape of flag leaf, affect photosynthesis to a certain extent, thereby influencing production [20].

In the trial year, a higher yield of winter wheat was obtained in the minimal soil tillage system, when the precrop was wheat (8.2 t ha^{-1}), but in the conventional soil tillage, when the precrop was field beans (6.8 t ha^{-1}), the relationships are not significant ($p>0.05$) (Figure 2). The larger winter wheat flag leaf area was determined in both tillage systems, if the winter wheat precrop was field beans (MT 14.4 cm^2 and CT 13.7 cm^2), the relationships are not significant ($p>0.05$).

In turn scientific studies in Latvia [21], [22] determined that the area of flag leaf had significant $p<0.05$ effect to winter wheat grain yield. Therefore, it was reasonable that wider crop flag leaf may increase photosynthetic area, so that the source supply was enhanced, and thereby crops yield improved [20].

Weather conditions in 2023 were with heat wave und with a great drought of Latvia (in provided in Materials and methods). This means that winter wheat plants were in stress conditions, which affected the formation of fewer productive stems, grain mass and others winter wheat yield structural elements. Table 1 shows results evidenced the remarkable influence of the environmental conditions that occurred during the study on same the winter wheat agronomic traits evaluated. The winter wheat root weights of conventional soil tillage (CT) and minimal soil tillage (MT) treatments were not significantly ($p>0.05$) different in all investigated factors, except at MT W–FB had the highest root dry weight (0.18 kg m^{-2}) of sample sheaf compared to W–W–W (0.09 kg m^{-2}) of sample sheaf, it was not statistically significant. The difference in root distribution can be attributable in part to the slower preliminary growth of plants in minimal soil tillage systems due to competition of weeds. In addition, scientists emphasize that the shoot: root ratio is generally affected by nutrient status of soil, climatic conditions [23].



W–FB wheat after field beans; W–W wheat after wheat; W–W–W wheat in repeated sowings.

Fig. 2. Winter wheat flag leaf area and yield analysis.

The higher biomass not only helps crop plants compete better with weeds, thus reducing herbicide applications, but also enhances the quality of degraded rainfed soils, clearly being advantageous for sustainable agroecosystems [24]. Scientists from Spain [24] reported the increased root biomass contribute to improve wheat plant's ability to capture resources and can lead to a greater ground cover, reducing soil temperature and water lost by evaporation.

Despite the fact that winter wheat number of spikes (490 to 710 pcs. m^{-2} of sample sheaf) was higher by minimal soil tillage system but it was the lowest (420 to 535 pcs. m^{-2} of sample sheaf) by minimal soil tillage system it was not significantly ($p>0.05$) affected by soil tillage systems in all field trial variants (provided in Table 1).

Significant spikes mass, kg straw mass and grain weight, kg difference was not found ($p>0.05$), whether the precrop was W–FB, W–W, W–W–W. Significant differences ($p<0.05$) of spikes mass, kg straw mass and grain weight, kg were observed depending on soil tillage systems.

Gluten content (GC). Soil tillage systems affected the gluten content not significantly ($p>0.05$) are in provided in Table 2. Under conventional soil tillage system the gluten content was higher (22.90%) than minimal soil tillage system (19.22%). Precrop also affected the gluten content in grain not significantly ($p>0.05$). Higher average gluten content was observed when wheat was grown after field beans. Scientists from Uman National University of Horticulture, Ukraine Hospodarenko and Liubych [7] reported that the protein and gluten content are most dependent on weather conditions during grain maturation and the use of nitrogen fertilizers [7].

TABLE 1. WINTER WHEAT STRUCTURAL ELEMENTS OF THE SAMPLE SHEAF M^{-2} DEPENDING ON INVESTIGATED FACTORS

Factors	Root mass, kg p=0.68	Spikes, pcs. p=0.23	Spikes mass, kg p=0.71	Straw mass, kg p=0.83	Grain weight, kg p=0.72
Precrop / Soil tillage system					
W–FB	0.18	560	1.20	0.58	0.99
W–W	0.12	710	0.91	0.49	0.74
W–W–W	0.09	490	0.80	0.38	0.66
MT	0.13	587	0.97*	0.48*	0.80*
Precrop / Soil tillage system					
W–FB	0.13	535	1.25	0.59	1.00
W–W	0.13	497	1.02	0.42	0.83
W–W–W	0.09	420	0.84	0.38	0.71
CT	0.12	484	1.04*	0.46*	0.85*
MT/CT	p=0.11	p=0.39	p=0.01	p=0.01	p=0.01

W–FB wheat after field beans; W–W wheat after wheat; W–W–W wheat in repeated sowings; MT – minimal soil tillage system; CT – conventional soil tillage system; significant at p<0.05.

Starch content (SC) is not among the traditionally evaluated indicators for food wheat grain quality. It is should be evaluated in cases when wheat grain is intended for the production of ethanol [25]. Results of our trial show that the average starch content in wheat grain was 68.93 to 71.23%. In our study, soil tillage system (p>0.05), precrop (p<0.05) had a significant impact on starch content.

TABLE 2. WINTER WHEAT GRAIN QUALITY INDICATORS DEPENDING ON INVESTIGATED FACTORS

Factors	GC, % p=0.07	SC, % p=0.01	ZI, % p=0.08	CP, % p=0.05	TGW, g p=0.79
Precrop / Soil tillage system					
W–FB	20.95	70.57	37.99	11.53	50.35
W–W	20.17	70.50	34.36	11.10	45.86
W–W–W	16.53	71.23*	29.69	10.07	46.88
MT	19.22	70.77	34.01	10.90	47.70*
Precrop / Soil tillage system					
W–FB	24.00	68.93*	42.36	12.43	50.90
W–W	22.77	69.17	39.92	12.17	45.64
W–W–W	21.93	69.23	38.35	11.93	48.26
CT	22.90	69.11	40.21	12.18	48.27*
MT/CT	p=0.55	p=0.92	p=0.49	p=0.63	p=0.01

GC – gluten content; SC – starch content; ZI – Zeleny index; CP – crude protein; TGW – 1000 grain weight; W–FB wheat after field beans; W–W wheat after wheat; W–W–W wheat in repeated sowings; MT – minimal soil tillage system; CT – conventional soil tillage system; significant at p<0.05.

Zeleny index (ZI) determines quantity and quality of gluten proteins [26]. In addition, soil tillage system had a not significant (p>0.05) effect on Zeleny index. Conventional soil tillage system Zeleny index was higher (40.21%) than minimal soil tillage system (34.01%). Zeleny index was affected not significantly (p>0.05) by the precrop. Higher results were observed when wheat was grown after field beans. An opposite effect was found in field trial in Latvia, where higher Zeleny index was gained in minimal soil tillage system [27].

Grain crude protein (CP) content is the most important indicator of wheat grain quality [4]. Results show that the soil tillage did not significantly affect (p>0.05) the CP content in grain. Under minimal soil tillage system (10.07 to 11.53%) the protein content of winter wheat was lower than conventional soil tillage system (11.93 to 12.43%) in all field trial variants are in provided in Table 2. The highest protein content was established when the conventional soil tillage system were used and by precrop wheat after field beans and the next significant increase was observed by precrop wheat after wheat (https://www.syngenta.lv/product/ seed/zeppelin). An opposite effect was found in field trial in Latvia, where higher protein content was gained in minimal soil tillage system [27]. Scientists from Ukraine Hospodarenko and Liubych [7] reported that moisture deficiency and high temperature during the growth stage BBCH 73 in contributed to higher protein and gluten content in grain.

Winter wheat thousand grain weight (TGW) characterizes the size of seed and is used as one of the parameters for assessing the quality of grain. Grains with higher TGW have better milling quality and ensure better emergence [28]. Our results showed that the soil tillage system had a significant (p<0.05) impact on TGW. Data in our experiment suggest that the average TGW depending on soil tillage system was 47.70 to 48.27 g. Data mathematical processing showed influence were small effect of precrop on the TGW. Average TGW increased when wheat was grown after field beans if compared with growing wheat after wheat, such a relationship has also been reported by Latvian scientists [27].

IV. CONCLUSIONS

In our trial year scientific study did not prove that any of the soil tillage systems could be the most suitable to obtain a higher grain yield of winter wheat. Significant differences were not found in winter wheat structural elements of the sample sheaf m^{-2} and winter wheat grain quality depending on soil tillage system and precrop in our study, only in some cases it was higher or lower depending on affected by soil tillage system and precrop. The minimal soil tillage system and conventional soil tillage system can be considered as an appropriate tillage systems for winter wheat production in the Latvian region. This is one year trial study, that this indicates the need to continue research under various soil tillage systems and climatic conditions, including research on the long-term effects on tillage on winter grain quality.

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Possible Improvements of Personal Income Tax in Latvia

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In the European Union lot of taxes are as equal between the Member States as possible to the extent of interests of each Member State. At the same time there are some taxes that can make a big competition between countries. Personal Income Tax is the tax that affects competitiveness between the Member States, including between Latvia, Lithuania and Estonia. This was especially relevant in 2023 and is becoming more and more important in 2024, when many international companies are choosing a country to build their central office or manufacture in the Baltic region or make decision on continuation or extension of presence in the particular country. Thus, in addition to various other aspects, competition for workforce is impacted by tax rates applied to personal income having direct impact on each individual and interests. The balance between interests of the state and private individual is being managed via amendments in legislation which are also based on theories.

The methods applied in this study are literature review and regression analysis. They help to assess Latvian progress in comparison to Lithuania and Estonia via method of comparison analyses development and relationship among strategic indicators of Personal income Tax development in Latvia. Due to confirmation of authors analyses expertise assessment method is used.

The most popular theory on the issues is connected to "The Laffer Curve" and the two effects on revenues: the arithmetic effect and the economic effect. Thereby, the practical aspects of competition for higher salaries and number of residents needs to be highly evaluated by minimizing the risk of decrease of income and lack of expected result.

Keywords: Income Tax, Taxation systems, Tax in Latvia

I. INTRODUCTION

Since ancient times tax issues have faced conflicting opinions, conflicting interests and goals. Interests of private persons are usually strived to be balanced with the interests of the public sector, having regard of the vision of public development of the national economy, economic growth or the social and ecological aim in the specific territory.

At the same time the operation in particular geographical territory shall attract the private sector to conduct business, develop and maintain infrastructure, employ employees. These interests shall be balance with the necessity to provide the public sector with a certain amount of money and employees.

The methods applied in this study are literature review and regression analysis. They help to assess Latvian progress in comparison to Lithuania and Estonia via method of comparison analyses development and relationship among strategic indicators of Personal income Tax development in Latvia. Due to confirmation of authors analyses expertise assessment method is used.

More than thirty years have already passed since restoring of the independence the tax system has been maintained in the territory of the Republic of Latvia. There have been several reforms, usually with the aim of improving the system and obtaining a relatively logical balance between the development of the business environment, social policy, employment, the country's economic environment, infrastructure development and other factors. At the same time, in the case of Latvia, as an open economy which is also a member of the European Union, it is essential to be equal to an investment-attracting economy, especially compared to the neighboring countries.

Along with the other factors, Latvia's economy is not isolated from the rest of the world, which also means the impact of global events on the economy, as well as a certain set of actions in cases where global events or challenges occur.

If changes in global prices or other events can be considered as finite and long-term transitory challenges,

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where in some cases tax adjustments must be made for a certain period, then at the same time there is a global long-term vision (global direction) in the direction of sustainability. It is the vision of the United Nations to reduce the confounding issues of ecological and social problems to make the planet Earth suitable for habitation and living from the point of view of human existence[10].

Looking at taxes from the point of view of their optimal taxation, the foundations can be traced back to around 1970. [1]] In particular, you can look at the question - at what point should taxes be different depending on the applicable asset, and at what point should they be unified.[2] An important prism of taxation is from the question of whether taxes should be linear, or when they should aim to be non-linear - basically progressive. An important turning point in the review of these theories was the creation of A. Laffer's curve, which made it possible to look at the tax issue not only from the point of view of taxation and the theoretical approach of social justice - the largest beneficiaries pay more, but also from the point of view that higher taxes, expressed in percentage terms, do not always ensure higher budget income, which, as a result, can be used to achieve national goals more quickly or with better quality.

Many authors have described the correlation between the tax burden and tax revenue in the budget since A. Laffer's research. A fairly common use is the "Laffer Curve," named after an economist who visualized the idea that the amount of tax revenue may not coincide with a function of an increasing tax rate. According to Laffer, tax rates have two effects on tax revenue – the arithmetic effect and the economic effect. The essence of the arithmetic effect is that when the tax is increased, the income will increase proportionally, and when it is reduced, it will decrease proportionally. The economic impact has the opposite effect, because by reducing the tax, wages will increase, which will motivate even more to receive funds legally and, as a result, the amount of taxes will increase. Similarly, by increasing taxes, their payable amount will decrease.[3]

The purpose of the research is to develop proposals for the improvement of Latvian labour taxes from the perspective of small and medium-sized companies, recognizing the most important tax aspects of Lithuania and Estonia, which are strongly supported by the governments or in which Latvia has unused advantages.

This is especially relevant in 2024 and onwards, when many international companies are choosing a country to build their central office for the Baltic region and representative offices in other countries. The number of employees employed in representative offices is usually significantly smaller.

II. Materials and Methods

Measurement of Tax Systems and possible improvements in the systems are relevant in any country in the world. At the same time each of the neighbouring countries are the ones that are making their country as attractive as possible to international investors in comparison to other countries in the region.

As the cost of labour is one of issues that is analysed by the international companies, the need for tax analyses and the best possible tax system for being attractive to investors shall of importance.

The compilation of tax from year 2020 till 2024 was made to understand the current situation. At the same time in theory the effect of tax changes and the total government tax income changes are analysed by a lot of scientists, and each time in each specific situation different suggestions are made.

At first theoretical approaches are described by the analyses of theories. From that the authors made data analyses with comparison method. That lead to suggestions that needed appropriation from the experts of tax field as expert assessment method.

As there are a lot of issues to improve in the case of Latvia, to attract more educated human capital with bigger tax income at the later stage, authors made the best possible suggestions from the results that were approved by the majority of experts and in some cases even with improvements from expert comments and suggestions.

III. Results and Discussion

Application of Personal income tax in Latvia since 1994 up to now is governed in accordance with the law "On personal income tax" [6].

Table 1 Summary of personal income tax rates [8]

<table>
<tr><th>Country</th><th>Year</th><th>Minimal sallary, EUR</th><th>Till EUR 20004</th><th>From EUR 20004 till 78100</th><th>Above EUR 78100</th><th>Above EUR 101094
*[3]</th></tr>
<tr><td rowspan="5">Estonia</td><td>2020</td><td>584</td><td rowspan="5" colspan="4">20%</td></tr>
<tr><td>2021</td><td>584</td></tr>
<tr><td>2022</td><td>654</td></tr>
<tr><td>2023</td><td>724</td></tr>
<tr><td>2024</td><td>820</td></tr>
<tr><td rowspan="5">Latvia</td><td>2020</td><td>430</td><td rowspan="5">20%</td><td rowspan="5">23%</td><td colspan="2">31,4%</td></tr>
<tr><td>2021</td><td>500</td><td rowspan="4" colspan="2">31%</td></tr>
<tr><td>2022</td><td>500</td></tr>
<tr><td>2023</td><td>620</td></tr>
<tr><td>2024</td><td>700</td></tr>
<tr><td rowspan="5">Lithuania</td><td>2020</td><td>607</td><td rowspan="5" colspan="3">20%</td><td rowspan="5">32%</td></tr>
<tr><td>2021</td><td>642</td></tr>
<tr><td>2022</td><td>730</td></tr>
<tr><td>2023</td><td>840</td></tr>
<tr><td>2024</td><td>924</td></tr>
</table>

*Calculated as 60 average monthly salaries (in 2020 as 84 average monthly salaries), 2022 – 90,426 EUR; 2021 – 81,162 EUR; 2020 – EUR 104,277.60.

Despite continuingly having one law in Latvia, its application and the applicable rates have changed significantly over the time. In the case of Latvia, the last significant changes are related to the year 2018, when the progressive PIT rate has been introduced in opposite to the fixed rate of 23% applied until then.

The fact that the minimum wage differs among the three Baltic states and in the case of Latvia it is the lowest, creates significant differences between the countries. However, the lower minimum wage does not simultaneously mean the lowest tax application. Comparing the personal income tax rate of Latvia and Estonia, it is clear that the rate in Estonia is lower than in Latvia, while at the same time it is higher in Lithuania.

TABLE 2 PERSONAL INCOME TAXES AS A % OF GDP[9]

Year	*2018*	*2019*	*2020*	*2021*	*2022*
Estonia	5.442	5.516	6.016	6.825	6.3
Latvia	5.974	6.448	5.951	5.981	5.794
Lithuania	4.248	7.215	7.281	7.506	7.643

Looking at the amount of income tax and social contributions as a percentage of GDP, it is clear that regardless of the period, in the case of Latvia, it is lower than the indicators of Lithuania and Estonia. This confirms that the tax reform of 2018 has had a relatively small effect in the short term, when in 2019 the amounts are relatively close, but in 2021 there is a significant gap in terms of revenues for Estonia and Lithuania.

Swedbank expert Evija Kropa has calculated the total impact: "If it is assumed that an employee earns 1,500 euros per month before paying taxes without registered dependents, you can count on 1,097 euros "on hand" in Latvia. In Lithuania, such an employee would receive 120 euros less salary, or 977 euros, and in Estonia - 147 euros more, or 1244 euros." In addition, the total payment must be taken into account: "if the salary "on paper" is 1,500 euros, the employer pays another 507 euros in taxes in Estonia, 354 euros in Latvia and 27 euros in Lithuania. In the case of middle incomes, the highest total tax burden still remains in Latvia (41%), followed by Estonia (38%) and then Lithuania (36%).[4]

TABLE 3 EMPLOYER COSTS VERSUS EMPLOYEE INCOME [7]

	Neto income	*Employer costs*	*Bruto income*	*Income vs payment*
Estonia	1’500	2’007	1’244	62%
Latvia	1’500	1’854	1’097	59%
Lithuania	1’500	1’527	977	64%

To have an understanding of the opinions of specialists, interviews with scientists and focus groups, experts and certified tax specialists have taken place and answers received from:

Dr. oec. Anatolijs Prohorovs – author of the monograph "Corporate income tax in Latvia and Estonia (2017)";

Andris Jaunzemis – certified tax consultant, partner of SIA TaxLink Baltics;

Jānis Zelmenis – managing partner of BDO Latvija, author of the publications "If we don't think in the long term, only bad news awaits us with the decreasing number of taxpayers (Delfi, 19.07.2021)" and "Global CIT reform and Latvian interests (Dienas Bizness, 12.07.2021)";

Marina Bičkovska – certified tax consultant.

The opinion of experts was:

Anatoly Prohorovs: "Introduce a fixed PIT rate and by setting the fixed rate at 20%. By excluding the progressive rate and introducing linear. In the event that the introduction of a fixed rate of 20% is not possible, then introduce a regulation that is no more unfavourable than in Estonia and Lithuania, i.e. raise the thresholds from which the increased rate is applied."

Jānis Zelmenis: "Until 2018, there was a fixed PIT rate in Latvia, but from January 1st, 2018, a progressive PIT rate system was introduced in Latvia. The goal of the reform was to reduce the labour tax burden, especially for low-income workers, to increase the income of the working population and to reduce income inequality. Therefore, in our opinion, there is no need or justification to return to the fixed PIT rate.

Our proposal is, however, to continue the progressive system of PIT rates, but to divide the income thresholds according to a principle that takes into account, for example, the amount of the minimum wage, the amount of the average wage in the country, wages above the average level, high wages."

Andris Jaunzemis: "Personally, I do not think that the progressive system is demotivating for high salaries. Any employer will take into account the impact of PIT on the net salary when determining a higher salary. Accordingly, the employee will hardly feel it. Here we should look at what kind of system is offered by the countries with which we compete - Estonia and Lithuania. If they do not provide for the progressive system, then we should at least adapt our system to the systems of other countries so that we are competitive. If it is foreseen, then it should be evaluated so that we are not the most expensive in the Baltics, because the opportunities to attract the workforce and the costs of companies greatly affect it."

Marina Bičkovska: "I believe that in the case of Latvia, the progressive tax rates are applied to too low income threshold, thus encouraging the choice of highly qualified professionals to move to countries with lower taxes, which generally has a negative impact on the economy in Latvia.

Thus, a possible solution would be the introduction of a fixed rate to simplify accounting and ensure Latvia's competitiveness with other countries within the scope of PIT rates.

As an alternative, the thresholds of the progressive rate can be reviewed, however, in this case it should be taken into account that after the times of COVID, the rhythm of work in many industries switched to the remote work mode and there is a tendency for citizens to change their place of residence, having also evaluated the impact of taxes before that. "

The opinion of the authors in this case corresponds with the opinion of Andris Jaunzemis and Marina Bičkovska from the point of view that in the case of

Latvia higher tax than in neighbouring countries should not be introduced, thus decreasing the position of competitiveness. Although compared to Lithuania and Estonia the volumes are similar compared - in the conditions of regional competition, from total numbers it can be seen that an international investor will choose to hire employees in Estonia or Lithuania, rather than in Latvia, because of the lower PIT rate and, as a result, lower overall labour costs. The opinion of Jānis Zelmenis is supported in the event that the progressive application of PIT is maintained, because in this case it is important that as the economy and the total GDP grow, the PIT thresholds should also be proportionally increased. The options proposed by Jānis Zelmenis are also grounded PIT rate is linked with4 determined number of minimum wages or average wages. The average salary does not include the income of the shadow economy and thereby the actual numbers of average salary doe not correspond to real situation in market, while minimum salary is a constant unit. By applying the average salary, on the one hand it motivates to pay a larger amount of salary, but on the other hand it also demotivates certain part of taxpayers to pay more because of the statistic data of the shadow economy.

TABLE 4 CALCULATION OF MARGINAL VALUES AFTER MINIMUM WAGE AND INFLATION [5];[6]

Year	*Min. wage EUR*	*Marginal value by minimum wage EUR*		*Marginal value by inflation EUR*	
		Lower	*Higher*	*Lower*	*Higher*
2018	430	20004	55000	20004	55000
2019	430	20004	55000	20524.1	56430
2020	430	20004	55000	20984.2	57695
2021	500	23260.47	63953.49	20884.18	57420
2022	500	23260.47	63953.49	22524.5	61930
2023	620	28842.98	79302.33	27225.44	74855
2024	700	32564.65	89534.88	27385.48	75295

From the calculation, it can be seen that the upper limit value is similar, regardless of the methodology. At the same time, the lower limit value has not changed since the beginning of 2018.

IV. CONCLUSIONS

Results:

1) Until 2017 (including), the PIT rate was fixed at 23% in Latvia. Since 2018, there is an existing system with a progressive PIT rate in Latvia.

2) Estonia has a fixed PIT rate of 20%, and if the rate is higher in the case of Latvia, the motivation will remain not to employ Latvian residents in Latvia, but to employ Estonian residents in Estonia.

3) As a result, since 2018, PIT revenues in Latvia compared to GDP are lower than in Lithuania and Estonia (before the reform they were higher than in Lithuania and Estonia).

4) Looking at the tax thresholds, if the highest threshold has been revised twice and is proportionally equivalent to changes in the minimum wage or inflation, then the lower threshold has not been revised and increased since its introduction.

Suggestions:

1) By cancelling the application of progressive PIT and returning to a fixed PIT rate, taxpayers who receive income in the amount subject to application of the highest PIT rate (including wages), would be less motivated to optimize costs and consider distribution of income in alternative ways. Although the authors initially proposed to introduce a fixed 23% PIT rate, after receiving expert opinions and arguing (Latvian taxes cannot be viewed separately from Estonian and Lithuanian taxes) that any rate higher than 20% gives Estonia an advantage over Latvia, the authors propose to introduce a fixed 20% PIT rate, similar to Estonia;

2) In the event that a fixed PIT rate is not introduced, and Latvia continues to be in a worse position than Estonia, the thresholds should be adjusted according to inflation. Inflation from January 2018 to March 2023 is 38.6%, but the amounts of income to which the progressive PIT rate of 23% is applicable have not changed. The rate is 31% from January 2022 - inflation 23.1%:

o 20,004 * 1.386 = 27,725, rounded to EUR 30,000;

o 78 100 * 1.231 = 96 141, rounded to 100 000 EUR.

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Evaluation of the Graphene Dispersions for Kevlar Fabrics Functionalization Obtained by the Liquid-Exfoliation of Graphite

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Abstract. The process where pristine graphite is subjected to a solvent treatment seems simple and scalable and has attracted the attention of researchers over many years. However, for successful exfoliation, overcoming the van der Waals attractions between the adjacent layers of graphite is necessary. Over time, several methods have been created to overcome the attraction between layers. Graphene's liquid phase exfoliation (LPE) occurs due to the strong interactions between the solvent molecules and the basal planes of graphite, overcoming the energetic resistance to exfoliation and subsequent dispersion. Ultra sonication used for exfoliation can produce single or few layered graphene flakes. During sonication the sound waves propagate through liquid medium in alternating high- and low-pressure cycles, strong mechanical and thermal energy released by acoustic cavitation results in splitting up large particles into fine ones and dispersing them. Simultaneous insertion of solvent and/or intercalation molecules in between the graphite layers takes place supporting graphite separation into graphene layers.

The dispersion capacity of graphene flakes depends on how appropriate the solvent properties are to the corresponding properties of graphene, such as surface tension, Hildebrand, and Hansen solubility parameters. Only certain solvents can disperse graphene well and form a dispersion appropriate for specific future applications. In addition, after exfoliation by ultra sonication graphene flakes aggregation due to the van der Waals attractions must be overcome to prepare in long-term stable dispersions of nanometres-size graphene sheets.

The research has focused on the preparation of stable dispersion ready for transfer without intermediate processes to the Kevlar fabrics. An experimental comparison of the potentials of the 4 solvents for the application resulted in three corresponding to the intended use, two of them examined in detail, supplementing the composition of the LPE liquid medium with triethanolamine to obtain sufficient performance graphene coverage on Kevlar textile fibres.

Keywords: Dispersion, Graphene, Solvents, Zeta potential.

I. Introduction

Enhanced mechanical properties of aromatic polyamide fibres or films can be very useful as ultra-strong membranes, coatings, and other advanced applications [1]. Carbon nanostructures is considered a promising ballistic protection material, due to their low density and excellent mechanical properties. Recent experimental and computational investigations on the behaviour of graphene (Gr) under impact conditions revealed exceptional energy absorption properties and suggest that superior performance can be obtained in ballistic applications by applying Gr nano-coatings over other materials. Recent experimental and computational investigations on the behaviour of graphene under impact conditions revealed exceptional energy absorption properties and suggests that superior performance can be obtained in ballistic applications by applying graphene nanocoating's on other materials [2]. A homogeneous and uniform dispersion of Gr on the matrix is required so that the external load may be efficiently transferred under the stress condition through strong interfacial interactions between Gr layers and the polymer. The inherent nature of

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Gr, however, makes its dispersion difficult within the majority of polymers [3]. The non-covalent bonding of pristine Gr can be developed with aromatic polyamides that have extended aromatic rings on the chain of molecules, as they have highly mobile electrons π and π^* located on their chains. The multiple π–π interactions between the exfoliated layer's crystalline structure of Gr and aramids can provide improvement in the mechanical properties [4]. To ensure this an appropriate dispersant–solvent system that interacts with the graphene and Kevlar fibre's surface must be selected to improve the liquid medium interface properties and realize the uniform and stable dispersion of graphene [5].

Due to the existing industrial knowledge and equipment, graphite liquid exfoliation is possibly the most viable option for upscaling graphene production. Graphene's liquid phase exfoliation (LPE) occurs due to the strong interactions between the solvent molecules and the graphitic basal planes, overcoming the energetic resistance to exfoliation and subsequent dispersion [6].

The principle of LPE lies in assisting the separation between graphene layers held together by electrostatic attractions that require strong mechanical force to separate [7]. To reduce this energy, the attractive forces holding layers of graphene together must be disrupted. This is done by first dispersing graphite flakes into liquid media, followed by graphite intercalation (division into microlayers) and microlayers exfoliation. At the final stage, maintaining a stable dispersion of isolated flakes in a liquid medium must be ensured (Fig.1). The challenge is that graphene suffers from a limited dispersibility even in its suitable solvents, which is due to the small mixing potential and strong π-π attraction between two-dimensional graphite structures. Several studies have shown graphite can be exfoliated in liquid environments by using ultrasound to extract individual layers [8]. In this case LPE involves three steps: the dispersion of graphite in a solvent; the exfoliation of dispersion via sonication; the dispersion stabilization (Fig.1).

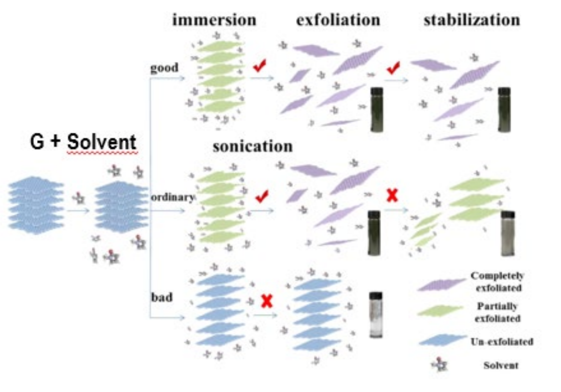

Fig.1. LPE involves three main steps: The dispersion of graphite in a solvent; The exfoliation of dispersion via sonication; the dispersion stabilization [9]

During sonication, ultrasonic waves produce in the liquid medium local compressions and rarefactions, forming vacuum cavities which then collapse, generating high pressure jets. These jets peel off graphene layers from graphite and weaken the Van der Waals interaction between the layers. The intercalation of solvent molecules between graphitic planes allows for further exfoliation and consequent stabilization of dispersion [10]. Attention must be paid to the choice of the dispersing solvent as the solvent is a crucial factor in the exfoliation process, and to be effective, it must comply with three main requirements: transmit the exfoliating power efficiently, minimize the energy needed to disrupt the van der Waals forces among layers and stabilize the exfoliated layers by providing steric hindrance to prevent re-agglomeration [11].

Matching an appropriate graphene dispersant–solvent system, the potential energy studies of the graphene surface and its relationship with the potential energy of the dispersant–solvent system were carried, eventually believing that the stability of the graphene dispersion and dispersant–solvent system is characterized by Hansen's solubility coefficient [12] and a three-dimensional representation of Hildebrand solubility parameters - the dispersion (δd), polar (δp) and hydrogen bonding (δh) interactions in the Hansen 3D space is considered as framework to predict if and how a material will disperse in a particular solvent and form a solution [13, 14]. Typically, 1-methyl-2-pyrrolidone (NMP) or dimethylformamide (DMF) is used as a solvent in LPE since both are successful for exfoliating graphite and producing stable dispersions of graphene. et al., boiling point of these solvents make them difficult to remove and results in major material loss and degradation of quality, the generation of toxic waste [15, 16] turning to the feasibility research of replacing NMP and DMF with green solvents. A group of scientists [14] has released Dihydrolevoglucozenone (Cyrene) as one of the most performant graphene solvents in a large-scale comparative analysis of possible solvents.

Biological solvent Cyrene is extracted from cellulose in a two-step process using the levoglucosenone (biomass) process, which at the same time guarantees a low environmental impact and economic feasibility. Cyrene is a waste-derived and fully biodegradable seven-membered heterocyclic cycloalkanone which is fully biodegradable an environmentally friendly [17] alternative to dimethylformamide (DMF) and N-methyl-2- pyrrolidine (NMP). It is miscible with water and many organic solvents. Unlike traditionally used polar aprotic solvents, the Cyrene molecule does not contain nitrogen and sulphur heteroatoms [18]. As part of a previous study, the possibility of creating a Cyrene-based dispersion and para-aramid fabric variants modified with it has been demonstrated [19].

Given the hitherto approved use of solvent DMAc in aramid and other textile fibres obtaining processes, it would be premature to exclude it from comparative studies, especially since its solubility parameters are also relatively close to those of graphene (Table 1).

N, N-Dimethylacetamide DMAC is a dipolar aprotic solvent used in many organic reactions and for industrial purposes. It is a universal solvent due to its high boiling point, good thermal and chemical stability. It is indispensable in the processes of obtaining many textile fibres, used as a solvent for producing fibres and for organic compounds synthesis. Its broad range of miscibility makes it useful in mixed solvents. It is also stable to strong bases but hydrolyses in the presence of acids.

TABLE 1. HILDEBRAND SOLUBILITY PARAMETERS, SURFACE TENSION AND VISCOSITY OF USED SOLVENTS

	Solubility parameters, $MPa^{0.5}$				**Surface tension, mN.m-1**	**Viscosity, g·s-1·m-1**
	δ_D	δ_P	δ_H	R		
Graphene	18	9.3	7.7	-	46.7	-
DMAc	16.8	11.5	9.4	3.7	32.4	0.9
Cyrene [11]	18.8	10.6	6.9	2.2	33.6	14.5
TEA	17.3	7.6	21	-	45.9	607*

*TEA viscosity dramatically decreases with temperature increase.

Although previous studies had shown that green solvents can be used to produce graphene by means of LPE, it has not progressed much further. To enhance the graphene yield in green solvent LPE, which currently is ca. 50−75% lower than in DMF or NMP [20., 21], additives such as surfactants and/or dispersants have been intensively explored [22]. Key factors that influence the graphene yield in LPE - *exfoliation efficiency*, and the *dispersibility* of the solvent could be considered [23].

Given DMAc's low dynamic viscosity (Table 1) and based on previous successful experience of incorporating triethanolamine (TEA) into dispersion and improved adhesion to the modifiable Kevlar fabric fibres surface [19], both variants of the comparable solvent-based liquid medium included TEA (Table 1).

TEA is a viscous organic compound that is both a tertiary amine and a triol - a molecule with three groups of alcohol. As amine, TEA can accept hydrogen and as a surfactant, it can reduce the interphase stress in the mixture or solution, preventing the emulsion from layering or the deposition of compounds from the solution. TEA offers close correspondence of δD and δP to Gr and Cyrene, and as a nucleophile exhibits a much higher δH (Table 1), suggesting the ability to bind to the desired molecule more easily in the coating process. There are no examples of successful TEA use in previous studies related to the Gr extraction.

II. MATERIALS AND METHODS

1) Theoretical Methods

Viscosity Determination of Liquid media

To determine the particle sizes and their distribution in dispersion, viscosity values of the solutions to be measured are required. Since the liquid medium of the dispersion (suspension) to be analysed often consists of mixtures of solvents, viscosity values could not be obtained from the literature, they had to be determined experimentally. In a rotational type of viscometer, speed is controlled, corresponding to its force measurement is used to calculate viscosity, which is necessary to ensure the rotation of a solid body in a viscous environment. This viscometer type proved to be inadequate for the dispersions to be tested, as large volumes are required to obtain stable measurements and very low viscosities difficult to measure with sufficient accuracy. Instead, the method of falling ball was used.

The solution to be analysed is poured into a capillary, a ball of stainless steel is placed in it. The falling ball micro viscometer measures the time t required for the ball to move from one end to the other in the capillary (Fig. 2.). This measurement principle also ensures that the measurement requires a small sample volume – already around 1 mL is sufficient to obtain the measurement. The dynamic viscosity by this method is calculated according to equation (1):

$$\eta = \left(\frac{1}{6\pi v}\right)[4/3\pi r\,2(\sigma-\rho)g], \qquad (1)$$

where - η, Pa s; r - the sphere's radius (m), σ - the density of the sphere (kg/m^3), ρ - the density of the liquid (g/ml), g: acceleration due to gravity (9.81 m/s^2), v - the terminal velocity of the sphere (m/s).

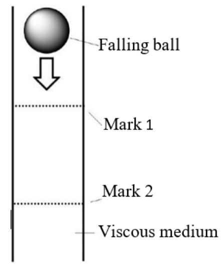

Fig.2. Viscosity method testing scheme.

Characterization of Nanoparticles and Microparticles

The LitesizerTM 500 is designed to characterize particles in liquid dispersions. Instrument makes it possible to determine particle sizes, ζ-potential and molecular weight by measuring dynamic (DLS), electrophoretic (ELS) and static light scattering (SLS), as well as sample light transmission and refractive index. The equipment operates on the principle of scattering dynamic light: the smaller the particles, the higher the speed of Brown's movement in the liquid. By measuring the change in light scattering, which depends on the speed of movement of particles, it is possible to calculate particle sizes and characterize the particle size distribution. The distribution of dispersed particles is characterized by particle diameters, while the scattering of diameters with the Polydispersity Index.

The hydrodynamic diameter of the particles is measured together with the layers surrounding the particles in solution (Fig. 3). The Polydispersity Index PDI is calculated, equation (2):

$$PDI = \left(\frac{\sigma}{d}\right)^2, \qquad (2)$$

where σ is particle size standard deviations (nm), d average particle diameter (nm).

The PDI value can vary from 0 to 1: if the PDI of colloidal particles is less than 0.1 (10%) the dispersion contains monodispersed particles, and if the PDI value exceeds 0.1, this may mean the size distribution of polydisperse particles. International Organizations for

Standardization have determined that PDI values of < 0.05 (5%) are more common for monodispersible samples, while values of > 0.7 (70%) are common for a broad particle size distribution, so the corresponding variances are classified as highly polydisperse [24] standard. It should be noted that polydispersity may occur due to particle size distribution in the sample, as well because of agglomeration or aggregation of the sample during isolation or analysis of the sample.

The physical properties of suspensions (nanoparticles) and colloids largely depend on the interface properties of particles and liquids, knowing the potential of Zeta is important for their assessment. From the fundamental theory's perspective, zeta (ζ) potential is the electrical potential in the interfacial double layer at the location of the slipping plane (Figure 3). Thus, zeta potential can be regarded as the potential difference between the dispersion medium and the stationary layer of the fluid attached to the particle layer.

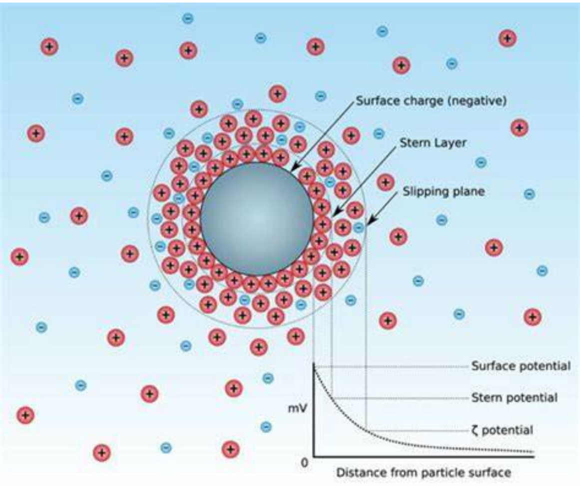

Fig.3. Potentials difference of a particle suspended in a dispersion media as a function of distance from the charged particle surface [25]

ζ-potential describes the electrochemical balance at the particle-liquid interface by measuring the magnitude of electrostatic repulsion/attraction between particles. Thus, it has become one of the basic parameters for assessing the stability of colloidal particles. ζ- potential cannot be directly measured. It is calculated according to theoretical models or calculated from experiments, often based on the mobility of electrophoresis.

In capillary electrophoresis the sample is injected into a buffered solution filled in a capillary tube. When an electric field is applied to the capillary tube, the sample's components migrate in result of electrophoretic mobility and electroosmotic flow.

Electrophoretic mobility is the solute's response to the applied electrical field in which cations move toward the negatively charged cathode, anions move toward the positively charged anode, and neutral species remain stationary. The other contribution to a solute's migration is electroosmotic flow, which occurs when the buffer moves through the capillary in response to the applied electrical field. Under normal conditions the buffer moves toward the cathode, sweeping most solutes, including the anions and neutral species, toward the negatively charged cathode. Basically, to determine the zeta potential, the speed with which a charged particle moves in response to an electric field electrophoretic velocity is measured, equation (3):

$$vep = \mu ep\, E \qquad (3)$$

where μep is the solute's electrophoretic mobility ($mm^2h^{-1}v^{-1}$), and E is the magnitude of the applied electric~~al~~ field (N/C). A solute's electrophoretic mobility is defined as:

$$\mu\mathrm{ep} = q/6\pi\eta\mathrm{r} \qquad (4)$$

where q is the solute's charge (C), η is the buffer's viscosity (Pa s), and r is the solute's radius (mm).

The migration rate is proportional to ζ-potential. Speed is usually measured using a laser doppler anemometer. The calculation is based on the theory described by Marian Smoluchowski in 1903 [26]. Smoluchowski's theory is valid for any concentration or shape of dispersion particles. However, it takes on a sufficiently thin double layer and ignores any surface conductivity.

ζ-potential, also known as electrokinetic potential, is measured in millivolts (mV). When the zeta potential is equal to zero, the colloid precipitates to a solid state.

0 to ± 5 mV, rapid coagulation or flocculation occurs (the formation of flaky aggregates in solution);

±10 to ± 30 mV initial area of stability;

±30 to ± 40 mV moderate stability;

±40 to ± 60 mV good stability;

Above ± 61 mV excellent stability [25].

2) Experimental Methods

The Table 2 shows dispersion comparison, and they process parameters, where US (ultra sonification) and C (centrifuge) was applied.

TABLE 2 DISPERSIONS COMPOSITION AND PROCESSING PARAMETERS [27]

	Variants designation			
	G-DMAc-TEA_d1	**G-DMAcb-TEA2_d2**	**G-CIR-TEA_d3**	**G-CIRb-TEA2_d3**
Graphite, Wt., %	2*	25**	2*	25**
DMAc, Wt., %	78	60	-	-
Cyrene, Wt., %	-	-	80	50
TEA, Wt., %	20	15	18	25
US, min	60	30	60	30
C, min/ rad $^{s-1}$	20/272	20/126	20/272	20/126

* Pristine graphite flakes
** Recovered sediments

Graphite flakes, 99% carbon basis, -325 mesh particle size (≥99%), natural (Sigma-Aldrich)

The densities of the dispersions d1 and d2 are 0.968 and 0.973 g/mL, respectively (DMAc 0.937 g/mL). The densities of the Cyrene-based dispersions d3 and d4 are 1.258 and 1.257 g/mL, respectively (Cyrene 1.25 g/mL).

Viscosity measurements carried out with a viscometer Lovis 2000 M/ME (Anton Paar) at 20 °C.

Particle size analysis and ζ- potential has been determined with the LitesizerTM 500 instrument (Anton Paar) using appropriate software.

Particle size measurements performed on undiluted samples. ζ- Potential measurements made with samples at a 1: 30 dilutions. Samples for the tests were taken with a disposable pipette from the upper part of the tube before settling the samples for at least one hour. Glass cuvettes were used for measurements. The dispersion cells were in a thermostatic chamber at 20 ºC during the test process. A series of measurements have been carried out for each sample, from which the distribution of the average dimensions and ζ- potential have been calculated.

III. DISCUSSION

High viscosity is, in principle, beneficial for the LPE process, as it increases the outcome of exfoliation and reduces the proportion of defects and sediments. However, too high viscosity contributes to the stable retention of coarse particles and agglomerates in dispersion by centrifugation of them, thus not separating them from the desired thinner and lightest flakes. The measurements of the dynamic viscosity of the four dispersions considered are very different. The viscosity of DMAc-based dispersions 1.89 mPa-s and 2.17 mPa-s after re-dispersion of recovered sediments confirms the above about the possible effect of components viscosity on the dispersion parameters (Table 2). By adding the modifier TEA to the liquid medium, it has succeeded in increasing the low viscosity of DMAc (Table 1) to the level required in subsequent modification processes of Kevlar fabric (Table 3).

TABLE 3 PARAMETERS CHARACTERIZING THE DISPERSIONS TO BE COMPARED

	G-DMAc-TEA_d1	G-DMAcb-TEA2_d2	G-CIR-TEA_d3	G-CIRb-TEA2_d4
Viscosity, mPa-s	1.89	2.17	99.4	231
HYDRO Ø, nm	387	392	1668	392
Polydispersity index, %	27.7	25.3	164.7	25.3
Diffusion coefficient, μm²/s	0.6	0.5	0	0
Deciles, nm				
D1	195	179	954	231
D5*	333	309	1359	332
D9	511	645	2159	514
Interdecile range, nm I_{80}	315	466	1205	283
Modal, nm	358	379	1528	369

*) D5 = median

Polidispersity indexes of dispersions d1 and d2 between 25% and 28% are well below the 70% limit of common for a broad particle size distribution. Figure 4 graph (a) and median < modal < mean particle sizes values (Table 3) suggest right side asymmetry of dispersion d1 particle sizes distribution, 80% of particle sizes located in a range between 195 and 511 nm. In turn, recovered sediment dispersion's d2 80% of particle sizes located in a wider interval between 179 and 645 nm, I_{80} increased by 1.5 times while the right-side particle sizes distribution asymmetry remains (Figure 4, b).

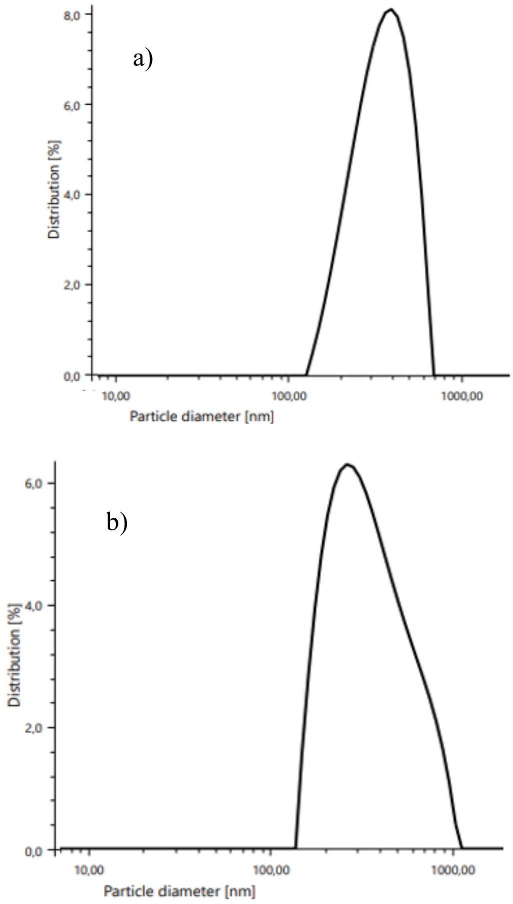

Fig.4. DMAc based dispersions particle size distribution by intensity, a) G-DMAc-TEA_d1, b) G-DMAcb-TEA2-d2.

Considering that the viscosity of Cyrene is almost 15 times higher than that of DMAc, while the viscosity of TEA is highly dependent on the temperature at the time of measurement (20 ºC), it is necessary to look very carefully at the obtained measurements of the dynamic viscosity of both Cyrene based dispersions respectively 99.4 and 231 mPa-s (Table 3), especially in cases where the further processing takes place at temperatures above 50 ºC.

Obtained PDI 165% of Cyrene based dispersion d3 indicates a broad graphene particle size distribution (Table 3). The graph of the image shows d3 distribution strongly shifted to a larger particle sizes area (Figure 5, top), with 80 % of the particle diameters in the range 954 to 2159 nanometres (Table 3) testifying to the exfoliated graphene layers agglomeration and aggregation during d3 samples isolation, transportation, and analysis. The measurements obtained suggest that graphite layers are partially exfoliated and perhaps the viscosity and other parameters of liquid media has not been sufficient to ensure dispersion d 3 stability. The assumption is confirmed by the relatively high viscosity of the dispersion d4, its corresponding PDI value of 25% and the other parameters characterizing the distribution, which differ only slightly from the corresponding indicators of dispersions d1 and d2. The interdecial range I_{80} of 283 nm that measures particle size variance is even lower compared to d1 and d2 I_{80} scores of 315 and 466 nm respectively.

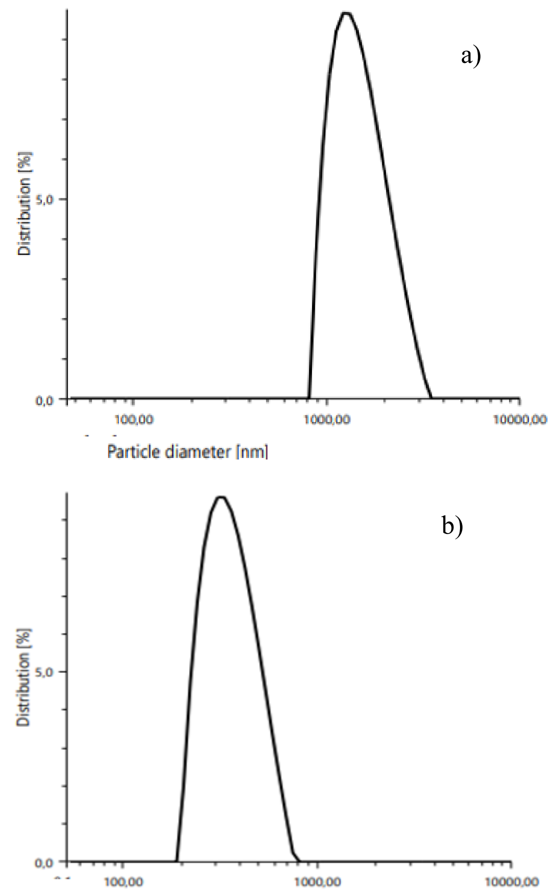

Fig. 5. Cyrene based dispersions particle size distribution by intensity, a) G-CIR-TEA_d3, b) G-CIR-TEA2-d4.

This could be explained by a significant increase in d4 viscosity due to changes in the proportions of the liquid medium composition: reduced the concentration of Cyrene from 80 wt% to 50 wt%, while the concentration of TEA increased from 18 to 25wt%.

The ζ-potential of the dispersion d1 at the peak of the distribution curve (Figure 6, a) and the mean values (-35.5) and (-39.4) mV, respectively, indicate the stability of DMAc-based dispersion d1 which has also been confirmed in by ensuring d1 shelf life at least one month. From the sediments obtained by centrifugation re-dispersion d2 values of the ζ-potential distribution peak (Figure 6, b) and the average zeta potential values respectively -44.6 and -43 mV are relatively higher, which is explained by repeated exposure to sonication. Experience gained during the experiments has shown that sediments re-dispersion allows fabric coatings richer in graphene [27].

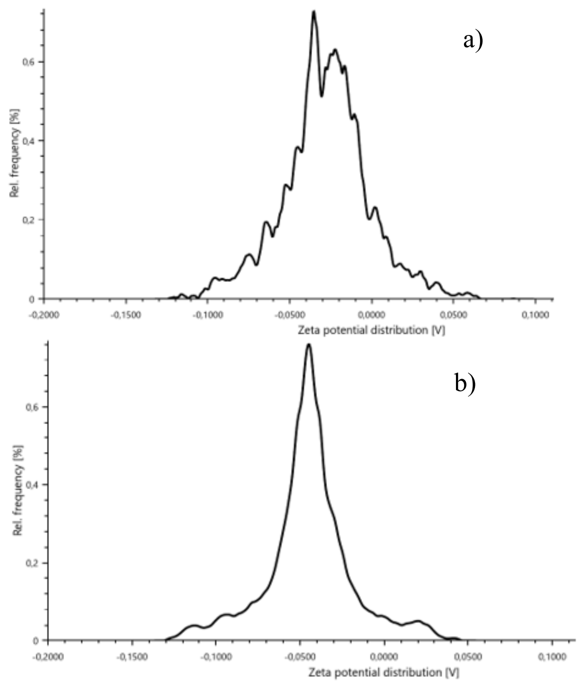

Fig. 6. DMAc solvent based dispersions ζ-potential distributions, a) G-DMac-TEA-d1, b) G-DMAcb_TEA2_d2.

The ζ-potential distributions of both solvent Cyrene based dispersions d3 and d4 failed to obtain by confirming the rapid dispersion stratification observed in practice and the formation of agglomerates. This is explained by the definition that the efficacy of exfoliation is determined by the solvent's capacity to separate individual layers of graphene from graphite flakes, but the graphene dispersibility is the solvent's ability to form uniform and stable graphene dispersions over a given time. The limited dispersibility of the graphene in green solvents is hindered by the limited dispersibility of the obtained graphene flakes in them. This means that these dispersions should be used immediately after preparation, but as practice shows the expected result cannot always be obtained.

IV. CONCLUSIONS

In order to predict the compliance of the dispersing solvent system with graphene exfoliation, the researchers have studied the potential energy of the graphene surface and its relationship to the potential energy of the dispersing system for a long time, ultimately believing that three-dimensional representation of Hildebrand solubility parameters interactions in the Hansen 3D space offered a framework to predict if and how a material will disperse in a particular solvent and form a solution.

Despite numerous studies the liquid-phase dispersion of graphene is still the core problem that must be overcome in the experimental studies of nanomaterials and matching the properties of the resulting dispersion with the application in subsequent technological processes to promote its industrial uses.

Creating a technological sequence in which pristine graphite is directly subjected to a solvent treatment and production of exfoliated graphene sheets in the form of stable dispersion suitable for an immediate modification of Kevlar fabric a very important aspect is the dispersion ability to provide Gr particles bonding to the fibres of the modifiable material at the nano/micro level. It is supposed the non-covalent bonding development in result of multiple π–π interactions between the exfoliated Gr particles and highly mobile pi electrons on aromatic rings of Kevlar molecule chains which ensures strong adhesion of the coating by modifying Kevlar fabric with the DMAc-based dispersion.

A comparative analysis of the two types of dispersions presented in the article based on experimental studies shows that the solvent Cyrene- based liquid media can provide Gr exfoliation from graphite flakes, especially after sediments re-dispersion obtaining an equivalent with the DMAc based liquid media Gr particle size distribution and equal PI 25.3% for dispersions d2 and d4. Mean value of Zeta potential of DMAc-based dispersions of d1 is (-39) mV (moderate stability) and increase after sediments re-dispersion till (-43) mV (good stability).

At the same time Gr dispersibility is low because Cyrene, as a solvent, does not provide the electrochemical balance at the particle-liquid interface necessary for stable Gr particles dispersion, resulting in the rapid agglomeration of exfoliated particles and dispersion stratifying. Exploring potential of Zeta of the proposed dispersions in parallel with the studies of the potential energy of the graphene surface and its relationship with the potential energy of the dispersant–solvent system can greatly facilitate the efforts into finding suitable and sustainable solvent alternatives.

In addition, the dispersion dynamic light scattering analysis system allows to evaluate the size distribution of particles suspended in a dispersion media and analyses the parameters characterizing the distribution, which allows optimizing the dispersing solvent system according to the intended use.

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Changes in structure of zooplankton communities in the Daugava River and Pļaviņas Reservoir

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Abstract.* In general 26 taxa of Rotifera, 8 taxa Cladocera and 3 taxa Copepoda group were found in the Daugava River in sampling site- Jēkabpils in 2019, but 25 taxa of Rotifera, 6 taxa Cladocera and 2 taxa Copepoda group were found in the Daugava River in sampling site- Veczeļķi in 2019. In contrast, 26 taxa of Rotifera, 7 taxa Cladocera and 1 taxon Copepoda group were found in the Daugava River in sampling site- Jēkabpils in 2020, and 23 taxa of Rotifera, 1 taxa Cladocera group were found in the Daugava River in sampling site- Veczeļķi in 2020. 28 taxa of Rotifera, 13 taxa Cladocera and 4 taxon Copepoda group were found in the Pļaviņas Reservoir (sampling site- Gostiņi) in 2019, and 25 taxa of Rotifera, 7 taxa Cladocera group and 2 taxon Copepoda group were found in 2020. In the Daugava River in sampling site- Jēkabpils and Veczeļķi the highest percentage of Rotifera taxa were Synchaeta sp., Keratella cochlearis, Brachionus calyciflorus, Brachionus quadridentatus, Euchlanis sp., Polyarthra sp., which were typical species of the Daugava. Cladocera and Copepoda compared with Rotifera have very small percentage of representatives. Rotifera taxa of Pļaviņas Reservoir the highest percentage are Synchaeta sp., Brachionus calyciflorus, Keratella cochlearis, Keratella quadrata, Polyarthra sp. and Asplanchna priodonta. From Cladocera here were found typical of lake zooplankton taxa i.e Bosmina longirostris, Chydorus ovalis, Diaphanosoma brachyurum, Ceriodaphnia sp. Water temperature in the upper layer of the Daugava River and of the Plavinas Reservoir were 22 0C, the dissolved oxygen content 12 mg/l and chlorophyll α concentration 4 µg/l.

***Keywords:* Daugava River, Pļaviņas Reservoir, zooplankton groups, Rotifera, Cladocera, Copepoda, water physico-chemical measurements**

I. INTRODUCTION

Zooplankton include diverse microscopic taxa, such as Rotifera, Copepoda, and Cladocera are very sensitive to environmental changes and, hence, are considered good indicators of ecosystems [1]-[2]. A change in the physical–chemical and biotic parameters in aquatic systems resulted in a change in the relative composition and abundance of organisms thriving in the water. Many species of zooplankton, by filtering food, reduce the effects of eutrophication of the water body, because they control the amount of bacteria and algae by participating in the process of biological self-purification of water. Zooplankton are primary production consumers in waterbodies and one of indicators of waterbodies productivity as they serve as food for many fish, so the organisms are bioindicators, which show water quality [3]-[9]. In general zooplankton is a dynamic system in which the composition of species may significantly change during the season. Numerous abiotic (e.g. temperature, salinity, stratification, pollution) and biotic factors (eg., food, predation, competition) affect temporal changes in the composition of zooplankton species of the temperate climate zones [3]-[6], [8]-[25]. It is really necessary to perform long-term systematic observations for receiving true structure of the ecosystem and for evaluating its natural variation scene ecosystem. The exact and frequent plankton quantitative determination is a prerequisite for accurate evaluation of productivity in rivers and other waterbodies. It is therefore important to carry out such studies in order to check the current composition of zooplankton species at Pļaviņas Reservoir in the Daugava River and in Pļaviņas Reservoir. Qualitative and quantitative variations of zooplankton help to make conclusions about changes in environmental factors and their impact on living organisms.

The obtained data and further long-term research are significant because the conditions of waterbodies which

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affect zooplankton are very diverse and changeable, as a result the data may vary significantly from year to year, so in order to make fundamental conclusions, long-term studies are required.

II. MATERIALS AND METHODS

A. The study area and sampling

Daugava is one of the largest rivers in Eastern European. Daugava is 1005 km long with 87 900 km^2 large catchment area. It is one of the ten largest rivers in the Baltic Sea basin [26]. The Pļaviņas Reservoir is the largest reservoir in Latvia by volume, it is 509.5 million m^3. The area is 35 km^2, the average depth – 14.5 m, the maximum depth – 47 m. The length is 45 km, the maximal width about 2 km, which the minimal is 1 km [27] (Fig. 1).

The study summarizes the data collected during the research of seasonal studies 2019 (June – September) and 2020 (April – September). Zooplankton samples were collected and analysis according to standard method was made [28]-[29]. Zooplankton samples were taken in the three sampling sites: in the River Daugava upstream Pļaviņas Reservoir (sampling sites- Jēkabpils and Veczeļķi) and in the area of Pļaviņas Reservoir (sampling site- Gostiņi). The zooplankton samples were collected using Apstein type plankton net (65 µm), through which 100 liters of water were filtered from the water surface layer (0.5 - 1m depth) (Fig. 1).

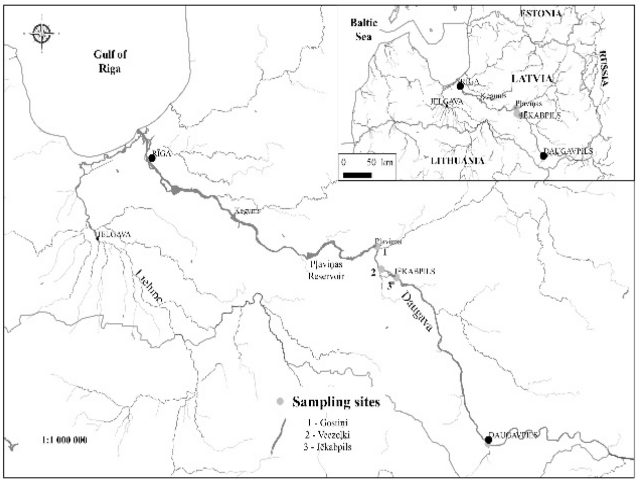

Fig. 1. Location of the sampling area.

B. Physical–Chemical analysis

Along with zooplankton sampling water physico-chemical parameters (water temperature (^{0}C), dissolved oxygen (mg^{-1}) and chlorophil α (μg^{-1}) were also carried out) which were determined at each site of waterbed using a *YSI Pro Plus Multi-Parameter Water Quality Meter* probe.

C. Zooplankton analysis

The collection of zooplankton samples and their quantitative and qualitative analysis was performed in accordance with the American Public Health Association (APHA) Standard method procedures for the water and wastewater analysis [28]-[29]. The quantitative estimation of the zooplankton was performed using a Sedgewick-Rafter chamber. A 1 ml sample was poured on a Sedgwick-Rafter cell, in total 6 ml sample's subvolume examined (1 ml x 6) from each sample [29]. The samples of zooplankton were analysed by using Zeiss Primo Star upright light microscope (100 - 400 x magnification). Having studied the samples in the light microscope the zooplankton organisms were then calculated and identified as species or families. The zooplankton identification was carried out according to the methods described in the zooplankton guides in [30]-[53].

The following formula was used to calculate the number of organisms in a sample:

$$N= (a \times b \times 1000) / (c \times d) /1000 \qquad (1)$$

where a - is a calculated number of organisms (average);
b - is a volume of concentrated sample;
c - is a sample volume;
d - is a volume of filtered water;
N - is a number of organisms per 1 l (litre).

D. Statistical analysis

The Shannon-Wiener function (H') was used to calculate as [54]:

$$H' = -\sum_{i=1}^{S} (pi)(\ln pi) \qquad (2)$$

where H'- is the index of species diversity,
S - is the number of species, and
p_i - is a proportion of the total sample belonging to i th species.

Since the resulting equation is a measure of bits, we used the following equation to move from the bits unit to the species unit [55]-[56]:

$$N_1 = e^{H'} \qquad (3)$$

where e is equal to 2.71828 (base of natural logs),
H' - Shannon-Wiener function (calculated with base e logs), and
N_1 - the number of equally common species that would produce the same diversity as H'.

III. RESULTS AND DISCUSSION

In general 26 taxa of Rotifera, 8 taxa Cladocera and 3 taxa Copepoda group were found in the Daugava River in sampling site- Jēkabpils in 2019, but 25 taxa of Rotifera, 6 taxa Cladocera and 2 taxa Copepoda group were found in the Daugava River in sampling site- Veczeļķi in 2019 (Table 1, Fig. 2).

TABLE 1 DIVERSITY OF ZOOPLANKTON TAXA IN ALL SAMPLING SITES IN 2019

Species (taxa)	**Gostiņi**	**Jēkabpils**	**Veczeļķi**	**Species common to all places**
ROTIFERA	**28**	**26**	**25**	**19**
Asplanchna priodonta Gosse, 1850	+			
Brachionus angularis Gosse, 1851	+	+	+	+
Brachionus calyciflorus Pallas, 1766	+	+	+	+
Brachionus quadridentatus Hermann, 1783	+	+	+	+
Cephalodella gibba (Ehrenberg,1832)	+		+	
Conochilus sp. Ehrenberg, 1834	+	+	+	+
Dicranophorus Nitzsch, 1827	+	+	+	+
Euchlanis sp. Ehrenberg, 1832	+		+	
Filinia longiseta (Ehrenberg, 1834)	+	+	+	+
Gastropus stylifer (Imhof, 1891)	+	+	+	+
Keratella cochlearis (Gosse, 1851)	+	+	+	+
Keratella quadrata (Müller, 1786)	+	+	+	+
Lacinularia sp. Schweigger, 1820	+		+	
Lecane flexilis (Gosse, 1886)	+		+	
Lecane luna (Müller, 1776)	+	+	+	+
Lecane lunaris (Ehrenberg, 1832)	+	+	+	+
Lepadella sp. Bory de St. Vincent, 1826		+		
Mytilina mucronata (Müller, 1776)	+	+	+	+
Notholca acuminata (Ehrenberg, 1832)	+			
Polyarthra sp. Ehrenberg, 1834		+	+	
Proales sp. Gosse, 1886		+		
Rotifera sp. (Pallas, 1766)	+	+	+	+
Synchaeta sp. Ehrenberg, 1832	+	+	+	+
Taphrocampa selenura (Gosse, 1887)	+	+	+	+
Testudinella patina (Hermann, 1783)	+	+	+	+
Trichocerca capucina (Wierzejski & Zacharias, 1893)		+		
Trichocerca cylindrica (Imhof, 1891)		+	+	
Trichocerca longiseta (Schrank, 1802)	+			
Trichocerca porcellus (Gosse, 1851)	+	+		
Trichocerca pusilla (Jennings, 1903)		+		
Trichocerca rousseleti (Voigt, 1902)	+			
Trichocerca similis (Wierzejski, 1893)	+	+	+	+
Trichotria pocillum (Müller, 1776)	+	+	+	+
CLADOCERA	**13**	**8**	**6**	**5**
Acroperus harpae (Baird, 1835)	+	+	+	+
Bosmina (Bosmina) longirostris (O. F. Müller, 1776)	+	+	+	+
Ceriodaphnia sp. Dana, 1853	+	+	+	+
Chydorus ovalis (Kurz, 1875)	+	+	+	+
Chydorus sphaericus (O. F. Müller, 1776)	+			
Daphnia sp. (O. F. Müller, 1785)	+			
Diaphanosoma brachyurum (Liévin, 1848)	+	+	+	+
Eurycercus (Eurycercus) lamellatus (O. F. Müller, 1776)	+			
Kurzia latissima (Kurz, 1875)	+		+	
Pleuroxus (Peracantha) truncatus (O. F. Müller, 1785)	+	+		
Polyphemus pediculus (Linnaeus, 1758)	+			
Scapholeberis mucronata (O. F. Müller, 1776)	+	+		
Sida crystallina (O. F. Müller, 1776)	+	+		
COPEPODA	**4**	**3**	**2**	**1**
Acanthocyclops sp. Kiefer, 1927	+	+		
Macrocyclops sp. Claus, 1893	+			
Cyclops sp. Müller, 1785	+	+	+	+
Eucyclops sp. Claus, 1893	+	+		
Eudiaptomus sp. Kiefer, 1932			+	
Copepodite cyclopoid	+	+	+	+
Nauplii	+	+	+	+
Total taxa	**45**	**37**	**33**	**25**

In contrast, 26 taxa of Rotifera, 7 taxa Cladocera and 1 taxon Copepoda group were found in the Daugava River in sampling site- Jēkabpils in 2020, and 23 taxa of Rotifera, 1 taxa Cladocera group were found in the Daugava River in sampling site- Veczeļķi in 2020 (Table 2, Fig.3). There were only subadult specimens - nauplii and Copepodite from Copepoda group.

TABLE 2 DIVERSITY OF ZOOPLANKTON TAXA IN ALL SAMPLING SITES IN 2020

Species (taxa)	Gostiņi	Jēkabpils	Veczeļķi	Species common to all places
ROTIFERA	**25**	**26**	**23**	**17**
Asplanchna priodonta Gosse, 1850	+			
Brachionus angularis Gosse, 1851	+	+	+	+
Brachionus calyciflorus Pallas, 1766	+	+	+	+
Brachionus quadridentatus Hermann, 1783	+	+		
Cephalodella gibba (Ehrenberg,1832)	+	+	+	+
Conochilus sp. Ehrenberg, 1834			+	
Dicranophorus sp.Nitzsch, 1827	+	+	+	+
Euchlanis sp. Ehrenberg, 1832	+	+	+	+
Filinia longiseta (Ehrenberg, 1834)			+	
Kellicottia longispina Kellicott, 1879	+	+	+	+
Keratella cochlearis (Gosse, 1851)	+	+	+	+
Keratella quadrata (Müller, 1786)		+	+	
Lacinularia sp. Schweigger, 1820		+		
Lecane flexilis (Gosse, 1886)	+	+		
Lecane luna (Müller, 1776)	+	+		
Lecane lunaris (Ehrenberg, 1832)	+	+		
Lecane sp. Nitzsch, 1827			+	
Lepadella (Lepadella) ovalis (Müller, 1786)	+	+	+	+
Mytilina mucronata (Müller, 1773)		+		
Notholca acuminata (Ehrenberg, 1832)	+	+	+	+
Notholca squamula (Müller, 1786)	+		+	
Polyarthra sp. Ehrenberg, 1834	+	+	+	+
Pompholyx sulcata Hudson, 1885	+	+	+	+
Rotifera sp. (Pallas, 1766)	+	+	+	+
Synchaeta sp. Ehrenberg, 1832	+	+	+	+
Taphrocampa selenura (Gosse, 1887)	+	+	+	+
Testudinella patina (Hermann, 1783)	+	+	+	+
Trichocerca cylindrica (Imhof, 1891)	+	+	+	+
Trichocerca porcellus (Gosse, 1851)	+	+	+	+
Trichocerca similis (Wierzejski, 1893)	+	+		
Trichotria pocillum (Müller, 1776)	+	+	+	
CLADOCERA	**7**	**7**	**1**	**1**
Acroperus harpae (Baird, 1835)		+		
Bosmina (Bosmina) longirostris (O. F. Müller, 1776)	+	+		
Ceriodaphnia sp. Dana, 1853	+	+		
Chydorus ovalis (Kurz, 1875)	+	+	+	+
Diaphanosoma brachyurum (Liévin, 1848)	+			
Kurzia latissima (Kurz, 1875)	+	+		
Pleuroxus (Peracantha) truncatus (O. F. Müller, 1785)		+		
Polyphemus pediculus (Linnaeus, 1758)	+			
Scapholeberis mucronata (O. F. Müller, 1776)		+		
Sida crystallina (O. F. Müller, 1776)	+			
COPEPODA	**2**	**1**	**0**	**0**
Acanthocyclops sp. Kiefer, 1927	+	+		
Copepodite cyclopoid	+	+		
Cyclops sp. Müller, 1785	+			
Nauplii	+	+	+	+
Total taxa	**34**	**34**	**24**	**18**

28 taxa of Rotifera, 13 taxa Cladocera and 4 taxon Copepoda group were found in the Pļaviņas Reservoir (sampling site- Gostiņi) in 2019 (Table 1, Fig.4), and 25 taxa of Rotifera, 7 taxa Cladocera group and 2 taxon Copepoda group were found in 2020 (Table 2, Fig. 4).

Big zooplankton biodiversity in the Daugava River and in the Pļaviņas Reservoir is due to the Daugava large catchment area - 87,900 km^2 [57], which includes tributaries and the water system. When water level in the river changes the exchange of plankton fauna takes place between these water bodies. In the 60-ies of 20th century, Škute [58] carried out a research of 28 Daugava River tributaries and noted that the the upper reaches of the Daugava River tributaries have a significant effect on the Daugava zooplankton cenosis, zooplankton quantity even doubled in some of the tributaries of the river. Rotifera usually dominates in river plankton both qualitatively and quantitatively [59]-[68]. The results of our research show that the greatest diversity of zooplankton taxa is in Rotifera group both in the Daugava River and at the Pļaviņas Reservoir. The greatest diversity of zooplankton taxa was also established among Rotifera species that were found in the Daugava near Daugavpils [60]-[61], [68]. However, these authors in their studies mentioned that sometimes during the summer and autumn Cladocera group is also widely represented. In our case, taxa of Rotifera group were observed at the Pļaviņas Reservoir in July, however in September the number of taxa rapidly decreased, while many of Cladocera group taxa- *Acroperus harpae, Chydorus ovalis, Ceriodaphnia* sp., *Pleuroxus truncatus* taxa appeared in September.

However, taking into account that the weight of the majority of Cladocera and Copepoda representatives exceeds the weight of representatives of Rotifera group, it can be concluded in terms of biomass that all zooplankton groups in the Daugava are equally well represented. It should be noted that throughout all the stages of rivers and reservoir under research, the variation among zooplankton quantity is similar. Such variation is also determined by the influence of water body hydrological, hidrometreological factors, for example water temperature ^{0}C, the dissolved oxygen content, chlorophyll α concentration, where the thermal water regime and water level fluctuations are of particular importance, as well as overgrowth of the water body and the pollution degree.

The sections of the river where there are a lot of macrophyte in the coastal zone, macrophytes become the decisive factor for the formation of the river zooplankton [63], [69]. When compared quantitative and qualitative parameters of taxa (by Shannon-Wiener diversity) both in the Daugava before the Pļaviņas Reservoir and in the Pļaviņas Reservoir (Fig. 4). By contrast, there is no such a big diversity of taxa in the reservoir, but the dominance of certain taxa appears there, which is not typical of the river plankton. The number of the species does not only depend on the sampling time, habitat diversity, but also on the sampling frequency during the season and on the size of the water body [70]. Several authors in their researches [63], [71]-[73] noted the influence of fish on zooplankton cenosis, but the influence of fish is significant only in small rivers. The main influencing factors in large rivers that determine the number of zooplankton, in particular crustaceans, is the river hydrology and predators [63], [66], [69], [74]-[78].

The sections of the river where there are a lot of macrophyte in the coastal zone, macrophytes become the decisive factor for the formation of the river zooplankton [63], [69]. When compared quantitative and qualitative parameters of taxa (by Shannon-Wiener diversity) both in the Daugava before the Pļaviņas Reservoir and in the Pļaviņas Reservoir (Fig. 5). By contrast, there is no such a big diversity of taxa in the reservoir, but the dominance of certain taxa appears there, which is not typical of the river plankton. The number of the species does not only depend on the sampling time, habitat diversity, but also on the sampling frequency during the season and on the size of the water body [70]. Several authors in their researches [63], [71]-[73] noted the influence of fish on zooplankton cenosis, but the influence of fish is significant only in small rivers. The main influencing factors in large rivers that determine the number of zooplankton, in particular crustaceans, is the river hydrology and predators [63], [66], [69], [74]-[78].

IV. CONCLUSIONS

From the study, it can be concluded that there are variations in the number and diversity of species in the samples collected in the Daugava River and in the Pļaviņas Reservoir. Zooplankton taxa in the Daugava River are typical of moving water bodies, but zooplankton in the Pļaviņas reservoir is more characteristic for stagnant water masses. A large diversity of the Rotifera taxa was found in the Daugava River and in the Pļaviņas reservoir, but no taxa dominated in the River, however in the Pļaviņas Reservoir the dominance of certain taxa was identified. The diversity of Cladocera taxa in the Daugava River is very low, whereas, in the Pļaviņas Reservoir this diversity is much bigger. The dominance of individual taxa was also observed among the Cladocera group. Mainly subadult copepodite of Copepoda group were identified both in the Daugava River and in the Pļaviņas Reservoir. The identified differences could be due to the fact that zooplankton species are very sensitive to various changes in environmental factors, such as weather conditions, change in each specific place vegetation, overgrow, depth and physico-chemical parameters of the properties as well as with biological characteristics of each species, such as seasonality.

ACKNOWLEDGMENTS

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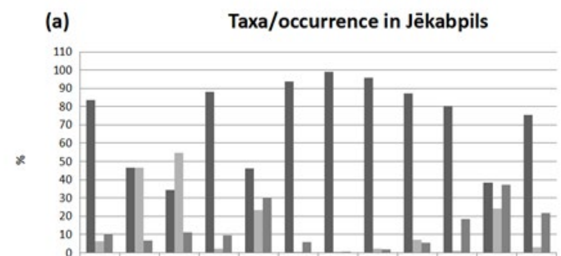

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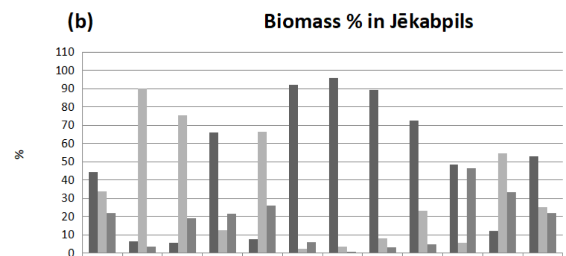
ROTIFERA	83.5	46.6	34.2	88.2	46.2	93.9	99	95.7	87.4	80.5	38.5	75.5
CLADOCERA	6.4	46.6	54.7	2.4	23.5	0.3	0.2	2.4	7	1	24.1	2.9
COPEPODA	10.1	6.8	11.2	9.5	30.3	5.8	0.7	1.9	5.5	18.5	37.4	21.6



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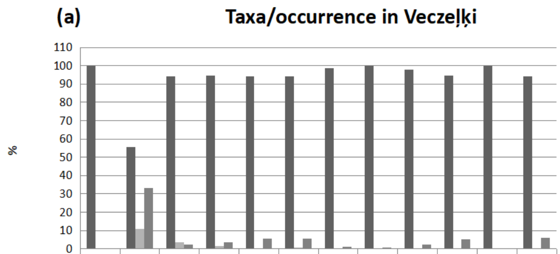
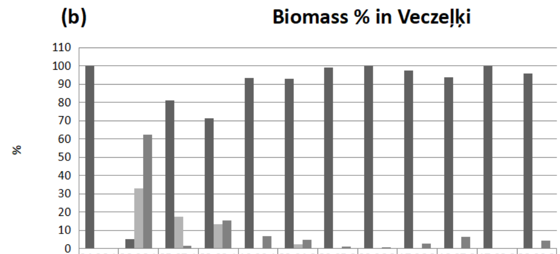
ROTIFERA	44.3	6.5	5.7	66	7.5	91.9	95.8	89	72.3	48.2	12.1	52.8
CLADOCERA	33.9	90.1	75.4	12.6	66.4	2.3	3.6	7.9	23.1	5.5	54.5	25.3
COPEPODA	21.9	3.4	18.9	21.4	26.1	5.8	0.6	3	4.6	46.3	33.4	22

Fig.2. The percentage of taxa (a) and biomass (b) of the Rotifera, Cladocera & Copepoda groups in sampling site Jēkabpils.

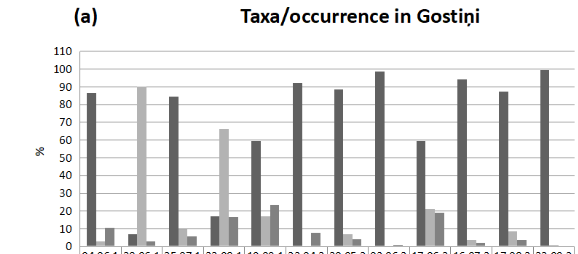


	04.06.19.	28.06.19.	25.07.19.	22.08.19.	19.09.19.	23.04.20.	20.05.20.	03.06.20.	17.06.20.	16.07.20.	17.08.20.	22.09.20.
ROTIFERA	100	55.6	94.1	94.7	94.3	94.2	98.8	99.7	97.8	94.7	100	94.1
CLADOCERA	0	11.1	3.6	1.7	0	0.3	0	0	0	0	0	0
COPEPODA	0	33.3	2.4	3.6	5.7	5.5	1.2	0.3	2.2	5.3	0	5.9

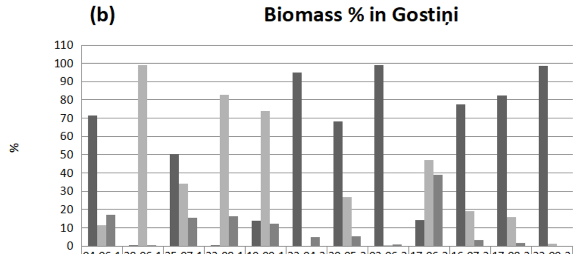


	04.06.19.	28.06.19.	25.07.19.	22.08.19.	19.09.19.	23.04.20.	20.05.20.	03.06.20.	17.06.20.	16.07.20.	17.08.20.	22.09.20.
ROTIFERA	100	5.2	81.2	71.4	93.1	92.8	98.9	99.9	97.5	93.8	100	95.7
CLADOCERA	0	32.7	17.5	13.4	0	2.3	0	0	0	0	0	0
COPEPODA	0	62.1	1.3	15.3	6.9	4.9	1.1	0.1	2.5	6.2	0	4.3

Fig. 3. The percentage of taxa (a) and biomass (b) of the Rotifera, Cladocera & Copepoda groups in sampling site Veczeļķi.

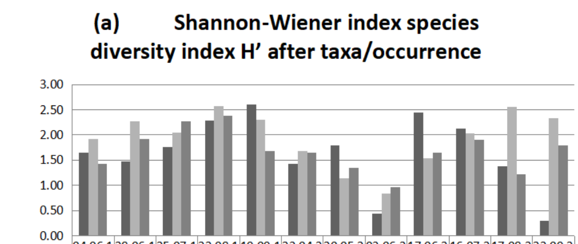


	04.06.19.	28.06.19.	25.07.19.	22.08.19.	19.09.19.	23.04.20.	20.05.20.	03.06.20.	17.06.20.	16.07.20.	17.08.20.	22.09.20.
ROTIFERA	86.4	7.2	84.4	17	59.6	92.2	88.7	98.8	59.7	94.3	87.5	99.6
CLADOCERA	2.8	90	9.7	66.5	16.9	0	7.2	0.2	21.2	3.7	8.8	0.4
COPEPODA	10.8	2.8	5.9	16.5	23.6	7.8	4.1	1	19.1	2.1	3.6	0

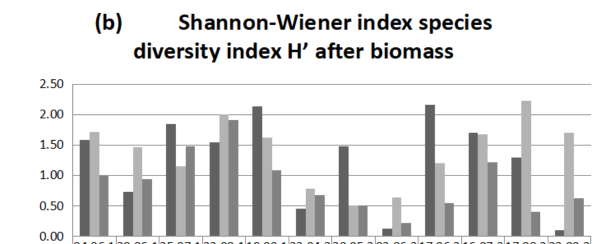


	04.06.19.	28.06.19.	25.07.19.	22.08.19.	19.09.19.	23.04.20.	20.05.20.	03.06.20.	17.06.20.	16.07.20.	17.08.20.	22.09.20.
ROTIFERA	71.5	0.5	50.3	0.6	13.7	94.9	68.1	98.9	14.1	77.4	82.5	98.6
CLADOCERA	11.4	99	34	83	74	0	26.7	0.6	47.2	19.2	15.9	1.4
COPEPODA	17	0.5	15.6	16.4	12.3	5.1	5.2	0.4	38.8	3.4	1.6	0

Fig. 4. The percentage of taxa (a) and biomass (b) of the Rotifera, Cladocera & Copepoda groups in sampling site Gostiņi.



	04.06.19.	28.06.19.	25.07.19.	22.08.19.	19.09.19.	23.04.20.	20.05.20.	03.06.20.	17.06.20.	16.07.20.	17.08.20.	22.09.20.
Gostiņi	1.64	1.47	1.76	2.28	2.60	1.43	1.79	0.44	2.44	2.12	1.37	0.30
Jēkabpils	1.92	2.27	2.04	2.58	2.30	1.68	1.14	0.85	1.54	2.02	2.56	2.33
Veczeļķi	1.42	1.92	2.26	2.39	1.69	1.64	1.34	0.97	1.64	1.90	1.22	1.79



	04.06.19.	28.06.19.	25.07.19.	22.08.19.	19.09.19.	23.04.20.	20.05.20.	03.06.20.	17.06.20.	16.07.20.	17.08.20.	22.09.20.
Gostiņi	1.59	0.73	1.85	1.54	2.13	0.45	1.48	0.12	2.16	1.70	1.30	0.10
Jēkabpils	1.71	1.47	1.15	2.00	1.63	0.78	0.51	0.64	1.20	1.67	2.23	1.70
Veczeļķi	0.99	0.94	1.48	1.90	1.08	0.68	0.51	0.22	0.55	1.22	0.41	0.63

Fig. 5. Shannon-Wiener diversity index of taxa (a) and biomass (b) of the Rotifera, Cladocera & Copepoda groups in sampling sites Gostiņi, Jēkabpils and Veczeļķi).

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The agriculture development in market oriented agricultural holdings in European union /Bulgarian case study/

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Abstract. This article explores the development of market-oriented agricultural holdings in the European Union (EU), with a specific focus on the Bulgarian agricultural sector. By analyzing agricultural holdings within the Farm Accountancy Data Network (FADN), the study aims to focus the challenges and opportunities faced by farmers in a market-driven agricultural landscape.
The EU's Common Agricultural Policy (CAP) has been instrumental in shaping the agriculture sector across member states. As the EU transitions towards a more market-oriented approach, agricultural holdings are required to adapt to changing market dynamics, technological advancements, and environmental sustainability. Hence these are the holdings which could deploy in practice the Agriculture 4.0 techniques.Through a comprehensive analysis of the FADN data, this article aims to identify the factors that contribute to the success or failure of market-oriented agricultural holdings in Bulgaria.
The Bulgarian case study provides insights into the challenges faced by market-oriented agricultural holdings. The country's unique socio-economic characteristics, including a rural population and a history of agricultural production, make it an interesting case for analysis. The study examines key indicators such as farm size, land use, production diversity, and income levels within the FADN database. Furthermore, it explores the impact of EU policies, market integration, and access to financial resources on the development of these holdings.
Keywords: Agriculture 4.0, European union, Bulgaria, FADN

I. INTRODUCTION

Agriculture remains a cornerstone of the European Union's economy, with market-oriented agricultural holdings playing a crucial role in ensuring food security, economic stability, and social welfare especially in rural areas. The transition towards market-oriented agricultural holdings has been a key aspect of Common Agricultural Policy (CAP) reforms within the EU. This shift aims to enhance competitiveness, efficiency, and sustainability within the agricultural sector. The market-oriented agricultural holdings are divided into different stages according to their standard output. The standard output (SO) of an agricultural product (crop or livestock) is the average monetary value of the agricultural output at farm-gate price, in euro per hectare or per head of livestock [1]. The standard output is used to classify agricultural holdings by type of farming and by economic size [2]. This article delves into the development of such holdings in Bulgaria, providing a case study that reflects the broader EU context. The analysis covered the period 2007 - the year of Bulgarian accession in the EU till 2022. Because of the specific of the statistical information and observations of these market oriented agricultural holdings the analysis is focused on data as: average economic size, numbers of represented farms, total utilized agricultural area, total livestock units, total output, farm net value added, as well draw conclusions through samples of equity standing years, i.e. 2007, 2010, 2013, 2016, 2019, 2022.

II. MATERIALS AND METHODS

The farm accountancy data network (FADN) will be the primary data source for this study, which provides comprehensive and detailed data on farm economics within the EU. The FADN monitors farms' income and business activities and is a reliable informative source for analysis of market-oriented agricultural holdings. This database of microeconomic variables is based on harmonized bookkeeping principles, i.e. covers only EU

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agricultural holdings which, due to their size, can be considered commercial.

The literature review method involves systematically searching for, appraising, and synthesizing research evidence from existing studies, reports, and academic papers relevant to this study. This is good method to known and identify gaps in the current knowledge.

The secondary data analysis is quantitative method which involves analysing existing data sets, such as agricultural productivity statistics, economic indicators, and demographic data. This data for agricultural holdings is from FADN EU databases, research institutions, and international organizations.

The comparative analysis as method is used to compare the situation in different types of agricultural holdings within Bulgaria. It helps to contextualize the findings and understand the relative performance or characteristics of the subject of study.

III. RESULTS AND DISCUSSION

The market-oriented agricultural holdings are the main driver for development and diversification of agricultural activities in rural areas. These holdings could apply new technologies leading to Agriculture 4.0 concept. Digital transformation (DT) is necessary to improve efficiency, productivity, and market access in the context of Green Deal and increasing competition. In the agri-food sector, DT is required to address the challenges of food safety, food waste, and sustainability [3]. All the recent challenges that both rural areas and agriculture in general had faced raised concerns that moving forward, the higher productivity should not be the only driving force. Sustainable practices must be followed to ensure that agriculture is responsible towards the natural resources, biodiversity, climate and the society itself [4]. The economic uncertainty since COVID-19 and different interventions in Europeans countries are the most relevant difficulties with which the market-oriented holdings must resolve. The EU managed to react timely to the new market developments and responded fast to the COVID-19 crisis by applying new rules and procedures, not only in sectoral policies, but also in the more general competition and competitiveness stimulating policy directions [5].

According to the SO classification the market-oriented agricultural holdings are divided in 6 economic sizes /in levels 1 to 6/ as follow:

(1) 2 000 - < 8 000 EUR

(2) 8 000 - < 25 000 EUR

(3) 25 000 - < 50 000 EUR

(4) 50 000 - < 100 000 EUR

(5) 100 000 - < 500 000 EUR

(6) >= 500 000 EUR

Fig. 1 indicates the dynamic of average economic size of the market-oriented agricultural holdings within every level of economic sizes through the analyzed period. The farms from the first four levels are without any change in economic size for the period of fifteen years. There is a change only in the biggest agricultural holdings at levels 5 and 6 but it is not sustainable and fluctuates up and down. The increase of average economic size of farms in level 5 is 7 per cent in 2022 compared to 2007, respectively in state 6 the increase is 15 per cent.

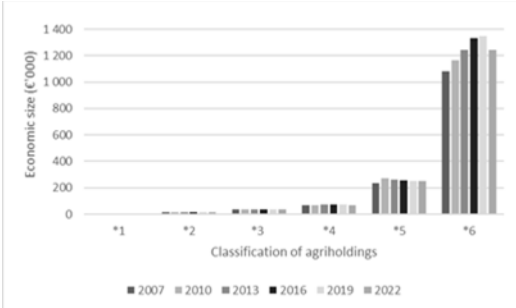

Fig. 1. Average economic size of the agricultural holdings.

Fig. 2 observes the numbers of market-oriented farms. During the period there are tremendous changes in this indicator. The smallest farms are on the verge of existence, i.e. their number drop by 7.5 times in 2022 compared to 2007 year.

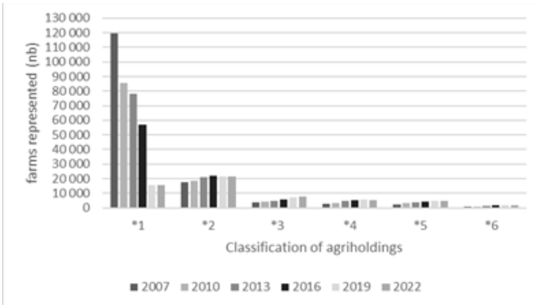

Fig. 2. Number of the agricultural holdings.

In contrast the number of market-oriented agricultural holdings in all other levels, is increasing considerably. In level (2) 8 000 - < 25 000 EUR the number of holdings is increased in 20 per cents, (3) 25 000 - < 50 000 EUR – increasing is 2 times, as well as the other levels above the increasing is between 1.5 and 2 times. All this turbulence as result in numbers of market-oriented farms in Bulgaria in 2022 – 56 987 compared to 146 769 in 2007 year.

The bigger farms in terms of economic point of view means better economic sustainability and more options of adoption of new Agriculture 4.0 related cut edge technologies. The application of smart village's concept is a forefront example of social innovation in rural areas [6]. However, tremendous decreasing of the smallest farms could indicate severe depopulation of the rural areas. Thus, will undeniably reflected in national security possible threats. The topic of career attitudes is rooted in human resource management, provoking academics, practitioners, psychologists, labor market analysts and others to seek solutions to real and potential challenges. The subject is dynamic due to changing generations, living environment, and career opportunities [7]. The lack of infrastructure and job opportunity add more negative effect of rural development areas in Bulgaria.

Fig. 3 analysis is focused on the average size of each of the 6 levels of market-oriented agricultural holdings. There is a clear trend among the farms, i.e. these from the first level ((1) 2 000 - < 8 000 EUR) are growing bigger – from 3.1 ha to 5.4 ha, as well as at the level (2) 8 000 - < 25 000 EUR – 14.3 ha to 16.5 ha respectively 2007 to 2022 year.

In contrast the size of farms – in terms of utilized agricultural area in the upper levels (3 to 6) is decreasing between 5 to 55 percent. This leads to the conclusion that the restructuring of the holdings and their activities which relate to land will be further developed. Must be said that maybe one of main drivers for decreasing the average size of farms, in levels 3, 4 and 5 is additional national funding for smaller holdings – this will be topic of discussion for further papers.

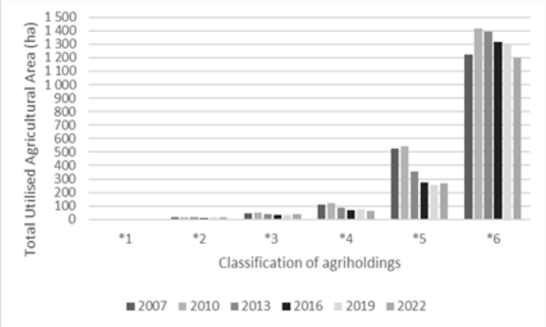

Fig. 3. Total utilised agricultural area (ha).

Fig. 4 is representative of Livestock units (LSU) [8] which are within the market-oriented agricultural holdings. Unfortunately, in all the farms in each level of classification (1-6) there is a decrease in this indicator.

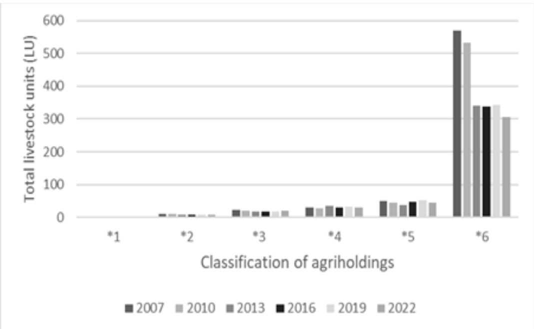

Fig. 4. Total livestock units (LU).

The animal breeding in Bulgaria was always suffer lack of support from the government as well as farm to fork strategy and was exposed in the goodwill of the free market. This could be changed if innovation and the concept of Agriculture 4.0 are applied in the future. This sub-sector of the agriculture could benefit in terms of added value, sustainability, innovation, and digitalization in rural area in Bulgaria. The digital social and economic transformation is the key for achievement of the digital future of Europe [9].

Till now the average number of LSU per farm indicates critical condition of the sector and even the biggest agricultural holdings decreased numbers of LSU with almost 35 percent. Must be mentioned that through the analyzed period there were few animal diseases in the poultry and pigs which led to their extermination in the biggest agricultural holdings in the country. We should consider that food security, where animal breeding plays a vital role, is crucial for national security in terms of the possibility of feeding your own population. Besides the animal breeding is the key for added value in the sector and export opportunities.

Fig. 5 is focused on total output (€/farm) which is crucial for farms' survival and future development. This indicator is total value of output of crops and crop products, livestock, and livestock products and of other output, including that of other gainful activities (OGA) of the farms. In other words - sales and use of (crop and livestock) products and livestock + change in stocks of products (crop and livestock). Here clearly is indicated the increase of the indicator which is corresponding to improved market efficiency within the small number of agricultural households.

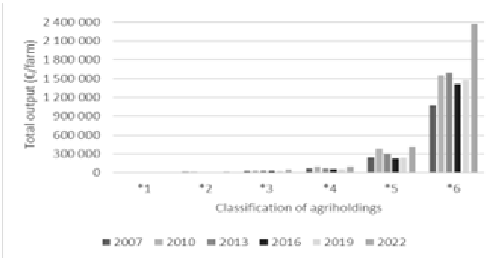

Fig. 5. Total output (€/farm).

However, it must be noted that the prices of agricultural products soared last 5 years. This is provoked from COVID-19 pandemic as well as the war Russia-Ukraine. This is one more evidence that sustainability in rural area could not be underestimate so intensification of production within EU rural development is crucial for further innovation. The increase of the indicator is between 15 and 55 percent respectively 2007 and 2022 year and the biggest share is in the biggest market-oriented farms (level 6 >= 500 000 EUR).

On the one hand, advances in science and technology have had an impact on how the results of human labour are presented, ac cessed, used, and disseminated. On the other hand, demand, market niches and sales have undergone revision and reorganization. Changes in supply, demand and affordability have become an opportunity and/or a threat [10].

Fig. 6 is the last analysed indicator which is Farm net value added (in €). This is remuneration to the fixed factors of production (work, land, and capital), whether they be external or family factors. This last indicator reveals that every market-oriented farm in all the levels of classification has significantly increase between 2 and 3 times during the period. This could be as proof that the successful market-oriented farm is more sustainable during market turmoil within the period. Consequently, there has been a shift in societal expectations, putting emphasis on the role of business in protecting and preserving the environment, with companies becoming increasingly sensitive to, and committed to, social and environmental issues [11]. The digitalization and innovations in market-oriented agriculture will be in great beneficent for the society and Bulgarian's economy. In recent years the interest in innovation and implementation of digital solutions in the public sector is growing at a rapid pace, both at global and regional level. [12]

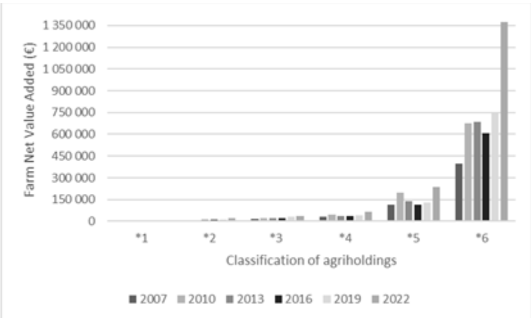

Fig. 6. Farm net value added (€).

IV. CONCLUSIONS

The development of market-oriented agricultural holdings in Bulgaria is not unique trends in the EU's agricultural sector. The competitiveness, restructuring, and social impact of these holdings are connected with the country's socio-economic context. Smallholder farms lack behind their development in Bulgaria's agriculture, emphasizing the need for a balanced approach that integrates technological innovation with ecological and social considerations. The competitiveness of these holdings should be shaped by effective management, innovation, and the integration into sustainable food supply chains. Smallholder market-oriented farms, despite facing challenges, remain integral to Bulgaria's food security and the well-being of rural communities. Policy initiatives and the goal of sustainability impact the future of agriculture. The central role of agriculture in environmental and climate challenges are aware in recent policy, such as the EU's farm to fork strategy, biodiversity strategy, and the common agricultural policy (CAP) for 2023-2027. The CAP Strategic Plan for 2023-2027 sets a strategic direction for the sector, focusing on sustainability, competitiveness, so it's essential for Bulgaria evolve its agricultural practices. This case study is attempted to serves as an understanding the broader trends and policies shaping agriculture in the European Union as well as in Bulgaria.

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From fossil fuels to renewable energy: Tracking Bulgaria's transition

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Abstract. The report examines Bulgaria's progress in transitioning from fossil fuels to renewable energy sources. It analyses the achievements and challenges faced by the country in this process. Recent changes in Bulgaria's energy mix, with a focus on the growth of renewable energy capacity, are discussed. The report outlines the achievements of Bulgaria's energy transition and emphasizes the importance of diversifying the energy mix. In addition, the challenges faced by the country in this transition are also addressed. The significance of factors such as policy and regulatory issues, economic and social considerations, technological and climate limitations is also highlighted. The research methods used include a review and analysis of relevant literature, examination of statistical data and reports from energy authorities, and interviews with experts in the field. This approach allows for a comprehensive understanding of Bulgaria's transition to renewable energy. The report draws conclusions on the performance of the sector and emphasizes the importance of different energy sources for the security and reliability of the electricity system and identifies key areas for further improvement.
Keywords: Bulgaria, electricity sector, renewable energy sources

I. INTRODUCTION

The energy transition is a global phenomenon that is a part of a broader transformation of the world economy towards climate neutrality. It involves a shift in the way society produces and consumes energy, with a key focus on replacing traditional fossil fuels with alternative renewable and low-carbon energy sources. This process of a fundamental change of the energy system is a complex and multifaceted task that brings a lot of challenges and opportunities. It involves various shareholders, different technologies and new infrastructure which require huge investment. In this process, finding the right balance between security, sustainability, and reliability of energy supply forces governments to take difficult decisions. The transition is also challenging for individual companies in the energy and resources industry as they face their own crises in the ongoing uncertainty of energy markets.

The purpose of this report is to examine the experience of Bulgaria in transitioning from fossil fuels to renewable energy sources. It focuses on the increasing integration of renewable energy sources into the country's energy mix. The key role of government measures in promoting the energy transition is also emphasized. The report evaluates the implementation of policies and measures related to low-carbon energy. Analysing the statistical data, it identifies and discusses the challenges and barriers faced by Bulgaria in its energy transition.

II. MATERIALS AND METHODS

Over the last ten years, advancements toward a new energy system have gained momentum. The growth in the renewable energy sector has stimulated significant research focus on this topic. A multitude of studies and reports have emerged, examining various dimensions of the shift to a low-carbon economy.

Researchers have been actively involved in constructing various models and making predictions about the future development of the renewable energy sector, providing insights into potential scenarios. Stefan Ćetković conducts comparisons of different energy transition models pursued by individual countries worldwide [1]. Authors such as Erik Gawel, Sebastian Strunz, and Paul Lehmann examine support policies for renewables from a public choice perspective [2], while Y. Yankov analyses energy transition from the perspective of geopolitics and diplomacy [3]. D. Stoilov develops model instruments for strategic planning of energy development in Bulgaria [4]. This research enables policymakers and stakeholders to develop strategies and improve energy planning.

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International organizations, including the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA), as well as specialized supranational energy organizations like the Agency for the Cooperation of Energy Regulators (ACER) the European Network of Transmission System Operators for Electricity (ENTSO-E), the Federation of the European electricity industry (Eurelectric) have also contributed to the body of knowledge on the subject. Their publications examine various aspects and challenges of the transition, including preconditions, ongoing progress and results observed in different countries.

A. The World context

Renewable energy has become the fastest-growing energy source in most of the developed countries. China has emerged as major player in clean energy, accounting for around half of the global wind and solar additions and well over half of global EV sales in 2022 [5]. While oil and gas continue to play a role in the global economy, the transition towards renewable energy is expected to accelerate. The share of renewables in the global power mix is projected to approach 50 % by 2030 from around 30% today [5].

There are factors worldwide that collectively contribute to the shift towards a more low-carbon economy. Policies and regulations play a critical role in driving the transition. Regulations are becoming stricter, and capital is increasingly being directed towards renewable energy investments. Technological advancements are driving progress, with solar energy becoming the most cost-effective source of new electricity generation in many markets, even amidst inflation and price increases [6]. Furthermore consumer attitudes are also changing, with a growing interest in sustainability.

On the other hand, global geopolitical tensions, especially the war in Ukraine have underlined the importance of energy security. They have led to a renewed focus on renewable energy especially in countries that rely on energy imports. Instead of slowing down, investments in the energy transition have soared to unprecedented levels. In 2022 investments in low-carbon technologies surpassed $1 trillion for the first time, driven by strong clean energy policies in major economies [7]. Notably, the US Inflation Reduction Act allocated $369 billion for greentech initiatives, and the European Commission provided $270 billion for cleantech companies. China emerged as the dominant recipient of energy transition investments, attracting $546 billion, which accounted for nearly half of the global total [7]. In 2023, global investment in the low-carbon energy transition experienced a remarkable 17% surge, reaching a record-breaking $1.77 trillion [8].

B. The EU context

The European Union has implemented a number of strategies that set targets and deadlines for making the EU the world's first carbon-neutral economy by 2050. In 2019 the European Green Deal was introduced, followed by the adoption of the Climate Law. Additionally, the EU Fit for 55 legislative package was presented, outlining a plan to reduce emissions in the EU by at least 55% by 2030. To reduce energy dependence and accelerate the energy transition, the REPowerEU plan was published in 2022. The EU has also established ambitious goals for the share of energy from renewable sources in gross energy consumption. By 2030, the EU aims to achieve an average share of 42.5%, with a further target of 45% as each Member State determines its own national contributions towards this target [9].

In 2022, the energy mix in the EU mainly consisted of five different sources. Oil and petroleum products have the largest share in it (37%), followed by natural gas (21%), renewable energy (18%), solid fossil fuels (12%) and nuclear energy (11%). The shares of the different energy sources in the gross available energy vary significantly among Member States. In 2022, the share of petroleum products in the overall energy was highest in countries like Cyprus (86%), Malta (85%) and Luxembourg (61%). On the other hand, natural gas plays a significant role in Italy (38%), Hungary (31%), Ireland and the Netherlands (30%). Renewables hold the largest share in countries such as Sweden nearly 50%, Latvia 42%, Denmark and Finland (40%). Nuclear energy accounted for a significant portion of available energy in France (35%), Sweden and Slovakia (25%). The use of solid fossil fuels was most prominent in Poland (43%), the Czech Republic and Bulgaria (32%). Notably, the share of solid fossil fuels in Germany increased from 15% in 2020 to 20% in 2022 [10].

In 2022, renewable energy represented 23 % of gross energy consumed in the EU, up from 21.9% in 2021 with Sweden, Finland, and Latvia leading the way. However, the majority of Member States have shares below the EU average, with countries like Malta, Ireland, Belgium, and Luxembourg recording the lowest share of renewables, all below 15% [11].

C. Energy Landscape in Bulgaria

The EU's goal of becoming the first climate-neutral continent by 2050 poses a significant challenge for member states, which varies depending on their specific local economic conditions, climate, energy resources as well as opportunities for cooperation with countries in the region. Bulgaria has aligned its policies with the EU's priorities on renewable energy, setting national targets to contribute to the overall European objectives. These targets include reaching a 16% share of renewable energy in gross final energy consumption by 2020 and increasing it to 25% by 2030.

The development and implementation of the Bulgarian institutional and legal framework to promote the production and consumption of energy from renewable sources started in 2007, which is significantly later than in other EU Member States. Nonetheless, during the first programming period 2007-2013 the government did implement policies and set out incentives, which created a favorable business environment. Among the most attractive of the measures were: the mandatory purchase of electricity generated from renewable sources at feed-in tarrifs, priority connection of RES electricity producers to the power grid and the establishment of long-term contracts. Changes in the legislation at the end of 2008 increased the term of contracts for geothermal and solar power producers from 12 to 25 years and for wind and hydro power producers from 12 to 15 years respectively [12].

Undoubtedly, these measures significantly enhanced investor interest in the sector and gave a strong initial impetus to investments. Evidence of this is the statistics that shows a clear periodicity in the commissioning of renewable energy capacities in Bulgaria.

III. Results and discussion

In the period 2007 - 2023, the installed capacity for electricity generation from renewable energy sources increased almost three times and reached 5896 MW. While hydroelectric capacity was mostly built before 2000, wind and photovoltaic capacities experienced two distinct periods of growth: a surge between 2008 and 2012, and a second significant increase in solar energy capacity 2020 - 2023.

Fig. 1 shows the RES capacity by type over the past twenty years. Two years stand out as peak with the highest levels of new renewable electricity generation capacity commissioned. These are 2012 and 2023 when 1 114 MW and 1 383 MW respectively were connected to the electricity grid [13]. The largest contributors to this increase are the new photovoltaic and wind power plants.

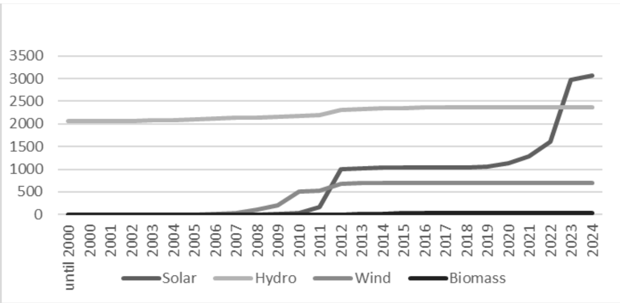

Fig. 1. RES capacity by type, 2000-February 2024, MW.

As a result of the incentives, Bulgaria has not only experienced a growth in renewable electricity generation, but also managed to reach its mandatory national target of a 16% share of energy from renewable sources in gross final energy consumption prematurely in 2012 instead of 2020. This early achievement of the target is a prerequisite for rethinking the policy by addressing some shortcomings, improving incentive mechanisms and discontinuing the implementation of some preferences for producers of electricity from renewable sources.

It should be noted that the main source of funding for the stimulus measures towards renewable energy producers is the demand side. It is through the feed-in tariffs paid by household and industrial consumers that the costs associated with the commissioning of new capacity, as well as the additional costs incurred by the energy system and grids for the construction of various facilities are subsidized. Additional financial support for renewable energy projects is provided from EU operational programmes and the European Regional Development Fund.

Regulatory changes have been made to address the negative impacts, as well as to align the support mechanism with the process of the electricity market liberalization and the gradual market integration of electricity from renewable sources on the free electricity market. The administrative procedures have been simplified and the deadlines for connecting facilities to the respective grid have been reduced. Furthermore, the support for the electricity produced from renewable sources through feed-in tarrifs is limited. Assistance is provided only for new energy facilities producing electricity from renewable sources with a total installed capacity of up to 30 kW, as well as for previously concluded contracts for the purchase of electricity from renewable sources produced by power plants with a total installed capacity of less than 1 MW. Since 2021 all electricity producers with an installed capacity of 500 kW and above, who have concluded long-term contracts for purchase at feed-in tarrifs, sell their electricity on the free market and receive premiums for the quantities of electricity up to the established net specific production. The premium is provided until the expiration of the respective contract for purchase at a preferential price [12].

Fig. 2 shows that Bulgaria has nearly tripled its installed solar capacity from a little over 1 GW in 2020 to almost 3 GW at the end of 2023. In 2023, 1,533 photovoltaic power generation assets with a total capacity of 1,381 MW have been commissioned [13]. Much of this boom is due to companies investing in solar to cover their own energy needs amid a sharp rise in the price of traditional fossil fuels triggered by the war in Ukraine.

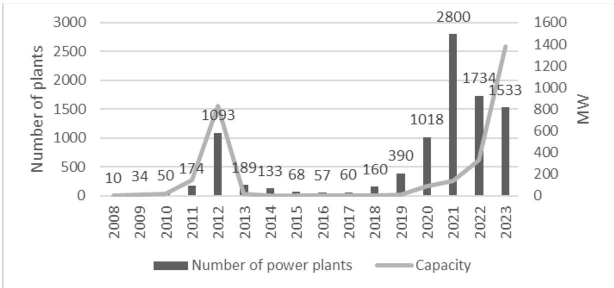

Fig. 2. Number and capacity of PV solar power plants

Concerning the country's origin of the investors in Bulgarian's renewable energy sector most of them are from Europe. Italian and German investors showed continued interest. Italy took the lead with 31 investment projects, while Germany held majority shares in 22 companies. The Czech Republic followed closely with investments in 16 Bulgarian entities. Luxembourg and Hungary were also noteworthy investors. Outside of Europe, notable investors included those from China, Republic of Korea, and Japan [14].

With the increase in 2023, the capacity of solar installations exceeded that of hydropower plants. It is noteworthy that no new wind farms were commissioned in 2022 or 2023. One of the main reasons is that the areas with wind power potential suffer from insufficient interconnections. Existing wind farms are exclusively onshore, and the country is taking steps to exploit its offshore potential in the Black Sea.

As a result of the changes, the structure of installed capacities for electricity generation from RES in 2023 is as follows: solar power plants have the largest share with 2782 MW (47%), followed by hydro power plants with 2365 MW (40%), wind power plants with 697 MW (12%), and biomass plants with 52.4 MW (0.9%) [13]. Fig. 3

represents that the increase in generation capacity has led to a near doubling of gross electricity generation from renewable energy sources over the period 2009-2023. In 2023, it increased by 3,635 GWh compared to 2009. The target for gross final energy consumption from RES was also achieved.

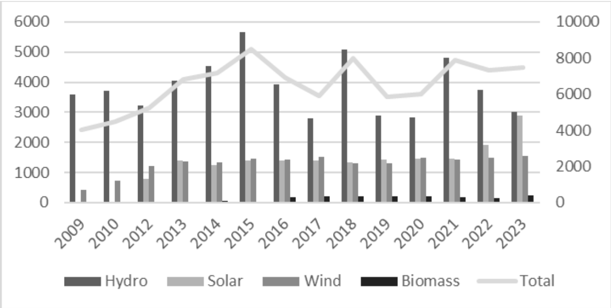

Fig. 3. Electricity generated from renewable sources, GWh

However, Fig. 4 shows that despite the significant growth in installed solar generation capacity, in 2023 hydropower generation remained the largest contributor, accounting for around 39.8% of gross electricity generation from RES. PV comes in second with a share of 37.8%, followed by electricity generation from wind at 20.4% and biomass 2.4% [13].

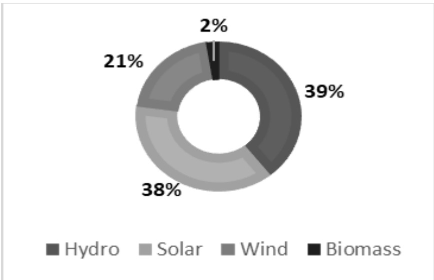

Fig. 4. Share of electricity generated from renewable energy sources in 2023

The commissioning of new renewable generation capacity has given rise to new problems that pose obstacles to the development of the sector. These obstacles include: the inability of the energy system to connect too many investment intentions for wind and solar farms, the construction of renewable energy projects in environmentally sensitive areas without proper environmental assessment procedures, the conversion of agricultural land for non-agricultural use resulting in the loss of fertile land, and the lack of serious investment intentions and readiness among potential investors [12]. These challenges bring attention to the work of transmission and distribution network operators. One particularly critical problem is the transmission of high capacities generated by photovoltaic and wind power plants. These types of power generation exhibit rapid fluctuations in output, necessitating the need for system balancing to ensure stability and reliability.

Despite the growth in installed capacity for renewable electricity generation, the share of renewable electricity generation in the country's total energy mix is still low at 14.5%. Even with this low percentage share in total generation, the summer months have seen record levels of green electricity generation, and there have already been times of negative prices. This trend highlights the need for investment in energy storage, balancing technologies and flexible tariffs to incentivise consumption during sunny periods.

In 2022 the energy mix of the country, shown in Fig. 5, was still dominated by thermal power plants and the Kozloduy nuclear power plant. The gross electricity generation reached 50 TWh, marking a 6% increase from the previous year. Domestic coal and nuclear power constitute the primary fuel inputs. Thermal power plants contributed the largest share at 52.3%. followed by nuclear power stations at 32.5%. Solar and wind sources combined made up 7%, while hydropower accounted for a 7.5% share [15].

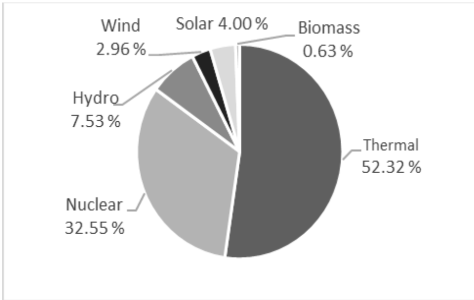

Fig. 5. Share of total gross electricity generation by plant type, 2022

It should be emphasized the significant growth in coal-based electricity generation in 2022, up by 22% compared to 2021. It can be attributed to the geopolitical dynamics and the war in Ukraine that changed the role of coal. The disruption in Russian gas supply has caused difficulties for major European energy facilities. The complex situation has had a positive impact on the operation of coal-fired power plants in Bulgaria. In the midst of the energy crisis, these plants have ensured the stability of the Bulgarian electricity system and have helped compensate for electricity shortages in the region. In 2022, Bulgaria's electricity exports reached 14 TWh, which is 28% higher than in 2021 and accounts for 27% of total generation. This has had significant financial benefits for the Bulgarian economy and society. However, with carbon allowance prices rising, it is unlikely that the spike in coal-fired power generation that was recorded in 2022 will be repeated.

On the other hand, low-emission baseload electricity generation capacities, such as nuclear power plants, will continue to be crucial for an extended period of time. In Bulgaria nuclear power has played a vital role in the country's energy security for more than 50 years, contributing to approximately one-third of its annual electricity generation. In 2022, nuclear power plants in Bulgaria produced 16,454 GWh of electricity, making them the second-largest electricity generation capacity in the country.

IV. Conclusions

In today's global system of international economic relations certain changes and trends are observed, determined both by purely economic, as well as by many other factors - social, political, security-related, etc [16]. In this context a global transition to renewable energy is also underway. Over the last two decades Bulgaria has made tangible progress in increasing the share of RES in total energy production and consumption. The most notable growth has been in photovoltaic plants. This development so far has been directly influenced by an administrative approach that sets administrative targets for the share of renewables in gross electricity consumption and creates artificial incentives to promote renewable electricity generation. As a result, there has been a non-market-driven growth in the proportion of specific types of generation capacity while other types are neglected. This alters the functioning of the energy system, introduces additional costs and inefficiencies, and presents new challenges for the sector.

On the other hand, coal has demonstrated its importance in guaranteeing energy supplies as a domestic resource. In the future, its role may evolve from providing baseload capacity to serving as a strategic reserve. The leading role of nuclear power plants in driving the energy transition should be highlighted. They provide low-emission, predictable, and controllable electricity, which is crucial for ensuring energy security and facilitating the large-scale reform of the European energy sector towards an increased share of low-emission energy sources.

As the proportion of renewable electricity generation capacity grows, the need for system balancing becomes more urgent. Giving priority to the development and upgrading of the electricity grid is crucial for the transition to a low-carbon economy. To address this issue substantial investments in the development of the power grid are needed in order to avoid distortions in system operation.

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Environmental Management for Sustainable Business in Chemical Industry in Bulgaria

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Abstract. Implementing effective environmental management for sustainable business is expressed in the integration of digital innovations, responsible sustainable practices, morals and motivation, environmental ethics, added value and recycling policies. The relevance of the topic is substantiated by the serious challenges modern businesses face regarding climate change, ecological sustainability, and social responsibility. The present study aims to prove that in the conditions of increasing public and corporate interest in environmental issues, organizations are brought to a growing need to adapt their business models by incorporating sustainability principles. Investors, regulators and consumers are directing their attention towards companies demonstrating commitment to environmental and social standards. The following research tasks have to be settled for reaching the above-mentioned goal: 1. to research the impact of the chemical industry on the environment; 2. to research the evolution of the way business is conducted; 3. to determine the extent of compliance of the business model of companies in the chemical industry with Sustainable Development Goals; 4. to identify new professions and roles in the context of environmental management for business needs. In the course of the study shall be justified the thesis that the combination of digital technologies, ethical principles and sustainability strategies provides Bulgarian companies in the chemical industry with the opportunity to adapt to current challenges, developing innovative business models, resp. meet regulatory requirements, create added value, competitive advantages and long-term sustainability. The methodology of questionnaire survey was used. The sample was formed by the method of random non-recurrent selection. The results of the research are expressed in the identification of best practices to serve as catalysts for balancing economic profitability and environmental responsibility. Additionally, innovative digital technologies to support businesses in environmental management, potential technological solutions to enhance the efficiency and sustainability of business processes and proposals for new professions and roles within the context of environmental management in enterprise practices are outlined.

Keywords: added value, chemical industry, environmental management, sustainable business

I. INTRODUCTION

The chemical industry plays an important role in economic growth and societal development. The significance of the sector is evidenced by the fact that chemical products are utilized by both large industrial enterprises and individual consumers in the production of everyday goods, agriculture, manufacturing and service activities. This includes the production of materials such as fuels, plastics, cosmetics, fertilizers and plant protection agents [1].

At the same time, today, environmental and climate policies are at the forefront of a comprehensive package of industrial, innovative and societal ambitions. The European Commission has announced its European Green Deal (EGD). The EGD includes a number of significant innovations including a Climate Law that enshrines the goal of net zero greenhouse gas emissions by 2050 and a revised EU Adaptation Strategy that recognizes that more ambitious and urgent efforts are needed to improve resilience to climate impacts. Taken together, it constitutes the most ambitious sustainability strategy produced by a supranational entity to date, with ambitious climate action at its core [2]. The condition, regulations and prospects within the chemical industry play a pivotal role in these processes.

The chemical sector is the 4th largest manufacturing producer in Europe in turnover terms and employs over 1.2 mln people directly. This makes Europe the second largest producer of chemicals in the world, with 2021 sales amounting to 594 billion EUR according to the report from CEFIC "The European Chemical industry Facts and Figures 2023. A vital part of Europe's Future" from 05 December 2023 after China (Fig. 1) [3].

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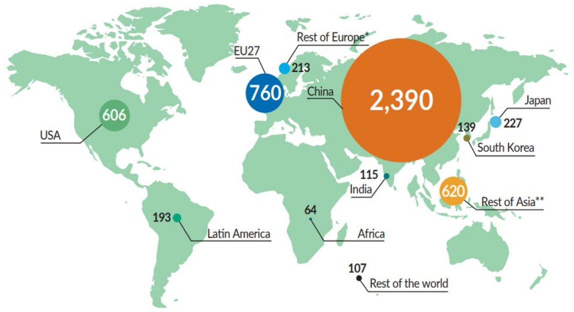

Fig. 1. World chemical sales, 2022 (€5,434 billion). Source: 2023 Facts And Figures Of The European Chemical Industry, https://cefic.org/a-pillar-of-the-european-economy/facts-and-figures-of-the-european-chemical-industry/

The Bulgarian chemical industry has traditionally been a leading sector for the country, contributing to enhanced productivity, GDP and improved foreign trade in selected products. Data up to date for 2022 indicate that the sector is characterized by a turnover of €4.541 billion, Capital Spending of €432 million and R&D Investment of €856 million. The number of companies is 634 with a direct employees of 12,850 [4].

The processes in chemical production are often associated with negative impacts on the environment. All of them cause a threat to the life, health and safety of people, animals and plants. This has prompted the widespread recognition today of the need for sustainable practices in business, including in the field of the chemical industry, to overcome existing risks to the environment, economy and society. In order to meet these expectations, the chemical industry is undergoing a significant transformation aimed at reducing negative impacts on the environment and maintaining a balance between the economic, social and ecological aspects of the business.

To regulate the sector and ensure accountability and promotion of sustainability, a series of international agreements, regulations, standards and voluntary instruments have been adopted, the most important of which are: The European Green Deal, Transition pathway for the chemical industry, Chemicals strategy for sustainability, Regulations for Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), etc. [5]-[10].

The review of scientific literature highlights the opportunities for intelligent, innovative and sustainable industry including Bulgaria [11] – [14], etc.

Chemical enterprises are faced with the necessity of transforming their business models by incorporating sustainability principles.

II. Materials and Methods

To achieve the research tasks, a practical study has been conducted through the methodology of questionnaire survey among 28 chemical enterprises in Bulgaria. The sample was formed by the method of random non-recurrent selection (January 2023- January 2024). The research is divided into three categories for diagnosing the economic, social and environmental sustainability of the respondents in accordance with the classical three pillars of sustainable development. (Triple Bottom Line/TBL). The survey technique is built on the Likert scale of questions. Each question has five optional answers, ranging between number 1 for "strongly disagree", number 2 for "disagree", number 3 for "neutral", number 4 for "agree" and number 5 for "strongly agree". A company meeting the criteria for an Eco-Minded Business was randomly selected for a fragmentary study using the Case method. NOISE Analysis was also conducted to identify the distinguishing characteristics of this company to the highest possible extent.

III. Results and Discussion

A. Impact of the Chemical Industry on the Environment

The processes in chemical production have impacts on the environment in two directions: direct (environmental) impact and indirect (social and economic) impact.

Direct negative impact is associated with environmental pollution of the air, water and soil. The specific pollutants generated depend on the type of chemical processes involved and the substances used. Some of the main environmental pollutants from the chemical industry include:

- air pollutants (ammonia (NH_3), volatile organic compounds (VOCs), nitrogen oxides (NOx), fine particulate matter (PM) and sulphur oxides (SOx), etc.),
- water pollutants (heavy metals, chlorides, sulfides, nitrates, and oxides),
- soil pollutants (heavy metals, organic compounds, pesticides and herbicides, salts and acids, petroleum hydrocarbons, dioxins and furans),
- greenhouse gas (GHG) emissions (carbon dioxide (CO_2)).

Indirect negative impact relates to interference with biodiversity, inefficient resource management, high energy consumption, the risk of emergency situations, working in hazardous conditions, etc.

The results indicate that the policies of companies in chemical industry should be oriented towards environmentally responsible practices, promoting commitment to climate change, effective management of chemicals and waste and stimulating innovative business practices to achieve sustainability. There is a need for the adoption of an appropriate managerial strategy for such a business model.

B. Analysis of Traditional management and Environmental management in chemical industry in Bulgaria

Traditional management and environmental management represent two different approaches to business management. While traditional management primarily focuses on financial results and short-term goals, environmental management aims to achieve a balance between economic, environmental and social responsibility. Integrating sustainable practices into the business model can enhance the company's reputation, reduce risks and contribute to long-term success.

Traditional management (Profit-Minded Business) is a standard approach applied to companies, including those in the chemical industry. It primarily focuses on short-term profit, efficiency in achieving specific business goals, centralized decision-making, etc. In traditional management, the priority is typically on financial metrics. *Environmental management* is a strategic approach focused on integrating sustainable and environmentally responsible practices into all aspects of a company's operations. This approach involves actively complying with environmental regulations and standards, improving energy efficiency, sustainable resource utilization, innovation in production processes and designing products with minimal environmental impact. The primary goal of environmental business management is not only to comply with regulations but also to engage in responsible and sustainable management that generates benefits not only for the company but also for society and the environment.

The research among companies in the chemical industry identified the following fundamental aspects, typical of traditional business management: Profit orientation (PO); Short term perspective (STP); Standard manufacturing methods (SMM); Traditional energy sources (TES); Not responsible for raw materials and water resources (NRRMWR); Passivity towards waste and recycling (PWR); Limited strategic focus (LSF) (Fig. 2).

Fig. 2. Traditional management.

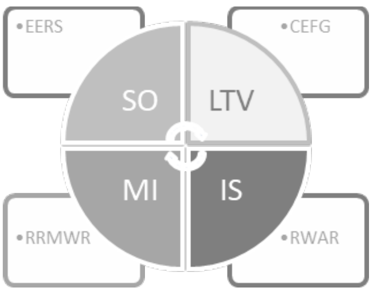

Fig. 3. Environmental management.

Results, regarding the important aspects in Environmental management, have found expression in: Sustainability orientation (SO); Long term vision (LTV); Care for the environment and future generations (CEFG); Manufacturing innovation (MI); Energy efficiency and renewable sources (EERS); Responsible use of raw materials and water resources (RRMWR); Reduces waste, actively recycles (RWAR); Integrating sustainability (IS) (Fig. 3).

Another aspect of our research found expression in the relationship between Environmental Management and Sustainable Business. It expresses the aspiration to achieve a balance between business objectives and the environmental responsibility of companies in the chemical industry, as follows: √ *Environmental Management* focuses on developing and implementing strategies, policies and practices that reduce the negative impact of business operations and production processes on the environment. This includes waste management, optimization of energy and water usage, as well as compliance with environmental standards. √ *Sustainable Business* is a broader and more comprehensive approach that encompasses the management of business in environmental, social, and economic aspects. This model aims for long-term success by combining profitability with social responsibility and environmental stewardship.

√ Companies in chemical industry in Bulgaria, aiming for sustainable business, frequently incorporate environmental principles into their *corporate social responsibility* (CSR) strategies. This involves caring for employees, the community, society and the environment, as they seek to create a positive societal and environmental impact. √ The integration of Environmental Management into Sustainable Business promotes *innovations* in production processes, designs and technologies. The approach is reflected in more *efficient* resource utilization and the creation of products/services with a lower environmental footprint.

C. Concept of Eco-Minded Business

In the context of the research *Eco-Minded Business* refers to enterprises actively adopting and implementing practices and strategies for environmental conservation. These are businesses that strive to minimize their negative impact on nature, embrace green technologies and processes and incorporate environmental principles into decision-making strategies. To present itself as an environmentally conscious company in the chemical industry to businesses and society, it should have developed and implemented strategies such as: ▪ environmental management and certifications; ▪ transparency in environmental and social practices, including publishing annual sustainability reports; ▪ participation in Ecosystem restoration programs; ▪ innovations in products and services with a focus on sustainability; ▪ employee training and cultivating an eco-responsibility culture; ▪ ecological partnerships; ▪ communicating and sharing corporate sustainability achievements. All of these efforts contribute to the company showcasing its environmental reputation to both the business community and the wider society.

For the purposes of the research, one company from the sample that meets the criteria of an Eco-Minded Business has been selected. A fragmentary investigation has been conducted using the NOISE Analysis (Table 1) to identify as many distinctive characteristics of this company as possible.

D. Determination the extent of compliance of the business model of companies in the chemical industry with Sustainable Development Goals

The research covers three categories of indicators related to the economic, social and environmental aspects of sustainable development, in accordance with

TABLE 1 NOISE ANALYSIS

STRENGHTS	NEEDS
● Extensive experience and a history in the chemical products industry; ● A wide range of products and services that can meet various customer needs; ● Stable financial position and strong resources for investment; ● Expertise in research and development activities.	● Optimization of production processes for greater efficiency; ● Comply with strict regulatory requirements in safety and environmental areas; ● Development of new products that meet market demand; ● Improvement in business sustainability in response to changes in societal preferences.
OPPORTUNITIES	**IMPROVEMENTS**
● Market expansion in developing countries; ● Potential for developing innovative products that cater to the demand for green technologies; ● Strategic partnerships with other companies for joint research and development; ● Growing societal interest in sustainable and environmentally responsible products.	● Enhancing the efficiency of production lines to reduce costs; ● Investments in new technologies to improve manufacturing processes; ● Improvement of quality management systems to achieve high-quality standards; ● Development of training and programs for staff.
EXCEPTIONS	
● Risks associated with instability in raw material prices; ● Possible challenges in the supply chain connectivity; ● Competition from emerging technologies and new market participants; ● Potential reputation issues in the event of accidents or environmental incidents.	

(Source: authors' own research)

TBL. In each of the three categories, eight indicators have been included, selected as a result of a review of specialized literature, indicators for assessing the degree of integration of sustainability into the business practices of the chemical companies in the sample [1], [15] – [22].

The indicators are following:

a) Economic Indicators (EI): The company's economic strategies align with global best practices for sustainable development (EI1); The organization recognizes the economic impact of its operations within the chemical manufacturing sector (EI2); The company actively invests in economically sustainable technologies to enhance efficiency (EI3); The company prioritizes the development of economically viable and sustainable products (EI4); The company has a well-defined economic efficiency plan in place (EI5); The organization is committed to optimizing resource utilization and minimizing economic waste (EI6); The company has strategies in place to enhance economic value while minimizing negative impacts on stakeholders (EI7); The organization consistently explores innovative economic approaches in its business model (EI8).

b) Social Indicators (SI): The company's social vision and strategies align with global best practices for sustainable development (SI1); The organization recognizes the social impact of its chemical manufacturing operations (SI2); The company actively adopts socially responsible practices, considering the welfare of its workforce (SI3); The company prioritizes the development of socially responsible and inclusive products (SI4); The company has a comprehensive social responsibility plan in place (SI5); The organization is committed to promoting social well-being and community engagement (SI6); The company has strategies to ensure fair and ethical labor practices in its chemical manufacturing processes (SI7); The organization consistently innovates to address social challenges within the industry (SI8).

c) Ecological Indicators (EL): The company's ecological vision and strategies align with global best practices for sustainable development (EL1); The organization recognizes the ecological impact of its chemical manufacturing operations (EL2); The company actively adopts ecological technologies to minimize environmental impact (EL3); The company prioritizes the development of environmentally friendly and sustainable products (EL4); The company has a well-defined ecological efficiency plan in place (EL5); The organization is committed to minimizing wastage and implementing recycling practices (EL6); The company has strategies to reduce energy consumption and promote ecological sustainability (EL7); The organization continuously innovates to introduce new ecological products and processes (EL8).

For evaluating the results, the one-dimensional statistical method of summing up Likert rating scores has been used. It assumes that the individual rating score for each of the responses is from -2 to +2, corresponding to "completely disagree" the score is -2, for "rather disagree" is -1, for "neutral" is 0, for "rather agree" is +1 and for "completely agree" is +2. After multiplying them by the number of respondents who preferred the respective answer and summing up the obtained products, the total rating score *(TRS)* for a specific indicator and a specific part of the scale is obtained. It is the basis for ranking the indicators and determining their *rank (R)*, which serves to draw the respective conclusions.

TABLE 2 DISTRIBUTION OF THE NUMBER OF RESPONSES WITH REGARD TO THE ECONOMICS INDICATORS FOR DIAGNOSTIC AND ASSESSMENT SUSTAINABILITY IN CHEMICAL ENTERPRISES IN BULGARIA

EI	1	2	3	4	5	TRS	R
EI1	8	5	4	2	9	-1	VI
EI2	0	0	1	11	16	43	I
EI3	1	6	4	7	10	19	III
EI4	2	7	1	10	8	15	IV
EI5	0	10	5	4	9	12	V
EI6	0	4	2	7	15	33	II
EI7	5	12	3	1	6	-9	VII
EI8	4	9	6	2	6	-1	VI

(Source: authors' own research)

The results of the arrangement, assessment and ranking of the indicators for diagnostic and assessment the economics, social, ecological sustainability in chemical companies in Bulgaria are presented in a tabular format (Table 2, Table 3, Table 4). They provide the foundation for the following conclusions:

First, companies acknowledge the economic impact of their activities and commit to optimizing resource utilization while minimizing economic losses (EI2 и EI6). The lowest rating concerns the companies' performance regarding their long-term economic strategies, which are simultaneously flexible and beneficial for stakeholders. (EI1, EI7 и EI8) (Fig. 4).

TABLE 3 DISTRIBUTION OF THE NUMBER OF RESPONSES WITH REGARD TO THE SOCIAL INDICATORS FOR DIAGNOSTIC AND ASSESSMENT SUSTAINABILITY IN CHEMICAL ENTERPRISES IN BULGARIA

SI	1	2	3	4	5	TRS	R
SI1	14	3	2	6	3	-19	VIII
SI2	1	5	1	8	13	27	I
SI3	2	5	5	6	10	17	III
SI4	5	4	9	4	6	2	VI
SI5	2	5	4	6	11	19	II
SI6	4	5	3	8	8	11	V
SI7	1	6	5	9	7	15	IV
SI8	5	15	1	4	3	-15	VII

(Source: authors' own research)

TABLE 4 DISTRIBUTION OF THE NUMBER OF RESPONSES WITH REGARD TO THE ECOLOGICAL INDICATORS FOR DIAGNOSTIC AND ASSESSMENT SUSTAINABILITY IN CHEMICAL ENTERPRISES IN BULGARIA

EL	1	2	3	4	5	TRS	R
EL1	11	4	3	6	4	-12	VI
EL2	2	4	2	12	8	20	I
EL3	4	3	1	14	6	15	III
EL4	6	4	0	11	7	9	V
EL5	2	5	3	10	8	17	II
EL6	2	6	1	8	11	20	I
EL7	6	1	4	9	8	14	IV
EL8	1	7	0	14	6	17	II

(Source: authors' own research)

Second, regarding the social impact, companies assess and consciously plan their socially responsible actions (SI2 и SI5), but the innovation activity of chemical companies is still low, leading to a lower alignment of their social vision and strategy with global best practices for sustainability (SI1 и SI8) (Fig. 5).

Third, concerning the environmental aspect of sustainability, companies highly acknowledge their environmental impact on the environment. They develop environmental plans, committing to environmental initiatives and innovations (EL2, EL5, EL6 и EL8). Companies have not yet reached the global best practices for ecological products and sustainable activities (EL1 и EL4) (Fig. 6).

E. Roles and Professions in the Context of Sustainability

Emerging careers of the future (resp. new sustainability-related professions / careers) is viewed as an extremely positive development. Nowadays, some of them belonging to the National Classification of Professions and Positions in Bulgaria (NCPP 2011) are: sustainability manager, sustainability coordinator, sustainability specialist, internal sustainability auditor [23]. Based on the study about the need for new types of knowledge, skills and competences in the context of

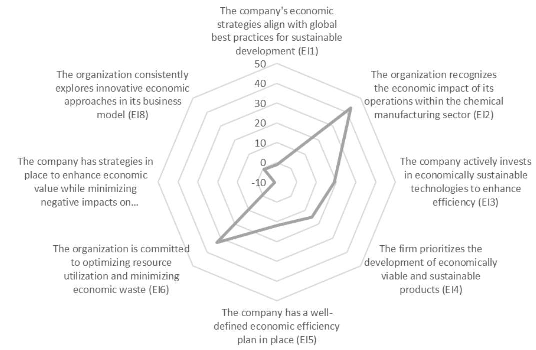

Fig. 4. Ranking of economic indicators for diagnosing and assessing sustainability in chemical companies in Bulgaria.

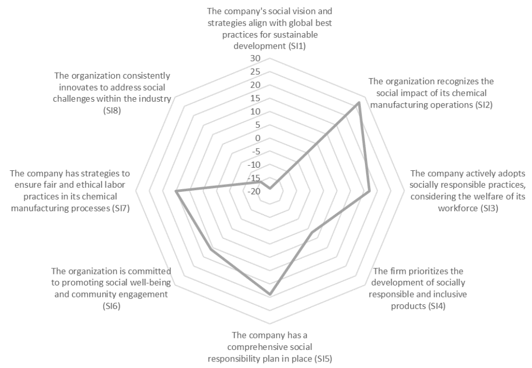

Fig. 5. Ranking of the social indicators for diagnosis and assessment of sustainability in the chemical companies in Bulgaria.

the researched issues, we can also propose some future professions:

● *Sustainable Management Specialist* (responsible for developing and implementing strategies for sustainable management of the company, assessing the impact of activities on the environment and developing practices to optimize sustainability). ● *Environmental Auditor* (will assess the environmental efficiency of business processes and assist the company in identifying areas for improvement while adhering to sustainable standards and regulations). ● *Green Innovator* (will implement new technologies and innovations that support sustainable practices; development of green products, processes, systems.

● *Social Responsibility and Sustainability Specialist* (will be involved in the social responsibility of the company, including interacting with the community and building sustainable values within the company). ● *Climate Analyst* (will research and analyze the impact of climate change on the enterprise and provide recommendations for reducing the carbon footprint). ● *Energy Manager* (responsible for using green energy sources and optimizing energy efficiency in all aspects of the business). ● *Circular Economy Specialist* (will develop and manage economic models that support the transformation of waste into resources and promote sustainable use of materials).

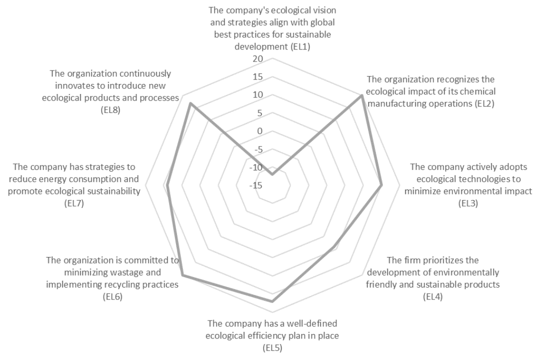

Fig. 6. Ranking of the environmental indicators for diagnosis and assessment of sustainability in the chemical companies in Bulgaria.

● *Green Public Relations Manager* (will coordinate the company's communication with the public regarding sustainable initiatives and will be responsible for building a positive business image in the environmental field).● *Ethical Manager* (will create and maintain ethical standards and procedures in the company, including environmental care and social responsibility). ● *Environmental and Legislative Advisor* (will inform the company about current environmental laws and standards, as well as advise on compliance with them).

These new roles and professions will be of crucial importance for companies. They will play a key role in integrating sustainable practices into all aspects of business and in creating successful environmental management strategies.

IV. CONCLUSIONS

The future of the chemical industry in Bulgaria is associated with modern technologies, digitalization of working processes, innovative software solutions and ways to protect the Environment. It is green and sustainable. The empirical research, that was carried out in the companies of the chemical industry from the sample, confirms that: 1. Environmental management and Sustainable Business are successfully integrated becoming an important part of the sustainable business strategy; 2. the connection between Environmental Management and Sustainable Business lies in rethinking and applying business models that strive not only for economic success but also for environmental sustainability; 3. the business of the future in chemical industry (including in Bulgaria) should adopt a broad approach to sustainability by integrating not only economic but also social and environmental responsibility into business activities. This includes care for people, the planet and profit. It promotes innovation and constant adaptation, including in connection with sustainability principles and demonstrates social responsibility.

The results of our research visualize the perspectives for the development of Environmental management for Sustainable Business with an emphasis on the companies of the chemical industry in the short and long term. It has the potential for strategic impact as well as to become catalysts for change and take on leadership roles in developing sustainable practices in chemical industry.

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Circular Economy as a Tool for Sustainable Development: A Theoretical Perspective

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Abstract. Climate change, depletion of natural resources, social inequality and poverty, a lack of food resources, etc. issues related to world sustainable development has become increasingly relevant in the last 50 years, negatively affecting people's opportunities, and living standards in various countries. Despite these problems, the average level of wealth of the population in the world is gradually increasing over time. Considering forecasts on population growth by the end of the 21st century, it must be admitted that the current world-dominant linear economic model is fully unsustainable in resource consumption, as there is a natural barrier to economic growth. The aim of the present research study is to explore the potential of the circular economy as a tool for achieving sustainable development, based on a theoretical framework. This paper was built based on a broad literature review to examine the limitations and conceptual gaps of the circular economy concept as a tool for achieving sustainable development. It has been concluded that the circular economy concept undeniably has huge potential to promote sustainability within planetary boundaries as well as it can be implemented to decouple economic growth from the utilization of finite resources. However, a broader analysis of the circular economy concept allows us to assert that to date, a clear and effective approach for the transition to this economic model, affecting all areas of sustainable development (i.e. environmental, economic, social) has not been developed. In addition, the circular economy concept is still evolving, there is a tendency to view the circular economy concept holistically, covering various sub-concepts of the circular economy under the common Sustainable Circular Economy concept's umbrella.
Keywords: circular economy, planetary boundaries, resource consumption, sustainable development.

I. Introduction

The sustainable development (SD) framework encompasses strategies and practices aimed at reducing our ecological footprint while fostering development rooted in principles of social justice and equality. The three core dimensions of sustainability are economic, environmental, and social. True sustainability is attained only when there is an equilibrium or a careful trade-off among these three aspects [1], [2], [3].

Since the creation of a definition of SD in the 1980s, many stakeholders still seek workable solutions to achieving SD at the macro (local and national government) and micro (entrepreneur and consumer) level. However, it is a complex process affected by various external factors. The United Nations (UN) Department of Economic and Social Affairs forecasts that the world population will increase by at least 2 billion people by 2100 [4], while World Bank data indicate an increase in the wealth of nations and the proportion of the middle class since 1995 [5], [6]. Although overall the changes can be viewed positively, it simultaneously raises concerns about the risks of resource overconsumption and social inequality: the populations of Global South countries lack equal access to education, health care and balanced diets, on the other hand the overconsumption of resources by the people of Global North countries causes the depletion of world resources, increases the greenhouse effect and environmental pollution, thereby contributing to an increase in social inequality in the world [7], [8], [9], [10]. Teixidó-Figueras et al. [11] argue that the top 10% of global income earners contribute to 25-43% of the environmental impact. At the same time, the bottom 10% of income earners worldwide are responsible for only approximately 3-5% of the environmental impact. Obviously, the current levels of consumption by most people in the Global North, in most cases overconsumption, is unsustainable, unethical or unjust on a global scale.

UN Environment Programme data show that resource extraction has more than tripled since 1970, including a fivefold increase in the use of non-metallic minerals and a 45 percent increase in fossil fuel use; by 2060, global material use could double to 190 billion tonnes (from 92 billion), while greenhouse gas emissions

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could increase by 43 percent; the extraction and processing of materials, fuels and food contribute to half of total global greenhouse gas emissions and over 90 percent of biodiversity loss and water stress [12]. Given that the current world-dominant linear economic model is inherently unsustainable, it is obvious that it is necessary to change the paradigm of existence and development of society through eco-economic decoupling.

It should be noted that there is a lack of specific management models or tools for putting the SD framework into practice. Among different management models used in the 21st century, the model (concept) of the circular economy (CE) is the one meeting the prerequisites for SD in the most accurate way [13].

In contrast to the 'take-make-use-waste' linear model, a CE is regenerative by design and aims to gradually decouple growth from the consumption of finite resources [14] (see Fig. 1).

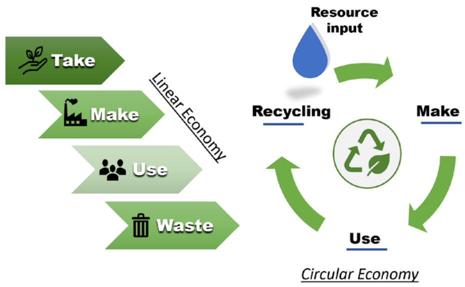

Fig. 1. Linear Economy model vs Circular Economy model (compiled by the author based on [2], [14], [15], [16], [17])

However, some authors criticize the CE for a lack of real definition, arguing that the goals and ways of implementation thereof are still unclear and inconsistent, and the limited conceptual basis thereof does not provide an idea of how the CE can contribute to SD [2], [15], [16], [17].

The research problem: despite the fact that the CE has emerged as a potential solution to achieving SD, there are still concerns and uncertainties about the implementation of the CE model, ignoring one or the other dimension of SD. Therefore, the main question of the research study is: could the CE be a tool for SD?

The research hypothesis: the dominant CE concept, which is primarily focused on resource efficiency, does not apply a holistic approach to linking economic growth, social justice and responsible environmental resource consumption. A theoretical analysis reveals the need for a more detailed CE concept to effectively integrate the above-mentioned dimensions, thus fostering SD.

II. Materials and Methods

The research methods applied: scientific literature review, reports and research papers by various organizations in the research field for comprehensive coverage of relevant research studies pertaining to the research question, logical construction for making judgments and analysis of results, the synthesis method for combining elements into a unified system for researching the concepts of SD and CE, the monographic method for an in-depth examination of specific scholarly works and comprehensive studies related to the research question.

III. The Evolution of the SD Concept

Historically, the concept of sustainability referred to the constraints of natural resources and economical use thereof, considering the need therefor in the long term and the future.

Table 1 Time periods and turning points in the formation of the SD concept (compiles by the author based on [1], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29], [30], [31])

Time periods and turning points in the formation of the SD concept
First period: before 1972
1798: predictions by Thomas Robert Malthus about a lack of food resources due to the constant growth of the population;
1864: George Perkins Marsh's articles on the risk of human extinction due to interference with the natural environment;
Turn of the 18th and 19th centuries: the idea of sustainability appeared during the industrial revolution;
19th century: there were two factions within the environmental movement: conservationists who advocated the responsible use of natural resources and preservationists who advocated the protection of nature from use;
1950-1970: negative environment impacts of rapid economic growth, leading to concerns about sustainability;
1972: the Club of Rome report The Limits to Growth - a warning that the growth of population, industrialization, resource depletion and pollution in the next century could exceed the capacity of the Earth.
Second period: 1972–1987
1972: *The UN Conference on the Human Environment* in Stockholm was the beginning of a global change agenda introducing the concept of SD, which emphasizes the alignment of human development with environmental constraints; under the slogan '*Only One Earth*', a declaration and action plan for environmental conservation was published; the United Nations Environment Programme (UNEP) was launched;
1983: the Brundtland Commission report *"Our Common Future"* defined SD as development that *"meets the needs of the present without compromising the ability of future generations to meet their own needs"*; the basic principles of SD include satisfying human needs while considering certain environmental constraints; a transition to a global socio-economic policy, with SD becoming a key aspect in environmental management and other areas of human activity.
Third period: 1987 – present
1992: the Earth Summit in Rio de Janeiro developed Agenda 21 - an action plan for creating a global partnership to solve environmental problems; the social dimension was integrated into the SD concept: the three dimensions of SD were considered to be the economy, society, and the environment; a holistic approach to solving SD problems;
2000: the UN Millennium Summit defined a set of *the Millennium Development Goals* (MDGs) as a globally accepted framework to shape development and cooperation in countries over the next 15 years;
2012: the Earth Summit *"Rio +20"* in Rio de Janeiro adopted *"The Future We Want"* declaration on SD and the green economy, recognizing poverty as the main challenge to humanity and defined a set of *Sustainable Development Goals* (SDGs) beyond 2015;
2015: the UN Sustainable Development Summit assessed the implementation of MDGs and adopted *"Transforming our World — the 2030 Agenda for Sustainable Development"* (includes a set of 17 SDGs to be met by 2030, which are accompanied by specific targets – 169 in total), thus emphasizing coordinated economic, social and environmental development towards sustainability.

Shi et al. [18] and Klarin [19] have distinguished three historical periods in the evolution of the SD concept: (1) The Embryonic Period (Before 1972, or the first period); (2) the Molding Period (1972–1987, or the second period), and (3) the Developing Period (1987–Present, or the third period) (see Table 1).

As shown in Table 1, initially, the concept of sustainability was mainly viewed in terms of lack of natural resources (environmental dimension of sustainability), yet over the course of two centuries, there has been a paradigm shift in the evolution of the SD concept, applying a holistic approach and integrating the social dimension into the SD framework.

IV. The Main Dimensions of SD

SD involves approaches and methods that reduce human environmental impacts and foster development based on social justice and equity. To achieve sustainability, it is necessary to harmonize the three dimensions of sustainability: economic, environmental and social, or at least reach a trade-off between them. There are several models that seek to conceptualize SD, and each of them provide a different interpretation of the three dimensions. The models could be represented in different ways, e.g. as "pillars", as concentric circles, or as interlocking circles (Fig. 2). As a result, the ambiguities have complicated the perception and understanding of the SD concept, which vary across literature sources [32].

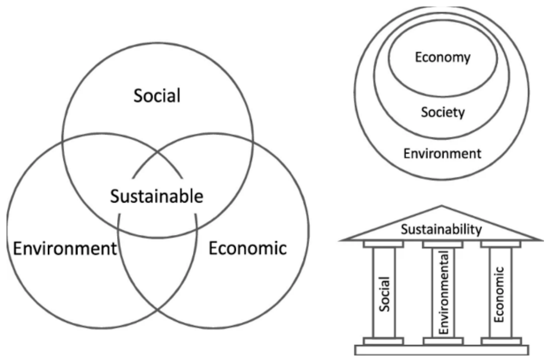

Fig. 2. Three dimensions of SD [3]

The recent reviews suggest replacing the environmental, economic and social dimensions with satisfying human needs, ensuring social equity and respecting environmental limits [33]. Despite this suggestion, it is widely recognized that in the context of SD, progress in one dimension should not come at the expense of the other two dimensions, and it is important to maintain a balance and take equal account of economic, environmental and social aspects in order not to harm overall sustainability [2], [34].

However, the widely used Brundtland definition [27] focuses on meeting global needs and ensuring intergenerational equity. According to research studies on SD, for an approach to be considered compatible with the principles of SD, it should not limit opportunities for future generations to live in conditions that are available to the current generation [35]. Accordingly, it could be concluded that the developments that disrupt or impede the ability of future generations to meet their own needs will not allow SD to be achieved if the three dimensions are not in harmony [2].

V. The Essence and Definition of CE

Tambovceva & Titko [36] have found that the CE concept was introduced by Pierce and Turner in 1990, developing a new economic model based on the principles of thermodynamics. Later this idea was explained by Ciegis and Ciegis [37].

The modern understanding of the CE is based on the principles of industrial ecology, the environmental economy and the green economy with the aim of reducing environmental pressure in industrialized nations [38], [39].

The basic principles of CE strategies are “reduce”, “reuse” and “recycle”, which are defined in the scientific literature as "3R" [38], [40], [41]; however, the European Union (EU) Waste Framework Directive refers to “4R”, with “recover” being the fourth R [42], as several definitions were found to refer to “regeneration” [43]. This framework has evolved into a framework of 10 strategies, with some authors referring to it as the “9R” [43], [44], or the “10R” (see Fig. 3).

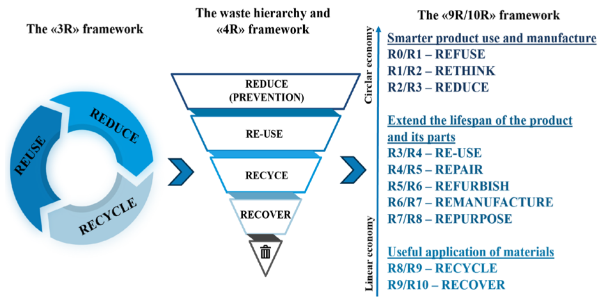

Fig. 3. Evolution of CE strategies (compiled by the author based on [38], [41], [42], [43], [44])

As regards the definition of CE, Millar et al. [2] have pointed out that no universal and generally accepted definition of CE has been proposed to date. The CE has gained momentum in the past decade, primarily through the approach of practitioners such as the Ellen MacArthur Foundation and often the CE is generally understood by the business world as *“a systems solution framework that tackles global challenges like climate change, biodiversity loss, waste, and pollution. It is based on three principles, driven by design: eliminate waste and pollution, circulate products and materials (at their highest value), and regenerate nature”* [14]. The CE concept as an alternative model that can promote production and consumption with lower environmental impact while promoting economic growth has been accepted in academic, policy-making and business circles [46], [47], [48]. The author points out that this widely accepted definition of CE does not include the social equity dimension, which is important if accepting the CE as a tool for achieving SD.

It should be noted that different definitions of CE have increasingly appeared in the scientific literature in recent years. In 2017, after analysing 114 definitions of CE available in the last decade, Kirchherr et al. [43] proposed defining the CE as “*an economic system that replaces the ‘end-of-life’ concept with reducing,* *alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish SD, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers"*. It could be concluded that this definition covers all the three dimensions of SD (environmental quality, economic development, social equity). According to Kirchherr et al. [43], of the total CE definitions analysed, only 11 percent referred to SD as a principal aim.

In 2023, after re-analysing the recent CE definitions, Kirchherr et al. [49] concluded that all the three dimensions of SD were mentioned more frequently in the new set of definitions – a threefold increase compared with the 2017 study –, pointing out that fewer authors agreed that economic prosperity should be an aim of the CE. Kirchherr et al. [49] also pointed out that the largest shift since 2017 has been within CE enablers who are not only consumers and producers but also policymakers and scholars.

However, the most important conclusion made by Kirchherr et al. [49] is that considering the continually changing landscape of technology, environmental factors, and economic and socio-political contexts, the definitions of CE are expected to undergo a continuous evolution and ***"the development of a 'final' and consensus definition of CE is elusive"***, and all current attempts to define the CE simply *"illustrate where the academic field currently sits in its own understandings of CE"* [49].

VI. THE CE AS A TOOL FOR SD

Millar et al. [2] argue that numerous contradictions and knowledge gaps exist regarding how the CE can improve social equity, promote economic growth and permanently reduce the rate of extraction of raw materials by closing material loops. And there have been no reviews that explicitly (i.e. by covering all the three dimensions of SD) analyse how the CE can serve as a tool for achieving SD.

To be able to answer the main question of the present research study, the limitations of the CE should be analysed, as pointed out by sceptical scholars who do not have a consensus about the contribution of the CE to sustainability [15], [50], [51]; therefore, the CE is viewed as simply a more environmentally sustainable model than the "linear" economy.

Despite the growing interest, the progress of the CE concept towards SD has not yet been formally identified. There are CE concepts that focus only on the reduction of raw materials and waste, the preservation of resource value and the reintegration of products [52], thereby indicating that the social dimension of SD is missing and creating potential limitations to achieving sustainability.

Limitations of the CE concept.

To be able to examine the limitations of the CE in more detail, the author of the study divided them into SD dimensions: economic, social and environmental, and also analysed the limitations of CE implementation (see Table 2).

TABLE 2 LIMITATIONS OF THE CE CONCEPT IN SD CONTEXT (COMPILED BY THE AUTHOR BASED ON [2], [16], [39], [43], [53], [54], [55], [56], [57], [58], [59], [60], [61], [62], [63], [64], [65], [66], [67], [68])

SD dimensions	Limitations
Environmental dimension	- The CE as a closed-loop system is not practically or theoretically possible due to the second law of thermodynamics, which states that the continuous need for energy in recycling processes inevitably creates waste and by-products, ultimately leading to resource depletion, pollution and waste generation; - The CE is seen as a potentially more environmentally sustainable tool than the linear economy. However, it could still lead to similar consequences of environmental degradation, albeit at a slower pace; - The "rebound effects" challenge arises in the CE model, where improved secondary production efficiency reduces costs, potentially leading to increased consumption; this could offset the initial environmental benefits gained from enhanced efficiency; - There is no evidence that secondary production in the CE model could fully replace primary production, as technological limitations prevent the breakdown of certain wastes and the treatment of certain liquids; - Extending product lifetimes proposed by the CE to reduce dependence on continuous extraction of finite virgin materials, poses uncertainties about its impact on material flows, threatening long-term sustainability and challenging the assumption that it is a better alternative to the current linear model.
Economic dimension	- Due to increasing consumption, achieving a closed loop in CE is not possible: *"if demand is growing, the circle cannot remain closed"*. The CE could be feasible only if global demand for products in terms of both volume and composition stabilizes; - Information resources on the CE do not emphasize the importance of changing consumption patterns: if the current unsustainable economic paradigm is not changed and consumption patterns are not revised, the CE may remain only a technical tool without enabling sustainability; - There is no certainty that the CE can stimulate economic growth without endangering the environment.
Social dimension	- Whilst the CE has the potential to benefit society, there is a lack of the social aspect being integrated into the current framework, especially with regards to issues of governance, justice, and cultural change; - The lack of social indicators, which prevents the evaluation of the impact of the CE on social aspects, which raises doubts about the ability of the CE to promote social equality; - The CE concept does not illustrate the ways in which the social equity on the intra-generational (between the Global North and South) and the inter-generational (between the current and next generations) levels could be promoted; - Limited extraction of natural resources proposed by the CE could be considered antisocial for developing economies that are still growing resource stocks to build infrastructure that are essential for well-being.

SD dimen-sions	Limitations
Implementation aspect	- There are still challenges in the implementation of SD strategies and tools, which suggests that the implementation of the CE could face similar problems: both "top down" (commonly characterized as implementation enforced by government institutions or their equivalents) and "bottom up" (generally identified as initiatives advanced from the individual level) approaches face conflicts with other stakeholders; - SD is a society objective concept defined at the macro-level ("top down" approach) while the CE approach is mainly defined at the micro-level ("bottom up") through a model of consumption and production; it is not clear if they meet mid-way; - There is a lack of comprehensive global overviews of CE implementation and its alignment with SD goals; - There are conflicting motivations among CE stakeholders that need to be aligned and combined for successful implementation; - There is a deficiency in collaboration among policymakers, governmental bodies, manufacturing industries, and consumers, along with an overall lack of vision on how they implement the CE; without the sharing of knowledge and responsibilities among stakeholders, there are no guarantees of enhancing the success of implementing the CE as a tool for SD; - The CE introduces a range of tools that can be utilized for sustainable purposes, yet the ultimate objective appears unclear and decidedly more limited than that of SD; - Implementation of the CE is always associated with extra cost as long as the benefit is greater than or equal to the cost.

After analysing Table 2, it can be concluded that the CE implementation within the environmental dimension faces significant challenges to achieving a fully closed-loop system. While the CE is seen as a potentially more environmentally sustainable economic model, concerns about rebound effects, technological limitations, and uncertainties regarding the extension of product lifetimes underscore the complexity of implementing it as a superior alternative to the current linear model.

Regarding the economic dimension, the feasibility of a closed loop in the CE is hindered by constantly increasing consumption, necessitating the stabilization of global demand for products in terms of both volume and composition. The lack of emphasis on changing consumption patterns and without addressing the unsustainable economic paradigm, the CE may merely function as a technical tool without achieving sustainability. Additionally, uncertainties persist regarding the potential of the CE to stimulate economic growth without posing risks to the environment.

The social dimension of the CE is also debatable. Obviously, the CE holds societal potential, but its current framework lacks integration of different social aspects as well as the absence of social indicators raises doubts about the CE's ability to promote equality and address global and intergenerational disparities. Additionally, the CE's proposed limited resource extraction may be considered antisocial for developing economies reliant on resource growth for vital infrastructure.

To effectively implement the CE as a tool for SD, addressing challenges is crucial. This involves reconciling conflicts between "top-down" and "bottom-up" approaches, clarifying the alignment between micro-level CE and macro-level SD, and resolving conflicting motivations among stakeholders. Enhancing collaboration, providing comprehensive global overviews, and establishing a clear vision for CE implementation are vital steps toward ensuring success. Despite the introduction of tools for sustainable purposes, the overarching objective of the CE remains uncertain, and the potential extra costs associated with implementation need careful consideration in the pursuit of SD.

VII. Results and Discussion

The potential of the CE to foster economic growth while concurrently safeguarding the natural environment and enhancing social equity for current and future generations remains uncertain, challenging the validity of this assertion.

Undeniably both SD and the CE rely on the decoupling of resource exploitation from economic growth. Although the SD concept prioritizes people, emphasizing economic prosperity as a path to fulfilling lives in harmony with nature, the CE remains focused on technological solutions, the implementation of which is driven by a promise of traditional economic growth [17].

To view the CE as a tool to accomplish sustainability, the full integration of the CE with SD is crucial. This requires a comprehensive reassessment of the CE, expanding its focus beyond closed-loop recycling and immediate economic benefits. Instead, the shift should be towards a transformed economy that strategically manages resource access to uphold or enhance social well-being and environmental quality.

The concept of the CE should address inquiries such as whether it is possible for individuals to genuinely replenish natural capital, especially critical natural capital, while promoting high quality of life and well-being. Determining the size of our resource economy without depleting natural capital and the planet's absorptive capacity, as well as evaluating the resource intensity of a service-based economy, are also essential questions to be considered.

The CE concept should be transformed towards regenerative socio-economic structures that align with the Earth's system boundaries. This transformation can address the CE's current shortcomings, particularly its insufficient consideration of the social dimension and the need for system-wide thinking regarding entropy and biophysical limits [38], [69], [70], [71].

The CE should focus on a set of environmental, social and economic values, in which the economy becomes a means to reorganize society and the environment and not an end in itself [17].

The model of the Doughnut Economics (DE) developed by Kate Raworth [72] was proposed as a framework for the enhancement of the CE concept, providing a comprehensive and integrated approach that incorporates not only the efficient use of resources but also a strong emphasis on social equity, justice, and environmental sustainability. The model of the DE shows the minimum and maximum limits that humanity must respect in order to develop [72] (see Fig. 4).

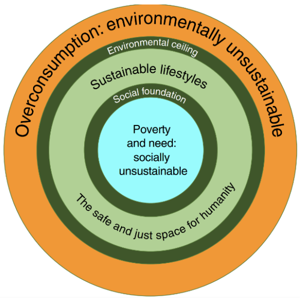

Fig. 4. Simplified version of the doughnut: a safe space within social and environmental limits [72]

The inner ring of the doughnut represents the social foundation (basic needs that everyone should have access to), the outer ring of the doughnut represents the ecological ceiling (planetary boundaries), between social and planetary boundaries lies an environmentally safe and socially just space in which humanity can thrive [72].

By aligning the principles of the DE with CE practices, it is possible to create an economic system that operates within a safe and just space for humanity, simultaneously meeting the essential needs of all individuals while respecting the ecological boundaries of the planet. This collaborative integration seeks to foster a regenerative and equitable economic paradigm, reinforcing the broader vision of SD and responsible resource management. DE mainly focuses on rethinking the purpose and goals of economic activity by applying holistic and systemic thinking to various domains and scales. It is a conceptual and normative model that offers a vision and a direction for achieving social justice and an ecological balance.

Friant et al. [15] classify the DE as one of a set of new holistic circularity views. In recent decades, the original concept of the CE has constantly developed and transformed, absorbing new holistic and transformational views on circularity such as the Blue Economy [73], the DE [72], the Spiral Economy [74], Transition Degrowth [75], Post-growth [76], the Permacircular Economy [77], etc. Limited attention has been given to transformational views of circularity and alternative concepts from the Global South, such as "ubuntu" [78], "ecological swaraj" [79], and the "Buddhist middle path" [80], which emphasize values and principles that promote a sustainable and harmonious relationship between humanity and the environment [15].

Friant et al. [15] identify two overarching trends within the CE concept: the first involves reformist discourses operating within the boundaries of the capitalist system, while the second encompasses transformational discourses aiming for a comprehensive overhaul of the socio-economic structure. Both types of discourse address concerns related to planetary boundaries, the rebound effect, social justice, and good governance. However, they differ in their perspectives on the ability of capitalism to surpass resource constraints and separate ecological degradation from economic growth. The term **circular society** is proposed to distinguish discourses that go beyond market-based solutions and economic considerations and **view circularity as a holistic social transformation** (see Fig. 5).

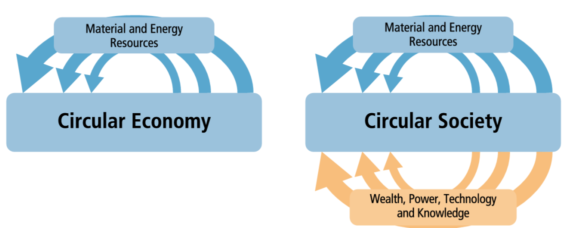

Fig. 5. Conceptual differentiation between the Circular Economy and a Circular Society [15]

According to Fig. 5, a circular society encompasses discourses with a vision of circularity where not only resources circulate in sustainable loops but also wealth, knowledge, technology, and power are circulated and redistributed throughout the society. These discourses, therefore, inclusively **embrace the three pillars of sustainability and perceive circularity as an all-encompassing transition, addressing issues of political empowerment and social justice**. In contrast, the CE concept primarily focuses on the circulation of resources, predominantly dealing with circularity through a technical lens of ecological and material efficiency alone [15].

VIII. Conclusions

The current concept and application of the CE does not fully cover all aspects of sustainability, as it may focus mainly on resource efficiency or waste reduction but may not sufficiently consider social issues. The SD framework establishes goals to be achieved to solve the problems and their consequences, whereas the CE is a tool to address some of the causes of these problems.

It can be concluded that the concept and definition of the CE are anticipated to undergo continuous transformation. It is acknowledged that all current attempts to define the CE merely serve to illustrate the present state of the academic field's understanding of this concept.

The concept of the CE should be viewed through the framework of SD, recognizing the synergy between economic practices, social well-being, and environmental conservation. This synergy would further enhance the holistic approach to achieving lasting global sustainability goals by addressing resource efficiency, social equity, and environmental stewardship within a unified framework.

Within the broad views of CE conceptualizations and adaptations, the overarching concept of **the Sustainable Circular Economy** emerges as a unifying umbrella concept. It synthesizes the multifaceted dimensions of circularity, encapsulating not only resource efficiency and closed-loop systems but also incorporating the crucial elements of social responsibility and environmental stewardship. The Sustainable Circular Economy concept signifies a paradigm shift towards a holistic and enduring approach to sustainability, where economic activities are intricately interconnected with the preservation of social well-being and the conservation of the environment.

The Sustainable Circular Economy thus represents a comprehensive evolution that acknowledges the interconnectedness of economic, social, and environmental factors in the pursuit of a resilient and regenerative global system.

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Prerequisites for the establishment of the Baltic-Black Sea Union

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Abstract. The emergence of new challenges and threats in the modern world raises the issue of creating alliances and sub-alliances that could ensure security issues in the Baltic countries and Eastern Europe as a whole. This, in turn, requires the definition of a new security system, built taking into account regional interests and new approaches to the system of collective provision of stable development. Global institutions in the context of new military conflicts show their inability to make decisions or their unwillingness to define new frameworks and conditions of security. Based on this, it seems important to form a new regional sub-alliance in Europe to ensure security and interpret the Trimoria alliance. The formation of military alliances leads to increased interaction between countries both in the military sector and in the economy as a whole. Within the alliances, a practically unified security system is formed, which works on the same standards, strengthening control over trade policy and forming a common control within the framework of military policy or security policy and protection from real or potential threats.
Keywords: security, defence, military-economic cooperation, Baltic-Black Sea Union.

I. INTRODUCTION

The modern system of collective security in Europe needs a fundamental revision, as well as the entire system of global security in the world. The current geopolitical situation is characterized by extreme turbulence: the situation and the balance of power in the world are changing rapidly. Undoubtedly, the increase in tension in the world is a milestone in the formation of not only a new world order, but in general - global civilizational shifts. In the modern context, there is a need to build a radically new system of regional, collective, Pan-European and even global security. Randomness and uncertainty are becoming integral features of today. Despite the successes achieved since the Second World War in achieving stable peace and order, we can state a constant increase in the number of new threats to the security of countries and peoples.

II. MATERIALS AND METHODS

Research on military alliances is indicative of their positive and negative effects. On the one hand, they certainly, contribute to the growth of trade, which generally gives reason to justify the benefits of such agreements [1] On the other hand, the economic interests of the parties may differ significantly, especially if at the initial point of the agreement the parties did not have the same potential, such as the separately taken Baltic countries and Ukraine, Poland or Great Britain. In this case, a larger player can impose its interests on smaller countries. However, it can also contribute to the strengthening of countries (as happened with the Baltic countries and NATO). A certain change in the quality of wars is also undoubted. In modern conditions, every country, regardless of size, can secure a competitive advantage for itself, for example, in the production of technology, spare parts or drones. Within the framework of the alliance, benefits can be formed that did not exist before the creation of the alliance. [2] – [5]

In a military-political alliance, an increase or intensification of trade can also occur if two countries pursue different goals but are ready to give in to each other in order to ensure the interests of each country separately. In this case, such an agreement would have compensating distributive effects. Moreover, a synergistic effect is created even in the case of unfavorable conditions during the execution of one of the contracts, and thus indirect compensation occurs for the realization of mutual interests. [6]

The main goal of the authors' scientific research is the study of the prerequisites for the emergence of the geopolitical prerequisites for the emergence and development of a new union in Europe, such as the Baltic-Black Sea Union (BBSU) in support of regional security in the context of the Three Seas Alliance.

The achievement of the goal thus set is through the applicability of the methods and tools known to scientific knowledge, based on dialectical principles, the unity of

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theory and practice, scientific abstraction. Methodological basis of the authors' research are system-structural analysis, methods of economic, historical and logical analysis, quantitative and qualitative analysis, expert evaluations, etc.

Within the framework of such an alliance, there may be preferences in the establishment of trade or customs barriers, changes in the terms of trade in exchange for participation in the alliance and ensuring security. If there are sufficient incentives to form a military alliance (and especially a small one, where the connection between countries is quite high and strong), there is a high probability of securing trade agreements. [1] The strengthening of trade relations leads to the financial security of all member countries of the alliance, which in turn can become the basis for ensuring security and, accordingly, strengthening the ability to protect markets. [7] Thus, the protection of a party that is a member of the alliance has higher levels of security than the protection of a country that pursues its interests on its own. It should be borne in mind that the size of the country, its capabilities, political and economic prerequisites are important. There are savings due to the scaling of production, specialization, or distribution of expenses, depending on the capabilities of the alliance members. Refusal to cooperate within an alliance may be caused primarily by fear of refusal to participate in military operations or the inability to realize their own military and economic interests [8].

Realization of long-term interests can outweigh short-term losses or costs, which was proved in a significant number of works at the end of the 20th century [9], [10]. Long-term prospects for military-political cooperation were studied in the works of Axelrod [11], McGinnis [12], Abbott [13]. As part of the work, it was proved that the increase in the value of the alliance occurs due to the confidence that the security promise will be fulfilled and, accordingly, a decrease in such confidence leads to a decrease in the density of contacts with each other within the alliance. Analyzing top-down relationships that are formed under the influence of a political decision and are implemented in cooperation already at the micro level, in cooperation between firms. A significant number of agreements on military or political alliances contain provisions or articles on trade relations or economic cooperation (for example, changing trade barriers or customs duties on certain types of goods).

The relevant data is provided on the ATOP website - The Alliance Treaty Obligations and Provisions project provides data regarding the content of military alliance agreements signed by all countries of the world between 1815 and 2018. Thus, out of 213 alliances within the ATOR, 18% contain such articles or other relating to specific acts of economic cooperation [14]. For example, the Union Treaty between Greece and Serbia of 1913 ensured the freedom of export-import operations of Serbia through the ports of Greece (Thessaloniki) [15]. The agreement between Bolivia and Peru regulates monetary policy and trade both between countries and external (Great Britain, Foreign Office, 1864–65). The agreement signed in 1921 between France and Poland had a limitation regarding entry into force only after such entry into trade relations and trade agreements [16]. The Treaty between Austria, Hungary, and Italy in 1934 indicates the need for trade agreements as a result of the implementation of the military-political alliance [17]. Among the 213 treaties analyzed, 16 agreements have articles relating to specific economic obligations, 23 treaties have articles that promote the implementation of economic relations or economic cooperation [14].

At the same time, not all agreements on military cooperation include articles on economic cooperation or cooperation. It is worth because in modern conditions both contracts and cooperation have a slightly different nature. The dependence of trade and military alliances can be traced in the treaties of the second half of the twentieth century. For example, the liberalization of Germany's trade policy was caused by the desire to preserve certain military-political alliances, such as the Austro-Ugric alliance, which improved the logistics of the agricultural market [18]. After the first world war, a treaty between France and Belgium to provide security against Germany and counter a possible attack [19] – [21].

The Belgian-French agreement is designed to maintain defensive lines [22] – [24]. The signing of this treaty was fraught with problems of cooperation in the United States of America and Great Britain, the former refused to ratify the treaty, the latter refused the treaty without the participation of the United States. In fact, both the United States and Great Britain refused to assume defensive obligations to France. Although Belgium considered a coalition with the participation of both the United States and Great Britain to be more valuable to itself, it was decided to sign a bilateral treaty with France for joint security [22] – [24].

This alliance was framed as an opportunity to counteract German policy and, moreover, Belgium was interested in the fate of Luxembourg, which was seen in close contact with Germany. However, Belgium is interested in such a relationship, because it is connected with Luxembourg in the issue of railway systems, which ensures profitable trade, as well as lower French tariffs for trade [26]. As a result of the military-political alliance, the possibilities for reducing French tariffs on goods transported through Antwerp were clarified and spelled out [26]. After the signing of the treaty, trade between the countries intensified significantly. The functioning of the union was terminated in 1936 by Belgium unilaterally, one of the reasons was the inability to provide sufficient access to the French market for Belgian exporters, which was the result of the use of tools to support the French economy after the Great Depression in the form of quotas and tariffs, as well as quotas for the exercise of the right to work in France [23] (Kieft David Owen, 1972). Thus, we can conclude that the military-political alliances and trade policies of countries are interdependent. Military agreements affect the level of trade, while trade relations affect the provision of the highest level of security [27] .

Based on the results of the creation and functioning of military-political alliances, their economic efficiency is calculated. The key parameters for assessing the effectiveness of trade and political alliances are changes in the population, the length of borders (including common ones), the level of GDP, the similarity of economies, the level and dynamics of trade between member countries of the alliance and between external countries with the alliance, the level of militarization and power political influence on the countries of the alliance.

In general, according to the results of the model, it was determined that trade between the countries-members of the military-political alliance is higher in terms of activity than between the countries of the alliance and other countries. Trade, its intensity and quality are also affected by the terms of agreements between countries - the closer and more specific conditions are prescribed, the higher the level of trade and cooperation, which in turn provides for the existence of economic agreements. Thus, the increase in trade flows is closely related to issues of security policy coordination. The assessment was carried out for the countries of the European continent before the Second World War. It has been proven that trade between allies whose treaties prioritize economic cooperation to ensure security is much higher than in other countries outside the union. The model indicates that trade relations between those countries that are members of the alliance, which have not identified economic cooperation as a priority for themselves, are at the same level as trade between countries that are not members of the alliances.

Justin George and Todd Sandler in his latest article also explores the economics of alliances to reveal the distribution of the burden of military spending in the North Atlantic Treaty Organization (NATO) between 1991 and 2020, until the Russian invasion of Ukraine in February 2022 [28]. This considered the relative location of NATO allies and applied various spatial or economic weights to Allied defense spending. Sandler T. Concludes that the Allies' free use of the total military spending of other Allies has led to a decrease in the military spending of NATO allies located near Russia. This division, the asymmetry within NATO, contributed to the Russian invasion [28].

What is now becoming a reality is increased EU cooperation in deterring future Russian aggression, especially against eastern allies such as Poland or the Baltic states. [28] An increase in military spending by all NATO countries will also be unconditional.

III. RESULTS AND DISCUSSION

Analyzing the possibilities of creating the Baltic Black Sea Union, we can determine the advantages of such a military-political sub-alliance both in terms of security and in matters of economic alliance. The history of the creation of the Baltic-Black Sea Union (BBSU) and the assessment of the total military power of the countries of this region, studied in other works of the authors, suggest that there are objective prerequisites of the widest spectrum for the creation of such a union. We should emphasize here that we are talking about emergencies in different formats. BBSU_1 - represents the very core of this union, Poland, Latvia, Lithuania, Estonia, and Ukraine. BBSU_2 includes, in addition to the named countries, Great Britain. BBSU_3 - plus countries with access to the Baltic and Black Seas (Sweden, Finland, Germany, Denmark and Bulgaria, Romania, Turkey, and Georgia). In addition, this union (BBSU_4) may include countries that are landlocked but interested in participating (Moldova, Croatia, Czech Republic, Slovakia, Hungary, Greece, Belarus, etc.). In this case, the political aspirations of different countries do not matter, it's just about potential participants. In BBSU_3 and BBSU_4, the composition of countries can also be different, since not all countries can join this alliance at the same time.

First, there are long-term historical prerequisites for this alliance, which were detailed in Section 2. The entire history of relations between these countries, of course, is based on certain geographical prerequisites. The countries that are potential participants in the BBSU are not just neighbors, they form a clear vertical axis connecting the Baltic and Black Seas. The Baltic countries and Poland occupy about 3,000 km of the 8,000 km coastline of the Baltic Sea. There are two segments in the Russian Federation: 520 km near St. Petersburg and 150 km near Kaliningrad. The rest - more than 4000 km - falls on Finland, Sweden, Germany, and Denmark.

As for the Black Sea, we will proceed from the situation that developed before the war, as well as about the legal borders. Out of 4725 km of the total Black Sea coastline, individual countries own: 1629.1 km (34.5%) - Ukraine, 410 km (8.7%) of the Russian Federation, 315 km (6.7%) - Georgia, 1701 km (36 .0%) - Turkey, 385 km (8.1%) - Bulgaria and 285 km (6.0%) - Romania. The total length of the coast of the Sea of Azov is 1860 km [29].

Thus, in the Baltic Sea, the BES countries own more than 40% of the coastal territory, and the Russian Federation - 8.5%, while the rest belongs to other NATO countries (current and potential). In the Black Sea - BBSU - 34.5%, RF - 8.7%, and in addition, another 50.1% - to potential members of the BBSU. Obviously, there are predominantly BBSU countries in access to the seas, both for the core of the BBSU, and for a wider range of countries. Most likely, it is this insignificant share of the Russian Federation that is, to a certain extent, the source of its aggressive behavior.

The economic prerequisites are also unconditional, which include a whole range of more detailed favorable conditions for cooperation. Each country in this union has certain economic advantages, selling its products and getting what it needs. In the most general terms, Ukraine sells its agricultural and food products, mineral fertilizers and chemical products (we are not talking about metal yet, since the base of the metallurgical industry has been destroyed). Poland has the most developed industry, the products of which are important for all countries.

It should be noted that all the Baltic countries (Latvia, Lithuania, and Estonia) have created a customs union, which leads to a large volume of trade between these countries:

Latvia exports: electrical machinery and equipment, machinery and mechanisms, lumber, pharmaceutical products, iron and steel products, round timber, knitwear and textiles, non-ferrous metals, and their products, etc. The weaknesses of Latvia are the dependence of energy supply on imported oil products, gas and electricity; scarce resource base; growing shortage of able-bodied labor force and the number of pensioners in the structure of the population.

Estonia is one of the most developed countries. GDP per capita is $27,280.7. Until the 1990s, Estonia specialized mainly in agricultural products, mechanical engineering, shipping, and transportation. After gaining independence, the country was able to create favorable conditions for the development of innovation and attracting start-ups. Now, there are 4 world-famous unicorn companies (with a capitalization of more than $1 billion) operating in Estonia: Skype, Bolt, Transfer Wise, Playtech. In addition, it specializes in mechanical engineering, shale mining, electrical products, ships, marine transportation, woodworking products, textile and meat industries.

Lithuania has a high rate of development and a fairly developed industrial base. The main sectors of the economy are services, industry, and agriculture. The main Lithuanian exports are agricultural products and foodstuffs, chemical products and plastics, machinery and equipment, mineral products, timber, and furniture. It should also be noted that the government creates conditions for the widespread dissemination of ICT (information and communication technologies), including in the financial sector. The country has significantly simplified the procedures for obtaining licenses for the activities of electronic money and payment institutions. The first block chain center in Europe was opened in Vilnius in 2018.

Poland is the second largest country in this group of countries, and at the same time the most developed. Poland has large reserves of minerals: gas, coal, iron, nickel ore, silver, gold, zinc, shale gas, etc. A powerful industrial base is formed by such industries as: engineering, ferrous and non-ferrous metallurgy, chemical, textile, clothing, cement industries, production of furniture and various products of light industry, electronics. Highly developed agriculture is represented by the production of sugar beets, wheat and other cereals, potatoes, berries, apples, etc., as well as developed pig breeding, dairy and meat cattle breeding, and poultry farming. Sea fishing is developed.

Ukraine has the largest territory in this union and ranks second among European countries - 603,550 square meters. km. (for 2013) [30]. At the end of 2022, the economic base has been largely destroyed not only in the eastern regions, but throughout the country. Nevertheless, we can talk about Ukraine as a country with developed metallurgy, energy, chemical and mining industries, engineering, automotive, fertilizer and chemical products, agriculture, and services. Ukraine has reserves of almost all mineral resources, vast agricultural land, which leads to great potential for the development of its economy and exports. The ICT sector is also developing.

Therefore, the BBSU union can become a very powerful economic creation since it will unite both resource-rich countries and developed countries that have formed their specialization in the new conditions of the digital economy. Of particular importance in the context of economic prerequisites is the transport factor - the formation of a through transport corridor between the Black and Baltic Seas. Moreover, this corridor can be provided by almost all types of modern transport: road, rail, pipeline, river. The implementation of this project will certainly increase traffic flows and reduce the time of transportation of various goods and passengers from the eastern regions to Europe.

The political prerequisites for the creation of the BES have a long history and have not lost their importance in modern conditions. They are related to the need to strengthen the contractual positions of the parties while protecting their interests. But the main circumstance is the need to form a shield to counteract the aggressive behavior of neighboring countries. The creation of such a union has great potential to strengthen a bloc of states, which in fact explains such determined resistance to its creation in historical retrospect.

Closely related to the political are also the military prerequisites. The basis for this is the fact that in the 21st century the world has already achieved considerable success in achieving collective security. Nevertheless, the events of 2022 once again confirm that, despite the developed mechanisms and institutions of world security, we must not stop thinking about military security as well. The security of European countries is guaranteed by the NATO bloc and a high level of military-technical support.

In general, the formation of an integral line of defense within the framework of the military-political unification between the Baltic countries, Poland, Ukraine, and Great Britain is a rather important and topical issue. The countries participating in such an alliance, as analysis shows, have sufficient potential to ensure security in the region and counter external challenges.

IV. CONCLUSIONS

The formation of alliances and sub-alliances brings with it both military-political and economic benefits. Economic modeling confirms that economic benefits are primarily derived from trade intensification. A significant number of treaties on military alliances have separate articles that regulate trade relations, are aimed at or contribute to the intensification or liberalization of trade in both military (dual) use goods and trade in general. The intensification of trade leads to an increase in the economic potential of partner countries or alliance member countries, which in turn leads to an increase in the ability to build a security.

The formation of military-political alliances is a necessary condition for ensuring security in modern conditions. All these and many other processes exacerbate the need to create military alliances and alliances for security purposes. Regardless of the features of the new configuration of international security and the agreements reached after the end of hostilities, the development of cooperation in the Black Sea-Baltic region in the aspect of building the North-South vertical, the Baltic-Black Sea axis has great prospects. The idea of creating such an axis has a long history, and in the modern context it can unite states that are ready to develop military, economic, and other forms of cooperation in countering Moscow's imperial ambitions. Areas of cooperation among members of the Baltic-Black Sea Cooperation (BBSU) could include: multilateral trade cooperation; building unified transport corridors; creation of unified logistics and energy systems; coordination of economic and other sanctions; broad military cooperation: multilateral coordination of economic and other sanctions; mutual deliveries of lethal defensive weapons; cooperation in matters of energy security and transit of energy carriers; mutual assistance in the combat training of troops and the modernization of weapons; exchange of strategic, counterintelligence and other data; joint military-industrial enterprises and developments (especially high-tech ones); joint international initiatives to counter propaganda; exchange of military advisers and other experts.

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A New Approach To Sustainable Management – The Concept Of Social Farming

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Abstract. The present scientific paper examines a new approach to sustainable management, related to the concept of social farming. The socio-ecological nature of the social farming makes it a valuable asset, contributing to the welfare, wellbeing, intercultural learning, labour integration and social inclusion of the most disadvantaged groups of society. The potential of the social farming for achieving sustainable development in the rural areas is enormous, including social entrepreneurship and social innovation, increased employment rates and incomes, social inclusion, training, recreation, innovation and environmental protection. Social farming, as a multifunctional model, contributes both, to the public welfare and the alternative entrepreneurial business model. The proposed systemic model represents a more comprehensive approach to the complex nature of the social faming. The results of the study encompass the theoretical review of the concept, an effective social farming model and the existing problem-solving opportunities.

Keywords: employment, environmental protection, social entrepreneurship, social farming, sustainable management.

I. INTRODUCTION

In recent years, agriculture has taken on new roles, moving from a simple economic activity for the production of goods for human and animal nutrition to activities capable of improving the environment (land protection, reduction of pollution) and providing services to the community, also connected to social and labour policies [1].

According to the European Economic and Social Committee, *social farming* could be described as “a cluster of activities that use agricultural resources—both animal and plant—to generate in rural or semi-rural areas, social services such as rehabilitation, therapy, sheltered jobs, lifelong learning and other activities contributing to social integration” [2].

The multifunctional character of social farming has been studied and examined [3]. Social farming aims to enhance the multifunctional character of agriculture and it’s linked to a model of territorial and proximity welfare, based on public action to regulate and safeguard the protection of citizens starting from the weakest groups and considers workers, local institutions, the third sector and others as protagonists. Different practices are related to “safeguarding biodiversity, fostering environmental and food education and making the area known by organising social and educational farms” [4]. Social farming recognizes and enhances the heritage of agriculture, made up of natural assets (land, water, landscape, etc.), material assets (tools, buildings, plant varieties, animal breeds) and the set of knowledge, values, traditions (intangible assets) that characterize this sector [5].

Social farming develops on a logic of environmental, social and economic sustainability, with particular attention to the protection and conservation of natural resources for future generations in each individual territory. In particular, social farming tends primarily and progressively towards organic production and environmental protection [6].

Social farming includes a variety of activities, e.g. integration of disadvantaged people, social services for the local communities, services accompanying medical, psychological and recreational therapies [4]. The different social farming activities could contribute to sustainable management and promote sustainable rural development [1]. The complex nature of social farming encompasses the concepts of: social inclusion, labour integration, welfare, wellbeing and learning [7], [6], [8], [5], “connective agriculture” [9], social innovation [10].

With regard to the global health crisis in the past few years and the following economic and social measures, we witnessed dramatic changes globally. The pandemic situation led also to marginalization of many farms [11]. The recent farmers’ protests development, due to climate

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change conditions and lack of adequate modernized policy in the sector, evidenced the necessity of introducing new measures and alternative business models. In view of the challenges of the green and digital transitions, "Europe will need innovative solutions and all entrepreneurial talent should be encouraged" [12].

The socio-ecological nature of the social farming makes it a valuable asset, contributing to the welfare, wellbeing, intercultural learning, labour integration and social inclusion of the most disadvantaged groups of society.

II. Materials and methods

The aim of this paper is to review the theoretical concepts related to the social farming and its multifunctional character, as well as to propose a model of its effective introduction. During the first stage of the analysis a systematic literature review was conducted, in order to collect and synthesize research evidence in the selected field. Different European and national strategies and policies were examined in order to highlight the main development trends, existing measures and incentives. The second stage of the research encompassed a comparative analysis of the development in selected EU countries and in Bulgaria. The data for Bulgaria was collected from different sources, including existing information about the social farms in the country and information gathered from interviews. The information gathering encompassed quantitative and qualitative data. The third stage of the research included the elaboration of a model of social farming from the systemic perspective and the social-ecological framework. In the last part of the study the main elements of the system model of social farming were analysed, including the stakeholders, the process itself, the most relevant activities and the results of the social farming. Descriptive and comparative analysis have been used in the study, applying qualitative data review.

III. Results and Discussion

A. Brief historical overview, development of the social farming concept and legislative framework

The first example of social farming is the so-called "welfare farms" created in the Netherlands in the 1990s, and there are currently many such initiatives, distinguished by extreme diversity in terms of the activities involved, target groups and method of financing [13].

Of course, social farming has been developed to varying degrees in different European countries.

In the 1970s the birth of City farms in Great Britain became the solution for recovering abandoned places, often transformed into landfills in peripheral urban areas, or the union of a group of family gardens and urban farms. The City farms carry out varied activities: training courses, school visits, hippotherapy and horticultural therapy, vegetable cultivation, composting and recycling of waste, recreational and sporting activities, summer and after-school centres.

In Italy the typology of social agriculture is consolidating, which offers new potential and opportunities for the development of rural areas and communities by providing responses to the needs of personal services, promoting knowledge and mutual trust.

There are good practices and traditions in Italy – e.g. the health care sector identifies and uses social agriculture as a means of therapy, the economic sector as a tool for providing employment, agricultural producers as a source of income and an opportunity to develop new areas. All this is possible thanks to the existing strong normative and financial support from the state (regardless of the fact that, as a relatively new phenomenon, it is not yet considered comprehensively regulated in a legislative aspect). Social farms in Italy include also the educational farms. In recent years, educational farms have been able to develop all the potential inherent in the agricultural enterprise and have revealed themselves to be dynamic structures, capable of designing complex courses and modifying their training offer according to the needs of the territory. Today, the farm presents itself as a place of active learning and a tool for permanent education, no longer linked exclusively to school users - which nevertheless remains fundamental -, while the service offered is enriched with numerous proposals, up to the organization of cultural and sporting activities, training for adults (cooking courses, vegetable cultivation, recognition of mushrooms or wild plants, etc.), theatre shows for children, activities for disadvantaged children and other.

In Lombardy, "social farms" are growing, accompanying agricultural production with social activities, with a view to multifunctionality. These are corporate projects that offer alternative forms of participatory, territorial and proximity welfare and which open up new spaces for agricultural businesses.

In 2013, with the issuing of the Opinion (2013/C 44/07) by the European Economic and Social Committee [2], the long process of regulation, at European and national level, of this specific area of intervention began. Through this opinion, the formal foundations were laid for EU Member States to work quickly to promote and support this sector, among other things by adopting, at different levels, an adequate and favourable regulatory framework, recognizing its added value and improving its governance" [2].

The operation of an agricultural business is considered, not only from an economic-productive point of view, but also and above all as an intervention aimed at the social and working inclusion [14] of disadvantaged people and the reference explicit to the world of social cooperation and social entrepreneurship as well as other organizational forms of the third sector, with respect to social agriculture interventions, represents an incentive to create forms of collaboration between the world of agricultural entrepreneurship and that of social entrepreneurship to in order to guarantee the provision of services aimed at achieving:

- training and job placement: experiences oriented towards the employment of disadvantaged individuals or those with relatively less serious disabilities (internships, job grants, hiring for disabled people, prisoners, drug addicts, migrants, refugees);
- rehabilitation/care: experiences aimed at people with disabilities (physical, mental, mental,

social), with a main socio-therapeutic aim (social workshops, day centres, community accommodation);

- recreation and quality of life: experiences aimed at a wide spectrum of people with more or less special needs, with socio-recreational purposes, including particular forms of social agritourism, the experiences of peri-urban social gardens for the elderly;
- education: actions aimed at broadening the forms and contents of learning to bring young or less young people closer to environmental issues (educational farms, summer camps);
- services for daily life: as in the case of "agri-kindergartens" or day care services for the elderly.

It is clear that the recognition of social agriculture, both by ad hoc legislation and by that of social enterprise, means that new initiatives are implemented with greater awareness that actively involve public institutions, the community and the world of social entrepreneurship leading to the development of specific measures in the development plans of territorial welfare systems. These processes, which have become increasingly consolidated over the years, have allowed social agriculture to acquire considerable importance in both quantitative and qualitative terms. The multifunctional characteristic of agriculture, in fact, is the basis of a reconsideration of this sector: in the past it was mostly the recipient of public policy interventions aimed at reducing the differences between urban areas and rural areas, while today, especially with the recognition regulations of social agriculture and thanks to the active involvement of social entrepreneurship, it becomes the tool through which companies and individuals operating in the agricultural sector are able to offer services of social interest for the communities of reference [15]. Therefore, agricultural companies become the main protagonists in the development processes of rural areas, promoting participatory welfare paths in which local communities, and the various subjects that compose them, act actively in taking care of the most vulnerable categories.

B. Development in Bulgaria

Fostering social enterprise has become a national priority, as is clear from the adoption, in October 2018, of the Act on Social and Solidarity-Based Enterprises [16], which entered into force in May 2019. This law aims to create a favourable ecosystem for social enterprises, providing them with a better access to the market and improving their competitive-ness. Moreover, a Social-Economy and Social-Responsibility Department was established in 2018 within the Ministry of Labour and Social Policy [17].

According to art. 3 “The social and solidarity economy is a form of entrepreneurship aimed at one or more social activities and/or social goals carried out by enterprises, including through the production of various goods or the provision of services, in cooperation with state or local authorities or independently” [16].

“Social agriculture” is a very varied set of processes and actions that use agricultural activities to promote aggregative activities for the community or accompany therapeutic, rehabilitation and social and work inclusion actions of disadvantaged people (art. 4 L. 381/ 1991) or at risk of social exclusion.

"Social activity" could be defined as any activity that produces social added value and is aimed at achieving a social goal in support of persons and their social inclusion, raising their standard of living, improving their access to the labor market and to education and the protection of their rights, as well as to improve the living environment through the protection of the environment and biodiversity and in support of the ecological balance.

Social economy serves as an instrument for the development of social services; inclusion of disadvantaged groups on the labour market; improvement of the social services system’s functionality; development of local economies as well as fight with poverty and social exclusion.

The development of social economy sector helps expand the possibilities to increase economic growth and contribution to GDP, employment and creation of conditions and a favourable environment for innovative, socially significant entrepreneur solutions.

Social entrepreneurship is an economic activity entirely aimed at the creation, operation and development of social enterprises. It is a relatively new concept for Bulgaria and nevertheless a number of organizations all over Bulgaria perform such activities. The essence of the social entrepreneurship is the creation of public good through activities that combine economic and social goals, provide support for socially vulnerable groups of society, stimulate socially positive changes, satisfies social needs, while utilizing the available resources optimally, applying innovative approaches to the social economy’s development.

The social farming activities are part of the social economy and social entrepreneurship.

In the field of employment social entrepreneurships provide services related to:

- Encouraging employment opportunities and career development for the long-term unemployed, people with disabilities and other people on the labour market, as well as providing assistance in finding a suitable position, providing employment and going back to work;
- Encouraging the possibilities of self-employment, entrepreneurship and establishment of cooperatives and starting one’s own business.

By providing employment for society’s vulnerable groups, social economy helps unite the economic and the social resource for overcoming social isolation and leads to the reduction of the risk of poverty and social exclusion, to enhance the sustainability of the social policy measures.

In Bulgaria, the role of social economy in the country’s general development is hardly visible, unlike that in most of EU countries.

C. Social farming in the context of social entrepreneurship and social innovation

Social farming is a relatively new phenomenon that still lacks both a sufficiently comprehensive definition and legislative regulation. However, it is clear that:

- is one of the functions of multifunctional agriculture;
- includes activities related to farms, animals, plants, gardens, forests, parks, etc.;
- has a multidisciplinary nature;
- represents an innovative way of linking agricultural practices and social activities/services [18];
- includes cultural, educational, training, etc. activities aimed at people in difficult situations;
- has an entrepreneurial character and pursues profit (the farm is not a non-profit organization), regardless of the generation of positive effects on public welfare [19].

In the most general sense, social entrepreneurship represents a specific type of economic activity that balances social and economic goals. Similarly, a social enterprise is a type of enterprise that carries out economic activity in the name of a social cause, i.e. some socially significant goal. Each social enterprise:

- has as its main objective the performance of a socially beneficial activity - achieving a social effect and exerting a beneficial influence by solving a specific social problem (e.g. improving the quality of life of vulnerable groups);
- in connection with the above, it also aims to generate income from economic activity, but not to make a profit for its owners, but to be self-sustaining, avoiding dependence on project financing, volunteering and donations - i.e. social objectives or public interest are the reason for its commercial activity;
- performs activities often in the form of social innovation;
- is managed in a transparent manner, in particular by involving workers, customers and employees in the management stakeholders affected by its economic activity.

A social enterprise always functions for the benefit of its employees by providing them with employment, or for the benefit of other vulnerable groups or social causes. In this sense, social economic activity can be divided into two main forms:

- provision of social services to vulnerable users, such as access to housing or care, healthcare, assistance for the elderly or disabled, childcare, access to employment and training, inclusion of risk groups, coping with addiction, etc.;
- production of goods or services in a way that contributes to the labour integration of disadvantaged people, isolated and marginalized mainly due to insufficient qualifications or social or professional problems, i.e. employment provision.

At European level, there is a lack of a clear definition of the concept of "innovation in rural areas". On the one hand, this provides more opportunities, but on the other hand, it carries the risk of diverse interpretation, and also creates difficulties in terms of stimulating innovation (due to the lack of developed guidelines or financial incentives).

Main areas of innovation in rural areas are: renewable energy sources; rural tourism, economic integration and local partnerships; entrepreneurship; development, food processing and food supply chains. Projects related to the use of renewable energy sources and those related to innovation in services (e. g. facilities for the disabled, broadband internet for more remote settlements, etc.) are considered particularly innovative. Projects focused on youth and women, the structure of the aging population and the emigration of young people from rural areas are considered priorities. Considerable attention is also paid to the relationship between the quality of the environment and tourism, as well as to the addition of value to the main products.

Every social innovation represents a priori a new solution (product, service, model, market, process) that meets specific social needs and problems more effectively than the previous ones. It is always related to the realization of an idea that brings value because it leads to social change and has a direct impact on the quality of life of people and communities. In this sense, social innovation is a tool for long-term change – it increases the capacity of society to function better in the long term.

Social entrepreneurship and social innovation (including in rural areas) are subject to significant financial support, which easily argues for their identification as a European and national priority.

Social entrepreneurship and social enterprises have been identified as a key tool for innovation and overcoming the problems of poverty and social exclusion. In this context, it's important to develop social entrepreneurship and establish it as a business model that generates social value, resilience and contributes to the achievement of smart and sustainable growth, while helping to reduce poverty and social exclusion. In this sense, social farming is seen as valuable asset with enormous potential.

D. Systemic model of social farming

Systems thinking is a way to understand the complexity of economic, social and ecological systems [20]. Having in mind the complex nature of social farming, the systems' perspective would be appropriate for the elaboration of an inclusive model, explaining the dynamic interactions withing the system [23].

Central to a systemic sustainability management perspective is the "interdependence between organizations and the natural environment, given that organizations depend on the natural environment for inputs and organizational actions directly impact the natural environment through feedback loops" [20] -[22].

The proposed model of social farming encompasses the systemic approach, including the *input* to the system –

public authorities, academia, business and society; the *process* – social farming; and the *output* – social inclusion, labour integration, therapy, training, environmental protection and increased income (Fig. 1).

E. System's input elements.

- Government (public authorities) provide the legislative framework, different strategies and funding programmes. The regional and local authorities have a crucial role in supporting the social farming. The regions have a significant role in achieving the sustainable goals because of their vicinity to the ecological problems and the local know-how for overcoming and adapting to the ecological challenges [24].

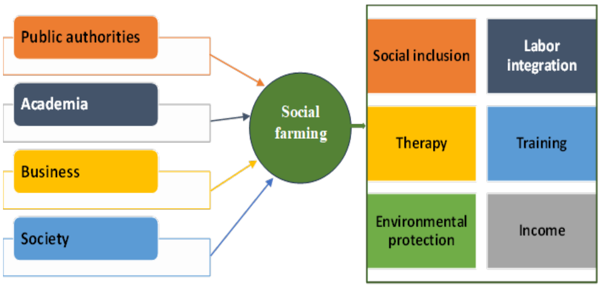

Fig. 1. Systemic model of social farming.

- Academia (educational and research institutions) – provides the training and research activities.
- Business (industry) – provides the expertise and specialists in the sector.
- Society – the engagement of the society as a whole is important in order to implement a successful social farming model. The citizens are both contributors and end-users.

F. System's output elements.

- Labour integration - all studies show that there are certain vulnerable groups in our country with very small chances of employment [25]. The reasons for this are numerous, but in many cases, they are related to the presence of barriers and stereotypes (prejudices) about people of different gender, age, ethnicity, race, health status, etc., built up over centuries. These vulnerable groups include: young people, elderly, women, disabled, Roma minority, immigrants, refugees and citizens of third countries. When the mentioned stereotypes (signs of discrimination) are combined, the inclusion of the vulnerable groups in question in employment becomes almost impossible. For example, it is particularly difficult to integrate persons with low education and without a professional of qualification.
- Social inclusion - in the light of the persistent tendency to isolate the certain groups from the society, social farming can be seen as one of the possibilities to overcome it. Active participation in the daily life of a farm enables disadvantaged people, from different social strata, to improve their mental and physical health, gain access to paid employment, integrate fully and, accordingly, improve their quality of life - people with physical, intellectual or psychological disabilities, behavioural problems or learning difficulties, permanently unemployed, immigrants, drug addicts, socially weak, criminals, elderly people, etc. [26]. In this sense, with its medical-therapeutic, rehabilitative, educational and integration orientation, social agriculture can make an extremely serious contribution to the development of any society [27].
- Training - educational farms are realities that bring young people and adults closer to the countryside to rediscover the link that exists between the land and the table, enhance the flavours and culture of the rural world, spread knowledge about quality productions, offering growth opportunities for everyone. There is no shortage of expert opinions and hypotheses for the future, which sees generational change and the qualification of the sector as key points. Social agriculture promotes actions to bring environmental, agricultural and social issues closer to all people, especially younger ones; to this end it organizes educational and training activities, in connection with schools and other training agencies in the area.
- Therapy - social farming, by offering activities in contact with plants and animals, contributes to the improvement of individual well-being and of all living beings and of the health conditions of the people involved in therapeutic, rehabilitation and care processes. The outdoor and indoor activities, along with carefully planned therapeutic activities, have beneficial effect for a wide range of mental diseases, e. g. autism [28].
- Increased income – social farming could be considered as an alternative business model, providing additional income to the farmers along with the production of traditional goods. Social agriculture aims to enhance the multifunctional character of agriculture - that is, the fact that this activity simultaneously has the function of producing food goods [29] and other social functions - in the field of personal services, strengthening quality agricultural production, experiment and innovate agricultural practices with respect for people and the environment, integrate the production of goods and services with the creation of informal networks of relationships. It promotes healthy and balanced lifestyles and tends to raise the quality of local life in rural and peri-urban areas through the creation of contexts of social cohesion and the offer of services for people and local populations. With regard to the twin transition, the European Commission aims at "strengthening economic and social cohesion, by for instance, reinforcing social protection and the welfare state, with regional development strategies and investment also playing an

important role” [30]. Social agriculture is part of the cultural movement that sees the production of goods and services oriented not only to containing public spending and satisfying needs, but also to strengthening the quality of social bonds, according to principles of solidarity, subsidiarity and sharing.

- Environmental protection - social farming develops on a logic of environmental, social and economic sustainability, with particular attention to the protection and conservation of natural resources for future generations in each individual territory. In particular, social agriculture tends primarily and progressively towards organic production, capable of safeguarding the health of all living beings and the environment at the same time. Furthermore, social agriculture protects the environmental context through the valorisation of the natural and cultural heritage, the promotion of the typical features and excellence of the territory.

IV. Conclusion

The proposed systemic model of social farming includes the main stakeholders as the output to the system, providing the necessary political and legal framework, training and research, as well as financial support and expertise.

The process of social farming is the core of the system, interconnecting the actors in the process, generating social value, inclusive communities, resilience, smart and sustainable growth.

The most important part of the model is the output, the results of the process – social inclusion, labour integration, therapeutic and recreational activities, acquired skills, increased income and environmental protection.

The practical implications of the model could be seen in the potential of social farming to reduce poverty, to enhance the social inclusion, contributing to the climate neutrality, the sustainable management of natural resources, as well as to acquire new skills and develop innovation and entrepreneurial capacity.

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Uranium Mines In Bulgaria - Analysis Of The State 30 Years After Their Closure

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Abstract. Uranium mining in Bulgaria dates back to 1939 and was made a historical aspect of uranium mining in Bulgaria until its liquidation in 1992. The measures taken under Decree No. 74 / 27.03.1998 to liquidate the consequences of mining and processing are described of uranium and the omissions to be made. eliminated in this regard. Until the end of uranium mining in 1992, the annual production of uranium was 660-680 t, of which 430 t was obtained by geotechnical method - drilling with sand-type uranium drilling. They are poor in uranium (below 0.05%), but with several times cheaper yields (average $40/kg for 1970-1990). The problems related to the reclamation of lands around uranium deposits and enterprises are shown. The condition of the terrain around the mines and the results of the samples from 2000 and 2010 have been analysed and recommendations for improving the condition and subsequent investigation of the condition of the adjacent terrain have been identified.
Keywords: mines, mining, reclamation, results, samples, uranium, uranium processing.

I. Introduction

Uranium mining in Bulgaria has a 47-year history (1945-1992) and is one of the earliest in Europe. Uranium deposits in Bulgaria (48 in number - Fig. 1) include diverse genetic and industrial types [1], [2]. 48 mines were extracting uranium according to Decree No. 74 of the Council of Ministers from 1992, with which the government of Philip Dimitrov decided to liquidate uranium mining, and another 30 were in the stage of exploration and trial exploitation.

Many experts believe that the liquidation of uranium mining in our country in 1991. was carried out hastily, as a result of which in a number of sections complete technical solutions for this activity have not been implemented. Adequate measures have not been taken for full reclamation of the areas surrounding the uranium mines and uranium processing plants [3], [4]. [5]

World practice indicates that no country, except for Bulgaria, has protected its uranium deposits without them being completely exhausted, and even then it extracts uranium from the old embankments around the mines. And no country liquidates its uranium production if it has nuclear plants. However, Bulgaria closed uranium mining in 1992 and spent over 50 million BGN from the budget and a lot more on the Phare program for the liquidation of mines and land reclamation [6].

The purpose of the research is to analyze the situation near the uranium mines and processing plants that were closed in 1992 and to track the change in radiation pollution in these areas. Such research was done at the end of the 20th century under the PHAR program and in 2010-2011 by the University of Plovdiv. There was an idea to start a follow-up study in 2020, but the Covid epidemic thwarted the start of this study, and therefore the results shown are partial and incomplete for now, but with the normalization of the situation, we hope to complete this started study. This will be very important for the development of municipalities, tourism, local business and the livelihood of the population.

II. Materials and methods

A. *Development of uranium mining in Bulgaria*

a) Historical overview of uranium mining in Bulgaria

The Germans were the first to start extracting uranium in Bulgaria - in 1938 in Buhovo. Already in the first year they extract 100 tons of metal. In 1939, with the beginning of the war, they stopped. After the end of the Second World War, uranium mining was resumed in strict secrecy, but now by the Soviet-Bulgarian Mining

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Company [1], [7], [8]. It existed until 1956, when the "Rare Metals" union, which was called "a state within a state", was created as a cap of uranium mining. 13,000 people worked in it. It controlled the geological exploration, extraction, processing and export of the resulting uranium concentrate. The rest of the enterprises were also under his umbrella: "Buhovo", "Trakia" - Plovdiv and "Vazkhod" - Smolyan. The Bulgarian product is called "triuranium osmoxide" (or oxide-oxide).

The classic technology of mining uranium ore is at a loss. This is an expensive process, but due to the strategic production of the raw material, it is still supported in a number of mines [2], [9].

Fig. 1. Gallery in a uranium mine [bta}

The other scheme is the geotechnological one. It is clean and very cheap. There are only two uranium ore processing plants - "Eleshnitsa" and "Buhovo" - with tailings storage facilities. Modern technology allows uranium to be extracted from much poorer ores, and uranium can again be extracted from the tailings in both tailings. The yellow cake - the commercial product with a uranium content of 30% to 60% was obtained after processing at the Eleshnica plant, and in Buhovo it was further baked and a concentrate with a uranium content of about 80% was obtained. From there it was transported in containers to the Soviet Union, where the nuclear fuel was produced and returned to our Kozloduy NPP [10].

According to genetic types, the uranium deposits in Bulgaria are magmatic, hydrothermal and exogenous (sand and infiltration type). As industrial types, they refer to small (stocks up to 1000 t) and medium (up to 10,000 t) deposits. Magmatic deposits are associated with alkaline and acidic magma masses and are characterized by high contents of radioactive elements (uranium and thorium). They are not of industrial interest. However, the deposits associated with primary enrichment of uranium in the leptitoid gneisses (the Narechen and Zdravets deposits from the Narechen ore district) can be attributed to them. The infiltration deposits formed as a result of uranium enrichment of the weathering crusts developed on granites are also connected with them (Igralishte, Senokos, Selishte, Smilyan-Lipets, Beslet, etc.).

The group of hydrothermal deposits is comparatively the largest. In terms of age, they are old-mid-alpine, located in the Balkan and Srednogorsk zones (Buhovo, Proboynitsa, Kurilo, Sliven, Rosen) and young-alpine - in the Rilo-Rhodope region (Partizanska polyana, Beli Iskar, Kostenets, Dospat, Chetroka, Sarnitsa, Planinets and dozens of ore occurrences. Common characteristic features of this type of deposits are: strict structural control of the ore; relatively large vertical range (up to 600-1000 m); close mineral associations - nasturane-quartz-carbonates, often also zeolites [3], [11], [12].

Another, equally large group are the exogenous (sandstone) deposits of Paleogeneogen age, located in the peripheral and internal graben basins of the Rilo-Rhodope massif: Upper Thrace (14 deposits - Momino, Belozem, Haskovo, Maritsa, Okop, Tenevo, etc.), Mestenskii (Eleshnitsa) and Strumski graben (Simitli, Melnik, Zlatolist). Only the uranium deposits of the Smolyanovtsi and Vinishte deposits (Montansko) are associated with unoxidized Upper Permian sediments.

The explored and proven reserves in the entire history of uranium mining in Bulgaria are 35,374 t [1]. The amount of uranium extracted from them is 16,255 t by the classical (mining) and geotechnological method. As of 1992 (the year of cessation of uranium mining activity), residual reserves and resources of 19,748 t are distributed in 31 deposits, referring to two genetic types - endogenous (hydrothermal) and exogenous (sandstone and infiltration). Then the Proboynitsa, Smolyanovtsi, Simitli and Gabra deposits were studied and prepared for mining. The exploitation of the deposits from the Buhovo and Smolyan ore fields, Eleshnitsa and Sborishte, as well as a large part of the deposits from the Thracian-Tundzhan region [13], [14] was incomplete.

Currently, based on geological, ecological, economic, infrastructural and other considerations, 14 studied and partially exploited deposits of exogenous (sandstone) type from the Thracian-Tundzhan uranium ore region are of industrial interest. They are located in 3 geographical areas: Plovdivski, Haskovski and Yambolski and are localized in permeable rocks (sandstones), limited in section by marglite. As a result of the research and geological exploration works in the period 1970 - 1985, paleo-channel (Mominska, Marishka, Sokolishka, Tundzhanska) and paleolagun (Iztochnomarishka) structures were established in these areas (Fig. 2) [2]. Proved reserves and resources of these deposits are 10,384 t, of which 6,750 t are potentially recoverable. The industrial interest in them is determined by the proven possibility of applying the geotechnological method of extraction (drilling variant), one of the most progressive and ecological methods of extracting minerals in the world. Currently, 45% of the world's uranium mining is done by this method [15], [16].

Fig. 2. Measurement of the radioactive background next to a mine in the Eastern Maris region [nova tv]

The Eleshnitsa, Smolyan and Simitli deposits, exploited so far by the classical (mining) method, with total reserves and resources of 7828 t of uranium, may in the future be exploited by the so-called combined method.

b) Brief geological-economic evaluation

The uranium deposits on which uranium mining is supposed to be organized are of the sandstone type, from which 430 t of uranium was obtained by the geotechnological method in 1988. The cost of the mined concentrate at this period did not exceed $40/kg of metal. The area on which the deposits for geotechnological uranium mining are located is ~11,700 decares on the territory of the Thracian-Tunjan uranium region [1], [5].

After the cessation of mining (1992-1994) and the technological liquidation, technical and biological reclamation, all exogenous (sandstone) deposits are at the stage of explored reserves and resources and the beginning of mining construction, including the construction of a new re-extraction plant to obtain finished product "yellow cake" - ammonium uranyl tricarbonate (AUTC) [2], [4].

Expert estimates, including the 7 exogenous deposits of this uranium region, show that the production cost of the uranium concentrate will be between $60 and $80/kg (average $70/kg). With the price of uranium concentrate currently averaging ~$100/kg (according to Ux Consulting Company, LLC), mining in this area will be efficient. This cost price includes all the necessary costs for ecology and reclamation of the worked areas on the deposits. The annual yield can reach 200-350 t, an amount that would fully satisfy the needs of Bulgaria's nuclear power industry [7]. To this quantity will be added the extracted uranium concentrate (AUTC) as a result of the purification of mine waste water from the Kutina uranium mining sites (Iskra site), the Chora mine from the Bukhovo ore field, the Byalata Voda mine, as well as in perspective, construction of new sorption installations on shaft No. 9 of the Eleshnitsa deposit, shaft No. 93 of the "V-th shaft" section of the Seslavsko deposit, shaft No. 1 of the "Selishte" section, vert. shaft No. 3 from the "Izgrev" section of the Dospat ore field, etc. This is, in fact, a roadside extraction of uranium concentrate, obtained mainly as a product of the purification of mine waste waters, contaminated with radionuclides and, in particular, with natural uranium dissolved in them [2], [16].

In the scope of the classic, underground mining mines ("Druzhba" mine 1 and 2 in Eleshnitsa, the Smolyan and Bukhovo ore fields, the Narechen ore area, etc.) after the liquidation and reclamation activities have been completed, huge amounts of mine water are currently accumulated, as a result of the stopped water outflow in the mines after the cessation of uranium mining and the natural restoration of the pressures and SVN (static water level) in the sites. Only in the "Druzhba" mine 1 and 2, about 42-45 million m3 of mine water accumulated, which flooded all the mining areas with residual and off-balance sheet stocks. Through shaft No. 9, the mine waters with the uranium dissolved in them come to the surface under pressure. The construction of a water pumping installation (mobilization of mine waters), through which instead of 10¬20 l/sec, 200-300 l/sec will pass, will increase the yield of AUTK to 20-25 t per year only from the Druzhba mine area " 1 and 2. If installations at the Bukhovsko, Narechensko ore field and other classical mines are equipped in the same way, the output can reach 50-60 t AUTK per year only from the accumulated mine waters and their passage through batteries of sorption columns. Such is the practice in Germany of the main mine in the Königstein deposit, where the annual production together with the other two large deposits Lichtenberg and Rönenburg is ~200-250 t AUTC [2], [17].

This approach to building similar facilities for mining only from mine waters also has a certain ecological effect, because sooner or later the mine waters come to the surface and create a potential danger of contamination of the surface waters with radionuclides 2-3 orders of magnitude above the PDL (maximum permissible norms).

As a second stage, projects will be developed for the implementation of the so-called combined mining of uranium deposits located in hard rocks, with explored and blocked reserves, similar to the Byalata voda and Zdravets deposits, such as e.g. Gerzovitsa deposit (Smolyansk ore field) and/or Proboynitsa and Smolyanovtsi, which have completed the stage of detailed exploration [3, 18]. The project estimates for the possible extraction of uranium (concentrate) from the mine waters and the combined extraction in perspective for a period of 10 years are in an estimated amount of ~200-250 t.

The calculations made for the operating costs for this combined extraction are based on the currently operating re-extraction line (line for regeneration purification of ion-exchange resins - LROYS) in the village of Eleshnitsa and the production of the so-called "yellow cake" from the uranium-contaminated mine waters show that for the extraction of ~200 t of uranium the costs will not exceed BGN 10-15/kg. Along with the mining in this area, it will be necessary to build a suitable site for an installation for the re-extraction of the uranium-enriched resin and obtaining "yellow cake" as a finished product.

Mining and processing will create ~1,000 jobs, as well as ancillary industries with ~3,000 jobs. Sulfuric acid production will resume at ~50,000 t/year.

Prospects for discovering new uranium deposits in Bulgaria are mainly of the sandstone type and in the metamorphic rocks and granitoids of the Central Rhodopes. In both directions, it concerns uranium deposits with low uranium contents (0.02-0.05%), but with possibilities for applying a geotechnological extraction method in the drilling version and combined mining [1], [11].

In the Thracian-Tundzhan region, the prospects for discovering new deposits are in the pre-Abonoligocene sandstones, conglomerates and volcaniclastic rocks lying below the Neogene. In them there are established and partially exploited deposits and ore occurrences - Navusen, Troyan, Maritsa, Trud, Chirpan. Uranium resources can be increased as a result of applying technologies for extraction from greater depths (up to 600-650 m), which in world practice is already successfully applied.

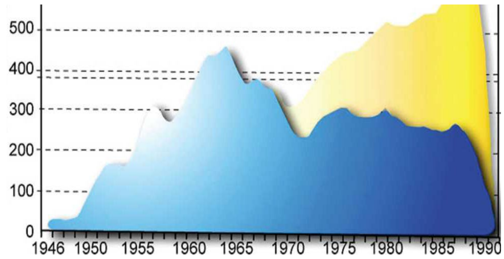

Fig. 3. Uranium extraction in Bulgaria for the period 1946-1991 (in blue - mining method; in yellow - geotechnological through chemical extraction) [2]

There are also prospects for discovering new sandstone deposits in the Strum basin, in the southern parts of the Mesten basin and in the so-called Jebel sandstones in the Eastern Rhodopes.

Some metamorphic rocks - the leptitoid gneisses from the Narechen region in the Central Rhodopes - are also of proven industrial interest. The 50-80 m thick gneiss pack has almost universal anomalous radioactivity and a uranium content of 0.01 to 0.03%. It covers an area of >200 km2 and in its northwestern part, the "Zdravets" geotechnological site for combined mining began to operate in 1991 [2].

There are prospects for uranium mining with the application of a combined mining method in the Central Rhodopes in the Smilyan granites ("Lipets" section) and in Southwestern Bulgaria (Igralishte and Senokos deposits).

After the start of mining activity and conducting geological surveys in the above-mentioned areas, the uranium resources in Bulgaria will be able to increase by 40-50,000 t [3].

III. RESULTS AND DISCUSSION

After the cessation of uranium mining and uranium processing, a number of biological reclamation activities were carried out in all sites. They include reclamation activities to restore the soil fertility of the agricultural lands within the boundaries of the geotechnological sections. In total, for the period 1997-2002, ~11,700 decares of arable land were recultivated and returned to the owners within real limits with restored soil fertility [4], [19].

The control in the MoEW system of the radiation status of the environment near former mines with uranium extraction includes field radiometric measurements and laboratory analyzes of soils, waste products in tailings and landfills, bottom sediments, underground and surface water. The radiological parameters of soils, bottom sediments and waste materials are assessed by means of analysis of samples from the EIA Network for Control of Potential Contaminants. The water samples are analysed radio chemically with regard to the indicators laid down in BDS 2823 "Drinking water" - total beta radioactivity, uranium content and radium content [5].

With the entry into force of PMS No. 74/27.03.1998 for the liquidation of the consequences of the mining and processing of uranium raw material, "Ecoengineering - RM" EOOD is assigned to organize and control the activities of technical liquidation, technical and biological reclamation, cleaning of also leads the implementation of complex departmental monitoring of the components of the environment. Despite the existence of a legal basis, monitoring networks have not been built and operated at all sites, according to the "Instruction for the organization of a monitoring system, design, construction and operation of environmental monitoring networks in the affected by uranium industry regions" [4].

The decommissioning of any mine begins with the closure of the shafts and horizontal galleries. The entrances are blocked with concrete walls, the above-ground bunkers and buildings are simultaneously demolished, and then technical and biological reclamation of the affected lands is undertaken.

In parallel with the above-mentioned activities, since 1998 and at the present time, radiation monitoring of waters is carried out in all sites to assess the qualities of underground and surface waters, the impact of uranium mining activities, as well as the results of biological reclamation. Water quality and radionuclide content as a consequence of uranium mining have been tracked over time through monitoring [3], [20].

Water pollution with natural radionuclides throughout the survey period was registered mainly in the sites with classical extraction. In them, a combined geotechnological method for uranium extraction with acid leaching or treatment with soda solutions is additionally applied. Contamination in and around these sites is mainly from mine runoff, self-flow drilling, open-pit drainage, and tabanized low-level ore bodies.

All sites from the geotechnological mining of uranium are classified by the NCRRZ to the Ministry of Health in the category "Objects with a low radiological risk for the waters". In the former geotechnological sites "Tsarimir", "Trilistnik", "Belozem", "Momino" and "Debar" and approx. among them, there are no registered over-normative contaminations with radionuclides of underground water, both in PTV and in soils. In the "Navasen", "Orlov dol", "Troyan" and "Vladimirovo" sections, the values of natural uranium in surface water, in water from pumping stations used for drinking and domestic water supply, local water sources, etc., organized as currently operating monitoring points, are significantly below the PDN according to Ordinance No. 1/15.11.1999.

What does the situation look like in the areas of the former uranium deposits to date.

The overall process of rehabilitation of these areas and their conservation has not been fully completed, despite worsened millions of BGN from our government and PHAR program and funds allocated by other countries and institutions. This arouses great concern both among specialists and among the local population, because it has a direct impact on their daily life, livelihood, livelihood and life. For the most part, these are mountainous areas and the population is mainly engaged in the production of plant and animal products and tourism. It is extremely worrying that there is no marking or it is not in good condition in these places, and they are located near tourist routes, eco-trails, populated areas, etc.

After the liquidation, some of the mines "resurrected" with new functions. The closed uranium mine in the Rhodope village of Barutin, for example, was turned into a regional waste dump for 4 municipalities - Devin, Borino, Dospat and Satovcha. Near Kostenets, there is also an idea to use a closed uranium mine as a garbage dump. Under conditions defined by law, mines could be used as landfills or quarries. All sanitary requirements and norms for preventing incidents related to the past of these objects must be observed.

Many people from the region of the Iskar Gorge, including from Svoge, worked in the uranium mine near Lakatnik. For its time, the mine was the newest and most modern uranium mine in Bulgaria. In search of ore, more than 600 meters of underground galleries and shafts were excavated. The area was thoroughly explored, probed and high hopes were placed on the "Balkan" mine, as it was once called, says Vasil Chanev, director of the state-owned company "Ecoengineering RM", liquidating and recultivating uranium mines in Bulgaria. According to the plan, more kilometers of galleries had to be excavated, even the bed of the Proboynitsa river was diverted and pushed through an underground channel. However, it never got to the actual deposits and mining. Ore was extracted, but in small quantities, from the gravel when the galleries were dug, and now uranium can only be found in the soles around it. Thus, the still unfinished mine went directly into a process of technical liquidation, and later also of technical and biological reclamation, and finally, to arrive at... its current semi-legal operation. Semi-legal, because according to residents in the area, inert materials are still used in the construction of roads and railway embankments from the uranium embankments from the former mines. And it is even used in construction [1], [6].

To the south of Melnik are the villages of Lozenitsa and Vinogradi. It is very curious for random people that 10 meters from the bus stop between the villages there is the shaft of the old "Melnik" mine. Those waiting here know about her, but she is not visible to the unknown passers-by, she does not bother anyone. Accidental passers-by on this road also do not pay attention to it, since there is no marking indicating an increased radiation background. And there is one.

At the foot of Western Pirin there are other uranium deposits - Brezhani, Senokos, Simitli, Eleshnitsa, Igralishte. Instead of a desolate and ominous place, a lunar landscape with contours of concrete, iron and ugly embankments, I saw a beautiful area with which the mine has merged - from the concrete on the shaft there is a beautiful view of the Melnik Pyramids in the foreground and the snowy peaks of Pirin in the background, the shaft is surrounded by fertile gardens and of course vineyards.

The mine was even useful to someone - the fittings from its concrete "plug" were stolen for secondary raw materials.

The Melnik mine was closed half a century ago and was therefore not considered too dangerous in the 1990s, when the list of mines for technical liquidation was determined. However, it is among the thirty sites designated by a government decree at the end of 2007 that are subject to risk assessment.

Some of the richest uranium mines in Bulgaria were located 25 km from our capital, in the immediate vicinity of the town of Buhovo. The first uranium mining activities in this area date back to 1938, when the Germans began mining this valuable raw material. Later, a plant was built there for processing the mined ore and extracting uranium and a tailings repository for it. For the reclamation of the tailings storage facility and its adjacent areas, more than 6 million BGN have been allocated under the PHAR program, the necessary measures have been taken and the necessary information has been placed in prominent places. But no one can prevent the local population from passing through these territories, growing fruits and vegetables near the reclaimed areas and feeding their animals from the pastures around the settlements.

In the immediate vicinity of the Seslavtsi neighborhood of Sofia, there are some of the richest uranium mines in Bulgaria. They are located next to the settlement itself and the end houses border the territory of the uranium mining enterprise. Even the fences of many of the houses are made of blocks from the former mines, the wind constantly blows radioactive dust, and the water flowing after rain floods the yards with "enriched" material. Unfortunately, the millions of leva given for the reclamation of the uranium massifs have not been able to reach this remote area of our country.

The problem with uranium mines in Bulgaria has existed for a long time and the measures taken to solve it are not effective enough or the result is not satisfactory.

In the area of the village of Eleshnitsa is the famous area for the processing and mining of uranium ore. There is also a tailings storage facility near the "Zvezda" processing plant. It is said that Eleshnica is the best rehabilitated area compared to the others in the country and perhaps with the most invested funds. However, there are reports of stolen funds and incomplete rehabilitation leading to landslides and leakage of water from the tailings storage facility into the Maritsa River. Regarding the measured values of the surface, they are around the norms.

It is not the first time that the issues of uranium resources and uranium mining activity in the Republic of Bulgaria have been addressed. It has been emphasized every time that the facts such as reserves and resources of uranium ores and the most modern mining technologies used (geotechnological drilling option and combined geotechnological) for decades in the last century are the most serious arguments for the restoration of this activity in the country.

No matter how much alternative sources of energy production are emphasized, humanity will solve and go hard to solve its energy problems by using nuclear energy. Uranium is needed for energy development. Nuclear energy guarantees long-term independence, even more so if it is tied to the resumption of uranium mining in Bulgaria.

After the closure of the uranium mines and our two uranium processing enterprises under the PHAR program at the end of the last century, measures were taken to restrict access to the mines and recultivate the lands around them. At the beginning of the 20th century, a study of the condition of the soils near the mines and enterprises was carried out, and the results obtained and the analysis of them showed gaps and measures were identified to overcome them. Measures were taken by the enterprises responsible for the storage of the objects to limit the negative impacts.

In 2010-2011, Plovdiv University, under a program with the United Institute for Nuclear Research in Dubna, took samples from potentially dangerous areas and performed spectroscopy for the presence of radioactive isotopes. The obtained results were close to those of the previous study, but in individual mines, where underground water passes through their galleries and comes to the surface, an increased level of certain radioisotopes is reported. Such deviations are observed in Barutin, Borino, Smolyan, Proboynitsa and others, for which specific proposals have been made to limit pollution.

After that, a new study was not done, and we at the Vasil Levski National Military University in 2019 prepared a project to carry out a new study of the problem areas, monitoring the condition of the mines and adjacent territories. This research will provide up-to-date data and will enable tracking the development of the environmental clean-up process in these areas. This will give information to the local authorities and the population, with which they will be able to develop the regions, tourism, agriculture and their livelihood. The availability of up-to-date information will be of great importance for the Rilo-Rhodope region.

IV. CONCLUSIONS

1. Government documents were adopted to deal with the problems of the consequences of priority liquidated uranium mining and uranium processing sites, which were updated until the beginning of the 20th century, but after that things were left almost to fate. Complete studies were carried out under the PHAR Program at the end of the 20th century and in 2010-2011 by the University of Plovdiv together with the United Institute for Nuclear Research in Dubna. These investigations found gaps in the sealing of the uranium mines and the subsequent control. There are open areas with an increased radioactive background and corresponding prescriptions have been written, but there is a lack of longer control;

2. Some sites of uranium mining and uranium processing have no established monitoring networks for radiation control and do not conduct departmental monitoring, there are no warning signs and no explanatory work is carried out among the local population. Humans and animals are allowed in unsecured and unexplored areas near the uranium deposits. There is uncontrolled groundwater and surface water discharge from the closed mines, which may contain elevated levels of radioactive substances;

3. Already completed liquidation and reclamation works have been compromised due to their poor design and/or implementation and insufficient technical support of already built facilities. A part of the equipment has been destroyed, and under the influence of time, another part of it does not fulfill its purpose. Vandalism of destruction or theft of safety equipment has also been observed, and no measures have been taken to repair the damage. There is an unclear status and responsibility for the control and monitoring of the condition of the objects under consideration;

4. There is a radio-ecological risk due to unresolved problems with the management and complex cleaning of waters contaminated with natural radionuclides, flowing from the uranium mining sites.

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Study of the Influence of Winds in the Potential Contamination with Hazardous Substances as A Result of Man-Made Accidents

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Abstract. The report presents enterprises on the territory of Bulgaria that store or use in their production dangerous chemical, radiation and biological substances. An analysis was made of the substances used and the conditions for use and storage. In the event of an accident, these hazardous substances will pollute the environment. Wind plays a major role in dispersal of released substances and will determine the contaminated area. The direction and strength of winds at different altitudes in the settlements where these enterprises are located were studied. The obtained results were analysed based on the prevailing winds in the last 20 years.
Keywords: direction, distribution, hazardous substances, man-made accident, storage, wind.

I. INTRODUCTION

Bulgaria built a powerful chemical industry in the second half of the twentieth century. It had a wide range of productions using many chemicals and in large quantities. Geographically, these plants were located all over the territory of Bulgaria, being aligned with mineral deposits, ports, airports and transport corridors. On the territory of Bulgaria there are many factories with chemical production or those that use chemical substances [1], [2].

The chemical industry is high value added, has a high return on investment and is constantly evolving. The products of the chemical industry are used in all branches of the modern economy, and any production without these products is unthinkable [3]

At the same time, enterprises using large quantities of chemical substances are under continuous monitoring and control by state, governmental control bodies and environmental organizations [4], [5]. This is due to the fact that harmful or dangerous substances are very often released during these productions and they are not always disposed of or released in the correct non-polluting way [6].

II. MATERIALS AND METHODS

A. Main operating enterprises from the chemical industry in Bulgaria

a) Agropolychem

Agropolyhim is a leading producer of nitrogen fertilizers in South-Eastern Europe and a leader in the production of phosphorus fertilizers in the Balkan Peninsula. The plant is located in North-Eastern Bulgaria, about 30 km from the city of Varna.

The plant was put into operation in 1974 with the main goal of meeting the needs of Bulgarian agriculture. In 2009, a new plant for concentrating phosphoric acid up to 54% was completed, which made it possible to export phosphoric acid to the Balkans and central Europe. The value of this investment is 11 million euros.

Here it became possible to produce new products depending on the needs of the market - monoammonium phosphate (MAP), diammonium phosphate (DAP) in a volume of up to 1100 tons per day.

In 2011, Agropolychem realized the construction of a new workshop for the production of pure ammonium nitrate solution and the utilization of condensates with a capacity of 1250 t/day at its production site in the town of Devnya.

b) "Neochim" JSC

"Neochim" JSC is the successor of the Chemical Combine in the town of Dimitrovgrad, which started its production activities on November 5, 1951. Initially,

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nitrogen and phosphorus fertilizers were produced. Subsequently, expansions, reconstructions and modernizations of the production facilities were made. In 1987, a new complex for the production of ammonia, nitric acid and ammonium nitrate was commissioned.

In the period 1992-1993, the installations for the production of sulfuric and phosphoric acid, phosphoric fertilizers, aniline and nitrobenzene were shut down. The activity of "Neochim" AD is the production and trade of mineral fertilizers, inorganic and organic chemical products.

Structurally, production capacities are grouped into: nitrogen fertilizer complex and organic production. The operated installations for the main products allow to produce: ammonia 450,000 t/year; nitric acid 480,000 t/year; ammonium nitrate 710,000 t/year; sodium nitrate 9,300 t/year; formalin 30,000 t/year; urea-formaldehyde resins 20,800 t/year; Ammonium bicarbonate 6,000 t/year.

"Neochim" AD is the only producer in Bulgaria of formalin, urea-formaldehyde resins, sodium nitrate, ammonium bicarbonate, paradise gas, polyethylene oxide, glass-filled thermoplastics, etc. Agropolichim owns a warehouse for the storage of liquid ammonia with a capacity of 10,000 tons.

The most significant potentially dangerous object on the territory of Haskovo region is "Neokhim" JSC - Dimitrovgrad, categorized as an enterprise with high risk potential (permit No. 01-10/2012, issued by the Minister of Environment and Water). The main production facilities are currently producing: ammonium nitrate; ammonia; nitric acid; formalin and urea-formaldehyde resins; nitrogen and oxygen; carbon dioxide; nitrous oxide (paradise gas); sodium nitrate and sodium nitrite. The company operates and stores: ammonia (by cryogenic method) - up to 10,000 tons; nitric acid - up to 6500 t; formalin - up to 2200 tons; liquefied hydrocarbon gases (propane-butane) - up to 113 t; natural gas – by pipeline; sulfur dioxide (liquefied) - up to 100 tons; ammonia (25% aqueous solution) - 100 tons; ammonium nitrate - up to 10,000 tons. Ammonia is an explosive and highly toxic gas, and in the event of an accident, a zone of lethal concentration will be formed in an area of 7.5 km^2, including 7 settlements, with a total number of affected population of 58,000 inhabitants and a zone of striking concentration in an area of 40 km^2, including 17 settlements and about 15,000 inhabitants.

c) Air Liquide Bulgaria

Air Liquide Bulgaria signs a long-term contract for the supply of oxygen and argon to Steel Industry in Pernik and uses this opportunity to invest in a new plant supplying Steel and also producing large quantities of liquid oxygen, nitrogen and argon. They have two air separation plants in Pernik and Pirdop, which supply large quantities of oxygen to the Aurubis Bulgaria and Stomana Industry plants.

For the needs of the Bulgarian industry, apart from oxygen, argon and nitrogen are also produced there. There are filling centers for bottles in Gabrovo and Pirdop. Distribution centers are open in Sofia, Varna, Gabrovo, Ruse and Dobrich.

d) "Plasthim-T" Bulgaria

"Plasthim-T" is among the main producers of flexible packaging in Bulgaria. The enterprise has existed since 1967, mainly as a manufacturer of household and electrical appliances. From the end of the 70s, the production of polypropylene twine began, and from that time, the production of polyethylene film. Since 1983, the production of flexible packaging has started. In 1990, the production of flexible containers began. They have a line for the production of biaxially oriented polypropylene (BOPP), which was successfully launched in 2004.

In March 2010, a production line for BOPP foil with a width of 6.6 meters was launched. The company's production also uses the metallization process. It consists in the vaporization of a metal at very low pressure, which causes a deposit on the substrate, which is actually an adhesion of the metal, giving it certain technical characteristics or improving its appearance.

e) Tecom Company

The company "Tecom" was established in 1984 with the subject of construction chemistry in the utilization of industrial waste for composite materials and technologies. The company builds modern technological lines for the production of concrete additives, formwork oils, flocculants, auxiliary products based on organic chemical synthesis and nanotechnology.

In 2002, the company acquired the "Tecom" factory - the village of Gorna Malina, where it built a technological line for the production of polymer and silicone primers, silicone impregnators and hydrophobizers for protection against aggressors, polymer and silicone plasters, dry construction adhesives, floor coverings, systems for sanitation, waterproofing products, etc. based on nanotechnology.

The company specializes in the production of the following groups of products: additives for cement concrete and solutions; ancillary products; formwork oils; polymer and silicone primers; silicone impregnants and hydrophobizers; polymer and silicone plasters; dry construction adhesives; floor coverings; sanitation system; waterproofing products; flocculants.

Since 2010, Tecom has included in its production list the Carboplast series of superplasticizers based on polycarboxylate ethers.

B. Major industrial toxicants

a) General information about industrial toxic substances

Modern technical progress is unthinkable without the intensive development of chemical science. In the various productions, a large part of the substances obtained (intermediate or final) are toxic. Their storage is carried out in warehouses (drums, bottles or tanks), installations and technological lines. They are equally dangerous for personnel and the population both in peacetime and in wartime. Contamination with them can be large in area and, depending on the physico-chemical properties, persistent for minutes, hours and days [2], [7].

Regardless of strict safety measures, emergency situations accompanied by the release into the atmosphere of poisonous vapors (aerosols) or liquid spills are not a rare phenomenon.

For example, in the Indian city of Bhopal, 43 tons of methyl isocyanate and other industrial poisons leaked due to an accident at the plant of the American corporation "Union Carbide", as a result of which 3,150 people died, and more than 200,000 remained crippled for life [1], [8].

A large chlorine leak in one of the city's chemical plants is threatening the lives and health of people in Toulouse, France.

At the beginning of 2017, in the village of Hitrino, a tanker truck crashed with a subsequent explosion. It's basically a volumetric explosion of propane and acrolein. Over a hundred houses were destroyed and dozens died. For more than 10 days, the security of the tankers, carriers of various industrial substances, continues [2], [9].

That is why it is advisable to know the striking effect of industrial poisons, the ways of using the means of personal protection and the abilities of self-help and mutual aid.

Commanders and staffs are required to have a competent assessment of the complex chemical situation that has arisen and the ability to creatively organize measures to protect against industrial accidents [10].

What should we understand by industrial toxic substances (POS). They include not all harmful components of the industry, but only those that are capable of contaminating the air in dangerous concentrations and thereby causing mass destruction of varying degrees of severity.

The main industrial poisons are chlorine, hydrogen chloride, ammonia, sulfur dioxide, sulfur trioxide, phosphorus halides, hydrogen fluoride, carbon monoxide, methyl mercaptan, benzene, dichloroethane, etc.

These chemicals are obtained and used by our chemical plants and factories.

Based on the fact that in the event of an accident in peacetime (including an accident as a result of a terrorist act) and in the case of deliberate use in wartime, industrial poisons will have a significant impact on the chemical situation in the nearby areas of chemical plants (and in the case of an inversion - on a large part of the country's territory), it is necessary to know the basic properties of the troops that will operate in these areas when providing assistance to the population or when conducting combat operations [2], [11].

Table 1 gives the concentrations of some thought poisons that affect the skin and poisons that cause death at the corresponding exposure (residence time in the contaminated atmosphere or workplace).

TABLE 1. CONCENTRATIONS OF SOME INDUSTRIAL POISONS

№	Industrial poisons	Toxic properties			
		skin damage, mg/l	exposition	lethal concentration, mg/l	exposure in minutes
1.	ammonia	0,2	6h	7	30
2.	chlorine	0,01	1h	0,1– 0,2	60
3.	carbon monoxide	0,22	2,5h	3,4– 5,7	30
4.	carbon disulfide	1,5–1,6	1,5h	10	90
5.	phosphorus trichloride	0,08–0,15	30 min	1,05	30
6.	hydrogen fluoride	0,4	1,5h	1,5	5

Industrial poisonous substances can be divided into four types according to toxicity, depending on the maximum permissible concentration (MPC). This is the maximum amount of substance in a unit volume of air, which does not lead to damage to the body during prolonged exposure:

- extremely dangerous - MPC less than 0.1 mg/m^3;
- highly dangerous - MPC 0.1-1.0 mg/m^3;
- moderately dangerous – MPC 1.0–10 mg/m^3;
- slightly dangerous – MAC more than 10 mg/m^3;

When the highly effective poisonous substances are poured or leaked, the so-called chemical contamination zone (3X3). It includes the place of the accident (destruction) - the so-called focus of defeat, and the territory within which the contaminated air (CA) spreads with striking concentrations. This area can reach hundreds of hectares.

The seriousness of the problem of the spread of industrial poisons can be seen from the following example. In the event of an accident (release) into the atmosphere of 10 tons of chlorine ($C1_2$), the dimensions of the cloud with lethal concentrations will be 4.8 km long and 1 km wide, and with striking concentrations - 22 km and 4 km, respectively. When 100 tons of chlorine are released into the atmosphere, the dimensions of the deadly cloud are: length 22.1 km and width 4.4 km, and the cloud with striking concentrations - 100 km and 20 km, respectively. From the example, it can be seen that depending on the direction of the surface wind, large areas will be infected. The depth of spread of contaminated air (CA) depends, first of all, on weather conditions. So, for example, with increasing temperature, rapid evaporation of IOB occurs, the concentration in the air increases, and hence the areas of damage. A strong wind, on the other hand, leads to rapid dispersion of the cloud with dangerous concentrations [12], [13].

b) Classification of air pollution accidents.

Accidents in the chemical industry with air pollution, depending on their degrees of contamination, are local, local and major (severe) accidents.

- Local air pollution accidents.

These are accidents that affect only a separate part of the production and contaminate the air to a limited extent with POW. These accidents are accompanied by leakage of small amounts of POW from the gas communications /pipelines, apparatus, vessels/, which can be easily removed. With them, only individuals can be affected and the plant does not need to stop production.

- Local air pollution accidents.

These are accidents in which a large amount of POW leaks and a high degree of contamination occurs, which spreads throughout the workshops, but there is no danger of contamination outside the site. Production is partially or temporarily suspended.

- Major /severe/ production accidents with air contamination.

These production accidents lead to sudden stoppage of production, loss of material values and injury to people, as well as contamination of the air not only in the factory but also outside.

These accidents are often accompanied by explosions, fires and the dispersal of large amounts of POPs.

Large foci of chemical contamination are created, resulting in the formation of toxic clouds kilometers away, which are dangerous because they cause mass damage to people, farm animals and plants [5], [14].

Major industrial accidents can be divided into two groups:

- Major production accidents that cause contamination of the air with POW in large areas;
- Major production accidents accompanied by explosions, fires, destruction and contamination of large areas.

The second group of KPA are the most dangerous. With them, in addition to massive human casualties, material values are also destroyed, and in individual cases, entire factories.

This type of KPA will be the most common, given that the majority of POPs form explosive mixtures with air.

Chemical production enterprises, depending on the amount of produced, used or stored POPs and their toxicity (I, II, III or IV degree), can be graded according to their emergency danger in three categories (I, II and III category). Major production accidents with air pollution will also be a frequent occurrence in wartime, when the chemical industry will be exposed to enemy strikes and sabotage. The most common Industrial poisonous substances in the production sector are: ammonia, chlorine, sulfuric acid, caustic soda, sulfur oxides, blast furnace and coke gas, propane-butane, cyanides, pesticides and other substances.

TABLE 2. GRADING OF ENTERPRISES PRODUCING CHLORINE AND AMMONIA ACCORDING TO EMERGENCY RISK.

Category	chlorine /t/	Ammonia /t/
First category of emergency safety	Production over 200	Over 2,500
Second category of emergency safety	Production from 50 to 200	From 500 to 2,500
Third category of emergency safety	Production from 1 to 50	From 20 to 500

IV. RESULTS AND DISCUSSION

Meteorological elements can have an impact on the pollution of our surrounding environment - atmosphere, soil and water, and each indicator has a different weight in forming the degree of pollution with toxic or industrial poisonous substances. Naturally, the winds at different heights from the surface of the earth's crust have the strongest influence on the spread of gases from a chemical accident, accident or terrorism. In the different layers of the Earth's atmosphere, the direction and speed of air currents sometimes have radically different values. Different types of horizontal and vertical precipitation and the permeability of the atmospheric layer to the solar radiation reaching us also have an influence. The other meteorological components have a negligible influence on the distribution of radioactive rays, particles and isotopes and are therefore not the subject of this report [2], [15].

Several of Bulgaria's large chemical enterprises are located in the considered region of Central Northern Bulgaria. There are also chemical industry enterprises here on both sides of the border river Danube and former enterprises that are currently not working, but have worked and have raw materials or can work again. All of them can have an impact on people and our surroundings in the event of an accident. There are also many medium and small enterprises that work with hazardous substances and we should not ignore their influence in the event of a release of hazardous or toxic substances.

An analysis of the results of the movement of air masses in the last nearly 40 years has been made, and relevant conclusions and recommendations have been made based on them.

Influence of winds

Wind and air currents have the greatest influence on the change in our environment after an accident occurs in facilities where there are large amounts of chemical substances. The direction and speed of the average wind determine the location, scale and degree of contamination of the trail of released gases. Therefore, when assessing possible pollution, the parameters of the air currents must always be taken into account. In the event of an accident or an increase in the concentration of chemical substances or gases, we must constantly monitor the change in air currents, as well as inform ourselves about the possible changes that meteorologists give in their forecasts. It is also necessary to quickly collect information about the usual winds in the given area, in order to predict the direction of the spread of gassing, using also local signs to determine the winds and their future development. In Bulgaria, you can use the National System for Continuous Environmental Control at the Ministry of Environment and Water and the website of the National Institute of Meteorology and Hydrology at the Bulgarian Academy of Sciences, where you can see what the distributed chemical substances will be after a certain set time and at a certain height on the earth's surface for a specific enterprise [1], [3], [16].

Wind direction and speed data allow us to solve the following tasks:

1. Determining the direction of spread of gassing and the scale of pollution, as we can define it for a certain time segment;

2. Determination of the arrival time of the chemical pollution to the designated area under the current and predicted air currents;

3. Determining the level of the assumed change in the concentration of gases in a certain time range.

The most dangerous enterprise in Central Northern Bulgaria is the chemical plant "Sviloza" in the city of Svishtov, where synthetic fibers are produced and there is a large content of heterogeneous chemical substances.

The analysis was made on the basis of detailed statistical data on the direction and strength of the wind and air currents over the territory of Bulgaria in the last more than 40 years after 1992 from the database of the National Institute of Meteorology and Hydrology (NIMH) at the Bulgarian Academy of Sciences (BAS).

In addition to the daily data for the period after 1992, generalized values for the direction and strength of the winds were used, both near the border areas with neighboring countries and over the territory of our entire country. Here, data for a period of 30 years is used, which is quite sufficient to capture the trends in the change of the atmospheric masses and the adjacent water and land surfaces. I must point out that the tracking of air masses for the last 30 years only gives us the trends and the main directions of movement, but as we all know these processes are too dynamic and do not obey cyclical uniform repeatability and predictability. Therefore, at the same time as the in-depth research and data processing, we must not stop the constant monitoring of our environment and its parameters [17], [18], [19].

Of particular interest to us are the changes in the direction of the movement of air currents in the border regions, near which there are nuclear facilities, and this applies most strongly to the cities along the Danube River. This is explained by the fact of the location of the largest chemical enterprise in the region - "Sviloza" in the town of Svishtov. Further down the river, about 100 kilometers away, is the city of Ruse, where since the 1980s significant gas emissions have been observed, both from the Bulgarian and Romanian sides. Along the Danube River is also the battery plant in the city of Nikopol (which has been capacity-constrained in recent decades) and the Kozloduy NPP in Bulgaria, the Cherna Voda NPP in Romania and the site of the frozen Belene NPP in Bulgaria [1], [20], [21].

TABLE 3. WIND FREQUENCY IN 8 DIRECTIONS AND AVERAGE SPEED IN THE CORRESPONDING DIRECTION FOR THE PERIOD 1992 - 2024 FOR THE AREA OF THE TOWN OF SVISHTOV.

Direction	N	NE	E	SE	S	SW	W	NW	Quietly
Number of cases with quiet, %	6.2	14.1	7.1	3.8	5.9	8.2	15.6	7.6	31.5
Number of cases without quiet, %	9.0	20.7	10.3	5.6	8.6	11.9	22.8	11.1	
Average speed, (m/s)	4.7	4.4	2.6	2.9	3.6	3.4	3.8	3.0	

Table 3 shows that the main wind direction in this region is west and northeast. To the west of Svishtov is located "Svilosa" Svishtov and the construction site of the NPP "Belene" and it is from there that 22.8% of the winds originate. Adding the nearby northwesterly and southwesterly winds, it turns out that more than 40% of the winds in this area would contribute to an increase in pollution in the event of an accident at the nearby enterprise within the city limits. Here, the wind speed must be taken into account when assessing the situation. Table 3 clearly shows that the west wind has a high speed - more than 3.8 m/s, with a higher speed only the pure north wind - 4.7 m/s and the northeast wind - 4.4 m/s.

TABLE 4. WIND FREQUENCY IN 8 DIRECTIONS AND AVERAGE SPEED IN THE CORRESPONDING DIRECTION FOR 2023 FOR THE AREA OF THE TOWN OF SVISHTOV.

Direction	**N**	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**	**Quietly**
Number cases wi quiet, %	9.1	20.7	9.0	2.9	4.6	7.0	11.5	5.3	29.9
Number cases without quiet, %	13.0	29.6	12.9	4.2	6.4	10.0	16.4	7.5	
Average speed, (m/s)	4.3	3.6	2.4	2.5	2.3	2.6	3.2	3.1	

Table 4 shows the similar study, but taken only for the year 2023. Here, the trend with the prevailing direction of the winds is even more clearly defined - almost 30% of the days with wind were westerly, north-westerly and south-westerly. This shows us how necessary the functioning of environmental monitoring and weather forecasting systems is mainly with preventive activities [4], [20], [22], [23].

The wind roses in other border areas of Bulgaria, which are located next to potential sources of chemical enterprises, are of interest, but due to the limited volume of the report, I will present them in detail in another development. Similar are the results obtained in Ruse, Silistra, Kozloduy and Vidin, which are located along the Danube River and are respectively located east, next to and west of the Kozloduy NPP. Predominantly, the winds are westerly and are along the Danube River, with 33% being purely westerly and another 12-16% northwesterly.

IV. CONCLUSIONS

1. Air currents have the greatest influence of meteorological elements on the distribution of hazardous chemical substances in the air and the surface soil layer. Knowledge of the gases that are released in a chemical spill or chemical accident at a manufacturing facility is paramount in early action. The availability of data for previous years allows us to make predictions about possible impact and take preventive measures to limit the impact.

2. The topography of the area also has a significant influence on the spread of hazardous chemicals and released gases. A good knowledge of the surrounding environment significantly increases the possibilities of adequate behavior and limiting the impact in the event of an accident or emergency.

3. Air currents are a very dynamic process both in time and at different heights above the earth's surface. This change must be continuously monitored in order to be able to react quickly and adequately in the event of a chemical emergency. It is desirable to use forecasts of air transformations at different heights above the earth's surface.

4. Knowledge of the enterprises and warehouses where chemical substances and gases are stored or used is essential when managing an incident, accident or emergency situation. Strict control over the transportation of dangerous goods and compliance with the relevant documentation is also necessary.

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Construction Of A System For Monitoring The Pollution Of Water Bodies With Waste

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***Abstract.** In recent decades, there has been a sharp increase in waste that pollutes the environment. It can be categorically stated that non-degradable waste has the largest share in them. They are most easily discharged and condensed in water bodies on land, and subsequently in the world's oceans.*

Still, measures are usually taken after floods or other emergencies occur. Not enough preventive measures are being taken.

The report proposes a model for monitoring and recording unregulated dumping in and around mainland water bodies. The aim of the research is to develop a system for monitoring pollution in and around water bodies, transmitting this information, analyzing it and making decisions about the removal of pollutants. As a secondary goal, a preventive measure to limit pollution can also be indicated, because when there is control and subsequent punishments, the violations also decrease to a significant extent. A review was also made of good practices in the collection of waste in water bodies. A system for collecting information and removing the accumulated waste is proposed.

It is also proposed to implement a method put in place last year in Australia to collect waste in running water. A mobile version will also be developed to signal the presence of waste, when every citizen will be able to signal the presence of such unregulated pollution.

You will also use your knowledge after equipping the astronomy club to observe space debris and to create floating island fruits from the plastic waste in the world's oceans. In addition, technologies are used that are innovative and have the potential to solve these global problems.

In carrying out the research, various methods were used - analysis, data synthesis, data processing and others.

***Keywords:** collection, monitoring, monitoring system, pollution, waste, water bodies.*

I. Introduction

The protection of the environment and the preservation of the ecological balance has been a hot topic since the end of the last century and the beginning of the XXI century [1], [2]. Particularly dangerous are non-biodegradable wastes, which in natural conditions cannot break down or require thousands and tens of thousands of years to do so. The topic of the presence of waste, mainly plastic, in water bodies around the world is very topical, because pollution in the world's oceans and riverbeds is constantly increasing. According to researchers, there are several islands of plastic and other waste in the Pacific Ocean with a total area larger than the area of Bulgaria, for example. Developed economies dispose of much of their waste there, and it is also a graveyard for space debris, which is obtained from the downfall of decommissioned space man-made objects. The fact that the amount of used and non-recycled plastic is increasing every year is alarming, and at a significant rate [3]. Despite the introduced restrictions on the use of plastic packaging, they are still extremely widely used. The pollution of the earth's surface with non-degradable waste increases every year, and in Bulgaria this is visible everywhere around us - in populated areas, in the mountains and forests, along the roads and railways and especially along the streams and rivers. There is a lack of elementary culture in the disposal of waste, and traveling around Bulgaria by car, bus, railway or even on foot, we come across large amounts of waste, including plastic [4]. Almost every settlement has unregulated dumps and places filled with construction, plastic, household and other waste [5], [6].

The goal of the development is to help limit the pollution of the environment with this type of waste and to promptly detect illegal dumps, even in hard-to-reach areas of riverbeds. The development, in which students and cadets from Vasil Levski National Military University also participate, aims to first study the pollution, collect information and map the polluted areas, take actions to reduce the pollution and carry out subsequent control. Since the pollution is the greatest in water bodies, it is precisely them and their pollution that are considered, and in particular those located on the earth's surface [1], [7], [8].

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II. Materials And Methods

In turn, water bodies are divided into land water bodies on the one hand and seas and oceans on the other. Therefore, we divided our project conditionally into two parts - in the first part we will examine the waste in the streams, rivers, lakes and swamps on the continental part of the Earth, and in the second part we will pay attention to the pollution of the world's oceans. In both parts, there are many human-contaminated sites, but each has its own specifics for monitoring, mapping and taking measures to reduce the existing waste [2], [9]. Each contamination can also have its own specifics for its tracking and subsequent removal. It can be said that the same river that flows through different countries has different characteristics of the terrain through which it flows and the degree of pollution both of the river itself and of the nearby land areas. There are enterprises that dump their waste at night, when the controlling authorities are not working, and therefore one of the directions to limit pollution is the use of sensors and cameras that work in a continuous mode and can be traced back in time when, who and how caused the pollution of water bodies and the coast or dumped unregulated hazardous waste. During the last floods in September 2023 along the Southern Black Sea coast of Bulgaria, many discharges of waste water were seen near the coast, no larger than 20 meters. The development is also in this direction.

Fig.1. Waste along the river Iskar, 02.2021

To work on this topic was the pollution caused 4 years ago along the Iskar river near Svoge and many others that we see traveling around our homeland. For more than a week, the cleaning of the water mirror next to the wall of the "Prokopanik" HPP in the Iskar River from the accumulated garbage, the area of which was about 12 decares, was carried out. Additional machinery was also provided to ensure that the process was not interrupted while the lorries took the removed rubbish to the Kostinbrod Regional Landfill. The main goal is to prevent part of the garbage from passing through the hydroelectric plant facilities, so as not to pollute the riverbed towards Svoge and further north. The torrential rains of January 11 and 12, 2019, which caused flooding in Sofia Field, collected all the waste from the ravines of Sofia Field. Most of the garbage is the result of unconscious human activity, but there are also those that are the result of conscious and deliberate work. It is necessary to work in several directions, and above all it is the change of consciousness, together with the system of control and sanctions, and no less important factor is the policy of prevention. In the presence of facilities such as hydro-electric plants, before them, along the course of the river, there should be barrier filters to collect waste [4].

This pollution has sparked interest in creating systems to monitor pollution in or around water bodies and limit environmental pollution. To create these systems, an initial collection of information mainly for Bulgaria was used, but information from other countries was also analyzed. This information was systematized and analyzed, and based on the obtained results, the main tasks to be solved during the construction of the systems were identified. After that, the idea of how to solve the tasks of detecting waste and limiting its quantity has already begun to be discussed. Based on options for finding a solution, models were developed for mapping pollution, waste removal and finding preventions to limit pollution.

And this was not an isolated case. Instead of taking preventive measures, clean up the pollution and continue in the same way until the next big pollution is caused and there will still be no one to blame.

Fig. 2. Drops on the branches of the bushes along the banks of the Mesta River

Siltation and flooding are always observed after an increase in the level of rivers, and after their retreat in a normal state, piles of waste, especially plastic, remain on the banks and vegetation. The riverbeds are an unpleasant sight in the summer, when after the runoff of the violent spring waters and the increased level of the rivers, they return to their normal beds and we see on the surrounding vegetation "flags" made of polyethylene bags, foil and others left on the branches of the trees on the banks. Very often you can even notice "landed" plastic bottles, tubes and even more bulky objects. And the cleanup initiative in April can't make up for pollution the rest of the year. The reporting of the activity with pictures of the cleaned waste is very negative. You just can't imagine how many pictures were taken with 5 bags of collected waste. Similar initiatives are organized annually in different parts of Bulgaria, but trumpeting in the media does not produce results, but real daily activities are needed - little by little, but without interruption. and in other areas this year. But we cannot in 1 day clean up all that we have polluted the other 364 days of the year. It will be much better if we do not pollute for 364 days, then there will be nothing to clean in this 1 day to clean the river, lake or dam. During the COVID pandemic and after its passing, these initiatives again sank into oblivion and proceed as before, with great disregard for environmental protection [1], [10].

If you go along many streams and rivers you will see that there are many unregulated dumps in the river beds and thousands of waste channels connected to the river networks. As a result of the "cleaning" of the riverbeds, the long-standing trees are cut down and bushes are obtained instead, and thus the condition of the riverbeds deteriorates. As a result, instead of improving the permeability of the water bed after 2-3 years, it is significantly more overgrown with bushy vegetation, and when the river level rises, the flow of water masses becomes difficult. At the same time, the branches of this low and medium-sized vegetation also hold a lot of plastic bags and other waste that people have thrown illegally near the river. In recent years we have witnessed many such pollutions, some of which we show in figures 1 and 2.

III. RESULTS AND DISCUSSION

The goal of the project, which was generated in the gatherings of the "Curious" club at Vasil Levski National Military University, is to make a prototype of a floating device that can move autonomously along the river bed and photograph and study the terrain of the river bed and the surrounding area for the presence of waste and channels that drain into the river. The device will record and transmit information to a central point. The information will be collected and a characterization of the riverbeds along the entire length will be made, based on the collected information, maps of the rivers, landfills and waste pipes will be made. This information will be very valuable because the government authorities do not know or care about such dumps and there are many waste canals built and discharged that are not regulated, legal and do not have basic treatment facilities. The device will be small in size, which will allow it to pass in small streams, and an all-terrain function can also be offered to be able to pass through fords and when the water level drops. There will also be navigation to manage and location tracking for on-demand detection and theft prevention. At the same time, it will store and transmit information about the status of the areas it has checked. After completing his mission, an operator will download the collected information from his memory and it will be processed by a team.

Fig. 3. Prototype of a device for transmitting information

The countries of the European Union are gradually limiting and banning the use of plastic and plastic dishes, bottles, tubes and other products. Until then, countries must comply with the requirements and stop the production of the described plastic items. In some countries such as Austria, the Czech Republic, Greece, Germany, France and others, they have already significantly limited the use of plastic products, but in countries such as Bulgaria, these measures are lagging behind and practically nothing is being done.

At the same time, it will be proposed to place nets on all drain pipes to collect the waste found in the running water. There are already such developments in Australia. Such nets can also be placed at the inlets of streams where large amounts of waste have been found. These networks will be equipped with overflow type devices to signal when their capacity is full. The waste is then hauled away, sorted and recycled. In this way, it will help to limit the spread of waste in our surrounding nature [6], [11], [12].

Fig. 4. Plastic waste collection in Australia [6]

In the summer of 2020, Australian authorities installed a new water filtration and waste collection system. This system is incredibly simple and useful. Both the government and citizens have already seen the benefits of its use and its effectiveness. It consists of a simple mesh placed at the outlet of a drainage pipe, which helps to catch large wastes and protect the environment from pollution. These pipes discharge water from residential areas into natural areas, and the waste from these places can be in huge quantities, which harms the environment a lot. Additionally, this trash is usually washed away by heavy tropical rains, which carry it into drainage systems.

The Australian authorities started by installing 2 nets and were amazed by the results – their new filtration system was able to collect more than 360 kilograms of garbage over several weeks. So, it was decided to install these facilities and to minimize the pollution of nature and specifically water. Although installation and maintenance costs money, the overall system is quite cost-effective, as the authorities save significant costs of maintaining the state of the environment. For example, they now save on manual labor costs that they previously had to pay for people to pick up all the waste [6].

The constructed device will also carry out subsequent control to monitor changes in pollution. In this way, the information will be superimposed over a certain period of time, half a year or a year, and an analysis and comparison will be made of the distribution of the waste in the studied sites - streams, rivers or lakes. The information will be passed on to the competent government authorities and they have the power to impose sanctions on violators and to grant or revoke relevant permits. After a certain period of time has passed, the most critical points can be checked more often, and even continuous monitoring of the situation and the disposal of non-degradable waste can be carried out. In this way, in the club, realizing extracurricular employment of students, we stimulate the development of their habits and skills [4], [13].

No less important is the problem with the accumulation of non-degradable and plastic waste in marine water areas. Every year, more than 14 billion tons of waste are thrown into the world's oceans, the majority of which is plastic. Many world experts go so far as to predict in their studies that if pollution continues at the same rate, in 30 years there will be more waste than life in the oceans. And this is tantamount to an eco-catastrophe.

The reason why this type of waste occupies the largest share is that the material is cheap, easy to shape into various products and, at the same time, is very light and relatively durable [12]. However, it is the last factor that makes it extremely harmful to nature. It is recyclable, but not in all its forms. Along with that, when burned, it emits many gases harmful to the atmosphere [2], [3], [5]. When it gets into nature, it degrades as follows:

- Plastic for making straws: about 200 years;
- Plastic plates and cups: about 450 years;
- Diapers made from materials related to the production of plastic materials - between 500 and 800 years;
- Plastic bags - depending on the thickness - from 50 to 200 years;
- Plastic bottles - between 180 and 200 years.

According to various sources, there are about 150 million tons of plastic waste in the world's oceans, and every year between 4.8 and 12.7 million tons of plastic waste fall into the waters of the seas and oceans. According to data from the European Parliament, more than 730 tons of plastic waste fall into the Mediterranean Sea alone every year. The area of floating islands only in the Pacific Ocean is larger than the territory of a country like Bulgaria. And this is as of today, and we can imagine what it will be like in 20 or 30 years, if adequate measures are not taken.

Plastic doesn't just mean uglier beaches, even in untouched places. Marine animals can become entangled in larger floating pieces or become confused and swallow smaller particles. Plastic also attracts toxic substances that end up in the fish's digestive system. From there, along the food chain, it can also reach humans [9]. The effect on human health is unknown at least for now, but it is certain that the damage is significant.

Fig. 5. Island of plastic [13]

Litter also brings economic losses both to the sectors and people connected to the sea, but also to producers. Only 5% of the value of plastic packaging finds reuse in the economy, the rest is simply wasted. The need for more recycling and to prevent more plastic from entering the oceans is obvious [1], [8], [14].

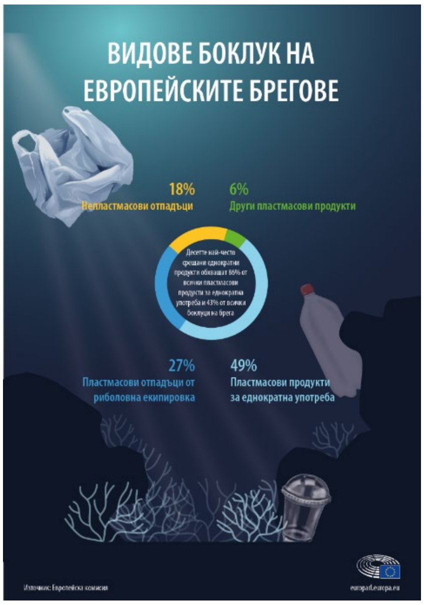

Fig. 6. Types of waste on European shores [15]

Our university is about to build its own astronomical station. We have the assurance of fellow teachers and astronomers from related universities such as Sofia University, VVMU, and the Varna Observatory that we will start joint activities of our club with related clubs in the field of astronomy and in particular and work on projects and programs of the EU, NASA and others [10]. One of our priorities will be to monitor and map both space debris and debris in marine and ocean areas that cannot be hidden from observation from space.

A system based on artificial intelligence (AI) came to our attention, which was able to distinguish plastic waste in the moped by analyzing passenger images captured by the driver. According to the people behind the technology, this is the first time [13].

The combined system analyzes the images taken by the Sentinel-2 passengers of the European Space Agency to distinguish debris floating in the world's oceans [11]. This is possible thanks to the captured and preserved image of these objects - a secure "certificate signature" of what the objects are.

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The algorithm is used in maps around Canada, Scotland, Ghana and Vietnam. The state-of-the-art system is able to distinguish plastics and other materials from water samples with 86% accuracy [13].

The team's plan is to perfect the technology so that it can more accurately detect floating spots in murky pipeline waters and large ponds.

The idea is that this method will be combined with bottoms to follow the platform shutdown and so that they support cleaning operations. However, scientists are adamant that the only way to clean the cloudy oceans is to practically reduce the amount of plastic we produce.

Based on the collected and analyzed information, a schematic diagram of a system for collecting information on pollution in and around water bodies was developed. The developed base unit consists of a device that moves through water, powered by a self-propelled autonomous propulsion unit, and collects information from the water surface and adjacent shoreline. At low water levels, the device can move along the bottom of the water body using an all-terrain chassis powered by the same engine. The device transmits the collected information and also stores it with itself, because there may not be a continuous connection due to movement in rough and difficult areas. After the research is completed, the collected information is removed from the device's memory and stored on a large and powerful medium. The information is analyzed and summarized and on the basis of the data the terrain is mapped, and the data can be superimposed and information about the dynamics of the processes and the results of previous studies can be obtained.

During the construction of the astronomical observatory, it will be possible to carry out the same observation through satellite systems and monitoring of areas potentially threatened by pollution. The general information will be analyzed and submitted to the relevant state authorities for control. The developed pollution control system will be summarized and a principle model of the system will be developed, which will be patented at the next stage of development. The concept project is only the first stage of the overall project for the construction, and there is hope that at the next forum, when funding is found, it will be possible to move to the next stage of implementing the idea.

As a result of the study and the possible implementation of the monitoring and mapping of the water bodies, it is expected that environmental pollution will be reduced and the polluted areas and their pollutants will be detected in a timely manner. This will lead to both an economic and an environmental effect for society, an effect that will be calculated upon final completion of the prototype.

IV. CONCLUSIONS

1. On the basis of the collected information about the pollution of water bodies and the terrains around them for the last more than 5 years, it was concluded that it is necessary to develop a system for control and collection of information about pollution, even in hard-to-reach areas. The information was synthesized and analyzed and based on this assessment, 4 data collection models were created to monitor the spread of plastic and other non-degradable waste. After an analysis of the efficiency and cost of the proposed models, it was chosen to develop a principle scheme for collecting and transmitting information using a light floating vehicle that can move on its own even in conditions of reduced content of water resources. The results will not be achieved easily, but it is necessary to start and step by step to help the development of our planet, because we want to live in a better world!

2. The proposal is not revolutionary, but we should not wait for a revolution to happen to save ourselves from the huge amount of non-degradable plastic waste that is all around us. Everyone should do something small so that all people can live better and everyone should preferably limit the use of plastic in their daily life.

3. Further development of the idea and creation of a prototype of the device for monitoring the presence of waste in riverbeds is yet to come. There is still a lot of work to be done, but the first steps have already been taken and now the work will continue on building the specific segments of the system and presenting it in the next edition of the conference. We sincerely hope that our conceptual development will attract the attention of interested government institutions and companies and that we will find funding to complete the project.

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Analysis of Carotenoids in Sweet Potatoes Using HPLC to Help Combat Vitamin A Deficiency

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Abstract. The fascinating and diverse family of organic compounds called carotenoids is widely found in plants, as well as some bacteria and algae. These natural pigments, with vibrant colours ranging from bright yellow to deep red and flamboyant red, attract attention for their importance in plant biology and their effect on human health. One of the most common vitamin deficiencies in the world is vitamin A deficiency.

The name carotenoids come from the vegetable carrot (carrot in Latin), where there are many well-known beta-carotenoids. These compounds are essential to biological processes beyond contributing to nature's variety of colours.

A deficiency, a persistent public health problem in many parts of the world. The precise quantification of carotenoids, in particular beta-carotene, makes it possible to evaluate the specific contribution of these sweet potatoes to the intake of vitamin A in the diet.

This study offers important data that could guide efforts to promote sweet potato consumption, particularly in regions where vitamin A deficiency is a concern. These tubers can be strategically included in diets to improve the availability of vitamin A, helping to mitigate the risks associated with this nutritional deficiency.

In sum, this HPLC analysis of carotenoids in sweet potatoes provides a solid basis for the promotion of these tubers as a dietary resource rich in provitamin A, thereby contributing to the fight against vitamin A deficiency and the promotion of health. in the communities concerned.

Keywords: analysis, beta-carotene, carotenoids, pigment, potato, vitamin A.

I. Introduction

The fascinating and diverse family of organic compounds called carotenoids is widely found in plants, as well as some bacteria and algae. These natural pigments, with vibrant colours ranging from bright yellow to deep red and flamboyant red, attract attention for their importance in plant biology and their effect on human health. Their numerous occurrences in a variety of fruits, vegetables and edible plants are both a manifestation of their visual beauty and a reflection of a variety of important biological functions [1], [2].

There are many possibilities today to detect ingredients in various samples ranging from food to cosmetics. The instrumental method that is suitable for analysing carotenoids is HPLC (high performance liquid chromatography). In this report we will explore the analysis and validation of a method for measuring carotenoids by HPLC and its application to the determination of carotenoid content in ten varieties of sweet potatoes. This analysis is done to help fight vitamin A deficiency in children.

This journey through the world of carotenoids will immerse us in the diversity of these molecules by exploring their chemical structures, their food sources, their biological functions and their implications for human health. Carotenoids may play an important role in promoting overall well-being, whether in combating chronic diseases or improving vision. This study provides in-depth insight into how carotenoids have moved beyond their aesthetic function to become essential players in plant biology and human health, as research into these compounds continues.

II. Materials And Methods.

A. Theoretical Analysis of Vitamin A Deficiency

One of the most common vitamin deficiencies in the world is vitamin A deficiency. More than 100 million people are affected and it occurs in regions where provitamin A carotenoids provide the majority of vitamin A [3]. Vitamin A deficiency affects more than 250 million children under the age of five worldwide.

A better understanding of the mechanisms of absorption and metabolism of provitamin A carotenoids could help alleviate the nutritional problems associated with vitamin A deficiency.

Vitamin A was the first essential vitamin discovered. Its chemical structure is shown in Figure 1. Vitamin A is also toxic at high levels. The toxicity of vitamin A has limited its use as a supplement, but most Western diets are rich in

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vitamin A-fortified products and preformed natural products, such as meat. Plant sources also contain high levels of vitamin A from pro-vitamin A carotenoids such as β-carotene, α-carotene, and β-cryptoxanthin, with β-carotene being the most potent source of vitamin A [4].

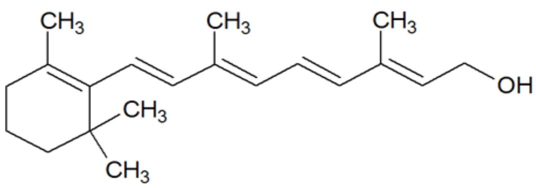

Fig. 1: Vitamin A formula [4]

Vitamin A deficiency may be due to a diet low in vitamin A or an absorption or liver disorder. Vitamin A (retinol) is necessary for the photosensitive nerve cells (photoreceptors) in the retina of the eye to function properly, allowing night vision to be maintained. In addition, it contributes to the protection of the skin, pulmonary, intestinal and urinary mucous membranes against infections.

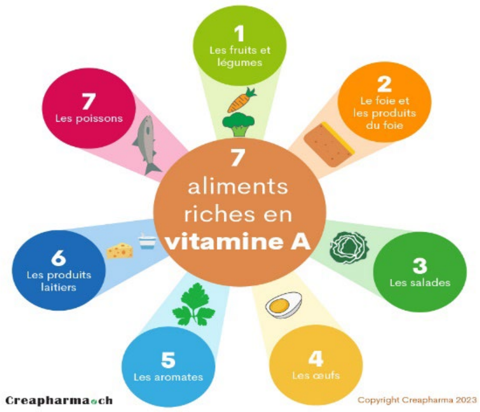

Fig. 2: Foods rich in vitamin A, [5]/

So it is very important to consume food rich in vitamin A. The main sources of vitamin A (See Figure 2) are: fish liver oil, liver, egg yolk, butter, cream and fortified milk [6].

TABLE 1: ESTIMATION OF VITAMIN A REQUIREMENTS, BY A JOINT FAO/WHO (WORLD HEALTH ORGANIZATION) COMMISSION [4]

Groupe	Age	Basic needs	Security contribution
	Years	mg of retinol equivalent/day	
Infants	0-1	180	350
Children	1-6	200	400
	6-10	250	400
	10-12	300	500
	12-15	350	600
Boys	15-18	400	600
Girls	15-18	330	500
Men	18 +	300	600
Women	18+	270	500
Pregnant Women		370	600
Lactating Women		450	850

Seeds, nuts, vegetable oil and most dark yellow-orange or dark green leafy vegetables provide a good supply of vitamin A. A whole sweet potato, with its skin included, contains approximately 1400 micrograms of vitamin A, while half a cup of raw carrots contains more than 450 micrograms, almost 51% of the daily requirement. Other foods rich in vitamin A include spinach, broccoli, squash, watermelon, grapefruit, peaches and apricots [7]. Table 1 shows the estimated vitamin A needs of different people according to their age and sex.

The role of carotenoids

Carotenoids play a crucial role in this process. Once consumed, carotenoids are slowly transformed into vitamin A in the body. Carotenoids are optimally absorbed when they come from cooked or pureed vegetables, served with fat or oil. Good sources of carotenoids are dark green, yellow or orange vegetables, as well as yellow or orange fruits [6], [8].

Causes of vitamin A deficiency

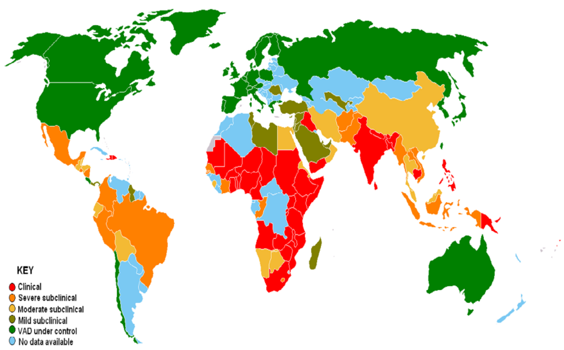

Fig. 3: Vitamin A deficiency worldwide, [9]

Vitamin A deficiency is usually caused by a diet low in the vitamin. This problem is prevalent in parts of the world where people do not consume certain foods that are good sources of vitamin A in sufficient quantities. The African continent, particularly the regions south of the Sahara, are the most affected. Indeed, of the 34 countries in the world where the WHO considers vitamin A deficiency to be a public health problem, 18 are located in West Africa, as can be seen in Fig. 3. Vitamin A deficiency is responsible for 57,000 annual deaths among children aged 6 to 59 months in French-speaking West Africa [8].

For example, in South and East Asia, where plain rice, which does not contain vitamin A, is the main food, there is vitamin A deficiency. Golden rice can prevent deficiency in vitamin A because it contains more beta-carotene. Disorders that affect fat absorption in the intestine can decrease the absorption of fat-soluble vitamin A and increase the risk of vitamin A deficiency. Chronic diarrhoea, celiac disease, cystic fibrosis, certain pancreatic disorders, and Bile duct obstruction are some of these disorders. The same effect can be produced by surgical interventions on the intestine or pancreas.

The symptoms are numerous but they can be easily overlooked. Night blindness is a first symptom. Shortly after, the white part of the eye (the conjunctiva) and the cornea may dry out and thicken. The skin becomes dry and scaly, and the mucous membranes of the lungs, intestines and urine become thick and stiff. The functioning of the immune system is disrupted, which favors the occurrence of infections, particularly in babies and children. The growth and development of children may be slowed. More than half of children with severe vitamin A deficiency may die. Diagnosis is based on symptoms and blood tests. Administering high doses of vitamin A for a few days can remedy the deficiency. Vitamin A deficiency can be prevented by eating products rich in vitamin A. Children who live in countries with high rates of food insecurity and are at risk of vitamin A deficiency should take vitamin A supplements [5].

B. Carotenoids

The name carotenoids come from the vegetable carrot (carrot in Latin), where there are many well-known beta-carotenoids. These compounds are essential to biological processes beyond contributing to nature's variety of colours. Certain carotenoids, which are precursors of vitamin A, are necessary for healthy vision, strengthening the immune system and maintaining skin health. However, many varieties of carotenoids have powerful antioxidant properties, protecting cells from free radical damage, meaning their effect is not limited to vitamin A.

More than 700 natural carotenoids have been identified [10] are two types of carotenoids: xanthophylls and carotenes [11]. Xanthophylls contain oxygen and carotenes are pure hydrocarbons. Animals do not have the ability to synthesize carotenoids and must obtain them from plant sources. Carotenoids are synthesized in plants and serve to harvest blue light in photosynthesis and to protect the plant from reactive oxygen species (ROS). Carotenoids are strongly hydrophobic compounds and are therefore associated with other lipids. In the plant cell carotenoids are located in organelles such as chloroplasts and chromoplasts. In fruits, carotenoids are more concentrated near the rind than near the stone.

Epidemiological and biological studies have implicated carotenoids as anticarcinogenic and antioxidant foods [12]. The antioxidant properties of carotenoids come from their ability to quench singlet oxygen through their conjugated double bonds. For example, lycopene has eleven conjugated double bonds and is a powerful antioxidant [13]. In the eyes, lutein and zeaxanthin protect the macula from harmful blue light and ultraviolet light. Much of the beneficial effects of carotenoids come from their vitamin A activity. There is a subclass of carotenoids that can be cleaved to produce retina. This subclass is known as provitamin A carotenoids and includes β-carotene, α-carotene, and β-cryptoxanthin. [4]

In the food industry, carotenoids are widely used as natural colorants. They are offered in food supplements because of their antioxidant properties and their potential ability to protect against the effects of the sun. They are considered capable of preventing cardiovascular diseases, certain cancers and certain eye conditions linked to aging (such as retinal degeneration) as well as strengthening the immune defenses of the elderly.

III. RESULTS AND DISCUSSION.

A. Carotenoid analysis

The most popular carotenoids

Lycopene

It is the carotenoid that we consume in the greatest quantity: between 5 and 25 mg per day. Lycopene is a carotenoid belonging to the tetraterpene family. It is widely recognized for its intense red color and is mainly found in certain fruits and vegetables, particularly tomatoes. It is the compound responsible for the red coloring of the fruit. Besides tomatoes, lycopene is also found in other fruits such as watermelons, pink grapefruit and guavas, as well as some vegetables, such as red pepper. (Fig. 4)

A distinctive feature of lycopene is its linear chemical structure (Figure 5), which gives it powerful antioxidant properties. As an antioxidant, lycopene works by neutralizing free radicals, which may help protect cells from oxidative damage. Some researchers suggest that regular consumption of lycopene may be associated with health benefits, such as reducing the risk of certain chronic diseases, including some forms of cancer and cardiovascular disease.

Fig. 4: Products rich in lycopene, [4]

Separately, studies have also explored the potential role of lycopene in skin health, suggesting that it may help protect the skin against the damaging effects of the sun's ultraviolet rays, although this does not replace conventional methods of sunscreen.

It should be noted that the bioavailability of lycopene can be improved when consumed with fat, as it is fat soluble. So, adding a small amount of fat to a meal containing lycopene sources can potentially increase its absorption.

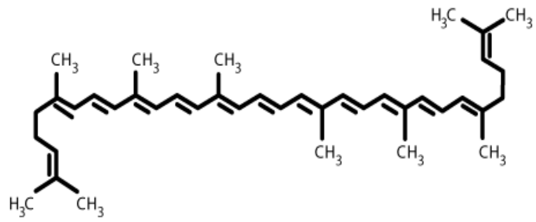

Fig. 5: Chemical structure of lycopene, [6]

Beta-carotene

Beta-carotene, one of the best known and studied carotenoids, occupies a predominant place within this family of plant pigments. It owes its name to the core, in which it was initially discovered and isolated. This reddish and orange-tinted molecule is part of the group of provitamin carotenoids, which means that it can be converted into vitamin A in the body.

Chemically, beta-carotene consists of 40 carbon atoms and is structured in two identical parts, forming a symmetrical "V" molecule. (Fig. 6) This unique structure gives beta-carotene specific properties that distinguish it within the carotenoid family.

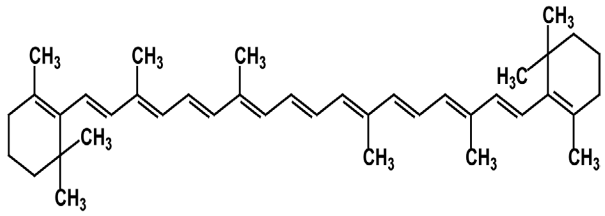

Fig. 6: Chemical structure of beta-carotene [8]

One of the most remarkable characteristics of beta-carotene is its ability to act as a precursor to vitamin A. When ingested, beta-carotene is converted in the liver to retinol, the active form of the vitamin A. This conversion is crucial for maintaining healthy vision, cell growth, reproduction, and proper functioning of the immune system.

In addition to its role as a precursor to vitamin A, beta-carotene plays a significant role as an antioxidant. By acting as a free radical neutralizing agent, it helps protect the body's cells from oxidative damage, thus playing a potential role in the prevention of certain chronic diseases.

Food sources rich in beta-carotene are varied, encompassing a multitude of colourful fruits and vegetables such as carrots, sweet potatoes, spinach, mangoes, and melons, to name a few. (Fig. 7) Including these foods in the daily diet offers a natural strategy to promote health, harnessing the benefits of beta-carotene and other carotenoids.

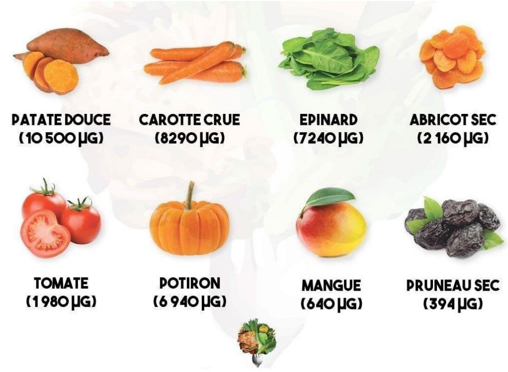

Fig. 7: Foods rich in beta-carotene, Vie Zen [6]

We consume on average 3 to 6 mg of beta-carotene per day, mainly in carrots, oranges and green vegetables. Once absorbed, it is stored in adipose tissue. When the body needs vitamin A, it draws on these reserves: 2 mg of beta-carotene provides 1 mg of vitamin A. The long-term effects of large quantities of beta-carotene have shown the major risk of increasing the lung cancer in people with risk factors, such as smoking or a diet already rich in beta-carotene.

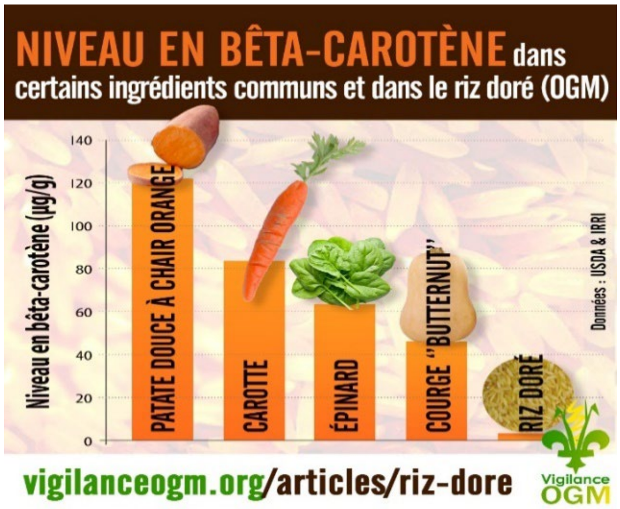

Fig. 8: Level of beta-carotene in certain foods, [6]

Astaxanthin

Astaxanthin is a carotenoid belonging to the xanthophyll class, which is a subfamily of carotenoids. This natural compound takes its name from the microalgae Haemapodous pluvial is, where it is produced in abundance. Astaxanthin is responsible for the pink to red color seen in various marine organisms such as salmon, shrimp, lobsters and crabs.

Chemically, astaxanthin has a unique structure featuring aromatic rings and conjugated double bonds. (Fig. 9) This configuration gives it exceptional antioxidant properties, making astaxanthin one of the most powerful antioxidants among carotenoids.

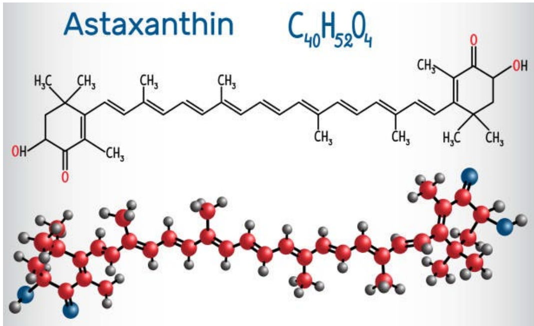

Fig. 9: Chemical structure of astaxanthin IStock, [11]

One of the best-known sources of astaxanthin is wild salmon, which acquire the substance by feeding on astaxanthin-rich marine organisms, such as shrimp and krill. (Fig. 10) The health benefits of astaxanthin are increasingly being studied, and several research studies suggest that it may play a crucial role in promoting human health.

Fig. 10: Sources of astaxanthin [11]

As an antioxidant, astaxanthin protects cells against damage caused by free radicals, helping to alleviate oxidative stress. Some researchers have explored its potential effects in preventing chronic diseases, protecting the skin from ultraviolet rays, and supporting eye functions.

Additionally, due to its anti-inflammatory properties, astaxanthin has also been studied for its potential in the management of inflammatory disorders and muscle recovery after exercise.

Lutein and zeaxanthin

Lutein and zeaxanthin are two carotenoids that also belong to the xanthophyll class. (Fig. 11) These compounds stand out for their antioxidant properties and their particularly high concentration in the retina of the eye, where they play an essential role in visual health.

Lutein:

Origin: Lutein is mainly found in green leafy vegetables such as spinach, kale and broccoli. Eggs and some other food sources also contain lutein.

Role: Lutein is particularly known for its benefits for eye health. It is concentrated in the macula of the retina, where it acts as a filter of potentially harmful blue light. By acting as an antioxidant, lutein helps protect retinal cells from oxidative damage and may help reduce the risk of age-related macular degeneration (AMD), a progressive eye disease.

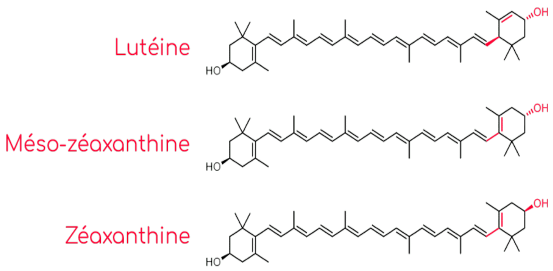

Fig. 11: Chemical structure of lutein and zeaxanthin, [14]

Zeaxanthin:

Origin: Zeaxanthin is also found in green leafy vegetables, but it is particularly abundant in foods such as corn, oranges and peppers.

Role: Zeaxanthin, like lutein, is present in the retina, and it also helps protect photoreceptor cells from the harmful effects of light rays. These two carotenoids are often associated in the scientific literature due to their common presence in the eye and their synergistic benefits for ocular health.

Research suggests that regular consumption of lutein and zeaxanthin through diet or supplements may help maintain healthy vision and reduce the risk of certain eye conditions. These carotenoids are also being studied for their potential in preventing cardiovascular disease and other disorders linked to oxidative stress.

On Table 2 you can see the main sources of carotenoids.

TABLE 2: SOME CAROTENOIDS AND THEIR FOOD SOURCES, [13]

PROVITAMINES A	BÊTA-CAROTÈNE, ALPHA-CAROTÈNE, BÊTA-CRYPTOXANTHINE	CAROTTES, ORANGES, BROCOLIS, ÉPINARDS, VERT DE BLETTES, JAUNE D'ŒUF, HUILE DE PALME ROUGE
Autres	Lutéine zéaxanthine	Choux verts, épinards, courgettes, brocolis, petits pois, maïs, kiwis, oranges, mangues, jaune d'œuf
	Lycopène	Tomates et produits dérivés (sauces, jus, etc.), pastèques, goyaves
	Astaxanthine	Crustacés (krill), algues microscopiques

Three complementary approaches are proposed to combat this problem, which is a real obstacle to progress in certain countries. These include preventive vitamin A supplementation, the enrichment of foods with vitamin A and dietary diversification through the consumption of foods rich in provitamin A carotenoids.

The organization Helen Keller International (HKI) has invested a lot of money in Burkina Faso, in collaboration with other national or international institutions, to combat the shortage of vitamin A. It has started the production of sweet potato varieties to orange flesh in the Fada region as such. Sweet potato (Ipomea batata) is a commonly consumed tuber. Promoting a specific variety requires appropriate knowledge about provitamin A carotenoid levels.

High-performance liquid chromatography is the most commonly used method for measuring carotenoids in the scientific literature. This method is used to extract carotenoids in different ways. Detection methods include ultraviolet and visible spectroscopy at fixed wavelength or with diode array detectors, electrochemistry and mass detection. [14], [15], [16], [17]

The results are presented in Table 3 [14].

TABLE 3: QUALITATIVE AND QUANTITATIVE COMPOSITION OF THE DIFFERENT VARIETIES OF SWEET POTATOES ANALYZED, (ISSA T. SOMÉ ET AL., 2004)

Sweet potato varieties	carotenoids (mg/100 g)				
	ZEA	CRYP	LYCO	ACAR	BCAR
CN	17.2 (11.2)	9.9 (11.1)	–	–	95 (83.5)
MS	19.5 (1.1)	13.5 (1.6)	–	–	6.66 (1.6)
LA	3.17 (1.51)	–	–	–	38 (8)
KA	17.2 (4)	5.1 (2.2)	17.8 (0.3)	89.8 (0.01)	429 (525)
CA	43.9 (15.2)	16.9 (2.2)	24.2 (18.4)	202 (114)	2046 (1192)
JE	38 (3.1)	15.7 (1.2)	9.6 (1.03)	136 (11)	1911 (148)
TAI	12.32 (3.6)	12.6 (2.7)	5.9 (2.9)	–	774 (357)
NA	28.4 (3.5)	17.2 (2.4)	10.4 (2.7)	151 (17)	2348 (210)
KO	6.71 (2.48)	–	–	–	170 (50)
LB	72.1 (24.8)	10.6 (6.7)	–	–	

IV. CONCLUSION

Completing this in-depth analysis of carotenoids in sweet potatoes by high-performance liquid chromatography (HPLC), which is not the subject of this article, it is clear that these tubers represent a significant source of provitamin A-rich compounds, especially beta-carotene. Research and laboratory analyzes by a number of independent authors have established that the HPLC method is a reliable and sensitive tool for the accurate quantification of the various carotenoids present in sweet potato samples, providing a detailed understanding of the specific composition of these pigments.

The significance of this analysis in the paper goes beyond simple chemical characterization. Sweet potatoes, as a natural source of beta-carotene, show significant potential in combating vitamin A deficiency, a persistent public health problem in many parts of the world. Precise quantification of carotenoids, in particular beta-carotene, makes it possible to estimate the specific contribution of these sweet potatoes to dietary vitamin A intake.

This analysis leads us to conclusions and offers important data that could guide efforts to promote sweet potato consumption, especially in regions where vitamin A deficiency is a problem. Areas with fewer sunny days (Northern Europe, Canada, Russia) and vitamin A deficiency are well suited for conducting research with increased consumption of sweet potatoes. These tubers can be strategically incorporated into diets to improve vitamin A availability, helping to mitigate the risks associated with this nutritional deficiency.

It is also good to do research based on this analysis by extending the sampling to different sweet potato cultivars, taking into account the environmental and agronomic factors that may affect the carotenoid content. This will allow a better understanding of potential variations in carotenoid composition and guide further dietary recommendations.

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Economic efficiency of the GHG emissions from energy use in agriculture: comparative analysis of Ukraine and the EU member states

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Abstract. The article is devoted to the study of the economic efficiency of GHG emissions from the use of energy in agriculture in the EU and the candidate country for accession - Ukraine. Using the abstract-logical method, the essence of the category "economic efficiency of greenhouse gas emissions" was clarified and an indicator for its assessment was proposed. By actual statistical data and the method of economic analysis, calculations of the economic efficiency of carbon dioxide emissions from the use of energy in agriculture of the EU member states and Ukraine were made. The key factor influencing the economic efficiency of GHG emissions from energy consumption in the agricultural sector was identified. Due to econometric method of approximation estimation and the Excel software package, the presence of a direct, high-density linear relationship between energy consumption and carbon dioxide emissions in agricultural production was established. By ranking method and comparative economic analysis, a threshold value of energy consumption per hectare of agricultural land was found, which corresponds to a relatively high value gross production per ton of carbon dioxide emissions among the studied countries. It was established that for the candidate country for joining the EU - Ukraine and for the two Baltic countries - Latvia and Estonia, in order to increase the level of economic efficiency of GHG emissions in terms of implementation the European Green Deal, it is worth paying primary attention to the growth of economic productivity. Also, due to graphical and tabular methods of processing statistical data, it was established that the use of environmentally friendly energy (in particular, electric energy) in the process of agricultural production is not a key factor affecting the economic efficiency of GHG emissions.

Keywords: Economic efficiency, GHG emissions, agriculture, energy use, European Green Deal.

I. INTRODUCTION

Achieving full climate neutrality in Europe by 2050 continues to be a strategic goal within the framework of the European Green Deal. For this, the European Commission intends to reduce the GHG emission towards 50 or 55% compared with the 1990 levels [1]. This plan applies not only to transport, industry and energy sector (the largest emitters of GHG into the atmosphere), but also to agriculture. According to the general aim, the target level of carbon dioxide (equivalent) emissions in the EU's agriculture should be decreased up to 244.9 million tonnes (1.35 tonnes per hectare of agricultural land) [2].Many technological processes in agricultural

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output produce GHG emission, including the direct use of energy from various sources. Thus, the share of energy as one of the sources of GHG emission in agriculture is: for, example, in Ukraine - over 10%, while in the EU - 14% (as a share in the structure of carbon dioxide emissions directly - 22 and 37%, respectively). Moreover, these types of energy resources are mostly fossil, and therefore they are based on carbon, which is the main culprit of global climate change.

The desire to meet the criteria of climate neutrality puts agricultural producers in the EU member states and in Ukraine, as a candidate state for joining the EU, in a difficult position: to ensure the high economic potential of agricultural land use against the background of improving the quality of the environment. Under such conditions, the issue of analyzing the economic efficiency of greenhouse gas emissions from the use of energy in agriculture becomes quite relevant.

II.MATERIALS AND METHODS

The fundamentals of the information and analytical base of the conducted study were the statistical materials of the FAO for the period 1990-2021, represented by the FAOSTAT database. The theoretical basis of the research was taken from the scientific works of Ukrainian and foreign scientists on the selected issues. The European Green Deal was the main strategic legal document for conducting this study. In turn, at the national level, the legal framework is represented by the National Energy Efficiency Action Plan for the period up to 2030 and the new strategy of the low-carbon development of Ukraine by 2050.

Among the general scientific methods for conducting the study, the following were singled out: the method of analysis, based on the essence of which the structure and algorithm of the study were constructed; the method of comparison, which made it possible to compare generalized and derived indicators of the economic efficiency of GHG emissions from the energy in agricultural production of the EU member states and Ukraine; an abstract-logical method, by which the category «economic efficiency of greenhouse gas emissions» was substantiated and the approach to its assessment was specified.

Also, the several specific scientific methods were used, particularly: the method of economic analysis and ranking to identify key factors affecting the economic efficiency of carbon dioxide emissions from energy used in the agriculture of Ukraine and Member States; the econometric method of probability approximation of data in the Excel software package to confirm the existence of a quantitative relationship between GHG and energy use in the region's agriculture; tabular and graphic methods in order to improve the analytical perception of statistical data and build correct studying conclusions.

III.RESULTS AND DISCUSSION

According to the general scientific interpretation, efficiency is the result of activity (effect) that society, an enterprise or a person receives per unit of used (or applied) resources [3]. In turn, economic efficiency is such a ratio between resources and production results, according to which cost indicators of production efficiency are obtained [4]

It should be noted that Japanese scientists were historically the first who made an attempt to interpret the concept of economic efficiency of greenhouse gas emissions. Particularly, Kaya and Yokobori defined carbon emission efficiency as carbon productivity from a single-factor perspective. On other words, they determined the issue at a macroeconomic level as the ratio of GDP to carbon emissions in the same period [5].

In turn, Mielnik, Goldember, and Ang used carbon dioxide emissions per unit of energy consumption as an important assessment of carbon emission efficiency [6, 7]. Zaim and Taskin reviewed carbon emissions as a non-expected output variable in the field of environment. Moreover, the scientists proposed the concept of the comprehensive efficiency index, and applied this index to the OECD national research [8]. Multifactorial interpretation of the concept of «carbon emission efficiency» belongs to Ramanatha who suggested integrating it into the three frameworks of energy consumption, economic development, and, particularly, carbon emission [9]. Arjan Trinks, Machiel Mulder and Bert Scholtens define carbon efficiency as the extent to which a given level of output is produced with minimum feasible carbon emissions relative to direct sector peers [10].

However, the question of explaining the identification of GHG emissions as a resource, and not a result, remains unresolved.

As well-known, greenhouse gas (GHG) emission is the result (effect) of economic activity, in particular from the use of various types of energy. But also it is that part of the total amount of resources (including energy) used that has not been converted into useful work and transformed into a type of negative externalities (entropy). It follows that greenhouse gases (particularly, carbon dioxide) at the theoretical level can be viewed not only as an effect that is a powerful factor of climate change, but also as a modified resource that was used to create a product in the economic system. Thus, the economic efficiency of greenhouse gas emissions (in particular, carbon dioxide) can be used in the research theory and can be defined as the ratio of the economic effect in value terms (e.g., net profit, gross production value) to the amount of greenhouse gas emissions in physical units (e.g., carbon dioxide).

The study revealed that the leaders by value of agricultural production (constant prices 2014-2016) per 1 t CO_2 emissions from energy used in agriculture among EU member states in 2021 were Romania (10525 USD), Greece (10375 USD) and Ireland (9475 USD). It should be noted that Romania has been occupying a leading position since 2000, i.e. even before joining the EU. In turn, Ukraine, as a candidate country for EU membership, demonstrated a relatively medium level of economic efficiency of carbon dioxide emissions from energy in agriculture – 5205 USD per 1 t carbon dioxide in 2021. In contrast, the EU member states with high economic productivity of agricultural land productivity show low economic efficiency of GHG emissions. For example, the Malta`s, Netherlands`s and Cyprus`s agricultural gross production value per 1 t CO_2 emissions were only 2912; 1057 and 3562 USD accordingly (fig.1).

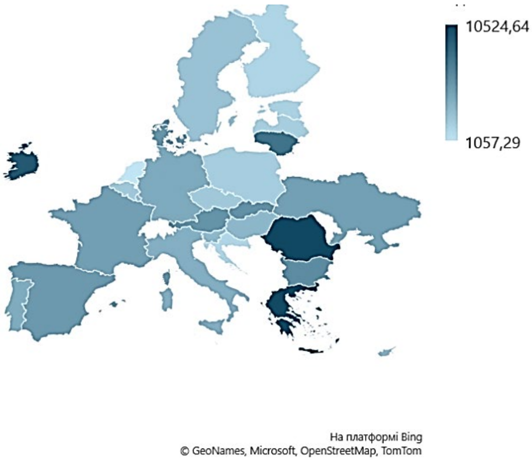

Fig. 1. Economic efficiency of GHG emissions from energy use in the EU and Ukrainian agriculture in 2021, USD per 1 t CO2 emissions
Source: complied by the authors

Obviously, the economic effect is not a determinative factor of the resulting indicator. In turn, GHG emissions are closely related to energy use. Thus, as a result of the research conducted on the basis of data from EU member states and Ukraine, it was established that there is a high level of approximation probability (R^2=0,95) and a direct linear relationship between energy use and carbon dioxide emissions in the process of agricultural production (fig.2). Also this conclusion was previously confirmed by Gołasa, P.; Wysoki ´ nski, M.; Bie ´nkowska-Gołasa and other scientists [11].

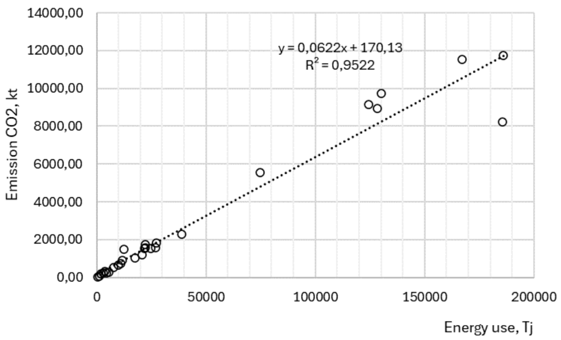

Fig.2. Quantitative relationship between carbon dioxide emissions and energy use in agriculture of EU member states and Ukraine in 2021
Source: complied by the authors

Therefore, in the countries with a high degree of economic efficiency of greenhouse gas emissions in agriculture, also high energy efficiency of production should be observed. Thus, the gross production value (constant prices 2014-2016) in agriculture per 1 terajoul of energy use in Romania was 750 thousand USD, in Greece – 1232 thousand USD and Ireland – 712 thousand USD. To compare, in Ukraine, Malta, Cyprus and Netherlands the meaning of resulting indicator were 387; 226; 379 and 73 thousand USD accordingly.

In addition, the results of the study of energy use in agricultural production of the EU member states and Ukraine indicated that gross production value per ton of carbon dioxide emission over 6000 USD was achieved by energy using volume less than 3 terajoules per 1 hectare of agricultural land (table 1). In the group of leading countries, the example of Lithuania deserves attention, because a high level of economic efficiency of carbon dioxide emissions was achieved at the expense of the lowest value of energy consumption per unit of agricultural land. The greater impact on the reduction of GHG emissions came from energy efficiency measures, which were more pronounced especially in the period from 2011 to 2013 and from 2018 to 2019, when energy intensity in Lithuania decreased significantly [12].

TABLE 1. COMPARATIVE ANALYSIS OF INFLUENCING FACTORS ON THE ECONOMIC EFFICIENCY OF GHG EMISSIONS BETWEEN THE EU MEMBER STATES AND UKRAINIAN AGRICULTURE IN 2021

№	Country	Gross production value per 1 t CO_2, USD	per hectare of agricultural land		
			Gross production value, USD	CO_2, kt	Energy use, Tj
1	Romania	10525	1253	0,12	1,7
2	Greece	10375	2634	0,25	2,1
3	Ireland	9475	1944	0,21	2,7
4	Lithuania	7901	693	0,09	1,6
5	Bulgaria	6431	863	0,13	1,9
6	Slovakia	6046	979	0,16	2,9
7	Austria	5966	2423	0,41	6,7
8	Denmark	5750	3455	0,6	10,3
9	Spain	5611	1913	0,34	4,9
10	France	5251	2160	0,41	6,5
11	Ukraine	5205	700	0,13	1,8
12	Germany	4628	2721	0,59	7,8
13	Portugal	4521	1825	0,4	5,6
14	Italy	4301	3170	0,74	10,0
15	Hungary	3825	1377	0,36	5,4
16	Slovenia	3789	1366	0,36	4,9
17	Luxembourg	3708	2210	0,6	8,5
18	Cyprus	3562	5670	1,59	14,9
19	Sweden	3142	1265	0,4	6,9
20	Malta	2912	10079	3,46	44,4
21	Belgium	2855	4766	1,67	28,5
22	Czechia	2790	1381	0,50	6,3
23	Poland	2496	1414	0,57	12,8
24	Latvia	2469	643	0,26	3,8
25	Estonia	2222	755	0,34	3,7
26	Finland	2007	1342	0,67	11,0
27	Croatia	1971	1004	0,51	7,4
28	Netherlands	1057	6740	6,38	92,2

Source: compiled by the authors

However, Ukraine, which has almost the same energy use and GHG per hectare of agricultural land as Romania, is significantly inferior to the group leader by the economic efficiency of carbon dioxide emissions and ranks only 11th in the ranking. It means that Ukrainian agricultural producers have not been still using the available energy resources efficiently enough, creating relatively small added value per unit of energy. This reserve should be used in the process of further European integration and implementation of the European Green Deal. Also, the situation in Latvia and Estonia is also somewhat similar. Their agricultural sectors continue to be inefficient by the economic efficiency of both land use and GHG emissions, despite of low level of energy use. As a result, special attention should be paid not so much to the environmental criterion as to the development of the economic potential of agricultural production. Instead, countries with highly productive agricultural land use (primarily Malta, the Netherlands, Cyprus, and Belgium) should make significant efforts to move faster to a climate-neutral agricultural production model under the European Green Deal.

The low level of carbon dioxide emissions from energy consumption in the agriculture of European countries, which belong to the group with a high indicator of economic efficiency of greenhouse gas emissions, was achieved primarily due to ensuring high energy efficiency of production. Since the main source of energy (more than 60% in the structure of total consumption), excluding Greece, was fossil resources – petroleum products and natural gas. It is well known, that these energy sources are powerful carriers of carbon and significant pollutants of the atmosphere (fig.3). At the same time, the example of Greek agriculture can be a bright vector of the future ecological and economic transformation of the industry on the basis of the European Green Deal. In turn, the Ukrainian strategy «Energy Efficiency, Renewable Energy, Modernization and Innovation, Market and Institutional Transformation» by 2050 provides a gradual transition from the use of equipment running on diesel fuel to biodiesel [13]. Furthermore, with constant consumption, non-renewable sources of energy raw materials (oil, natural gas, coal) will be exhausted in the future [14].

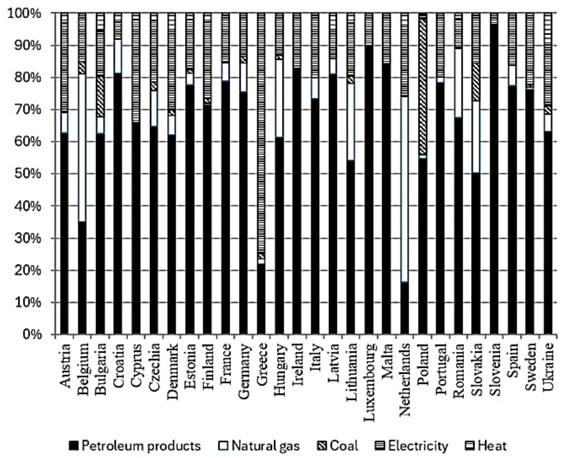

Fig.3. The structure of energy use in agriculture of EU member states and Ukraine in 2021 by types, %
Source: complied by the authors

IV.CONCLUSIONS

1. A key indicator of the economic efficiency of GHG emissions from the use of energy in agriculture can be the ratio of the value of gross production (in constant prices of a certain period) to the volume of carbon dioxide emissions from the energy used, which was spent on the agricultural production process;
2. Among the Member States and Ukraine, the highest level of economic efficiency of GHG emissions from energy use in agriculture was achieved by those countries where there were a low level of GHG emission and energy use per hectare of agricultural land but not a high economic effect;
3. As a result of the analysis, it was found that the main factor affecting the economic efficiency of GHG emissions from the energy use in agriculture is the intensity of energy use (energy consumption per unit of land area). That is, the lower the intensity of energy use in agricultural production, the higher the economic efficiency of GHG from its consumption;
4. The presence of a close direct linear relationship between energy consumption in agricultural production and carbon dioxide emissions was clarified and confirmed.
5. It was found that the type of energy (fossil energy or electricity) that is consumed to ensure agricultural production is not a determining factor affecting the economic efficiency of carbon dioxide emissions; however, it can be a promising factor in the further advancement of European agriculture towards climate neutrality.

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Quantum Computing Applications for Addressing Global Warming and Pollution: A Comprehensive Analysis

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Abstract. **Pollution and global warming become more and more of a threat recently, so creative solutions are required to tackle their overwhelming complexity, surpassing the limitations of traditional computational methods. Using the concepts of quantum physics, quantum computing presents a revolutionary approach for solving such environmental problems. With the help of a variety of data in usage from reputable global scientific sources, including world databases, pollution monitoring networks, and climate models in addition, the current scientific paper explores the quickly developing potential of quantum computing to reduce pollution and global warming. The complexities of quantum algorithms are object of our exploration, focusing on those that have relevance in resource management, in order to shed light on how quantum computers might transform decision-making processes toward global environmental sustainability. Techniques for quantum optimization show promise in maximizing energy grid distribution and reducing waste generation in complex supply chains.**

Keywords: global warming, pollution, quantum algorithms, quantum computing.

I. Introduction

The escalating threats of pollution and global warming demand solutions that surpass the limitations of traditional computational methods. This is where quantum computing emerges, wielding the enigmatic principles of quantum mechanics to offer a paradigm shift in our approach to these formidable challenges.

Traditional computers rely on bits, which are confined to the binary states of 0 or 1, mirroring the on/off states of transistors. In stark contrast, the fundamental unit of quantum information, the qubit, transcends this binary restriction. Qubits possess the remarkable ability to exist in a state of superposition, simultaneously embodying both 0 and 1 until measured. Imagine a spinning coin, representing both heads and tails until it lands – that's the essence of superposition, a quantum phenomenon defying classical logic yet unlocking immense computational potential [1].

Another cornerstone of the quantum realm is entanglement, a phenomenon where two qubits become intricately linked, sharing a unified fate regardless of physical separation. Any operation performed on one entangled qubit instantly affects its partner, even across vast distances. Picture two coins spinning in perfect unison, no matter how far apart they are thrown – that's the essence of entanglement [2]. This interconnectedness offers powerful tools for solving complex problems that elude classical methods.

The unique properties of qubits and entanglement empower quantum computers to perform calculations in ways unimaginable for classical machines. By exploiting superposition, quantum algorithms can explore vast solution spaces exponentially faster, potentially revolutionizing fields like drug discovery, materials science, and financial modelling [3], [4]. Entanglement, meanwhile, fuels optimization techniques promising solutions to intricate problems in resource management,

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logistics, and artificial intelligence, including the very challenges of mitigating climate change and pollution [5].

While still in its early stages, quantum computing holds immense potential for tackling some of humanity's most pressing challenges. Particularly in resource management, applications like optimizing energy grids, reducing waste in supply chains, and designing sustainable materials are within reach. Imagine maximizing renewable energy distribution using entangled qubits or minimizing resource consumption in complex production networks through quantum optimization algorithms – these are just a glimpse of the possibilities [6], [7].

Unlike their classical counterparts, quantum algorithms are designed for qubits, unlocking unique problem-solving capabilities. Grover's Search, for example, can find solutions in databases exponentially faster with applications in drug discovery and machine learning [8]. Quantum optimization algorithms like Variational Quantum Eigensolver (VQE) and Quantum Approximate Optimization Algorithm (QAOA) excel in tackling complex problems in logistics and materials design [5], [9]. Quantum Phase Estimation even allows simulating complex systems like molecules and markets [3].

Quantum programming languages combine all this knowledge to allow the developers to create and use the power of quantum computing to their advantage. programming frameworks like Qiskit and Cirq translate human algorithms into sequences of quantum gates for execution on specialized hardware. These frameworks simplify development by abstracting away hardware complexities, but challenges like error correction and limited hardware capabilities remain. However, rapid advancements in both hardware and software promise to unlock the full potential of quantum computing in the near future [7], [9].

In table I we briefly described and systematized how quantum computing differs from classical computing.

The escalating urgency of environmental issues demands novel solutions beyond the capabilities of traditional computing methods. This motivates our exploration of quantum computing, a rapidly evolving field with the potential to revolutionize resource management. To gain a comprehensive understanding of the current landscape and identify potential applications in this domain, we conducted a thorough literature review encompassing scientific papers and reports. This initial phase has provided valuable insights into existing research on quantum algorithms and their potential applications in resource management, laying the groundwork for further exploration and the development of innovative solutions.

This paper is structured as it follows: Section II. is about the research methodology – how the research was conducted step by step. Section III. summarizes the results of the research. Section IV provides additional information about different types of quantum programming frameworks, libraries and development platforms. Section V discusses the current situation and potential future of the field. Section VI concludes the paper.

TABLE I DIFFERENCES BETWEEN CLASSICAL COMPUTING AND QUANTUM COMPUTING

Feature	**Classical Computing**	**Quantum Computing**
Fundamental Unit	Bit (0 or 1)	Qubits (can be 0, 1, or both simultaneously)
State Representation	Binary	Superposition
Operations	Based on logic gates	Based on quantum gates
Parallelism	Limited to parallel processing of individual bits	Exploits superposition for simultaneous exploration of multiple solutions
Strengths	Well-established, efficient for well-defined problems	Powerful for complex optimization, breaking cryptographic codes, and simulating quantum systems
Weaknesses	Limited by the "0 or 1" paradigm	Prone to errors, requires specific algorithms, and hardware is still under development
Applications	General-purpose computing, simulations, data analysis, machine learning	Optimization, cryptography, materials science, and drug discovery (potential for future)

II. MATERIALS AND METHODS

The motivation behind this comprehensive analysis research is to find, analyse and structure a variety of quantum algorithms for dealing with the threats posed by environmental problems. To ensure a comprehensive and focused investigation, a well-designed and defined research methodology is crucial.

Our research as seen in Fig. 1 began with defining the central topic: "Quantum computing applications for addressing global warming and pollution". By defining the main theme of the research additional questions aroused - Which specific resource management challenges (e.g., optimizing energy grids, reducing waste in supply chains) hold the most promise for benefiting from quantum computing algorithms? What existing quantum algorithms offer the greatest potential for tackling these challenges?

What are the current limitations and future prospects of utilizing quantum computing for these applications?

The second step in our research was choosing the appropriate scientific databases, which is crucial for identifying relevant and contemporary research. Prominent databases like Web of Science offer a broad search scope, while IEEE Xplore and APS focuses on specific fields like the one, we are interested in - quantum computing. Additionally, open-access repositories like arXiv and curated databases like Scopus contribute to a comprehensive search strategy.

Third, we defined the keywords we would use in our research. Effective searching relies on carefully chosen keywords like "quantum computing,", "quantum algorithms" "resource management," "optimization," and "environment." Additionally, through query method and applying filters like publication date for capturing only recent advancements and document type - focusing on research articles, ensures targeted results. As we want only the most recent up to date papers, we filtered those search result to only include papers from 2019 up to nowadays.

Once retrieved, the research articles underwent further filtering based on inclusion and exclusion criteria. Those criteria ensured the chosen research directly contributes to our investigation. After the initial research we used pagination for structuring and were left with a total of 198 papers, but after additional filtering based on new acceptance criteria, quantitative analysis on the metadata and qualitative analysis of the abstracts the result list was shortened to include 9 papers.

To conclude our research, we analysed the steps we went through and tried to draw conclusions from that experience. This involves objectively assessing the strengths, weaknesses, and potential limitations of the research, identifying areas for further exploration. Recognizing recurring themes in the scientific papers offers valuable insights into the current state of the field and potential future directions. Identifying areas where research is limited lays the foundations for future investigations and expands the knowledge base in this evolving field.

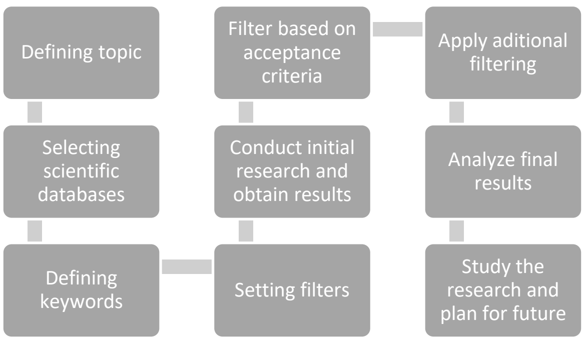

Fig. 1 A comprehensive analysis research - step by step

This structured research methodology could serve as a roadmap for navigating the vast landscape of scientific literature and facilitates a comprehensive understanding of the potential of quantum computing in tackling environmental challenges through advanced resource management. By employing this systematic approach, this research aims to uncover new avenues for utilizing the power of quantum algorithms and contribute to building a more sustainable future.

III. Results and Discussion

Out of all 198 results in all scientific databases combined, we managed to narrow down the final result to 9 papers for quantum algorithms which are or could be exploited to combat global warming and help lower pollution.

1. Research by Parrish *et al.* [10] demonstrates the power of the Variational Quantum Eigensolver (VQE) for designing novel carbon capture materials. VQE aims to find the ground state energy (the most stable configuration) of molecules, a key property for determining their ability to bind greenhouse gases. It works by iteratively preparing and measuring adjustable quantum states on a circuit. A classical optimizer then refines the circuit parameters based on the measurements, progressively lowering the calculated energy until it converges towards the true ground state of the molecule [9]. This approach offers the potential to computationally screen vast numbers of candidate materials, accelerating the discovery of those with optimal properties for atmospheric carbon removal.
2. Li Hao [11] proposes a novel angle-expressed quantum evolutionary algorithm (AQEA) for solving the Quadratic Knapsack Problem (QKP). Unlike traditional approaches, AQEA expresses qubits as angles and initializes them based on the items' value densities. The algorithm dynamically determines the rotation angle for each qubit by comparing the current solution against the best solution found so far. To prevent premature convergence, a small-angle rotation (Hε gate) is applied. In cases of infeasible solutions (exceeding the knapsack's capacity), a dynamic value density approach is used to select items for dropping from the solution, ensuring feasibility while aiming for optimal value. Simulations demonstrate that this AQEA achieves excellent optimization performance for QKP.
3. The paper by Nikita A Nemkov, Evgeniy O. Kiktenko and Aleksey K. Fedorov [12] focuses on the Fourier expansion of the loss function in variational quantum algorithms (VQA), providing a classical algorithm that computes coefficients of all trigonometric monomials up to a degree mm for an NN-qubit circuit and a single Pauli observable in time bounded by $O(N2^m)$. It reveals several novel aspects of Fourier expansions in Clifford + Pauli VQA.
4. This work by Giacomo de Palma *et al.* [13] presents tight limitation bounds for standard NISQ proposals, both in noisy and noiseless regimes, with or without error-mitigation tools. It introduces newly developed quantum entropic and concentration inequalities, providing a theoretical toolkit from the quantum theory of optimal mass transport.

5. Hari Krovi [14] presents generalized and improved quantum algorithms for linear and nonlinear ordinary differential equations (ODE), showing how the norm of the matrix exponential characterizes the run time of quantum algorithms for linear ODEs and extends the application to a wider class of ODEs.
6. This paper by N. N. Hegade *et al.* [15] investigates a discrete mean-variance portfolio optimization problem using digitized-counterdiabatic quantum computing, showing a drastic improvement in success probabilities of the digital quantum algorithm when approximate counterdiabatic techniques are introduced. The enhanced performance over variational quantum algorithms like QAOA and DC-QAOA is discussed, highlighting its potential for finance applications in the NISQ era.
7. This work by Xavier Bonet-Monroig [16] studies the performance of four commonly used gradient-free optimization methods (SLSQP, COBYLA, CMA-ES, and SPSA) on small chemistry and material science problems through variational quantum algorithms (VQAs). It tests a telescoping sampling scheme and hyperparameter tunes two of the optimizers, demonstrating that with appropriate tuning, CMA-ES can compete with or outperform SPSA. The study underscores the necessity of tailoring and tuning optimization techniques for inherently-noisy VQAs, providing guidance for future implementations.
8. While powerful, traditional quantum sensing suffers from limitations in accuracy and sensitivity. This work by Li-Zheng Liu *et al.* [17] proposes a novel approach using full-period quantum phase estimation and GHZ states to overcome these limitations. This approach theoretically achieves superior sensitivity, exceeding established methods. Experiments with eight photons confirm the technique's effectiveness in surpassing the shot-noise limit and achieving phase superresolution. This paves the way for advancements in quantum sensing and its broader applications.
9. Optimizing initial parameters remains a challenge for variational quantum algorithms employed on current noisy intermediate-scale quantum devices. This study by Pranav Chandarana *et al.* [18] addresses this issue by proposing a meta-learning technique utilizing recurrent neural networks. This technique is applied to the recently developed digitized-counterdiabatic quantum approximate optimization algorithm (DC-QAOA), demonstrating enhanced performance on benchmark problems like the MaxCut problem, while requiring fewer optimization iterations. By combining meta-learning and DC-QAOA, this work paves the way for efficient and powerful near-term quantum devices, notably through the design of short-depth circuits with optimal initial parameters. This approach integrates principles from shortcuts-to-adiabaticity with machine learning methods, potentially leading to significant advancements in near-term quantum computation.

The point of this research was not only to gather the newest and most prominent advancements in this field but also to try and summarize and sort them. While most of them were not created with the intention of solving the problems with global warming and pollutions, we tried to sort them as you can see in table II into different categories, in which we think they are most likely to help combating the world problems.

TABLE II AREA OF GLOBAL WARMING OR POLLUTION AND WHICH ALGORITHM COULD HELP

Area, which are most likely to support	Quantum algorithm
Material Design and Carbon Capture	1, 3, 7
Energy Optimization	2, 4
Environmental Monitoring	5, 8
Optimizing waste management	6, 7, 9
Developing sustainable food production systems	1, 5, 9

As a result of this research, we managed to differentiate and structure different quantum programming frameworks, libraries and development platforms.

A. Quantum Programming Frameworks

Qiskit is built upon the principles of quantum information science and uses a Python-based language for expressing quantum algorithms[19]. Its fundamental building blocks are quantum gates (operations on qubits) and quantum circuits (sequences of gates). Qiskit's modularity is evident in its Terra component (low-level circuit representation), Aqua (algorithms and applications), Ignis (noise and error characterization), and Aer (simulators). It works by translating higher-level algorithms into optimized quantum circuits executable on simulators or various hardware backends, including superconducting qubit processors.

Cirq is fundamentally a Python library for creating, modifying, and invoking NISQ circuits[20]. It emphasizes near-term quantum algorithms and is tailored for noisy hardware. Cirq employs data structures like Qubit, Moment (a collection of operations acting at the same time), and Circuit to construct quantum programs. It works with Google's quantum processors (e.g., Sycamore), and its key features include optimizers specifically focused on noise minimization for NISQ-era devices.

ProjectQ is a software framework centred on a compiler-based approach, enabling quantum code to be written independently of the target hardware. It utilizes a high-level internal representation (IR) for quantum circuits and features a compiler that transforms these circuits and optimizes them for specific hardware backends, such as trapped ion systems or superconducting circuits. This allows developers to focus on algorithm design rather than low-level hardware details[21].

Table III presents differences between the frameworks.

TABLE III QUANTUM COMPUTING FRAMEWORKS

Framework	Qiskit	Cirq	ProjectQ
Developer	IBM	Google	ETH Zurich
Focus	General Purpose	NISQ algorithms	Hardware-agnostic development
Language	Python	Python	Python
Features	Modular, flexible, access to hardware	Hardware-aware, noise optimization	Compiler-based, simulators

B. Quantum Programming Libraries

Strawberry Fields is a full-stack library for photonic quantum computing, where qubits are represented by modes of light (e.g., the squeezing or displacement of a light beam)[22]. It is based on the continuous-variable (CV) model of quantum computation, which handles infinite-dimensional quantum states as opposed to the discrete states in the more common gate-based model. Its core elements are quantum gates, states, and programs, defined using Python functions and specialized hardware instructions.

PennyLane is a cross-platform library centred on quantum machine learning (QML) and hybrid quantum-classical computations[23]. Its key feature is quantum differentiation, enabling users to compute gradients of quantum circuits, thereby treating them as nodes in classical machine learning models. PennyLane utilizes NumPy-like syntax for array manipulation, integrates seamlessly with libraries like PyTorch, and allows access to various quantum hardware platforms and simulators (including those specialized in photonic quantum computing).

TensorFlow Quantum (TFQ), an open-source Python library built on TensorFlow, simplifies development and deployment of hybrid quantum-classical machine learning (QML) models[24]. It offers functionalities like constructing quantum circuits using familiar TensorFlow syntax, optimizing classical control parameters within them, simulating and mitigating noise affecting quantum hardware, and seamlessly integrating with other TensorFlow tools. This empowers users to tackle various QML problems, including finding ground states (VQEs), approximate optimization solutions (QAOA), and generating data (GQMs).

C. Quantum Computing Platforms

IBM Quantum Experience provides access to IBM's suite of quantum processors, primarily superconducting qubit based. It features a drag-and-drop circuit composer for graphical design of quantum algorithms, in addition to its integration with Qiskit. Users can run their jobs on various simulators or opt to execute them on real quantum hardware. Additionally, this platform provides comprehensive educational resources and fosters a community around quantum programming[25].

Amazon Bracket is a fully managed AWS service connects users with various quantum technologies from providers like D-Wave (quantum annealing), IonQ (trapped ions), and Rigetti (superconducting qubits)[26]. Braket offers a familiar development environment with notebooks, task tracking, and integration with other AWS services. It accommodates hybrid quantum-classical workloads, facilitating the integration of quantum algorithms within broader application contexts.

Google Quantum Virtual Machine provides a simulated environment mirroring Google's quantum hardware. Users can design and run quantum circuits on the QVM, allowing them to test and optimize their code before deploying it on real quantum processors. The QVM incorporates noise models, mimicking the behavior of actual hardware and providing realistic insights into algorithm performance. Fig. 2 shows the quantum development stack – how each technology or area stacks on one another[27].

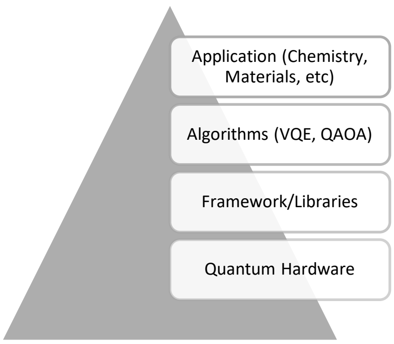

Fig. 2 Quantum Development Stack.

While the potential of quantum computing for addressing global warming and pollution is significant, the current state of the technology presents limitations. While research is actively exploring various avenues, many applications remain in the theoretical or early-stage development phase. Some promising areas include designing new carbon capture materials, optimizing energy usage, and enhancing environmental monitoring capabilities. However, directly translating these potential solutions into real-world applications requires further advancements in both hardware and software.

The future holds immense potential for quantum computing to contribute to the fight against global warming and pollution. As the technology matures, researchers envision breakthroughs in various areas like:

Materials science - Quantum computers could revolutionize the discovery and design of efficient and scalable carbon capture technologies, potentially accelerating the transition to a low-carbon economy.

Energy optimization - By optimizing energy distribution and management systems, quantum computing could contribute to significant reductions in energy waste and greenhouse gas emissions.

Environmental monitoring - Advancements in quantum sensing could lead to more precise and sensitive monitoring of environmental parameters like air and water quality, enabling earlier detection of pollution and facilitating more effective environmental management strategies.

Despite the promising potential of quantum computing for environmental solutions, several hurdles need to be overcome. Technical challenges remain, as the technology is still in its early stages and faces limitations in scalability, error correction, and overall performance. These limitations must be addressed before widespread adoption and practical implementation of quantum solutions can occur.

Furthermore, building and maintaining quantum computing infrastructure requires significant resources and expertise, potentially limiting accessibility and raising concerns about equitable access and potential economic barriers. Additionally, careful consideration needs to be given to the ethical implications surrounding the development and application of quantum computing. Ensuring responsible use of the technology and mitigating potential environmental impacts associated with its development and operation are crucial aspects to address in this journey.

IV. Conclusion

The intersection of quantum computing and the fight against global warming and pollution presents a captivating picture, filled with both promise and challenges. While the current state of the technology offers glimpses of impactful applications in areas like carbon capture, energy optimization, and environmental monitoring, significant work remains to translate theoretical potential into practical solutions.

Looking ahead, overcoming technical obstacles like scalability and error correction is crucial for unlocking the true potential of quantum computing in addressing environmental challenges. Moreover, ensuring responsible and equitable access to this technology, while mitigating potential ethical and environmental concerns associated with its development, is paramount. By addressing these challenges and harnessing the power of quantum computing, we can aspire towards a future where this innovative technology becomes a potent tool in tackling global warming and pollution, providing a way for a more sustainable world.

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Assessment of the sustainability of water and sanitation systems in rural villages through indicators. An experience of conceptual design and applied software in Peru

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Abstract. **The main objective of the present research was to apply the sustainability approach to the management of sanitation systems carried out by community-based organizations (JASS) in rural villages with the support of the district municipality. Given the limited capacity of rural district municipalities to supervise, monitor and provide technical assistance to these community organizations, a proposal for municipal technical assistance (MTA) was developed based on an index for the evaluation of the sustainability of rural sanitation systems (IESSSR). Such index allowed to evaluate not only the sustainability, but also to identify the deficient and unsustainable aspects of each system, which was crucial to develop improvement plans for each JASS.**

A first measurement of the sustainability of the two intervened systems was made – of the rural population centres of Palmira and Dos de Mayo, both located in the district of Leymebamba –, a general sustainability index (IGS) for JASS Palmira of 3.010 (Stable) and for Dos de Mayo of 2.997 (Unstable) were obtained. In the second measurement, using 5 dimensions, 18 factors, 48 variables and 66 indicators, the IGS of JASS Palmira was 3.179 (Stable) and that of Dos de Mayo was 3.233 (Stable). The reliability of the index was analysed using the test-retest method by comparing the May and December measurements of each JASS, obtaining a Pearson correlation index of 0.631 for Palmira and 0.602 for Dos de Mayo.

Finally, the index was developed into a software application to facilitate the storage, processing, monitoring, evaluation and presentation of the information, and is currently being tested in the municipality of Leymebamba.

***Keywords: assessment, rural, sanitation,* sustainability.**

I. INTRODUCTION

In rural areas, the sustainability of water and sanitation systems is not duly considered in the management carried out by community organizations known as the Sanitation Services Administration Board (JASS), nor in the technical assistance plans of district municipalities, due to the lack of technical capacities, human resources, management tools and training materials. Likewise, in rural areas there is a 24.7% gap in access to water, while the quality gap is 96.8%, and only 3.2% of the rural

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population consumes water with an adequate level of chlorine [1].

Thus, the drinking water offered by most community organizations is not healthy, safe, continuous, or of full social access; there is no adequate solid waste management, wastewater is not treated, and the natural sources that provide this resource are not protected, so the integral sustainability of these systems is not ensured According to current regulations, district municipalities are responsible for providing technical assistance, training, and supervision to the JASS in the management of water and sanitation services to the population in their jurisdiction. However, the fulfillment of these functions requires a comprehensive proposal that is currently lacking and, therefore, there is no comprehensive and sustainable management of rural sanitation systems [2].

Taking this context into account, this research proposed to develop a municipal technical assistance model. The rural sanitation systems selected for intervention were those of the towns of Palmira and Dos de Mayo, rural localities whose combined population is equivalent to 49% of the district's inhabitants and 76% of the rural inhabitants. The model consisted of an instrument to identify and evaluate the sustainability of the main factors, variables and indicators of the systems in their Social, Economic, Environmental, Environmental, Social, Economic and Environmental dimensions.

This model has been called the Index for the Evaluation of the Sustainability of Rural Sanitation Systems (IESSSR). Based on the results obtained, we expect to formulate improvement plans for each system. We applied the index in both systems in May and December 2022 and the results were compared. Finally, to operationalize the use of the index and carry out the technology transfer, the IESSSR was digitally developed in a software prototype that is installed in the municipality of Leymebamba [3].

The methodological contribution of this research consists in the conceptualization and operationalization of sustainability through the generation of a set of dimensions, factors, variables, indicators and rubrics that concretize these concepts of sustainability in observable and measurable aspects on which it can act with improvement plans, technical assistance and training. The IESSSR will help the municipality to periodically evaluate the JASSs in its area and, according to the results, identify, prioritize and organize technical assistance and training to design and implement improvement plans with all its JASSs. On the other hand, it will also serve the community organizations as a technical and comprehensive guide to the aspects to be considered in integrated and sustainable management.

II. MATERIALS AND METHODS

The research was carried out in the district of Leymebamba, province of Chachapoyas, department of Amazonas. Leymebamba has an estimated total population of 3,620 inhabitants, 36% of whom live in urban areas and 64% in rural areas, distributed among 57 villages. The Palmira JASS, which provides services to approximately 646 inhabitants, and the Dos de Mayo JASS, which serves a population of 1,132 inhabitants, were selected as the rural sample. Both populations serve 49% of the district's inhabitants and 76.7% of rural inhabitants [1].

The research was carried out using a quasi-experimental methodological design in which the IESSSR was applied twice in each of the sanitation systems intervened. The first version of the index was developed based on bibliographic research and the review of the monitoring and registration instruments of the governing bodies such as the Ministry of Housing, Construction and Sanitation (MVCS) and the National Superintendence of Sanitation Services (SUNASS). This first index, which considered 120 indicators, was validated by expert judgment and allowed the selection of the clearest, most coherent and relevant indicators according to the weighting given on a Likert scale from 0 to 3. As a result of this expert judgment, the content and construct validity of the instrument was confirmed, taking the average 2.4 as the minimum score to maintain an indicator, the number of dimensions remained at 5, but the number of factors was adjusted to 18, the number of variables decreased to 55 and the number of indicators dropped to 76. This first version was applied in May 2022 in both JASS [3].

The final version of the index was applied in December 2022, also in both systems, it considered 66 indicators, being constituted as follows:

- Social Dimension: 3 factors (Satisfaction of basic needs of the population, Perception of the population on the service and Health behaviors of families), 9 variables and 14 indicators.
- Economic Dimension: 3 factors (Economic profitability of the system, Economic situation of the users and Financing of the system), 6 variables and 6 indicators.
- Environmental Dimension: 3 factors (Natural availability of water resources, Natural quality of water resources and Threats and impacts to the system and biodiversity), 8 variables and 9 indicators.
- Technical Dimension: 6 factors (system productivity, water and sanitation system infrastructure, drainage and sewerage system infrastructure, supply system operation, drainage, sewerage and WWTP system operation, and system maintenance), 11 variables and 23 indicators.
- Institutional dimension: 3 factors (community participation in the management, Sanitation service provider and Governance and institutional articulation), 14 variables and 14 indicators.

To evaluate the sustainability of each of the indicators, a rubric was developed on an increasing scale from 1 to 5, where the lowest number -1- means less sustainability and the highest number -5- means more sustainability. The index allows the values obtained in each of the indicators to be averaged according to factor and dimension. The sustainability scale proposed by Sepúlveda (2008) was used to classify sustainability, so that, obtaining between 0-1 means a state of collapse; obtaining between 1.1 and 2 means a critical state; obtaining between 2.1 and 3 indicates a situation of instability; obtaining between 3.1 and 4 shows stability; finally, obtaining between 4.1 and 5 means an optimal state of sustainability, as shown in Table 1. [4]-[5].

TABLE 1. SUSTAINABILITY LEVELS

0.0 - 1	1.1 - 2	2.1 - 3	3.1 - 4	4.1 - 5
Collapse	**Critical**	**Unestable**	**Sstable**	**Optimal**

The reliability of the IESSSR was estimated using the test-retest method and Pearson's coefficient to compare whether the results are equivalent at the two points in time when the index was applied and its results can be considered reliable. In the case of JASS Palmira, the Pearson correlation index comparing the two moments in which it was applied (May 2022 and Dec 2022) and calculated with the EXCEL program was: Pearson 0.631. This value indicates an average positive reliability of the index applied in Palmira and a correlation of this type can be plotted. In the case of JASS Dos de Mayo, the Pearson correlation index calculated with the EXCEL program was: Pearson 0.602, which also indicates an average positive reliability of the index applied in Dos de Mayo.

In addition to the IESSSR, two instruments were developed to collect and process information from the JASSs involved: a survey of the population and a structured interview with the leaders of the Palmira and Dos de Mayo JASSs. In the case of the population survey instrument, validity was obtained from expert judgment, since the instrument consisted of a survey that - based on the indicators linked to the social dimension and institutionalism - turned them into a 19-question survey whose options were similar to the Likert scale used in the index, taking MODA as a representative trend. The reliability of this instrument was verified by comparing the application carried out in Palmira with that carried out in Dos de Mayo, which, being populations with very similar characteristics, yielded very similar results. The responses obtained were subjected to Pearson's correlation coefficient, obtaining a value of 0.952830642, very close to 1, which indicates a high correlation and therefore a high reliability in the results of its application.

In the case of the structured interview instrument for the JASS leadership, validity was also obtained from expert judgment, since the instrument consisted of a survey that - taking the indicators of the index - converted them into a structured interview of 47 questions, from whose answers the information for entering the IESSSR was obtained.

The reliability of this instrument was verified by comparing the application in Palmira with that carried out in the reliability of this instrument was verified by comparing the application carried out in Palmira with that carried out in Dos de Mayo, which, being populations with very similar characteristics, yielded very similar results. The responses obtained were subjected to Pearson's correlation coefficient, obtaining the following coefficient 0.86652830642, quite close to 1, which indicates a high correlation and therefore a good reliability in the results of its application.

III. RESULTS AND DISCUSSION

The evaluation of the two intervened systems, using the IESSSR in the Palmira and Dos de Mayo systems, is shown in Table 2 below.

In the case of the two-stage evaluation carried out in Palmira, in the first stage an IGS of 3.010 was achieved, reaching the STABLE level, but with several factors at the UNSTABLE level and even two of them at the CRITICAL level. The averages of values by factors allow us to elaborate the following radial graph, shown in Fig. 1.

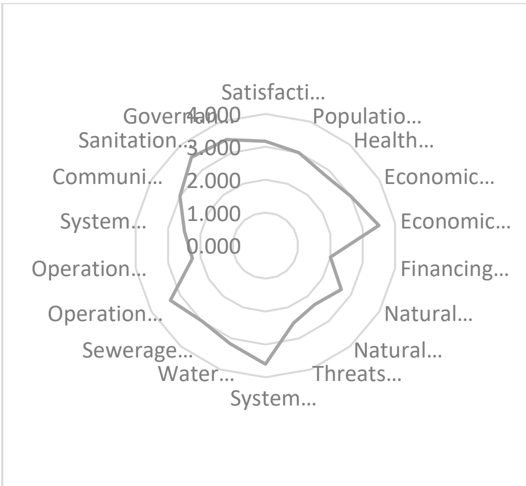

Fig 1. 1st IESSSR assessment in Palmira.

In a second evaluation, carried out 7 months later, the values obtained were quite similar, since an IGS of 3.179 was achieved, reaching the STABLE level, but with several factors in the UNSTABLE level and even one of them in the CRITICAL level. the STABLE level, but with several factors in the UNSTABLE level and even one of them in the CRITICAL level; and whose averages of values by factors allow to elaborate the following radial graph, shown in fig. 2.

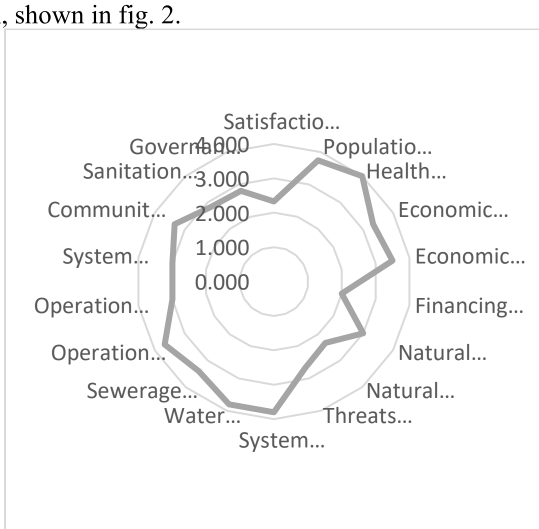

Fig 2. 2nd IESSSR evaluation in Palmira.

TABLE 2. RESULTS OF ASSESMENT SUSTAINABILITY WITH IESSSR

Factor	**Jass Palmira**			**Jass Dos de Mayo**		
	1ra Eval.	*2da Eval.*	*Level Sustainability*	*1ra Eval*	*2da Eval.*	*Level Sustainability*
Satisfaction of basic needs of the population	2.833	2.333	Unstable	2.833	2.833	Unstable
Population's perception of the service	2.75	3.75	Stable	2.75	3.75	Stable
Health behaviors of families	3.5	4	Stable	3.5	4	Stable
Economic profitability of the system	2.75	3.333	Stable	2.75	3	Stable
Economic situation of users	3	3.5	Stable	3	3.5	Stable
Financing of the system	2	2	Critical	2	2	Critical
Natural availability of water resources	3.333	3	Stable	3.333	3	Stable
Natural quality of water resources	2.333	2.333	Unstable	2.333	2	Critical
Threats and impacts to the system and biodiversity	2.333	2.667	Unstable	2.333	2.333	Unstable
System productivity	3.4	3.8	Stable	3.4	4	Stable
Water supply infrastructure	3.5	3.8	Stable	3.5	4	Stable
Sewerage and wastewater treatment infrastructure	3.167	3.4	Stable	3.167	3.4	Stable
Operation of the drinking water supply system	3.667	3.667	Stable	3.667	4	Stable
Operation of the drainage, sewerage, and WWTP systems	2.5	3	Stable	2.5	4	Stable
System maintenance	2	3	Unstable	2	3	Unstable
Community participation in management	3.333	3.333	Stable	3.333	3	Unstable
Sanitation service provider	3.167	2.833	Unstable	3.167	3.167	Stable
Governance and institutional articulation	3.571	2.806	Unstable	3.571	2.861	Unstable
General Sustainability Index (ISG)	3.01	3.179	Stable	2.997	3.233	Stable

There are variations in the values of some factors, but their ratings are not modified and are rather confirmed in the second measurement. This is also explained by the fact that in the second measurement the two instruments designed (population survey and structured interview with JASS) were used to better collect the information. It can be seen that steeper valleys indicate lower sustainability and higher peaks indicate higher sustainability.

In the case of Dos de Mayo, evaluations were also carried out at two points in time, in the first of which an IGS of 2.997 was achieved, falling very slightly in the UNSTABLE level, with several factors in the UNSTABLE level and even two of them in the CRITICAL level; and whose averages of values by factors allow the following radial graph to be drawn up, shown in fig. 3.

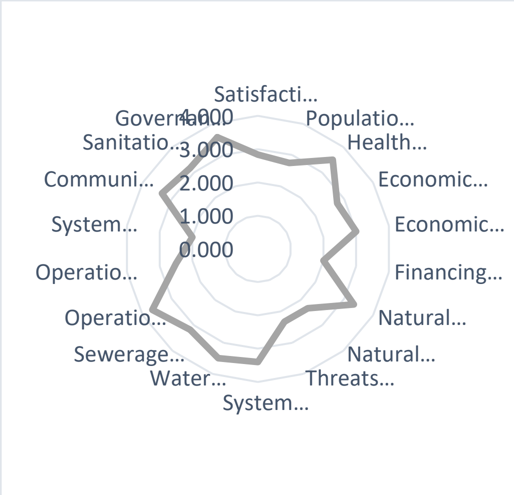

Fig 3. 1st IESSSR evaluation in Dos de Mayo.

In a second evaluation, carried out 7 months later, the values obtained were slightly higher, since an IGS of 3.233 was achieved, reaching the STABLE level, but with several factors in the UNSTABLE level, and even two of them in the CRITICAL level; and whose averages of values by factors allow to elaborate the following radial graph, shown in fig. 4.

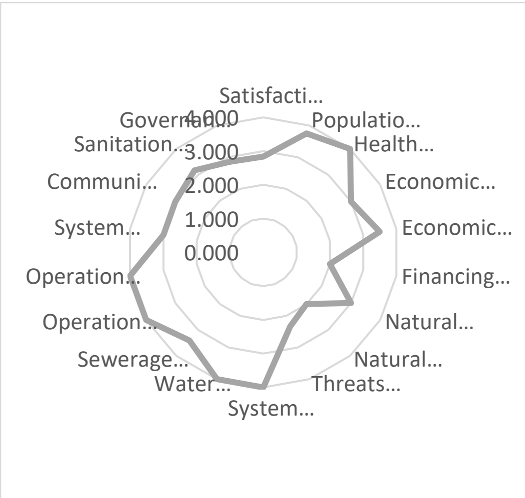

Fig. 4. 2nd evaluation of Dos de Mayo.

Variations are observed in the values of some factors, but in general their scores are not modified and are rather confirmed in the second measurement, confirming the reliability we obtained by applying Pearson.

The identification and measurement of these less sustainable factors makes it possible for the municipality to provide technical assistance on which factors and variables have been identified as the most at risk in terms of their sustainability and, consequently, to formulate improvement plans with the JASSs to remedy the deficiencies. From time to time, an overall measurement can be made and it can be observed whether the improvement plan has yielded results or not. In this way, the proposed technical assistance model contributes to the integrated and sustainable management of the rural sanitation systems under the responsibility of the JASSs.

It is important to highlight that the IESSSR designed makes it possible to introduce the sustainability approach in the supervision and technical assistance functions that the rural district municipality of Leymebamba should fulfill. This index proposes conceptual and methodological constructs and instruments that focus directly on the integrality and sustainability of rural systems. Thus, by using this index, the municipality will fulfill its function and contribute to implement the sustainability approach at the local level. Likewise, the JASS can learn to use it and it can serve as a training tool in the integrated and sustainable management of sanitation systems [6]-[7].

Likewise, with the IESSSR it was possible to diagnose the situation of the systems and their management in their social, economic, environmental, technical and institutional dimensions, thus responding to the characteristics of integrality that characterize the sustainability approach. However, we found some differences with respect to our precedents, such is the case of Burkina Faso and Niger [8], which in their analysis of 71 urban and rural systems, do not explicitly include the social dimension. On the other hand, Tonilli [9], proposes a multidimensional and systemic methodology emphasizing the need to achieve a measurement that contributes to make the concept more tangible based on valid and solid indicators that have heuristic value on the results; however, it is also noted that there are no universally used indicators nor a unique way to obtain them [7]-[9].

The Pan-American Center for Sanitary Engineering and Environmental Sciences- CEPIS proposes an index with 3 factors: System Status, Management and Operation and Maintenance, and about 20 indicators distributed among them. This research took the category "factor" and integrated it into the hierarchical scheme of the index created, but expanded the proposal by incorporating a hierarchical scheme consisting of dimension, factor, variable, indicator, rubric [10].

At the national level, there is an applied software that the Ministry of Housing, Construction and Sanitation- MVCS has called Diagnosis of Rural Water Supply and Sanitation - DATASS. This software collects information on access to sanitation services, sanitation infrastructure, quality of service, organizational management, cleaning, operation, maintenance and chlorination of the drinking water system, economic and financial management, and technical assistance and training to provide general reports on coverage and access to service [11].

In addition, the research proposed to complement this technological aspect of monitoring by developing the IESSSR in a prototype of computer software with which to operationalize and generalize the recording, analysis and evaluation of information evaluation indicators and the use of this information in the development and implementation of improvement plans. A search of the Peruvian patent database found no record of any index, software or method for evaluating the sustainability of sanitation services [12]. The same occurred when reviewing the PATENTSCOPE databases of the World Intellectual Property Organization (WIPO) and the ESPACENET database of the European Union, where indexes or evaluation methods were found for various activities but not for sanitation services [13]-[14].

Then, progress was made towards technology transfer through the development of a software prototype that can be installed in any municipality for permanent monitoring and periodic evaluations of the JASS and the systems under its responsibility. Thus, the Sustainability Approach is embodied in a technological instrument that operationalizes and integrates this paradigm in the management of the operators and supervisors of the sanitation systems.

IV. CONCLUSIONS

A conceptual instrument was constructed to measure and evaluate the sustainability of rural sanitation systems called the Index for the Evaluation of the Sustainability of Rural Sanitation Systems (IESSSR), which makes it possible to evaluate in the Social, Economic, Environmental, Technical and Institutional dimensions whether the sustainability of a system is in a situation of COLLAPSE, CRITICAL, UNSTABLE, STABILITY and OPTIMAL.

The sustainability of the sanitation systems involved was evaluated not only at a general level but also by factors and dimensions, which made it possible to identify the critical and unstable points of both systems and to plan measures to improve the situation.

Progress was made in the technological transfer of the IESSSR's conceptual proposal by developing this index in a computer program that enables the timely, efficient and systematic management of the large amount of information required to monitor the operation and sustainability of rural sanitation systems.

Finally, the implementation of interventions on the technical platform that supports the management of rural sanitation systems, such as the one carried out by this research, is a way of making the sustainability approach more tangible and operationalizing it for the population, civil society and the public entities responsible for guaranteeing timely and quality water and sanitation services.

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Critical review of Bulgarian legislation related to circular economy

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***Abstract.* This article presents the results of a critical review of Bulgarian legislation in the field of circular economy. It also defines recommendations and guidelines on creating favourable conditions for transition from linear to circular models based on all life cycle stages of processes, products and services.**

The main analysed policy document, directly addressing circular economy, is the Strategy and Action Plan for the transition to a circular economy of the Republic of Bulgaria for the period 2022-2027. It lays down the strategic framework towards achieving resource efficiency by applying waste management hierarchy, i.e. waste prevention, reuse and recovery through recycling, reducing landfilling and limiting harmful impact on the environment and human health.

The main pieces of legislation relevant to circular economy are the Waste Management Act and by-laws implementing Directive 2008/98/EC on waste (Waste Framework Directive), Directive 94/62/EC on packaging and packaging waste (Packaging Waste Directive), Directive 1999/31/EC on the landfill of waste (Landfill Directive), Directives 2000/53/EC on end-of-life vehicles, 2006/66/EC on batteries and accumulators and waste batteries and accumulators, and 2012/19/EC on waste electrical and electronic equipment, etc.

The review of provisions in the Waste Management Act and Local Taxes and Fees Act on implementing the 'Waste Management Hierarchy' and 'Polluter Pays' principles shows the need to promote economic incentives. Bulgarian municipalities should revise their ordinances and calculate local waste fees based on the quantity of waste generated (also requested by the current EC infringement procedure for failure to implement the 'Polluter Pays' principle at municipal level).

'Eco design' provisions are in place, and provisions protecting customers' right to repair are expected. In addition to implementing EU acquis, it is possible to promote further measures to reduce environmental impact of products throughout their entire life cycle.

The critical review also overs the main documents tackling climate challenges, i.e., the Climate Change Mitigation Act and by-laws, and the National Strategy and Action Plan by 2030 for adaptation to climate change of the Republic of Bulgaria, defining the framework for actions for adaptation to climate change and priority directions.

The review of 'horizontal' environmental legislation of the Republic of Bulgaria, i.e., provisions of the Environmental Protection Act and by-laws on strategic environmental assessment (SEA), environmental impact assessment (EIA) and integrated pollution prevention and control (IPPC), reveals the potential to address circular economy aspects in the recommendations issued as part of the relevant competent authorities' permits.

Other potential areas are the environmental protection standards and ESG (Environmental, Social, and Governance) as a framework for environmental and social impact.

Last but not least, the review considers circular economy financing opportunities.

Keywords: circular economy, environment, legislation, review

I. INTRODUCTION

During recent years, the cross-cutting concept of 'circular economy', which brings together environmental, technological and economic issues, is gaining more attention globally. Still, it remains largely unexploited in both literature and practice, mainly because of its complexity. The applicable policy and legislative framework are still incomplete and not operational. Market and economic aspects, as well as energy and climate implications, require deeper analysis. Sectors with high environmental impact and potential for circularity are not yet addressed [1].

In Bulgaria, policy documents and legislation on circular economy do not go beyond EU policy requirements and recommendations. Public responsibility and competence remain limited. The concept is not systematically covered by academic disciplines taught at Bulgarian universities. Research and business initiatives are still low and sporadic (with more than 50% of businesses being sceptical about the benefits of sustainable actions) [2].

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Addressing the described deficits, we undertook this critical review of applicable policy and legislative documents, as a significant factor enabling further development and practical implementation of the concept.

II. Materials and Methods

In the first place, our team selected the set of policy and legislative documents that will be subject to the critical review, considering their relevance to the topic (policy analysis).

Next, we reviewed the shortlisted documents by applying the method of content analysis, LogFrame matrix and mapped the results, whereby each of the reviewed group of strategic/ legislative documents was linked to circularity aspects such as circular extraction, processing, product design, technological process, consumption and disposal [3]. By applying the method of gap/ needs analysis, we identified the potential to integrate the concept.

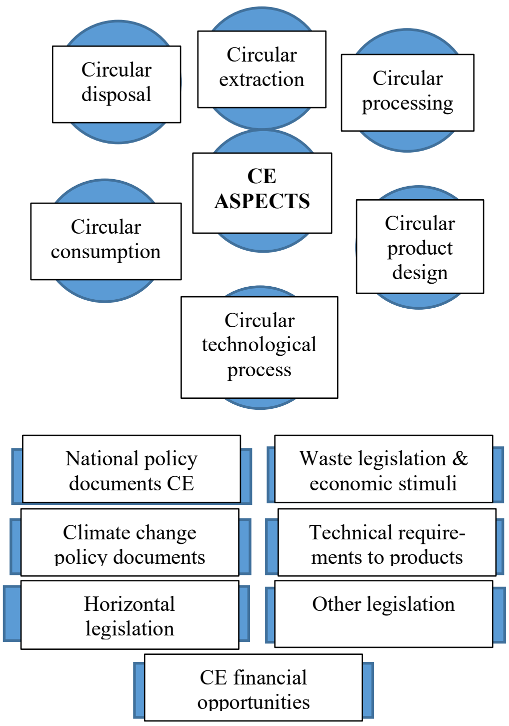

Figure 1: Main Circular economy aspects and groups of documents reviewed

III. Results and Discussion

Herein we outline and justify the main results of the performed critical review of Bulgarian policy and legislative documents with relevance to circular economy.

A. National policy documents on circular economy

The main analysed national policy document, directly addressing circular economy, is the Strategy and Action Plan for the transition to circular economy of the Republic of Bulgaria for the period 2022-2027 (adopted by Council of Ministers Decree 832 of 26 Oct 2022). It lays down the strategic framework towards achieving resource efficiency by applying waste management hierarchy, i.e. waste prevention, reuse and recovery through recycling, reducing landfilling and limiting harmful impact on the environment and human health.

The strategy provides an overall framework for further development in the field. Based on the EU Circular Economy package [4], it defines three strategic objectives (green competitive economy, less waste and more resources, and economy to the benefit of consumers), each of them implemented through specific objectives and measures, covering major circularity aspects:

– priority areas such as plastics, construction and demolition waste, food waste, biomass and bio-based products, raw materials;

– business models that cover design, optimal use, circular support, retaining value;

– main stakeholders, including society, business, government, local authorities;

– relevance to other strategic documents for the reference period 2021-2027 such as the National Strategy for small and medium enterprises and the National Waste Management Plan).

The Action Plan implements several key approaches, i.e., incentives to overcome barriers, educating and connecting market participants and proposing legislative changes. It defines specific short-term, medium-term and ongoing measures with attributed actions, budgets, financing sources, deadlines, expected results, output/ result indicators and responsible partners.

The main shortcoming is the lack of impact indicators. These should include both environmental and economic impacts such as prevented and recycled waste, growth of circular economy jobs, share of circular activities in all economic activities, added value generated by repair, reuse and recycling, as well as other indicators used to report at EU level [1]. Considering the motivating effect of such figures, it is important to include appropriate indicators within the foreseen strategy update.

Another typical risk for such documents is the insufficient effort of responsible institutions to uptake foreseen measures and reluctance to implement monitoring and reporting setup. We should note that since the adoption of the major documents in 2022, there has not been any centralised reporting on its implementation, at least publically available.

B. Waste management legislation, including economic stimuli to attain waste targets

The main pieces of legislation relevant to circular economy remain the Bulgarian Waste Management Act (Prom. SG N 53 of 13/07/2012, last supplemented SG N108 of 30/12/2023 [5]) and its by-laws implementing the provisions of Directive 2008/98/EC on waste (Waste Framework Directive), Directive 94/62/EC on packaging and packaging waste (Packaging Waste Directive), Directive 1999/31/EC on the landfill of Waste (Landfill Directive), Directives 2000/53/EC on end-of-life vehicles, 2006/66/EC on batteries and accumulators and waste batteries and accumulators, and 2012/19/EC on waste electrical and electronic equipment, etc. [6].

The very first article of the Waste Management Act refers to reducing the overall impact of the use of resources expected to contribute to the transition to a circular economy and ensuring long-term competitiveness. Still, this single reference to the term remains mostly principle, as the reviewed group of acts regulate the measures and control for the protection of the environment and human health by preventing or reducing waste generation, as well as the harmful impact of waste generation and management. They launch core waste management concepts and principles (e.g., the waste hierarchy and polluter pays principle), introduce specific requirements, restrictions and targets (e.g., the waste recycling and landfilling targets etc.), and define the main instruments to attain these targets (such as economic stimuli).

'Circular economy' (pretty much like 'sustainable development') is an interdisciplinary concept and as such, it cannot be regulated in one sector, neither managed by one competent institution. Implementation of such cross-cutting policies is a major challenge, as it is difficult to achieve the required sense of ownership of each player and spirit of partnership among them.

The review of provisions in the Waste Management Act and Local Taxes and Fees Act (Prom. SG N 117 of 10/12/1997, last amended and supplemented SG N 106 of 22/12/2023 [7]) on implementing the 'Waste Management Hierarchy' and 'Polluter Pays' principles shows the need to make use of the so called 'economic stimuli'. The first and most viable circular economy model is the 'circular household'. Bulgarian municipalities are called to introduce a fair method to calculate local waste fees, based largely on the quantity of waste generated by households, and thus educate citizens and encourage the long expected behavioural change.

The reluctance on the side of local authorities to start the expected change was overcome by a number of pioneering municipalities, implementing demonstration projects with promising results. The main challenge remains that most revenues from waste fees comes from economic entities. It is time to put an end to this cross-subsidy practice and finally start to apply economic instruments to meet the waste targets. This requires difficult and unpopular decisions at municipal level [8].

C. Climate change policy and legislation

The critical review also covered the main documents tackling climate challenges, i.e., the Climate Change Mitigation Act (Prom. SG N 22 of 11/03/2014, last amended SG N 16 of 23/02/2024 [9]) and the National Strategy and Action Plan by 2030 for adaptation to climate change of the Republic of Bulgaria, defining the framework for actions for adaptation to climate change and priority directions (adopted by Council of Ministers Decree N 621 of 25/10/2019 [10]). Same as with other reviewed groups of acts, the main Bulgarian climate change documents do not refer explicitly to circularity. However, the contribution of circular economy to climate challenges is acknowledged by outstanding organisations such as the well-known Ellen MacArthur Foundation aimed at accelerating the transition to a circular economy [11].

D. Technical requirements to products

Another group of relevant acts is the Act on Technical Requirements to Products (Prom. SG N 86 of 01/10/1999, last supplemented SG N 105 of 11/12/ 2020 [12]) and its by-laws, implementing the so-called Eco Design Directive 2009/125/EC reducing the products' environmental impact [13].

EU is preparing a new Regulation establishing a framework for setting eco-design requirements for sustainable products and repealing Directive 2009/125/EC. It is expected to expand eco-desing requirements to more products (steel, textiles, furniture, tyres, and chemicals) and protect EU customers' right to repair (by ensuring that products last longer and are easier to repair, upgrade, recycle [14]).

In addition to implementing the relevant EU acquis, Bulgaria may consider other means to regulate and encourage reducing environmental impact of products throughout their entire life cycle. These may be national and local provisions for establishing repair centres and promoting them among citizens etc.

E. Horizontal environmental legislation

The review of 'horizontal' environmental legislation of the Republic of Bulgaria, namely the Environmental Protection Act (Prom. SG N 91 of 25/09/2002, last amended SG N 102 of 08/12/2023 [15]) and by-laws implementing the provisions of Directive 2001/42/EC on strategic environmental assessment (SEA Directive), Directive (2011/92/EU as amended by 2014/52/EU on environmental impact assessment (EIA Directive) and Directive 96/61/EC on integrated pollution prevention and control (IPPC Directive) [16], reveals the potential to integrate all circular economy aspects across all stages of all procedures. However, currently circular economy aspects are not legally binding. Therefore, it is most appropriate to encourage their integration within the recommendations issued as part of the relevant competent authorities' permits. The capacity of the above procedures to integrate various cross-cutting aspects is excellent.

Other potential areas that may apply circularity targets are environmental protection standards and ESG (Environmental, Social, and Governance) as a framework for environmental and social impact.

F. Other relevant legislation

Other relevant legislation includes the Ordinance on criteria for sustainability of biofuels and liquid fuels obtained from biomass (Prom. SG N95 of 4 Dec 2012, amended and suppl. SG N10 of 1 Feb 2019) implementing the provisions of Directive 2009/28/EC on the promotion of the use of energy from renewable sources RES Directive); Ordinance on the use of sludge from wastewater treatment through in agriculture (Prom. SG N63 of 12 Aug 2016), implementing Directive 86/278/EEC on the use of sewage sludge in agriculture (Sewage Sludge Directive), etc. However, implementation of such acts is still lagging behind.

G. Circular economy financing opportunities

A major source of financing for circular economy projects are the grant award procedures under the Programme 'Competitiveness and Innovation in Enterprises' 2021-2027 to the European Shared Management Funds 2021-2027. Another important source is the National Recovery and Resilience Plan.

The institutions responsible for management of such financing instruments should ensure that their internal monitoring and external evaluation reports address both the environmental impact and economic efficiency of implemented circularity projects.

An excellent example is the special report of the European Court of Auditors, assessing efficiency and influence of EC action on member states' circular-economy activities. The messages of the report entitled 'Slow transition by member states despite EU action' are a good example of constructive criticism. The report concludes that there is limited evidence that EC Circular Economy Action Plans and in particular the actions regarding the circular design of products and of production processes, had been effective in influencing circular-economy activities in the member states [17].

TABLE 1 NUMBER OF ACTS REVIEWED

GROUPS OF DOCUMENTS	National policy docs CE	Waste legisl &econ. stimuli	Climate change policy	Techn. Require-ments products	Horizontal legislation	Other relevant legislation	CE financing opportunities
NUMBER OF ACTS REVIEWED	2	7+	3	3	4	2	2

IV. Conclusions

The results of the critical review are presented in table 2 below.

The only document explicitly addressing all circular economy aspects (extraction, processing, product design, technological process, consumption, and disposal) is the Strategy and Action Plan for the transition to circular economy of the Republic of Bulgaria for the period 2022-2027. <u>The main recommendations to these documents are to define environmental and economic impact indicators and implement the foreseen monitoring scheme.</u>

The Waste Management Act is the only other document explicitly referring to 'circular economy', albeit declaratively. <u>Actually, circular economy is expected to offer economic stimuli and contribute to implementation of waste targets, so CE regulation in waste legislation does not seem necessary/ appropriate.</u>

All other documents reviewed do not contain explicit reference to 'circular economy' but there is implicit existing or potential relevance.

<u>The situation with Climate change policy is similar to waste management legislation (CE is expected to contribute).</u>

<u>Horisontal legislation offers the greatest potential to integrate all CE aspects, especially within the recommendations issued as part of the relevant competent authorities' permits.</u>

<u>The main recommendation to financing instruments is to assess the environmental impact and economic efficiency of implemented circularity projects.</u>

We also acknowledge the analysis and legislative changes proposed in the Circular Economy Strategy and Action Plan.

As described in [18], the general weakness of national strategic planning documents and legislation is the absence of systematic basis for their elaboration. The methodology for strategic energy planning [19] is a good example to be considered. To this end, plenty of preliminary studies may be performed, e.g. on appropriate research avenues [20], possible optimisation criteria [21], significance and influence of public opinion [22], etc.

TABLE 2: MAP OF RESULTS FROM THE LEGISLATIVE REVIEW

DOCUMENT / CE ASPECT	National policy docs CE	Waste legisl &econ. stimuli	Climate change policy	Techn. Require-ments products	Horizontal legislation	Other relevant legislation	CE financing opportunities
Circular extraction	⇄	⇄	→	←	←	←	←
Circular processing	⇄	⇄	→	←	←	←	←
Circular product design	⇄	⇄	→	←	←	←	←
Circular technological process	⇄	⇄	→	←	←	←	←
Circular consumption	⇄	⇄	→	←	←	←	←
Circular disposal	⇄	⇄	→	←	←	←	←

← *CE aspect supported by document (passive)*
→ *CE aspect supporting document (active)*
← *Declarative relevance*
← *Potential relevance*
← *Strong (explicit) relevance*

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Fruit Shrubs' Twigs as a Source of Valuable Oligomeric Polyphenolic Compounds with Antibacterial and Antifungal Potential

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Abstract. **To obtain a good harvest, regular pruning of fruit trees and bushes is necessary, which results in the accumulation of piles of cut twigs. These twigs are underutilized and form a large number of agricultural waste. Finding a use for this lignocellulosic biomass is necessary for the sustainable use of resources, as well as for creating additional income for berry growers and rural workers.**

The purpose of the research was to evaluate the potential of branches of various fruit trees and shrubs as a source of valuable oligomeric polyphenolic compounds – proanthocyanidins, which have a wide range of biologically active properties, including antioxidant, antibacterial, anti-inflammatory, anticancer, etc. Hydrophilic extracts of twigs of sea buckthorn (*Hippopae rhamnoides* L.), black chokeberry (*Aronia melanocarpa*), black currant (*Ribes nigrum* L.), red currant (*Ribes rubrum*), gooseberry (*Grossulariaceae*), quince (*Cydonia oblonga*), raspberry (*Rubus* L.), and grape (*Vitis vinifera*) were studied for the first time. The main process for isolating proanthocyanidins from the twigs is the extraction by ethanol-water solutions. The amount of extractive substances in the branches containing proanthocyanidins varied from 6 to 28% per DM. The highest content of proanthocyanidins was found in black chokeberry, quince, and sea buckthorn.

The proanthocyanidins isolation from hydrophilic extracts was carried out by Sephadex LH-20. The antimicrobial activity of dominant hydrophilic extracts and purified oligomeric proanthocyanidins was studied against eleven pathogenic bacteria and fungus: *Pseudomonas syringae* pv. *syringae*, *Erwinia rhapontici*, *Fusarium culmorum*, *Verticillium dahlia*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Escherichia coli*, *Bacillus cereus*, *Candida albicans* and *Cutibacterium acnes*.

The MIC and MBC/MFC of extracts ranged from 2 to 6 mg/mL. The antimicrobial activity of purified proanthocyanidins was 10 times higher than that of the extracts.

Keywords: sea buckthorn, aronia, black currant, red currant, gooseberry, quince, raspberry, grape, antimicrobial activity

INTRODUCTION

The effective use of local renewable resources by industry is one of the important factors for the growth of the national economy, underlined in the Latvian Bioeconomy Strategy 2030 [1]. The total estimated orchard area in the European Union is around 11 mln hectares [2]. In Latvia, the cultivation of fruit trees is traditionally an important part of the rural economy, with a total orchard area of 10.4 thousand ha in 2022 [3]. Red currant, blackcurrant, sea buckthorn, quince, black chokeberry, raspberry, and gooseberry are traditionally popular species for growing in Latvia, and altogether they form 48% of the total orchard area in Latvia. All these species demand several types of pruning annually or even twice per year, and pruning and harvesting measures lignocellulosic waste forms approximately 15-20% of the total fruits. This plant material started to attract attention of the scientists in the last years, but it is very poorly studied so far. Our latest studies confirmed the potential of

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the sea buckthorn lignocellulosic biomass as an anti-microbial and anti-inflammation agent [4]. The studies for the sea buckthorn berries showed that they contain almost 200 biologically active substances, including vitamins, essential amino acids, low molecular and high molecular polyphenols (proanthocyanidins), trace elements, etc. [5], [6]. Several studies showed the multiple bioactivities, including antimicrobial, antiviral, and even anti-cancer activity of the sea buckthorn and aronia fruits [6], [7], and leaves [8], [9] [10]. Grape fruits are considered a major source of polyphenolic compounds; fruits, juice and by-products of grape processing, such as pomace and grape seeds, have proven anti-oxidant properties [11], [12], anti-microbial effect [13], polyphenols from grapes reduce the incidence of cardiovascular diseases, improve neuronal function, and have antimicrobial properties with no toxicity effect [14].

There is much less information available for the other fruit shrubs berries. It was shown that polyphenols-rich blackcurrant extract had beneficial effects on preventing atherosclerosis of diabetic patients [15], anti-inflammatory, antioxidant and antimicrobial effects [16]. Polyphenols-containing extracts from black currant, red currant and gooseberry fruits and extracts from black currant processing residues showed high antioxidant activity [17], [18], [19]. Quince fruit extract showed anti-obesity effect [20]; research showed that the concentration of procyanidins/flavan-3-ols has the biggest contribution to the quince fruits antioxidant activity [21]. Red raspberry fruit extracts and polyphenols could reverse the metabolically associated pathophysiologies [22].

Many described bioactivities are associated with the presence of polyphenolic compounds in berries [23].

Considering the high biological activity of the berries and leaves, as well as anti-microbial and anti-inflammatory activity confirmed in our previous research for sea buckthorn twigs, this research aimed to evaluate the potential of a range of the fruit trees/shrubs twigs formed as waste in a result of fruit-shrubs pruning as a source of valuable oligomeric polyphenolic compounds – proanthocyanidins and to evaluate and compare their antibacterial and antifungal potential.

Materials and methods

Plant Material

Fruit trees' twigs were collected in autumn of 2023 from Baldone parish, Kekava county of Latvia (DD: 56.77306/24.30162). The twigs were dried at room temperature and ground in a mill (Cutting Mill SM100, Retsch, Haan, Germany) until the particle size of 1–4 mm. The samples were stored at −8 °C.

Twigs Extraction

Twigs extraction was performed sequentially by hexane and maceration with ethanol (EtOH)-distilled water solutions (96% EtOH, 50% EtOH) and by distilled water, at 60 °C for 60 min. The extracts were freeze-dried using lyophilization equipment Heto Power Dry HS3000 (Thermo Fisher Scientific, Waltham, MA, USA) to yield a dry weight (DW) extract. The yield of the extracts is given as a percentage based on DW. The extracts were stored at −8 °C.

Proanthocyanidins Separation

The purification of proanthocyanidins from the extracts was done as described by Andersone et al. [4], using a cross-linked dextran-based resin Sephadex LH-20 packed in solvent-resistant column. 96% EtOH (v/v) was used for elution of low-molecular-weight phenolics, and 70% (v/v) acetone/water solutions were used as elution solvent for proanthocyanidins. Solvents remainders were evaporated using a rotary evaporator (Heidolph Instruments, Schwabach, Germany), and purified proanthocyanidins were freeze-dried using lyophilization equipment Heto Power Dry HS3000 (Thermo Fisher Scientific, USA) and stored at 4 ºC.

Determination of Proanthocyanidins Content

Determination of the content of proanthocyanidins was performed by oxidative depolymerization to anthocyanidins in acid butanol (butanol–HCl method) as described in Andersone et al. [24].

Determination of the Antimicrobial Activity

Antimicrobial activity was performed for autumn and spring biomass, 50% and 96% extracts and purified poanthocyanidins, against bacteria strains *Pseudomonas syringae* pv. Syringae MSCL 894, *Erwinia rhapontici* MSCL 651, *Fusarium culmorum* MSCL 1628, *Verticillium dahliae* MSCL 863, *Streptococcus pyogenes*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Escherichia coli*, *Bacillus cereus*, and *Candida albicans* as described in [25].

Results and Discussion

The Yield of Lipophilic Extracts

The yield of lipophilic extracts obtained by hexane from all fruit shrubs' twigs biomass was quite close and varied from 0.7 to 1.5% per DM. The yield of hydrophilic extracts from the same biomasses obtained using ethanol-water solution and distilled water differed statistically significantly and ranged from 9.3 to 18.2% per DM. With 50% EtOH, all extracts yield increased significantly, suggesting that the extractives are more soluble in the ethanol-water solution. The yield of hydrophilic extracts on dry matter (DM) obtained with 50% EtOH from the entire biomass under study were: *Cydonia oblonga* 18.22% > *Aronia melanocarpa* 17.76% > *Ribes rubrum* 16.03% and *Hippopae rhamnoides* L. 15.54% > *Rubus* L. 14.13% > *Vitis vinifera* 12.98% > *Grossulariaceae* 10.69% (Table 1).

The twigs biomass of *Cydonia oblonga* and *Aronia melanocarpa* differs among the studied fruit shrub species not only by the highest total yield of hydrophilic extracts (18.22% and 17.76% per DM) but also by the high content of oligomeric proanthocyanidins (62.7% and 74.01% per DM). The PACs content in *Hippopae rhamnoides* L. and *Ribes nigrum* L. extracts isolated by 50% EtOH was 36.2 and 33.9% per DM. *Grossulariaceae, Vitis vinifera*, and *Rubus* L. had the lowest content of proanthocyanidins in hydrophilic extract composition (Table 2).

TABLE 1 THE YIELD OF LIPOPHILIC AND HYDROPHILIC EXTRACTS FROM FRUIT TREES BIOMASS, %/DM

Biomass	**Yield of lipophilic extract from biomass, % per DM (solvent-hexane)**	**Yield of hydrophilic extract from biomass, % per DM (solvent-50% EtOH)**	**Yield of hydrophilic extract from biomass, % per DM (solvent-water)**
Hippophae rhamnoides L.	1.46±0.04	15.54 ±0.05	14.42±0.02
Aronia melanocarpa	0.97±0.01	17.76±0.02	13.99±0.04
Ribes nigrum L.	1.12±0.02	15.08±0.03	15.03±0.04
Ribes rubrum	0.88±0.05	16.03±0.03	15.41±0.03
Grossulariaceae	1.16±0.03	10.69±0.03	6.27±0.04
Cydonia oblonga	1.02±0.03	18.22±0.03	14.96±0.05
Rubus L.	0.66±0.04	14.13±0.03	14.76±0.05
Vitis vinifera	1.12±0.04	12.98±0.03	10.11±0.04

TABLE 2 PACS CONTENT IN EXTRACTS OF FRUIT SHRUBS TWIGS THE MINIMUM INHIBITORY (MIC) AND BACTERICIDAL CONCENTRATIONS (MBC) OF EXTRACTS

Biomass	**PACs content in water extract, % per DM**	**PACs content in 50% EtOH extract, % per DM**
Hippopae rhamnoides L.	12.1±0.1	36.2±0.2
Aronia melanocarpa	33.4±0.2	74.01±0.3
Ribes nigrum L.	12.9±0.1	33.9±0.2
Ribes rubrum	5.3±0.2	14.8±0.2
Grossulariaceae	2.1±0.1	4.6±0.2
Cydonia oblonga	35.7±0.1	62.7±0.2
Rubus L.	1.9±0.1	2.2 ±0.1
Vitis vinifera	8.2±0.1	11.0±0.1

The antimicrobial activity of hydrophilic extracts of *Aronia melanocarpa*, *Cydonia oblonga*, and purified PACs from A*ronia melanocarpa* extract was studied against 11 pathogenic bacteria and fungus: *P. syringae, E. rhapontici, F. culmorum, V. dahlia, P. aeruginosa, S. aureus, E. coli, B. cereus, and C. albicans. S. pyogenes, C. acnes*. The MIC and MBC/MF of extracts ranged from 0.8 to 6.2 mg mL^{-1}. The antimicrobial activity of purified proanthocyanidins was to 10 times higher than of the extracts (Table 3).

TABLE 3 THE MINIMUM INHIBITORY (MIC) AND BACTERICIDAL/FUNGUS CONCENTRATIONS (MBC/MFC) OF EXTRACTS AND PACS, MG ML^{-1}

Samples	***E. coli***		***P. aeruginosa***		***S. aureus***		***B. cereus***	
	MIC	**MBC**	**MIC**	**MBC**	**MIC**	**MBC**	**MIC**	**MBC**
PACs	0.78	0.78	0.20	0.20	0.10	0.39	0.10	0.10
Aronia melanocarpa extract isolated by 50% EtOH	0.78	0.78	0.78	0.78	0.39	0.78	0.78	>6.25
Cydonia oblonga extract isolated by 50% EtOH	0.78	0.78	0.78	0.78	0.39	0.78	0.78	6.25
	P. syringae		***E. rhapontici***		***F. culmorum***		***V. dahliae***	
PACs	0.39	0.78	1.56	1.56	3.13	12.5	3.13	6.25
Aronia melanocarpa extract isolated by 50% EtOH	1.56	3.13	1.56	1.56	6.25	12.5	3.13	6.25
Cydonia oblonga extract isolated by 50% EtOH	1.56	1.56	1.56	1.56	6.25	12.5	3.13	6.25
	C. albicans		***S. pyogenes***		***C. acnes***			
PACs	0.31	>1.25	0.04	0.04	2.50	2.50		
Aronia melanocarpa extract isolated by 50% EtOH	6.25	>12.5	0.39	0.39	1.56	1.56		
Cydonia oblonga extract isolated by 50% EtOH	3.13	>6.25	0.05	0.05	1.56	1.56		

CONCLUSIONS

The results showed that the most suitable solvent for obtaining proanthocyanidins-rich hydrophilic extracts was ethanol-water solution. The biggest yield of hydrophilic extracts obtained with 50% EtOH was for *Cydonia oblonga* (18.22%/DM) and *Aronia melanocarpa* (17.76% per DM), and they also had the highest content of oligomeric proanthocyanidins (62.7% and 74.01% per DM).

The antimicrobial activity of purified proanthocyanidins was up to 10 times higher than that of the extracts. The bactericidal and fungicidal properties of the fruit trees' lignocellulosic biomass proanthocyanidins and extracts under study allow us to consider them for the creation of antibacterial preparations. Yearly changes in the chemical composition of fruit shrubs' twigs and in the biological activity of isolated extracts and proanthocyanidins will be further studied.

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Soil amendments based on forest logging residues on dill (Anethum graveolens L.) productivity and composition

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***Abstract*. The purpose of this work was to evaluate the impact of low rates of application of environmentally friendly organo-mineral soil amendments on grown under organic farming conditions dill's green mass yield and it's composition, including the content of polyphenolic compounds. Soil amendments were obtained based on forest logging residues – lignocellulosic biomass, after isolation of polyphenols by water-ethanol extraction and enrichment with silicon (Si)-containing inorganic oligomer in various mass ratios. Lignocellulosic biomass is rich in polyphenols which can damage the functionality of the bacterial cell membranes thus inhibiting the growth of soil microorganisms. Polyphenols can be isolated from the lignocellulosic substrate and evaluated in further studies for their potential to protect plants from pathogenic microorganisms. The influence of the prepared soil amendments on soil microorganisms was tested. Field experiments were carried out in a certified biological field intended for scientific purposes. It was shown that soil amendments have a beneficial effect on the yield (42%) and a slight influence on the composition of dill at low amendment application rates. The addition of soil amendments also contributed to insignificant changes in the amount of polyphenols. The soil amendments didn't influence the soil microorganisms under study. The results confirmed the ability of the soil amendments based on the forest logging residues to activate dill growth.**

Keywords: Forest logging residues, growth activation, organo-mineral soil amendments, silicon

I. INTRODUCTION

In 2021, the EU had an estimated 160 million hectares of forests which on average covered 39% of the EU land area; whereas in Latvia, forest area amounts to 53% of the total area [1]. According to the European Commission terminology, forest logging residues that formed after forestry logging operations include branches with needles or leaves, tops, stumps, roots, and bark left in the forest, as well as small trees from thinning and clearing operations, and un-merchantable stem wood [2]. Forest logging residues comprise at least 11% of the total mass of wood [3], in Europe, they amount to an average of 32% [4].

Large quantities of forest logging residues result in forest degradation, pollution of the environment, and loss of potentially valuable raw material [5]. Until recently, the logging residues were mostly burned, which harmed the environment. Removal of the residuals from the forest, on one side, improves its sanitary condition, but on the other side, leads to the loss of nitrogen (about 40%), phosphorus (55%), and minerals [6]. It was estimated that around 30% of the residues on average should be left in the forest to minimize the depletion of soil fertility, especially in the areas, where the carbon content of the soil is small [7], [8].

Forest residues – lignocellulosic biomass – consist of lignocellulose (cellulose, lignin, hemicellulose), and extractives. Lignocellulose is the major renewable source of organic matter in soil [9]. It was proven that lignin

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contributes substantially to the formation of humic substances [10]. One of the possible alternative ways to increase the soil fertility is to return part of the logging residues back to the forest, but with a more easily accessible form of their organic part, and either enriched with largely missing mineral part or modified for increased uptake of the minerals by the plants. Moreover, lignocellulosic biomass is rich in polyphenols which can damage the functionality of the bacterial cell membranes thus inhibiting the growth of soil microorganisms. Therefore, for preparation of the soil additives, the polyphenols should preferably be preliminary extracted, for further use as antimicrobial agents in agriculture, veterinary or human health care.

In our studies, it was proven that organo-mineral fertilizers on the basis of lignin or lignocellulosic biomass of sea buckthorn, after extraction of the polyphenols, and enriched with silicon, had a positive effect on the plants growth and development [11]. It was shown that silicon increased the plant-available part of phosphorus in the soil, affected the uptake and accumulation of several mineral nutrients in various plants, and it's effect needs further investigation [12].

Thus, this work aimed to prepare, characterize, and test the soil amendments on the basis of forest logging residues. For this purpose the following tasks were set: to modify the forest logging residues after extraction of polyphenols with silicon-containing inorganic oligomer; to test antimicrobial activity of the obtained soil amendments against four pathogenic soil bacteria; and to evaluate the effect of the obtained soil amendments on dill (*Anethum graveolens* L.) productivity and composition.

II. Materials and Methods

A. Plant Material

Forest logging residues were collected in summer 2023, from Jelgava county of Latvia, Cenu parish. The residues were dried at room temperature and ground in a mill (Cutting Mill SM100, Retsch, Haan, Germany) until the particle size of < 2mm.

B. Preparation of Soil Additives

Soil additives were obtained on the basis of hardwood chip biomass after extraction of polyphenols, by modifying the biomass after extraction with a Si-containing component (further in the text – Si) in various mass ratios.

C. Field Experiments

The field experiments were carried out in 2023 at a certified biological field (56º 69.275′ Z, E 25º 14.173′) intended for scientific purposes. The test crop was the dill "Thalia". The field experiments with soil additives were carried out in 4 options in 4 repetitions:

1. Reference plot (without soil additive);
2. Soil amendment SA1 (biomass after extraction + 15% Si on DM);
3. Soil amendment SA2 (biomass after extraction + 10% Si on DM);
4. Soil amendment SA3 (biomass after extraction + 5% Si on DM).

The green mass of dill was harvested 63 days after sowing, according to the regulations of MK no. 461 "Requirements for food quality schemes, their implementation, operation, monitoring and control procedure" [13]. Total yield of green mass was calculated as kg m^{-2} (Fig. 1).

Fig. 1. Field experiments a certified biological field.

D. Dill Green Biomass Characterization. Py-GC/MS/FID Analysis

Analytical pyrolysis of dill samples was performed on Frontier Lab Micro Double-shot Pyrolyser Py-2020iD directly coupled with gas chromatography-mass spectrometry Shimadzu GC/MS/FID-QP ULTRA 2010 (Shimadzu, Kyoto, Japan), as described in [14]. Identification of the individual compounds was performed based on GC/MS using Library MS NIST 11 and NIST 11s, whereas the relative area of the peak of individual compounds was calculated using Shimadzu software based on GC/FID data.

E. Preparation and Yield of the Extracts

Hydrophilic extracts of dill green mass were isolated in two ways: 1) at 50 °C, 30 min using ethanol-water solution (1:1, v/v) or 50% EtOH; 2) at 50 °C, 30 min using distilled water. The ethanol-containing extracts after ethanol evaporation and water extracts were freeze-dried to yield dry extracts. The yield of the dry extract is presented as a percentage based on the dry mass (DM) of biomass. The CI for the results did not exceed 3% at α=0.05.

F. Chemical Characterization of the Extracts

The total content of polyphenols in the hydrophilic dry extracts was quantified by the Folin-Ciocalteu method using gallic acid as a reference compound according to Janceva et al. [15]. The total content of flavonoids was measured by a colorimetric assay using rutin as a reference compound according to Andersone et al. [16] The total content of condensed tannins in the hydrophilic extracts was measured by the butanol-HCl assay using procyanidin dimer B2 as a reference compound as described in Andersone et al. [16].

G. Determination of the Number of Functional Groups in the Biomass

The functional groups: aliphatic hydroxyl groups OH (aliphatic), phenolic hydroxyl groups OH (phenol), and carboxyl groups (COOH) were determined using the potentiometric and conductometric titration (InoLab level 3, Wissenachftlich-Technische Werkstatten GmbH & Co. KG, Weilheim, Germany), according to Zakis [17], [18].

H. Antimicrobial Properties

Minimum inhibitory concentration (MIC) and minimum bactericidal/fungicidal concentration (MBC/MFC) of the soil amendments, mg mL^{-1}, were tested on the pathogenic soil bacteria *Pseudomonas syringae* pv. *syringae* MSCL 894, *Erwinia rhapontici* MSCL 651, and fungi *Fusarium culmorum* MSCL 1628, and *Verticillium dahliae* MSCL 863.

I. Statistics

All measurements were conducted in triplicate, except for field trials where four replicates were done. The results are presented as the mean value. Statistical analysis was made using Microsoft Excel 2016. Confidence intervals for a mean using Student's T distribution were calculated at a significance level of 5% ($\alpha = 0.05$).
The analysis of variance by R-studio was used for statistical analysis of the experimental data. Bonferroni test was used for the comparison of means at $p<0.05$. Significantly different values were labelled with different letters in superscript ([a]).

III. Results and Discussion

A. The Yield of Dill Green Mass

The yield of dill green mass was 0.90 – 1.32 kg m^{-2}

(Table 1).

TABLE 1 DILL GREEN MASS YIELD DEPENDING ON SEED TREATMENT SUBSTRATE, KG M^{-2}

Sample	Total yield of green mass, kg m^{-2}	The above-ground part of dill green mass from the total mass of the plant, %
Control without soil additives	0.93	86.3
SA1 (biomass after extraction + 15% Si on DM)	1.32[a]	88.2
SA2 (biomass after extraction + 10% Si on DM)	0.96	87.2
SA3 (biomass after extraction + 5% Si on DM)	0.90	86.4

Compared to the control variant (without treatment), the yield of green mass increased significantly only after soil treatment with SA1 ($RS_{0.05} = 0.27$ kg m^{-2}) the yield of green mass at other treatment options (SA2 and SA3) was within the confidence interval.

To determine the soil amendments effect on dill chemical composition, the following studies were further carried out for all dill samples: analytical pyrolysis (Py-GC/MS/FID); quantitative analysis of functional groups of biomasses; extraction to isolate hydrophilic extractives to determine the content of total polyphenols, flavonoids, and condensed tannins.

B. Analytical Pyrolysis (Py-GC/MS/FID) of Dill Biomass

The Py-GC/MS/FID data represent volatiles formed from cellulose, hemicellulose, lignin, proteins, and extractives. Aliphatic acids and esters, aliphatic alcohols, aliphatic aldehydes, ketones, furan and pyran derivatives, cyclopentane derivatives, and sugars attributed to carbohydrates-derived volatiles represented 50.5-59.6% of the total dill biomass volatile organic products (Fig. 2).

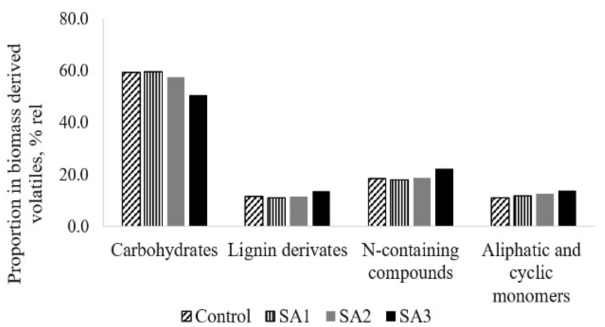

Fig. 2. Py-GC/MS/FID data of dill biomass-derived organic volatiles.

Besides the carbohydrates-derived, dill samples also contained N-containing volatiles, showing the presence of proteins and other nitrogen-containing compounds. According to Py-GC/MS/FID, nitrogen-containing compounds in dill were 17.8-22.1% of the total organic volatiles (TOV). The content of aliphatic and cyclic monomer derivates ranged from 11.0 to 13.9%/TOV. Relative proportion of guaiacyl-type derivatives attributed to lignin-derived volatiles was 0.9-1.1 %/TOV (Fig. 3).

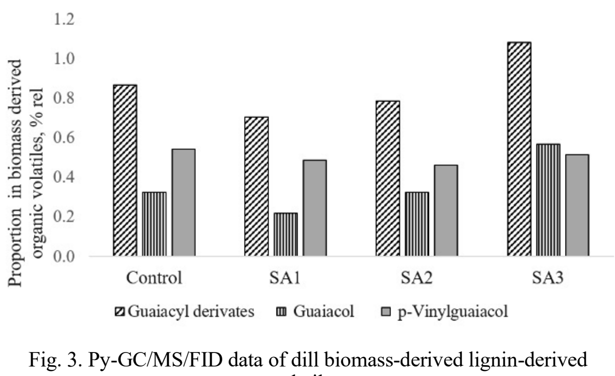

Fig. 3. Py-GC/MS/FID data of dill biomass-derived lignin-derived volatiles.

The total polyphenol-derived volatiles content in dill biomass composition ranged from 11 to 14 %/TOV.

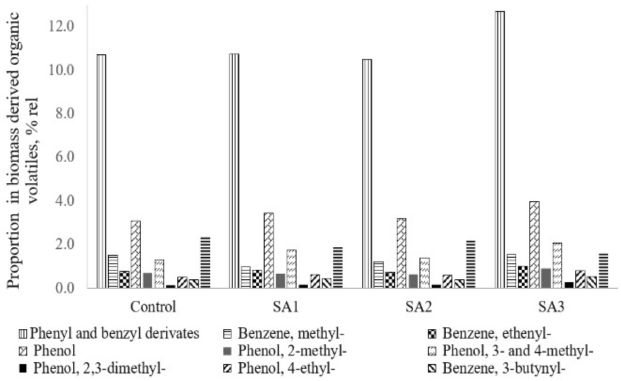

Fig. 4. Py-GC/MS/FID data of dill biomass-derived henyl and benzyl-derived volatiles.

The content of phenolic and benzyl derivatives formed from various phenolic extractives had similar content and proportions of chemical compounds between the treated and control dill samples within the confidence interval.

C. Total Content of Polyphenols and Functional OH Groups in Dill Biomass

Previous studies have shown that plant secondary metabolites, polyphenolic compounds, have a range of biological activities, such as antioxidant, antimicrobial, anti-inflammatory, antidiabetic and other [19], [20], [21], and, thus, are important compounds to be evaluated. The total polyphenol content in 50% EtOH extracts ranged from 60.1 to 65.0 mg GAE per gram of dry extract. The total polyphenol content in water extracts was slightly lower comparing to the extracts isolated by 50% EtOH (42.3 – 52.8 mg GAE/g extract). The total flavonoid content in 50% EtOH extracts ranged from 42.7 to 46.8 mg RU per gram of dry extract. The condensed tannins in the dill extracts were not found.

When comparing dill samples with each other, the composition of functional groups differed slightly. The effect of fertilizers on the content of total hydroxyl groups (OH) in the composition of dill was similar to their influence on the amount of total polyphenols. The total content of OH groups was slightly lower in the control sample. An increased content of acetyl groups and aliphatic OH groups in dill grown on treated soil (SA1-SA3) could indicate to an increased content of fatty acids and aliphatic compounds in dill composition (Fig. 5).

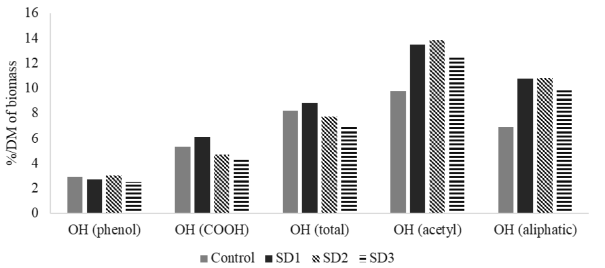

Fig. 5. Soil additive effect on dill functional group composition.

These results are consistent with the Py-GC/MS/FID data.

D. Antimicrobial Properties of Soil Amendments

The analysis of the anti-microbial properties of soil amendments obtained from forest logging biomass after extraction of polyphenolic compounds showed that they do not have detected antimicrobial activity (or MIC >50 mg mL^{-1}) against the pathogenic soil bacteria *Pseudomonas syringae* pv. *syringae* MSCL 894, *Erwinia rhapontici* MSCL 651, and fungi *Fusarium culmorum* MSCL 1628, and *Verticillium dahliae* MSCL 863.

IV. Conclusions

The results of the study showed the positive influence of the soil amendment with higher Si concentration (15% of Si on DM of biomass after extraction) on the yield of dill green mass, the green mass total yield increased 1.4 times in comparison with the control. The soil amendments with less Si concentrations (5% and 10% on DM) didn't influence the yield within the confidence interval.

The content of polyphenolic compounds in dill samples with or without treatments was similar; slight differences in the content of functional OH groups could indicate a bigger amount of fatty acids and aliphatic compounds in the composition of dill.

The antimicrobial activity of the studied soil amendments against four pathogenic bacteria and fungi was not detected (MIC >50 mg mL^{-1}). This may be indirect confirmation that polyphenols, which had proven antimicrobial activity in our previous studies, and which were separated from the forest biomass residues before preparation of the soil amendments, have a key role in antimicrobial effect. At the same time, such absence of antimicrobial activity of the studied soil additives could be considered positive for the beneficial soil microorganisms. The investigations of the effect on soil microbiota will be continued.

It can be concluded that the soil amendments based of the forest logging residues could be used for the creation of organo-mineral fertilizers and have positive effect on the yield of dill. Slight changes in the content of polyphenolic compounds of dill could be connected with the less stress of the plants growing on the enriched soil. Since the work with plants demands many repetitions, and depends also on the environmental changes, the studies have to be further continued in order to collect statistically significant amount of plants for making conclusions of the stable effect of the soil amendments in different weather conditions.

Acknowledgement

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Characteristics of the Beekeeping industry in the Latvia

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Abstract. **The activities offered by beekeeping (bee products, api-therapy, beehive air, bee museums, production activities, historical beekeeping activities, pictures, and others) are aimed at attracting beekeepers and people who want to earn and increase national income. The purpose of the study: to investigate the possibilities of using the beekeeping industry in the national economy of Latvia. Research object: Latvian agricultural sector - Beekeeping. Within the framework of the research, the literature of different countries related to beekeeping, data collection, processing, survey and observation, processing and description of the obtained data were studied. The beekeeping industry could play an important role in promoting the development of the national economy, because the export of honey in Latvia is already much higher than the import, which can be evaluated positively from an economic point of view, honey and beekeeping by-products are in demand. However, in order to achieve the set goal, it is important to involve the government and local governments, promoting the development of beekeeping in the regions, helping with realization opportunities. Utilizing the available potential requires high-level professionals, modernization of equipment and greater protection of the environment from pollution, all of which can be realized if the government increases informational and financial support for the beekeeping industry, because in the long term it would contribute to the economic growth of the country.**

Keywords: Agritourism, Api-tourism, Beekeeping, Enviroment, Honey.

I. INTRODUCTION

One of the objectives of European environmental policy is to encourage all types of companies to reduce their harmful effects on the environment [1]. Agricultural economics are linked to markets, agri-food industries, consumption and agricultural policy [2]. In today's world, when the demand for natural living conditions and natural products is growing, the interest in beekeeping, including api-tourism, is also growing. Thus, you can evaluate the development of beekeeping in the past by developing tourism, while simultaneously presenting the natural beauty, traditions, and cultural accumulations of your country, preserving them in a healthy way [3]. The interconnection of agriculture and tourism gives impulse to both sectors of the economy [4]. The beautiful natural landscapes, which can be seen more directly in the counties than in the cities, speak in favor of supporting the regions, especially this can be attributed to Latgale [5]. Bees are in the closest contact with their surroundings. Depletion of the soil by switching to a monoculture, treatment with herbicides, leveling of slopes, clearing bushes, plowing of meadows and floodplains, expansion of cities has a strong impact on the life of bees, changing the conditions of its existence [6]. Despite the fact that the world is talking about the need for environmental protection measures, people themselves are also destroying it. Beekeeping is an industry that can and should be developed, however, environmental pollution and destruction of the natural environment can hinder it.

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Interest in the development of bee products and their medicinal, health, nutritional and beauty benefits has increased, but little attention has been paid to the crucial role of beekeeping in maintaining ecological balance [7]. Humans and honey bees have a long history of association [8], as shown by the history of beekeeping.

Beekeeping is one of the oldest animal husbandry industries in the world. As early as 50,000 BCE (Before Common Era), hominids were able to collect honey with a stick in order to steal the honey by tearing open the nests of wild bees [8], but in the Neolithic, primitive people also ate honey from wild beehives. This is confirmed by the rock painting preserved in Valencia, Spain, which depicts people extracting honey [9]. Stealing honey from wild bees is the oldest documented interaction with bees. Rock paintings in Spain depict honey hunters suspended from rope ladders as they harvest the honeycomb. These paintings are believed to date back 7,000 to 8,000 years, but are not the earliest evidence of the bee product usage [8]. Bees were mentioned in the Pyramid texts and the ancient Egyptian Mythology [10], Drawings related to beekeeping have been found in cave paintings dating from about 10,000 BCE [3]. The domestication of bees is shown in Egyptian art about 4,500 years ago [11]. The first depictions of beekeeping can be found in Egypt the Solar Temple of king Nyuserra of the fifth dynasty at Abu Ghorab, north of Abusir [8], [10]. The ancient Egyptians, Romans and Greeks believed that the life of bees has a slave-holding system, but as early as 1950 it was suggested that the bee colony is similar to a single organism [6]. The fact that beekeeping was cultivated already in prehistoric times and still plays a significant role in the development of the national economy, shows its importance and the need not only to preserve it, but also to promote its development.

The nobles were honored with a honey drink by order of Princess Olga (Princess of Kiev from 945 to 964) [3]. Charlemagne (Charles the Great 747–814) ordered all manors to keep bees and give two-thirds of the honey produced to the crown [8]. Bee products were also respected among the nobles and were considered an exclusive product.

The European honey bee, *Apis mellifera* L., is considered more productive, so pilgrims took the first bees to North America in the 1600s [9]. In England, the honey bee (*Apis mellifora*) was described in the 17th century, and in the United States of America - in the 18^{th}-19^{th} centuries [12]. 16th century historical accounts indicated that the northern limit of beekeeping was Denmark, where natural conditions might be too harsh for bees to thrive [11]. The honey bee was introduced to Alaska in 1809 [12]. In addition to honey, honey wine and honey vinegar have also been found in the human food chain of the relevant historical period. [3]. History also confirms that Europe has a suitable environment for beekeeping.

Beekeeping flourished during the European Middle Ages as the demand for honey and beeswax for trade increased [8]. In the Middle Ages, beeswax was used as currency, used in writing, painting, sculpture and lighting, as well as protecting works of art [9], already in the Middle Ages, people were aware of the various possibilities of using honey and wax.

In the Middle Ages, forest beekeeping flourished in the forests of Eastern Europe, especially in the territory of present-day Poland, Ukraine, Russia, Latvia, Estonia, Lithuania and Germany [8]. where Forest beekeeping evolved as honey hunting, searching for wild nests in natural tree hollows. Honey hunters began enlarging tree hollows to encourage the growth of colonies of wild bees they found, and this eventually led to artificial hollows being cut in trees in hopes of attracting a colony, a practice that formed the basis of true beekeeping in Eastern Europe. When the hollow was completed, the opening was closed with a board fitted with a small entrance hole and marked to show ownership. To protect them from looting by bears and humans, the hives were placed 5-25m high, and if the tree was large enough, the beekeeper could cut two or even three hives in one tree, essentially creating a tree apiary. Several species of wood were used for these wooden hives, but many beekeepers preferred oaks and pines [8]. Interest in beekeeping has increased in Latvia in recent years. In addition, beekeeping opens up wide range of opportunities to work, which contributes to employment, entrepreneurship and the development of the national economy in general.

There are three categories of beekeepers in Latvia, as elsewhere in the world [13] (Fig.2):

- The first are professional beekeepers, for whom beekeeping is the main source of income.
- The second, beekeeping provides additional income. The main occupation in that case is agriculture, crafts, pond farming, sawmills, etc. This also includes farms where bees are needed to pollinate field crops (primarily clover) and gardens.
- For the third, beekeeping is a hobby, it gives the house a special atmosphere, the song of bees, stings to strengthen health and, of course, also honey for themselves and their loved ones.

Looking at the categories of beekeepers, it can be concluded that practically any interested person who has the desire and the means can become a beekeeper, it just depends on what the main goal is - making a profit, expanding economic activity or for a hobby.

The purpose of the study: to investigate the possibilities of using the beekeeping industry in the national economy of Latvia.

II. Materials and Methods

Research object: Latvian agricultural sector - Beekeeping.

Research methodology:

- General scientific research methods (scientific induction method, graphic method, monographic or descriptive method).
- Sociological research methods (survey, observation).
- Statistical research methods (statistical grouping or descriptive statistics, sampling method).

Within the framework of the research, the literature of different countries related to beekeeping, data collection, processing, survey and observation, processing and description of the obtained data were studied.

III. Results and discussion

The activities offered by beekeeping (bee products, api-therapy, beehive air, bee museums, production activities, historical beekeeping activities, pictures, and others) are aimed at attracting beekeepers and people who want to earn and increase national income [3]. During the last half-century beekeeping, as one of the agricultural industries in the world, increased globally by nearly 45% [14]-[15]. The importance of honey and beekeeping by-products is increasing day by day [3]. The study revealed that the beekeeping industry has far-reaching opportunities for further development, as there is a demand for honey and its by-products.

There are different kinds of honey. There can be monofloral (with specific sensory, physical and chemical characteristics) and multifloral; also honeydew honey, called forest honey [9]. The honey obtained in Latvia is polyflor, which contains a wide spectrum of biologically active substances [16]. Bees can also collect the so-called honeydew honey, which is a sweet liquid of plant origin that is exuded through the leaves, branches, or stems of plants [6]. Beekeepers in Latvia offer consumers a wide range of honey types (Fig. 1).

Bee colonies of various subspecies of Western honey bees (Apis mellifera L.) are used in beekeeping in Latvia [17]. The local honey bee in Latvia (*Apis mellifera mellifera* L.) or European (Western European) dark bee appeared 8000 years ago [18]. In the northern regions, also in Latvia, during the short flowering period of nectar plants, the nectar is more concentrated and richer in biologically active substances than in the southern regions [17]. Honey contains antioxidants, which are higher in bee honey than in bumblebee honey [19]. To increase antioxidant activity honey is added to food and beverages [3]. The most available honey in Latvia is from various flowers, however the nectar of a particular plant is becoming more and more popular [20]. The wishes and needs of consumers are growing, as a result beekeepers must regularly expand the range of offered products.

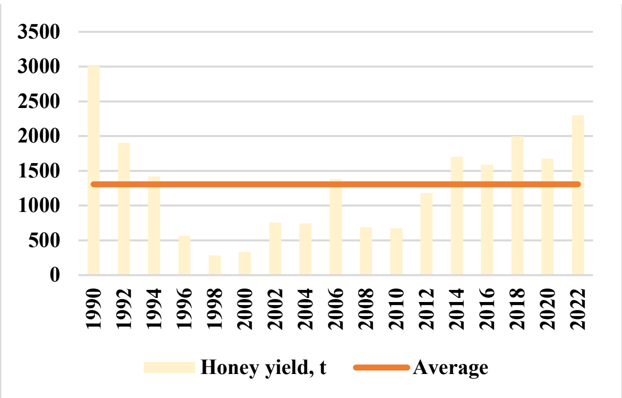

Fig.1. Honey production in Latvia 1990 - 2022, in tons [21].

In Latvia, the export of honey exceeds the import (Fig. 4). This means that Latvian honey is in demand worldwide, because it is of high quality and cheap. This indicates that in Latvia honey is sold below the cost price level. 39% of beekeepers do beekeeping at the hobby level (Fig. 2), and they distort the local honey market by selling honey below cost price [33]. However, this trend needs to be changed and the focus should be on increasing the beekeeping production of the country in the domestic market, defending the development of beekeeping [22]. Researchers [23] have pointed out that cross-border transport corridors are important for the development of beekeeping, to provide easy access to foreign markets, to showcase an area with a rich history and centuries-old traditions, crafts, festivals, culture, etc., including beekeeping. Latvia does not have traditionally developed beekeeping regions [24], the creation of which would significantly improve the honey sales possibilities.

Latvian statistics portal [25] shows the grouping of farms by the number of bee colonies (Fig. 2), where it can be seen that beekeeping in Latvia is more of a hobby, as less than 3,000 farms have 2-3 bee colonies. In 2021, there were almost 3.4 thousand beekeeping farms in Latvia with more than 100 thousand registered bee colonies [26]. In 2022, 3,496 beekeepers with 105,491 bee colonies were registered. Compared to 2021, no significant changes have taken place [27]. Despite the fact that for a large number of beekeepers, beekeeping is more of a hobby than a source of profit, income, there are still many beekeepers who are actively working in this industry to be able to provide demand for local consumers and for export. From an economic point of view, the large number of beekeepers for whom beekeeping is a hobby is a kind of market distortion, because they offer their products cheaper, which can be explained by the fact that making a profit is not their primary concern, as a result, it affects other beekeepers as well.

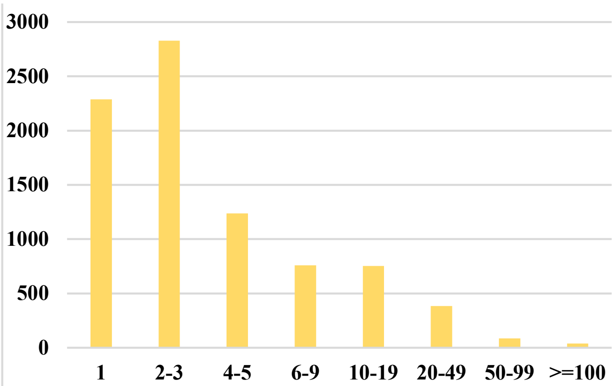

Fig. 2. Grouping of farms according to the number of bee colonies in 2001, number [25].

In Latvia (2018-2021), the average price of honey decreased (Fig. 3). Most of the honey produced is sold in direct sales and wholesale [16], part of the production is also exported (Fig.4).

The products produced in beekeeping are honey, pollen, bee bread, propolis, beeswax and royal jelly, as well as bee queens and bee colonies, which are sold to meet the industry's internal needs. In Latvia, beekeepers collect honey of various flowers, linden flower honey, buckwheat honey, rapeseed honey, heather and other types of honey from bee colonies [6], [27]. Various types of produced honey (Table 1) are commercially available, such as spread honey, cellular honey, creamed honey, pressed honey and other types [27]. In Latvia, consumers are offered a wide range of types of honey, including various honey by-products.

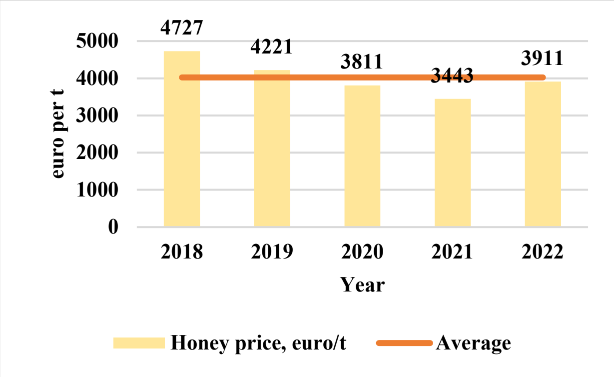

Fig. 3. Honey price in Latvia 2018 - 2021, euro per 1 ton [16] - [17], [27].

The average price of honey export in 2022 compared to 2020 has increased by 22%, and the average price of import – by 42%. [27]. The price of honey is influenced by both the geographical position of the country or region where the honey is collected, as well as the botanical origin of the honey, that is, the purity of the pollen collection. These parameters increase the value of the product and give it a specific aroma and taste, as well as have special medicinal properties [9]. It can be seen that the price of honey in Latvia is decreasing every year (Fig.3), which can be explained by the large number of beekeepers for whom beekeeping is more of a hobby, however, it is positive that the export price of honey is increasing, which indicates stability and growth in the wider market.

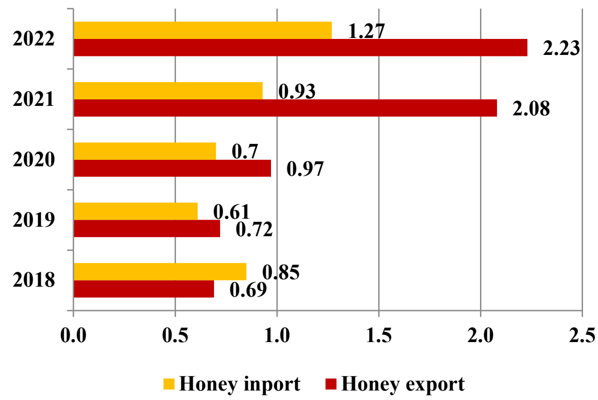

Fig.4. Export and import of honey in Latvia (2018-2021), million euros [16]-[17], [27].

One of the biggest problems in beekeeping is the identification of honey adulteration (Table 1). Because of this, beekeepers suffer both economic losses and consumer confidence [9]. This is a problem that is being fought at a global level.

TABLE 1 QUALITY INDICATORS OF DIFFERENT HONEYS FOR DETERMINING THE NATURAL ORIGIN AND QUALITY OF HONEY [9], [28]-[29]

Quality indicator	**The type of honey origin**	
	Flower honey	***Exudation-honeydew honey, exudation-honeydew and flower honey mixture***
Sugar content*	No less than 60 g/100 g	No less than 45 g/100 g
Water content	No more than 20 %**	No more than 20 %**
Electrical conductivity***	No less than 0,8 mS/cm	No less than 0,8 mS/cm
Free acid ****	No more than 50 milliequivalents of acid per 1000 grams	No more than 50 milliequivalents of acid per 1000 grams
Diastasis number *****	No less than 8	No less than 8
HMF ****** (Hydroxymethylfurfural content)	No more than 40 mg/kg	No more than 40 mg/kg

* Fructose and glucose content (total)

** The amount of water in excess of what is indicated contributes to the fermentation of honey

*** It is determined by the concentration of minerals in the honey. High electrical conductivity indicates that the honey should be considered as honeydew honey

****They play an important role in creating the aroma and taste of honey

***** According to the Schade scale. Diastase is one of the honey enzymes that bees add to the nectar during the honey-making process. The diastasis number is low if the bees have been fed sugar syrup, the honey has been overheated or stored for a long time

****** HMF is a thermal breakdown product of sugars. The amount of HMF is an indicator of the freshness and naturalness of the honey. A high HMF content indicates honey that has been heated at high temperatures or stored for a long time

Beekeeping faces several problems that affect the quality and quantity of honey produced [9]:

- One of the reasons in developing countries is the lack of qualified beekeepers, sufficient training in modern beekeeping techniques
- Availability of suitable equipment which is too expensive.
- In developed countries, damage to bees is caused by intensive agriculture, such as excessive use of pesticides.

In summary, it can be concluded that the beekeeping industry has high development potential, but to be able to use all available potential, high-level professionals, modern equipment and greater environmental protection from pollution are needed, all of which can be realized if the government increases support for the beekeeping industry, as well as informative, and financial, because in the long term it would contribute to the economic growth of the country.

The geographical position of Latvia is favorable for obtaining high-quality honey. Temperate mixed-tree forests, interspersed with wide swales, natural and floodplain meadows, scrub, bogs and heaths, are excellent habitats for nectar plants [27]. The diversity of nectar plants and its quality is the main prerequisite for the quality of collected honey. In addition, in the northern regions, including in Latvia, during the short flowering period of nectar plants, the nectar is more concentrated and richer in biologically active substances than in the southern regions [27]. The honey bee becomes a central node in pollination networks, visiting both generalist and specialist plant species [14]. The growing world population and the growing need for food have increased the focus on urban agriculture around the world. Most crops grown in urban environments require bees for pollination [30]. Due to the decline of natural pollinators, honey bees are used in crop production, however, *A. mellifora* has been shown to supplement rather than replace pollination services by wild insects. [14]. Plants related to beekeeping play an important role in the conservation of local bees and the development of beekeeping [7]. It has been proven that bees pollinating plants significantly improves their productivity [14]. Honey bees fly up to 5 km from the apiary, most bees are 1 km away, while bumblebees are found 5 km and more from the apiary and during most of the day [15]. The geographic location of Latvia is naturally suitable for the development of the field of beekeeping, it can be positively assessed that bees, when pollinating, also improve the agricultural environment, which contributes to the development of the agricultural field.

In developed countries, rural tourism is seen as an important opportunity to ease the burden of tourism on cities. Rural tourism is an instrument of regional development. In recent years, the quality of tourist demand has changed, so rural tourism is becoming more popular [3]. People want to be closer to nature, so the development of rural tourism is encouraged (Table 2).

Agritourism activities and services are very broad, which include, apart from accommodation or meals, additional services such as education, active involvement in farm activities, volunteer participation in agricultural activities, handicrafts, production of traditional arts, food offered from rural or local [4]. Rural tourism is moving towards agricultural tourism or agritourism, which also includes beekeeping tourism [3]. By popularizing beekeeping tourism, other types of rural tourism would also be popularized.

Api-tourism includes sustainable beekeeping, historical heritage, niche and health tourism as an intersection between alternative medicine, tradition, and the sustainable income generating activity of beekeepers [3]. Today, beehive therapy is also authorized in Austria, Slovenia and Hungary due to its possible contribution to the treatment of asthma, bronchitis, pulmonary fibrosis and respiratory tract infections, however scientific evidence is scarce and further biological and chemical analyzes are needed to substantiate this therapy [3]. It has long been believed that bees can also be used for medicinal purposes, but nowadays it is practiced more and more often.

A nature trail is an attractive, valuable sequence of natural objects in a natural area, where a path suitable for visitors has been created and whose purpose is to attract people to nature, to give them the opportunity to enjoy and explore it in an environmentally friendly way [31]. By creating a nature trail, tourists and its visitors could not only enjoy the closeness and beauty of nature, but also gain new knowledge by learning about nature, plants, etc.

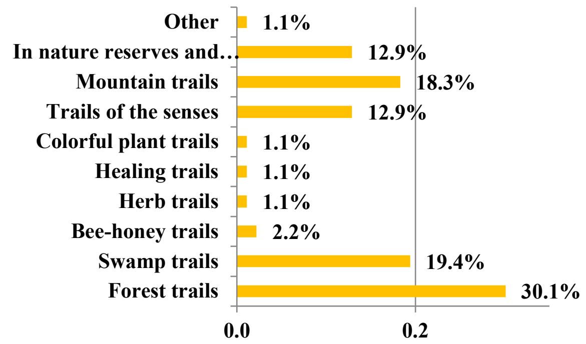

Fig. 5. Respondents' answers to the question: "What tourist trails in Latvia have you visited?" (N=1500).

In the study conducted (Fig. 5), it was revealed that Latvian residents have mostly visited forest, swamp and mountain trails, but they are also the most frequent tourist trails in Latvia. Theoretically, people are interested in getting closer to nature, visiting various tourist trails, so this industry can be developed by expanding the range with new trails, such as Bee-honey trails. In order to attract tourists and visitors, it is recommended to combine the visit of the tourist trail with the educational and practical part. 3 km was indicated as the ideal length of the tourist trail (Fig. 6).

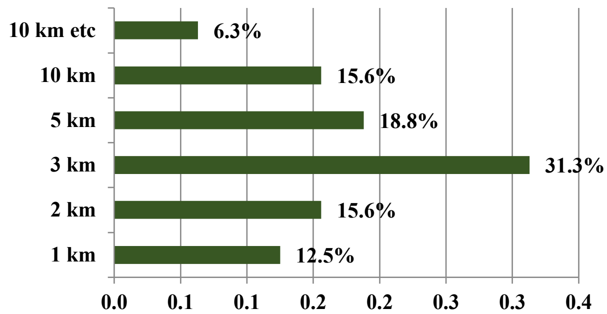

Fig. 6. Respondents' answers to the question: "How long do you want a nature trail?" (N=1500).

TABLE 2 SUMMARY OF THE RESULTS OF THE SURVEY ON THE USE OF BEEKEEPING IN 2023 (N=1500)

Indicator	Totally agree	Agree	Hard to say	Agree	Totally agree	Indicator
I use honey	800	300	213	52	135	I do not use honey
I use other beekeeping products	432	738	41	132	157	I do not use other beekeeping products
I visit agritourism trails	270	780	38	62	350	I do not visit agritourism trails

Indicator	Totally agree	Agree	Hard to say	Agree	Totally agree	Indicator
I visit nature trails once a year	280	780	38	342	60	I visit nature trails 5 times a year
I know Latvian plants well	287	506	501	168	38	I know bee plants well
I visit various beekeeping events	42	180	700	380	198	I do not attend various beekeeping events
Information about the type and name of the honey is available	400	389	120	307	284	Information about the type and name of the honey is not available
Composition is available	399	324	186	308	283	Composition is not available
The manufacturer is specified	422	392	118	288	280	The manufacturer is not specified
The manufacturer's contacts are indicated	413	379	123	301	284	The manufacturer's contacts are not indicated
The place of honey extraction and the country are indicated on the honey product	165	123	102	350	760	The place of honey extraction and the country are not indicated on the honey product
I use api-therapy	89	42	30	350	989	I do not use api-therapy

With the help of digitization the agricultural environment development leads to technological innovations and above all creativity, animal welfare, significantly reduces the negative impact on the environment [2]. The involvement of the state and local governments also plays an important role in the development of tourism, because by supporting the regions, both the level of employment and the income level of the population, as well as the level of economic development in general, would be positively affected [32]. It is increasingly said that the government should be more involved in the development of regions, however, support from the state and local governments is still not sufficient to make maximum use of the available resources.

Tourism in the rural environment can provide additional income for those farmers who have small properties, who want to diversify their farming, who like to cooperate with people who want to promote their products. In Latvia, farm open days are organized, when all interested parties are introduced and entertained by farm owners. It is often free, but is also part of various large-scale events.

IV. Conclusions

Latvia is suitable for the development of beekeeping both as a livestock breeding and tourism and health promotion industry. The quality of honey and the biologically active compounds contribute to the production of innovative products.

The demand for beekeeping products and related services (api-therapy, tourism, etc.) is growing. Therefore, as much as possible, environmental risks and honey adulteration, which may occur due to societal habits, should be minimized or eliminated.

Beekeeping can also be supported at the state and municipal level, creating favourable conditions for business, education and the introduction of modern technologies. This will create public interest and awareness with the perspective of increasing the competitiveness of the industry and the development of the national economy in general.

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Increasing The Fire Resistance Of Polymer Building Materials Based On Technogenic Waste

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Abstract. **Today, comprehensive measures are being implemented around the world and certain results are being achieved in the field of further deepening economic reforms in the building materials industry and the rapid development of the network, increasing the production of new modern building materials, structures and products, and expanding their range. Expanding the range of manufactured building materials, increasing the share of production of modern, convenient, and high-quality products based on a localization program, reducing imports, as well as the further development of the industry remain pressing issues of today.**
The studies present methods for increasing the fire resistance of polymer building materials obtained based on fly ash from the furnaces of the Shirin Thermal Power Plant and JSC Uzmetkombinat, waste phosphogypsum generated at JSC Maxam-Ammafos, physical, mechanical, and thermodynamic properties, and also studied optimal proportions for obtaining composites of fire-resistant polymer building materials.
To conduct an experimental study, particles of technogenic industrial waste of the most optimal size, types of filler, and necessary components were selected. Studies of the elemental composition of industrial technogenic waste and X-ray diffraction analysis have shown that they consist mainly of silicon dioxide, which consists of more than 80% of the amorphous phase.
Based on the analysis of the X-ray phase structure, it was determined that the introduction of additives into the fly ash fillers of the Shirin Thermal Power Plant and Uzmetkombinat JSC, as well as phosphogypsum waste from Maxam-Ammofos JSC, leads to an increase in the thermal stability of polymer materials. The main reason for this is explained by the fact that the composition of fly ash and phosphogypsum waste introduced into the polymer composite contains metal oxides, silicon oxide, and phosphorus compounds, which are resistant to temperatures and have fire-retardant properties.
The fire resistance properties of the proposed polymer-containing building materials modified with fire-resistant compositions of the PPA, PPK and PPM brands, consisting of polymer binders, fire-retardant additives and fillers, were studied based on experimental tests, while the oxygen index was increased from 18.5 to 33.0%, while the weight loss during thermal oxidation was reduced from 97.5 to 73–75.5%, and the flammability level according to state standard 28157 was changed from PV-2 to PV-0.

Keywords: composite composition, fire resistance, fly ash, man-made waste, phosphogypsum, polyethylene, polymer building materials, thermal analysis.

I. Introduction

Today, comprehensive measures are being implemented around the world and certain results are being achieved in the field of further deepening economic reforms in the building materials industry and the rapid development of the network, increasing the production of new modern building materials, structures, and products, and expanding their range. Expanding the range of manufactured building materials, increasing the share of production of modern, convenient, and high-quality products based on a localization program, reducing imports, as well as the further development of the industry remain pressing issues of today.

Particular attention in the world is paid to the production of new structures of building materials on a global scale. In this regard, the creation of modern compositions of multifunctional additives based on

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technogenic waste for the production of building materials is one of the important tasks of research in this direction.

To substantiate appropriate scientific decisions on the development of new compositions of multifunctional effective additives and, with their participation, highly effective building materials, such issues as the creation of new methods for obtaining effective types of building products based on artificial additives, the use of new compositions for obtaining multifunctional building materials with the participation of recycled materials are becoming increasingly relevant. raw materials, optimizing the composition of raw materials to increase the strength of heat-resistant and fire-resistant building materials, creating energy-efficient building materials, modernizing technologies for the production of heat-resistant and fire-resistant building materials, and using local alternative sources of mineral additives to increase their volume.

Currently, one of the most commonly used materials in the construction of modern buildings under construction is polymeric materials, which, in addition to their effective properties for resistance to aggressive environments, must be fire resistant. The scientific and technical literature on the development of fire-resistant and fire-resistant building materials, on ensuring the fire safety of buildings and structures, in particular, effective scientific solutions for the development and use of fire-resistant materials, as well as ways to improve them, is analysed.

In the Republic of Uzbekistan, comprehensive measures are being taken to produce high-quality building materials, aimed at meeting their demand, modernizing the economy, and creating new production capacities.

The Development Strategy of New Uzbekistan for 2022-2026 defines the tasks of “development of production facilities, modernization and diversification of industry, practical application of inexpensive energy-efficient methods, development of the industry for the production of building materials containing polymers, preparation of import-substituting and export products.” In this regard, scientific research aimed at developing new compositions of multifunctional additives based on technogenic waste, and with their participation new types of highly efficient building materials are extremely important [1].

This study will, to a certain extent, serve the implementation of the tasks set in the Resolutions of the President of the Republic of Uzbekistan dated February 20, 2019, № PP-4198 “On measures for radical improvement and comprehensive development of the building materials industry”, dated May 25, 2019, № PP-4335 “On additional measures to accelerate the development of the building materials industry", dated February 13, 2021, № PP-4992 "On measures for further reform and financial recovery of chemical industry enterprises, development of production of chemical products with high added value", dated January 24, 2022, № PP-99 “On measures to create an effective system for the development of production and expansion of industrial cooperation in the republic”, as well as in other regulatory legal acts related to activities in this area [2, 3, 4]

II. MATERIALS AND METHODS

A. Goals and objectives of research into increasing the fire resistance of polymer building materials

The purpose of the research is to develop a new technology for producing effective additives based on industrial waste to create energy-efficient, heat-resistant, fire-resistant building materials.

The objectives of the study are: to study the influence of technogenic waste on the formation of heat-resistance and fire-resistant properties of polymer-based building materials; study technological, heat-resistant, and physical-mechanical properties of heat-resistant and fire-resistant building materials; optimization of the composition of heat-resistant and fire-resistant building materials obtained from industrial waste; determining the feasibility of creating and implementing modern technology for the production of heat-resistant and fire-resistant building materials obtained from industrial waste [5, 6, 7]

B. Production of fire-resistant polymer building materials based on fly ash and phosphogypsum

Phosphogypsum waste from Maxam-Ammofos JSC was used as technogenic waste.

Fly ash is a finely dispersed material, which consists of particles up to 0.14 mm in size, is formed as a result of the combustion of solid fuel at a thermal power plant and is captured by electric precipitators, after which it is taken in a dry state using an ash collector for production needs, or together with water and the slag is sent to the ash dump [8].

Phosphogypsum is a calcium sulfate hydrate formed as a by-product during the production of fertilizers from phosphate rock [9].

Based on the experiments carried out, three composite compositions of the brand were obtained, which were named PPA, PPK, and PPM.

Composite composition of the PPA brand. 40 g of fly ash and 40 g of vermiculite powder were placed in a heat-resistant glass and mixed using a special mixer at a temperature of 100 -150° C, and the mass ratio should be 1:1. Then 10 g of ammonium sulfate was added to the mixture, and the reaction process was continued for 1.0 hours, stirring at a temperature of 100^{o} C. As a polymer binder, 10 g of polysulfide oligomer was added to the mixture, brought to a homogeneous state, and stirred for 0. 5 hours at a temperature of 80-90^{o} C. The resulting finished product was brought to a state of readiness for modification with polyethylene. Let us give the ratio of substances in the composite composition of the PPA brand:

The ratio of substances in the first composite composition of the PPA brand:

fly ash – 40%;
vermiculite – 40%;
ammonium sulfate – 10%;
polysulfide oligomer – 10%.

Composite composition of the PPK brand. 30 g of fly ash and 30 g of phosphogypsum waste powder were placed in a heat-resistant glass and mixed using a special mixer at a temperature of 100–150°C, and the mass ratio should be 1:1. Then 20 g of silicon oxide and 15 g of amorphous adduct (orthophosphoric acid and amorphous 1:1) were added to the mixture, and the reaction process was continued for 1.0 hours, stirring at a temperature of 100º C. As a polymer binder, the mixture was brought to a homogeneous state, and 5 g of polysulfide oligomer was added and stirred for 0.5 hours at a temperature of 80–90º C. The resulting finished product was brought to a state of readiness for modification with polyethylene. Let us present the ratio of substances in the composite composition of the PPK brand:

The ratio of substances in the second composite composition of the PPK brand:

fly ash – 30%;
phosphogypsum – 30%;
silicon oxide – 20%;
amorphous adduct (orthophosphoric acid and amorphous 1:1) – 15%;
polysulfide oligomer – 5%.

Composite composition of the PPM brand. 30 g of fly ash and 25 g of vermiculite powder were placed in a heat-resistant glass and mixed using a special mixer at a temperature of 100–150°C. Then 20 g of amorphous adduct (orthophosphoric acid and amorphous 1:1) and 15 g of montmorillonite were added to the mixture, and the reaction process was continued for 1.0 hours, stirring at a temperature of 100º C. As a polymer binder, the mixture was brought to a homogeneous state, and 10 g of polysulfide oligomer was added and stirred for 0.5 hours at a temperature of 80–90º C. The resulting finished product was brought to a state of readiness for modification with polyethylene. Let us give the ratio of substances in the composite composition of the PPM brand:

The ratio of substances in the third composite composition of the PPM brand:

fly ash – 30%;
vermiculite – 25%;
ammophos adduct (orthophosphoric acid and ammophos 1:1) – 20%;
montmorillonite – 15%;
polysulfide oligomer – 10%.

III. Results and discussion

The thermal properties of oligomers of the sulfur-containing class were studied by thermal analysis. The mass of the polysulfide rubber sample does not change up to 210 º C (Fig. 1). The thermal analysis curve shows a single endothermic peak (at 190.1°C) in the temperature range 30–210°C, which corresponds to melting of the sample.

A sample at temperatures above 210°C begins to decompose in two stages: up to 270°C at a rate of 7% per minute and above 270°C at a rate of 2.6% per minute with a total weight loss of 75%. The decomposition reaction is endothermic with a total decomposition energy of 308.7 J/g. Based on the experiments carried out, the kinetic constants, energetic activity, and reaction order change as a result of the formation of various reactions due to the influence of temperature.

Thermogravimetric studies without both temperature ranges are not specifically studied, since experiments were conducted with multicomponent fire-resistant polymer composites and results of thermogravimetric studies were obtained in the range from 20º C to 800 º C.

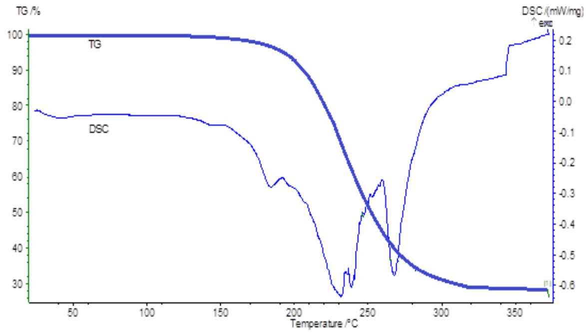

Fig. 1. Results of thermal analysis of polysulfide rubbers containing sulfur in their composition.

When calculating energy activity, the basic information depends on several methods for determining dynamic temperature indicators. The results obtained using these methods may vary. Based on the results of the research, scientific and theoretical research has proven that experimental research results obtained by the thermogravimetric method are highly effective.

In the process of modifying polyethylene building compositions at a temperature range of 200–220°C in an amount of 10, 20, and 30% wt. composite compositions of the PPA brand (fly ash, vermiculite, ammonium sulfate, polysulfide rubber), PPK brand (fly ash, phosphogypsum waste, silicon oxide, ammophos adduct, polysulfide rubber), PPM brand (fly ash, vermiculite, ammophos adduct, montmorillonite, polysulfide rubber) changes in the flow rates of fire-resistant polymer building materials are presented in Table. 1.

It should be noted that when a filler is introduced into a polymer composition at a temperature of 200–220°C, first the fluidity of polymers under the influence of temperature does not increase significantly, and then when the amount of filler (PPA: PE) was 10% wt ., it was found that when exposed to temperature the fluidity index was 1.0–1.5 g in 10 minutes, and at 20% wt. decreased to 0.7–0.6 g per 10 min. When the amount of fire-resistant filler (2–15 μm) reaches 20–30% wt. a significant decrease in the fluidity of polymers under the influence of temperature was observed [5].

As can be seen from the study results, the melt flow index changed little when the amount of filler was 30% wt. and particle size was 7 microns. It follows that the fluidity of compounds under the influence of temperature depends on the type of filler. It was revealed that the fluidity under the influence of temperature of fire-resistant polymer building materials in PPM: PE ratios of 10–30% wt. differs slightly compared to the original sample.

TABLE 1 FLOW INDEX OF FIRE-RESISTANT POLYMER BUILDING MATERIALS BASED ON MODIFIED POLYETHYLENE GRADE F-0220 WITH ADDITIVES GRADES PPA, PPK, AND PPM

Composition of compositions	Additive particle size, microns	Amount of polymer and fillers of PPA, PPK and PPM brands, % wt			
		100/0	90/10	80/20	70/30
		MTR g/10 min (200 °C; 2.16 kg)			
Polyethylene grade F–0220	–	1.5–2.5	–	–	–
PPA+PE	7	–	1.0–1.5	0.7–0.6	–
	10	–	0.7–0.6	0.4–0.3	–
	15	–	0.5–0.4	0.3–0.2	–
PPK+PE	7	–	1.0–2.0	0.8–0.7	0.5–0.3
	10	–	0.8–0.7	0.7–0.5	–
	15	–	0.7–0.6	0.5–0.4	–
PPM+PE	7	–	1.5–2.0	1.0–0.8	0.6–0.4
	10	–	0.8–1.0	0.9–0.6	0.4–0.2
	15	–	0.8–0.5	0.7–0.5	–

In the process of modifying polypropylene building compositions at a temperature range of 200–220°C in an amount of 10, 20 and 30% by weight with composite compositions of the PPA brand (fly ash, vermiculite, ammonium sulfate, polysulfide rubber), PPK brand (fly ash, phosphogypsum waste, silicon oxide, ammophos adduct, polysulfide rubber), grades of PPM (fly ash, vermiculite, ammophos adduct, montmorillonite, polysulfide rubber) changes in the fluidity indicators of fire-resistant polymer building materials are presented in the table. 2 [6].

From this table. 3. It can be seen that when a filler is introduced into a polymer composition at a temperature of 200–230°C, the fluidity of polymers under the influence of temperature does not increase significantly, and then when the amount of filler is 30% wt. With a particle size of 7 µm, it is possible to analyze the increase in the flow rate of polymers under the influence of temperature. As can be seen from the study results, the melt flow rate changed significantly when the amount of filler was 30% wt. and particle size was 7 microns.

TABLE 2 FLOW INDEX OF FIRE-RESISTANT POLYMER BUILDING MATERIALS BASED ON MODIFIED POLYPROPYLENE GRADE P-Y342 WITH ADDITIVES GRADES PPA, PPK, AND PPM

Composition of compositions	Additive particle size, microns	Quantity of polymer and grade fillers PPA, PPC, and PPM % wt.			
		100/0	90/10	80/20	70/30
		MTR g/10 min (200 °C; 2.16 kg)			
Polypropylene grade P-Y342	–	0.25–0.30	–	–	–
PPA+PP	7	–	0.25	0.2	0.1
	10	–	0.1	0.08	–
PPK+PP	7	–	0.20	0.15	0.1
	10	–	0.15	0.09	–
PPM+PP	7	–	0.2	0.15	0.09
	10	–	0.15	0.09	–

It follows that the fluidity of compounds under the influence of temperature depends on the type of filler. It was revealed that the fluidity index under the influence of temperature of fire-resistant polymer building materials in the ratio PPM: PP 30% wt. decreased slightly compared to the original polymer. This made it possible to scientifically substantiate the possibility of adopting an acceptable filler concentration of 30 wt.% for PP and an acceptable size of 7–10 microns.

Currently, polypropylene is one of the main products intended for the production of fire-resistant polymers. Taking into account the production of various products from it and its leading position among thermoplastics, we will also pay special attention to calculating percentages in the process of conducting a sequence of experiments.

Study of the thermophysical properties of building materials based on refractory polymers. The indicators of production and thermal decomposition of composites produced in our republic have been determined polyethylene with groups consisting of aluminum, calcium, magnesium, and silicon.

Polyethylene-based polymer composite materials are widely used in the processes of external and internal finishing of buildings and structures, in water-permeable pipelines, household electrical appliances, and the furniture industry, while the requirements for the fire resistance of these polymer materials are increasing from year to year. The indicators of thermal decomposition of a polymer composite material obtained by mixing at a temperature of 180-2000 s through a special extruder during laboratory processing of polyethylene brand F-0220S, produced in our republic, with 10-20% fire-resistant compositions of the PPA, PPK, and PPM brands, raw materials were studied which are available in our country (Fig. 2).

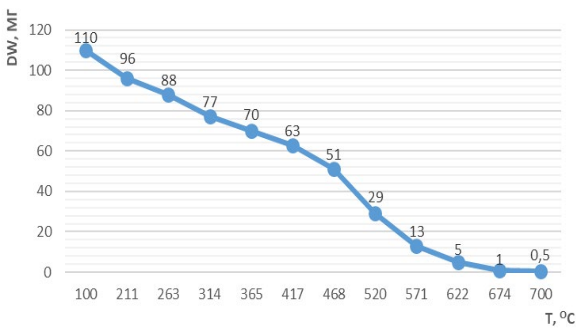

Fig. 2. Thermal analysis of polyethylene sample F-0220-S

On the derivatogram curve of a sample prepared by adding a mixture of polyethylene and fire-resistant compounds to obtain a polymer composite, five endothermic effects were detected at 114, 131, 183, 431, 657 o C, and nine exothermic effects at 241, 343, 369, 381, 512, 589. 621, 697, and 700 o C. The total reduction in mass in the temperature range of 100-700 o C of the thermogravimetric curve was 99.5% [7].

During the analysis, experimental tests were carried out to determine the average rate of mass loss of polymers and their composites, and the period of the experiment and the mass of the substance were determined. Thus, the properties of thermal-oxidative destruction of a polymer composite were studied, based on data from studies of the kinetics of processes in the temperature range from 440 K to 1023 K.

For oligomers with reactivity, the choice of modifier system is one of the main issues in the production of binders. Polymer composite materials with a modified polymer matrix must have high-performance properties. To achieve this, the polymer matrix must have high reactivity and high molecular mobility. On the other hand, the polymer matrix is subject to requirements for high heat resistance. This requires an increase in the crystallization temperature, and a high crystallization temperature, in turn, leads to a decrease in molecular mobility.

TABLE -3 DETERMINATION OF THE AVERAGE RATE OF WEIGHT LOSS USING THE THT ANALYSIS METHOD

Period, °C	Weight loss, mg	Average rate of weight loss, mg/min $v_m = \Delta m / \Delta\tau$
Polyethylene F-0220S		
211-314	33	1.8
365-520	48	1.98
571-700	28.5	1.19
Polyethlene (F-0220S) + PPA		
243-373	20	1.0
417-547	thirty	1.5
590-700	23	1.25
Polyethylene (F-0220S) +PPK		
268-364	19	1.26
412-508	40	2.66
556-700	24	1.23
Polyethylene (F-0220S) +PPM		
202-338	9.0	0.45
383-519	thirty	1.5
564-700	50	2.5

mass loss rate (v_m), Δm — lost mass, mg; $\Delta\tau$ - time.

The physical and mechanical properties of polymer building materials modified with fire-resistant fillers have been analyzed, and the influence of fire-resistant polymer building materials based on polyethylene and polypropylene, modified with fillers of the PPA, PPK, and PPM brands, on the properties of polymers has been studied. These filters are introduced into PE in an amount of 10–30% wt. and their properties are compared with analogs. The physical and mechanical properties of PE have been studied. A comparative analysis of the physical and mechanical properties of polymer building materials based on fire-resistant fillers is presented in Table. 4. When introducing a fire resistance modifier of the PPA brand into the polymer composite, it was found that the impact resistance partially increased from 48 to 50 kJ/m2 compared to the original polyethylene, and the tensile strength decreased from 25 to 23 MPa, and the bending strength decreased from 20 to 19 MPa, while it was analyzed that the indicators are higher compared to analogs [10].

TABLE 4 COMPARATIVE ANALYSIS OF THE PHYSICAL AND MECHANICAL PROPERTIES OF POLYMER BUILDING MATERIALS OBTAINED BASED ON FIRE-RESISTANT ADDITIVES AND POLYETHYLENE

№	Fire resistant composite	Impact resistance, kJ/m ^{2}	Tensile strength, MPa	Bending strength, MPa
1	PE	48	25	20
2	PPA:PE	50	23	19
3	PPK:PE	49	24	19
4	PPM:PE	48	22	18

The results of scanning electron microscopy (SEM) and elemental analysis of polyethylene with fire-resistant fillers of the PPA, PPK, and PPM brands were studied. SEM analysis shows that fire-resistant additives of the PPA, PPK, and PPM brands are evenly distributed over the surface of the polyethylene, in turn, this increases the heat resistance of the polyethylene.

As a result, it was found that adding fire-resistant additives to polyethylene makes it possible to create a more heat-resistant barrier to reduce the intensity of combustion and thereby actively increase the safety of polyethylene (Fig. 3, 4).

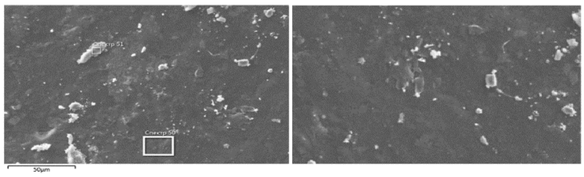

Fig. 3. SEM analysis of modified polyethylene with a fire-resistant additive of the PPA brand

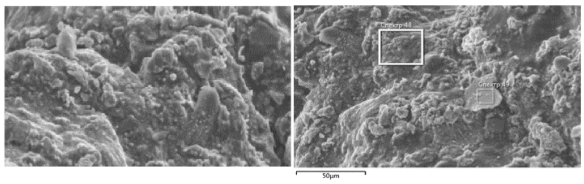

Fig. 4. SEM analysis of modified polyethylene with a fire-resistant additive of the PPK brand

From the obtained images it is clear that on the surface of polyethylene samples to which fire-resistant fillers are added, the filler molecules are distributed evenly. It has been revealed that when fire-resistant fillers of the PPA, PPK, and PPM brands are added to polyethylene, they retain their properties and fire resistance.

To ensure high bond strength between components, it is necessary to completely wet the metal compounds or fiber modifiers, which is achieved by applying a liquid binder to the surface of the fiber, and the energy of the fiber surface must be greater than the surface tension of the liquid matrix. Modification of polymers led to changes in their physical and mechanical properties.

TABLE 5 THE FLAMMABILITY CATEGORY OF VERTICALLY INSTALLED SAMPLES OF COMPOSITES OF MODIFIED PE WITH FIRE-RESISTANT ADDITIVES OF THE PPA, PPK, AND PPM BRANDS ACCORDING TO GOST – 28157

Composite compositions,%	Characteristics
100%, PE (polyethylene F-0220)	PV-2
90%PE + 10%PPA	PV-1
80%PE + 20%PPA	PV-0
70%PE + 30%PPA	PV-0
90%PE + 10%PPK	PV-0
80%PE + 20%PPK	PV-0
70%PE + 30%PPK	PV-0
90%PE + 10%PPM	PV-0
80%PE + 20%PPM	PV-0
70%PE + 30%PPM	PV-0
90% PE + 10% Fire retardant-EcoPirenes (analogue)	PV-1
80% PE + 20% Fire retardant-EcoPirenes (analogue)	PV-0
70% PE + 30% Fire retardant-EcoPirenes (analogue)	PV-0
90%PE + 10%Pirilax (analogue)	PV-1
80%PE + 20%Pirilax (analogue)	PV-0
70%PE + 30%Pirilax (analogue)	PV-0

Fire-resistant modifiers were obtained from composites of the PPA (fly ash, vermiculite, ammonium sulfate, polysulfide rubber), PPM (fly ash, vermiculite, silica, polysulfide rubber), PPM (fly ash, vermiculite, montmorillonite, polysulfide rubber) composites and studied the effect of fire-resistant fillers on polymer materials and mechanisms for increasing their fire resistance. Multifunctional fire-resistant modifiers of the PPA, PPK, and PPM brands were added to the polymer (polyethylene F -0220) up to 10 - 30%, and the most important physicochemical properties of this composite were studied. The experimental results on physical and mechanical properties and fire resistance are given in the table. 5 [11, 12, 13, 14, 15].

The physicochemical and fire-resistant properties of polymer materials with fire-resistant fillers PPA, PPK, and PPM were studied. It has been established that metal groups in the fillers during combustion form a coke layer on the surface of the polymer, which affects thermal conductivity and flame propagation.

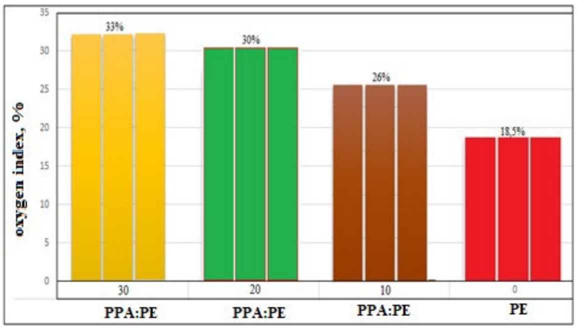

Fig. 5. Results of an analysis of the effect on the oxygen index of polymer materials modified with a fire-resistant additive of the PPA brand

As a result, this leads to a decrease in combustion duration in the polymer material. The introduction of the proposed additives significantly increases the oxygen index of polymer building materials, which is the main criterion for their non-flammability (Fig. 5–6) [5]. The parameters of the oxygen index according to GOST 12.1.044–18 also prove the effectiveness of the proposed additive, which has been studied to achieve the highest value when used in thermoplastics such as polyethylene [11].

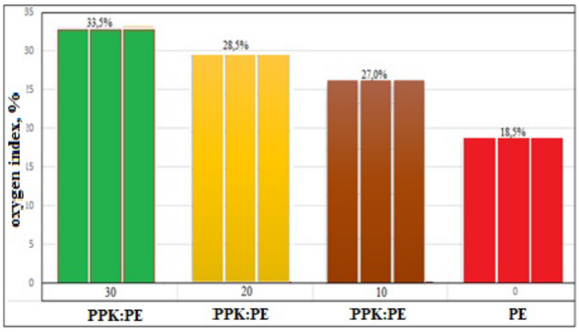

Fig. 6. Results of an analysis of the effect on the oxygen index of polymer materials modified with a fire-resistant additive of the PPK brand

Along with the creation of composites in optimal proportions from polyethylene and polypropylene with fire-resistant compositions based on polysulfide polymer binders, their physical and mechanical properties were also studied. The composition of additives has been fully studied using the most modern physicochemical methods (infrared, ultraviolet, elemental analysis, X-ray diffraction analysis, electron microscope, granulometric analysis, etc.), and their advantages have also been studied.

Fire-resistant compositions of the PPA, PPK, and PPM brands, proposed to increase the fire resistance of polymer compositions, have the same properties as their analogues, and, due to the use of domestic raw materials, they are determined to have higher economic efficiency.

IV. CONCLUSIONS

Based on the results obtained, it was determined that the introduction of additives into the fly ash fillers of the Shirin Thermal Power Plant and Uzmetkombinat JSC, as well as phosphogypsum waste from Maxam-Ammofos JSC, leads to an increase in the thermal stability of polymer materials. The main reason for this is explained by the fact that the composition of fly ash and phosphogypsum waste introduced into the polymer composite contains metal oxides, silicon oxide, and phosphorus compounds, which are resistant to temperatures and have fire-retardant properties.

During experimental tests, it was revealed that from the fire resistance properties of the proposed polymer-containing building materials modified with fire-resistant compositions of the PPA, PPK and PPM brands, consisting of polymer binders, fire-retardant additives and fillers, the oxygen index increased from 18.5 to 33.0%, while the weight loss during thermal oxidation was reduced from 97.5 to 73–75.5%, and the flammability level according to GOST 28157 was changed from PV-2 to PV-0..

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Examination of the variation of mta power when working with oil anamegators

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Abstract. **One of the main indicators of internal combustion engines, tractors and the machine-tractor unit as a whole it's the power. It can change in the process of operation and there comes a time when subsequent use is inadmissible or inexpedient. In such a state, it is appropriate to apply technology to improve this indicator and reduce the fuel or lubricant consumption.**

The power parameter of an agricultural power machine is essential to achieve high productivity with low operating costs with minimal environmental pollution. The monitoring of changing the power is generally carried out by equipment unbearable and unnecessary for the farmer. The possibility for determining the power of the tractor fitted with the working machine by means of a standard brake performance device is a suitable option for monitoring the technical condition of the machinery. In this way, timely detection of defects and prevention of serious consequences for the engine.

Worldwide, various technological options have been developed to improve the power of engines without the need for their disassembly. One of these technological options is the fitting of anamegators (additives) in very small quantities to the engine lubricant oil.

In this article is made the experiments to evaluating of the variation of the power performance of a diesel tractor engine treated with anamegators as part of a machine-tractor unit. The acceleration and speed of the machine-tractor unit is recorded through a specialized device ENERGOTEST SM4. On this basis of the experimental results obtained, the driving force and power of the tractor from the machine-tractor unit has been determined by theoretical relationships.

Keywords: anamegators, additives, power, engines, energotest

I. Introduction

The tractors are the main energy machines in agriculture. Together with various additional working machines, they make up the machine-tractor unit - MTA. The most energy-intensive operation is soil cultivation. Optimal selection of MTA parameters improves the economic efficiency of their use and reduces exhaust pollution. Increased consumption of plant products is forces more output to be produced. The stringent legislative measures worldwide is require optimization of the power characteristics and parameters of the engine of the MTA [1,2,3,4,5]. Apart from this, the poor technical condition of the engine will increase the farmer's expenditure on consumables.

The power of the machine-tractor unit can serve as an assessment of the efficiency of its operation. Models can be set up to estimate the aggregate tractive power requirement [6].

There are methods for the measurement of engine power from a single machine-tractor unit by means of a chassis dynamometer [7,8]. There are various dynamometer stands, which can be stationary and mobile [8,9]. However, the use of such stands is associated with a high cost for farmers in their purchase or transport of MTA to the place of measurement. In many cases, this cost is unacceptable and inappropriate.

For power measurement a methodology has been developed by measuring the GPS coordinates of the machine [10]. The method is successful, but in farmers without GPS it is not practical for using.

One of the ways to increase the performance of engines and reduce their maintenance costs is the application of oil additives [11,12].

Anamegator is a patent name class of substance (additive) added to the fuel in quantities less than 0.01% by mass and comprehensively improving the combustion process. The use of anamegators in the combustion process leads to a decrease in the increase in entropy due to the

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composition of the additive as a result of which the useful work is increased and the specific fuel consumption and toxicity of combustion products are reduced [12,13].

In this article, an attempt is made to evaluating the influence of anamegators to engine lubricant oils on the variation of MTA power indicators.

II. MATERIALS AND METHODS

The object of this experiments is an additive Gold Ozirol MP-8 oil. The amount of anamegator added is 7 ml/l oil [13]. The anamegator was added to the lubricant oil 5W40 to the New Holland T6/175 tractor (Figure 1) with a rated output of 129 kW [14,15].

The working machine mounted to the tractor is a deepener.

Fig. 1. General appearance of a machine-tractor unit

Fig. 2. General appearance of the measuring bench

The additive is filled into the tractor and it has started operation after 5 min work on idle speed. During a period of 10 motohours, the readings of a specialized device ENERGOTEST SM4 are reported (Figure 2) [16]. It is mounted on the windscreen of the tractor by vacuum, without the need for any other additional connection. One intermediate acceleration reading after 5 hours of operation was also made.

Fig. 3. General view of measurement area

Measurements are always carried out in the morning at the same time under the following weather conditions – air humidity between 50-60%, air temperature 18-220 C, wind speed 1-3 m/s, dry weather. The tractor has reached normal operating temperature and settles on a flat surface. In our case, this is a site at the base in the area of the village of Kostievo, Plovdiv region, Bulgaria (Fig. 3). One of the major rice producers in Bulgaria is located in the area and we used its technique.

The acceleration of the machine in free measurement mode is investigated. It is carried out in the second transport gear of the tractor. Accelerate to rated speed of the machine and read the acceleration value.

The driving force of the tractor is calculated on the basis of the measured acceleration of the machinery and the mass of the unit.

$$F = m_{MTA} . a_{MTA} \quad (1)$$

where m_{MTA} is the mass of unit;

a_{MTA} – acceleration of unit.

According to the developed methodology, power is defined as the dependence of the driving force of the tractor and the velocity of unit.

$$P = F . v \quad (2)$$

where v is velocity of unit.

III. RESULTS AND DISCUSSION

In defining the parameters, the following conventions have been adopted:

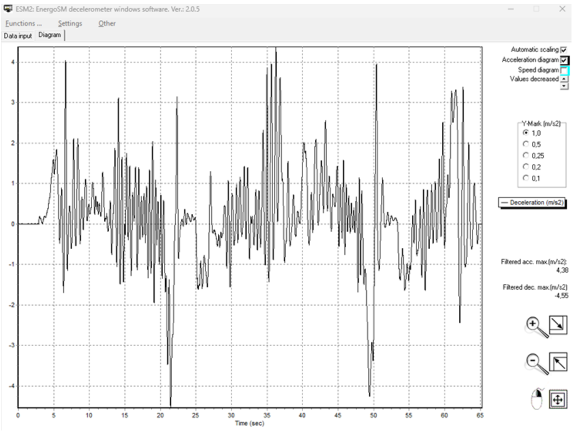

Fig. 4. Acceleration recording after 20 hours of MTA operation with anamegator

- Mass of the machine-tractor unit 7230 kg – measured;
- Gear ratio in second gear 2H (10) – 57,17 [17].

An authentic record of the measured acceleration after 20 hours of MTA operation when anamegator was added is shown in Fig. 4. The recording is illustrated by the ESM2 software of the ENERGOTEST SM4 device.

The results of the post-processing experiments carried out are summarized in Table 1 and graphically interpreted in Fig. 5, 6 and 7.

Observing the table and Fig. 5 it is noticed that the acceleration of the machine increases from 3,89 m/s2 in the initial stage of the experiment to 4,39 m/s2. This increase also shows an increase in the speed of the machine until the nominal speed of 4 km/h to 4,9 km/h is reached.

TABLE 1 VARIATION OF MEASUREMENT PARAMETERS

Work, hours	Acceleration a_{MTA} m/s^2	Velocity v, km/h	Driving force F, kN	Power, kW
0	3,89	4	28,12	112,5
5	3,92	4	28,34	113,36
10	3,95	4,4	28,56	128,52
20	4,38	4,7	31,67	148,85
30	4,39	4,9	31,74	155,23
40	4,38	4,8	31,67	152,02
50	4,39	4,9	31,74	155,53

The acceleration changes in the period 0-10 hours of operation of the MTA, because in this period the accumulation of the additive in the bearing and friction units of the engine occurs. As a result of the accumulation, friction in the nodes is reduced and the lubricating environment is improved.

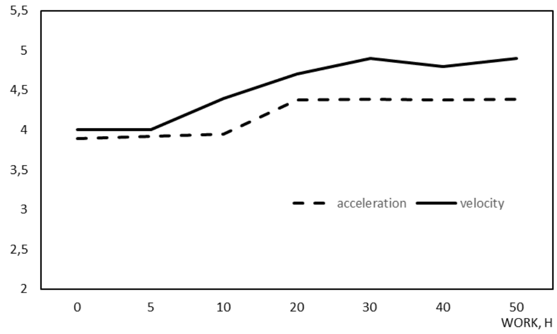

Fig. 5. Variation of MTA acceleration and speed when using oil anamegators

Reduced friction probably leads to an increase in the mechanical efficiency of the engine and hence affects the parameters of the entire unit. During the period 10-20 hours of MTA operation, there is a stabilization of the processes in the engine and an almost constant change in the acceleration of the unit.

The same can be applied to the MTA speed. The difference, however, is that here the increase in speed until the nominal engine power is reached increases smoothly to about 4,7 km/h or again 20 hours of operation of the unit. This modification starts from the fifth hour of operation of the MTA with the entry of the anamegator into the engine lubrication system and the reduction of friction in the units. As a result, the speed of the aggregate increases. This change in speed is more violent than in the change in acceleration due to the specifics of these parameters.

Looking at Fig. 6 the variation of the driving force of the tractor changes marginally in the period 0-10 hours of MTA operation. After the entry of the anamegator into the friction elements of the engine and improvement of the lubricating medium, stabilization of the driving force of the unit after 20 hours of operation is observed. The period of dynamic increase in driving force is 10-20 hours of MTA operation. The variation of this force is within 3,62 kN. The variation in driving force throughout the test period was within 11,4 %.

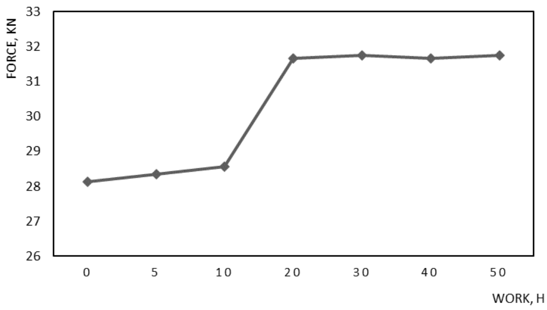

Fig. 6. Variation of MTA driving force when using oil anamegators

The variation in MTA power when operating with anamegators varies within 27,7% for a running engine with a range of approximately 9000 hours of operation. The increase in power based on a new catalogue data engine is within 20%.

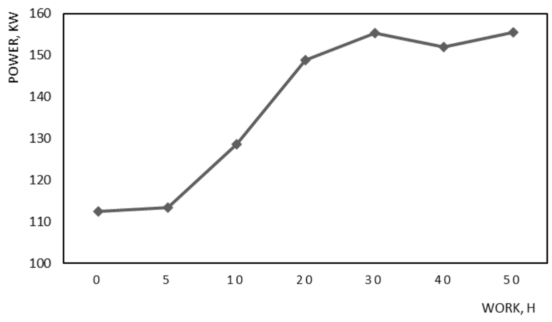

Fig. 7. Variation of MTA power when working with oil anamegators

Reduced friction probably leads to an increase in the mechanical efficiency of the engine and hence affects the parameters of the entire unit. During the period 10-20 hours of MTA operation, there is a stabilization of the processes in the engine and an almost constant change in the acceleration of the unit.

The power variation starts after a period of five hours MTA operation and ends after 20 hours of MTA operation. The actual power variation is from 113,36 kW to 155,53 kW.

IV. Conclusions

The variation of MTA power when working with oil anamegators is determined. The increase in power is within 20% of a new MTA. This increase takes place in the period of 10-20 hours of MTA work with the anamegator and is maintained during subsequent operation of the MTA. The increase in acceleration is within 11.4%, which at equal mass of MTA leads to an increase in driving force. The increase in the speed of MTA is 22.5% until the nominal engine speed is reached or from 4 km/h to 4.9 km/h.

The anamegators added to the oils can be used to preserve or increase the tractive properties of the MTA without the need for additional adjustment. They can significantly reduce the cost of farmers to obtain production.

The ease of use of ENERGOTEST SM4 makes it suitable for determining the current state of the machine and can be used in the assembly of MTA.

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Social Work Students' Attitudes Towards the Relevance of Their Studies

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Abstract. Social work education is the cornerstone of preparing students to address complex social problems with professional competence and ethical sensitivity. As the field of social work develops, it is imperative to understand social work students' attitudes towards the relevance of their studies to real world practice. Aim of the research - to explore social work students' attitudes towards the relevance of their academic studies to real-world social work practice.

Research subject - Social work students' attitudes towards the relevance of their studies. Research objectives: 1) identify the relevance of the study; 2) to explore how social work students perceive the relevance of their studies to their future professional practice. The study is based on a quantitative methodology, using a survey questionnaire to collect data from 97 students enrolled in a bachelor's degree programme in social work at a Lithuanian higher education institution. The study used descriptive statistics, correlation analysis and Kruskal-Wallis test to analyse the data. The results showed that students found the study process relevant and meaningful for their personal and professional development. Students generally appreciated the opportunity to apply their knowledge in real-life situations to improve their professional skills. However, state-funded students rated the study process as more relevant than non-state-funded students. The paper concludes that programmes can be attractive to social work students if they are designed and delivered in a way that promotes students' interest in their studies, the application of theory to practice, and support from lecturers and peers. This study contributes to the literature on social work education in higher education by providing insights into social work students' perceptions of the relevance of the study process.

Keywords: attitudes, learning process, support, relevance, social work, study.

I. Introduction

The landscape of social work education is constantly evolving to meet the dynamic needs of society. As such, social work students' attitudes towards the relevance of their studies are becoming a focus of academic inquiry. This research explores the complex relationship between academic pursuits and future professional practice and aims to uncover the underlying perceptions that shape students' educational experiences.

The research problem focuses on uncovering social work students' attitudes towards the perceived relevance of their learning process. It is hypothesised that social work students have positive attitudes towards their learning process, an assumption that will be explored in depth through this research.

The aim of the research is to explore social work students' attitudes towards the relevance of their academic studies to real world social work practice.

Research objectives:

1. To determine the relevance of study.
2. To explore how social work students perceive the relevance of their studies to their future professional practice.

Drawing on a rich tapestry of literature, this study draws on the National Association of Social Workers [1], who emphasise the importance of social work education providing essential knowledge, skills and values through social work education, researchers who assert that social work education must be a harmonious blend of theory and practice to produce skilled professionals, a curriculum that equips students with evidence-based approaches to critically analyse and improve professional practice [2], [3].

This study will contribute to the existing literature by providing insights into how social work education can be further tailored to increase its relevance and effectiveness in preparing students for the challenges of professional practice.

II. MATERIALS AND METHODS

Literature review.

The integration of academic study with professional practice is a central element in the education of social work students. Social work education aims to equip students with

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the necessary competencies for effective practice by combining theoretical knowledge with practical application, thus developing competent professionals [2]. Social work students are equipped with the necessary tools to critically analyse and improve their professional practice through evidence-based approaches [3]. Social work education equips students for professional practice by providing essential knowledge, skills, and values [1]. The relevance of coursework to practice is consistently emphasised, fostering a learning environment where students can see the direct link between what they are learning and the impact it has on their professional skills [4]. As they progress through their studies, students often gravitate towards subjects that resonate with their personal and professional interests. This intrinsic motivation not only enriches their academic experience, but also ensures that the knowledge they acquire is relevant and transferable to their future roles in social work [5].

The relevance of academic study to future professional practice is a critical concern for social work students. Research highlights the traditional focus on social work education and the increasing interest in social work education across higher education. Researchers in a longitudinal study of social work students, enriched with national registry data, found that classroom preparation positively influenced knowledge and competence, while the quality of placements indirectly influenced learning outcomes through programme coherence [6]. Research suggests that students' perceptions of the relevance of their coursework are significantly related to their academic engagement and motivation [7]. Furthermore, the integration of practice skills into the curriculum is considered essential to the preparation of competent social workers [8], [9].

However, challenges remain in bridging the gap between academic learning and practice in the field. Some scholars argue for a more practical approach to social work education to better prepare students for the realities of the profession [10], [11], [12].

A growing body of research suggests that social work students generally perceive their education as relevant and valuable for their future careers. For example, one study found that students who participated in fieldwork experiences reported a greater appreciation for the practical application of their coursework [13].

In addition, integrating contemporary issues such as digital literacy, cultural competence and evidence-based practice into social work curricula has been shown to increase students' perceptions of relevance [14], [15], [16].

In addition, research highlights the central role that lecturers play in shaping students' attitudes towards their education [17]. Lecturers' mentoring and teaching styles can have a significant impact on students' perceptions of the relevance of their studies [18], [19], [24].

Research also contributes to this discourse by demonstrating that field placements, particularly those that involve collaboration with peers, professionals and clients, are instrumental in enhancing the integration of theory into practice [20], [25].

In essence, the education of social work students in higher education is not an isolated academic endeavour, but a comprehensive preparation for their impending professional responsibilities. The congruence between academic content and practical relevance is what makes their studies invaluable, shaping competent practitioners who are well versed in the complexities of social work [21], [22], [26].

In conclusion, while social work students generally view their education as relevant to their future roles as practitioners, continued efforts are needed to align academic curricula with the dynamic demands of the social work profession.

Survey instrument.

Understanding social work students' perspectives on the relevance of their education is crucial for curriculum development and for ensuring that future professionals are well prepared for the challenges they will face. In Lithuania, a study was conducted to explore these attitudes among students enrolled in different social work programmes.

In order to assess the attitudes of social work students towards the relevance of their academic studies, this study adopted a quantitative research methodology, using an electronic survey as the primary data collection instrument. The survey was designed to capture students' perceptions of the extent to which their coursework matched their interests, contributed to their professional practice and was integrated with their current professional activities.

The survey instrument was derived from the established Constructivist On-Line Learning Environment Survey (COLLES) to ensure its suitability for the educational research context. Participants were presented with a series of statements that encouraged them to reflect on different dimensions of their learning experience, including the level of engagement, the perceived importance of the content learned for professional practice, and the practical applicability of their studies (Fig. 1).

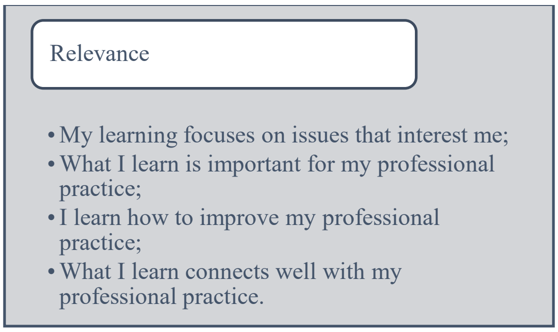

Fig. 1. Statements of relevance.

The responses collected from these electronic surveys provide valuable quantitative data that allows the analysis of student attitudes and the identification of trends. This information is crucial to understanding how students perceive the relevance of their studies to their future professional roles in social work.

Whilst maintaining rigorous academic standards, this methodology facilitates a thorough examination of the educational experiences of social work students. The findings from this research are intended to make a meaningful contribution to curriculum development in social work education programmes.

Data analysis was carried out using IBM SPSS Statistics version 23, with the reliability of the test items assessed using Cronbach's alpha coefficient calculations. In accordance with academic standards, a Cronbach's alpha value of 0.7 or higher was considered acceptable, indicating satisfactory internal consistency between survey items.

The study adhered to the fundamental principles of the European Code of Conduct for Research Ethics (ALLEA, 2019) [23].

Sample.

The study included 97 participants, both full-time and part-time students, who were studying their social work degree through blended learning methods. This diverse group included individuals from non-traditional, daytime and distance learning programmes, providing a wide range of student experiences and insights.

The study was conducted in January 2023. The survey data was analysed by funding, mode of study and course.

III. RESULTS AND DISCUSSION

Results.

The study presents the results of a survey of social work students' perceptions of their learning. The survey asked students to rate the extent to which they agreed with four statements about the relevance of the learning process on a five-point scale. The data presented in Figures 2-5 appear to be from a survey assessing the relevance and impact of learning activities on professional practice.

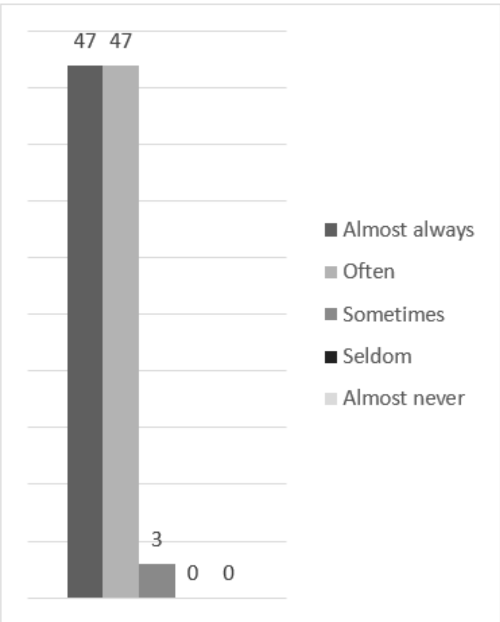

Fig. 2. Distribution of responses to the statement "My Learning Focuses on Issues That Interest Me".

The data presented suggest a strong positive correlation between the level of interest in the subject matter and the frequency of focus on learning (see Figure 2). With 94% of respondents indicating that they focus on topics of interest 'almost always' or 'often', it can be concluded that personal interest is a significant factor in the learning engagement of the study participants. This finding is particularly relevant for professional social workers, as it implies that fostering a genuine interest in their field could enhance their learning and, by extension, their competence.

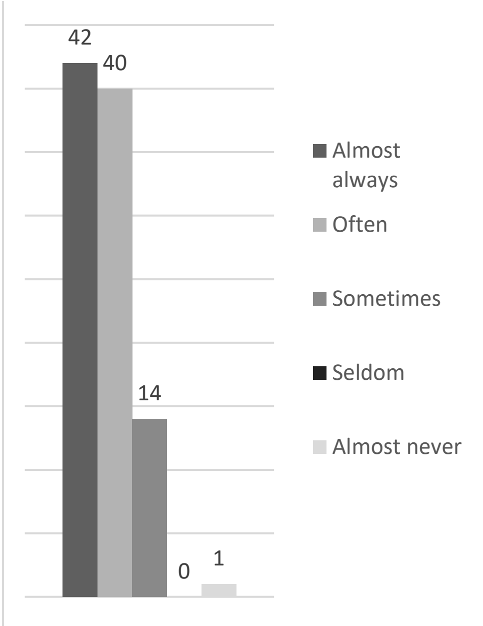

Fig. 3. Distribution of responses to the statement 'What I learn is important for my professional practice'.

The data presented suggest that a significant majority of respondents believe that what they learn is important for their professional practice, with 82 out of 97 respondents indicating that it is 'almost always' or 'often' important (see Figure 3). This implies a strong perceived relevance of the educational content to their social work practice. In summary, this study would highlight the high value placed on educational content by future social workers, suggesting that the curriculum is well aligned with professional needs.

In conclusion, the study shows that the current educational provision is considered by most participants to be highly relevant to their future careers. This relevance is essential for the development of the competencies required for effective professional practice in social work.

The data presented suggest that a significant majority of individuals feel that they frequently learn how to improve their professional practice, with 77 out of 97 respondents indicating that they do so 'almost always' or 'often' (see Figure 4). This indicates a strong commitment to continuous professional development among the participants. The study seems to underline the importance of continuous learning and adaptation in professional practice, which is particularly relevant for social workers working in dynamic and often challenging environments.

The summary of the study would highlight that the majority of participants are proactive in seeking opportunities to enhance their skills and knowledge. This proactive approach is crucial for social workers who need to remain adept at navigating complex social situations and adapting to new challenges and information.

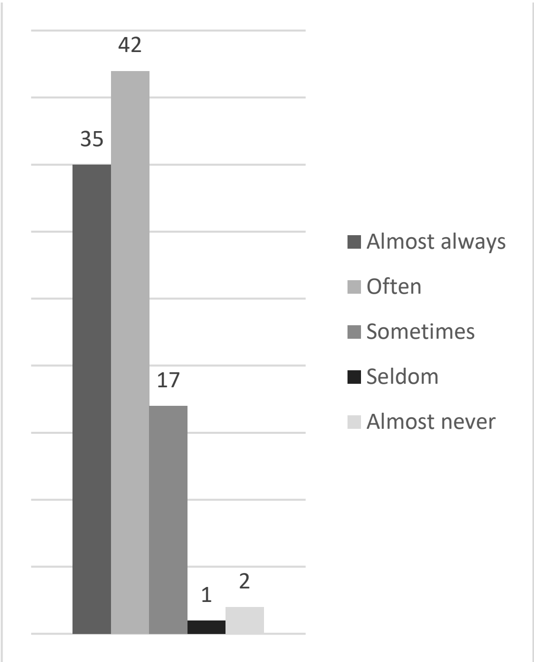

Fig. 4. Distribution of responses to the statement "I learn how to improve my professional practice".

One conclusion that can be drawn from the study is that there is a positive culture of self-improvement and skill enhancement among the professionals surveyed. This culture is likely to contribute to more effective and competent social work practice, ultimately leading to better outcomes for clients.

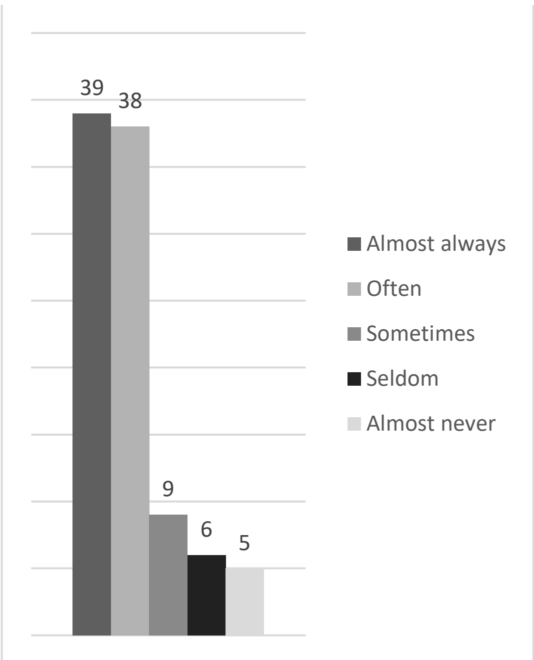

Fig. 5. Distribution of responses to the statement "What i learn connects well with my professional practice".

The data presented suggest that a significant majority of respondents feel that their learning is highly relevant to their professional practice, with 77 out of 97 respondents indicating that it is 'almost always' or 'often' well connected (see Figure 5). This suggests a strong link between educational content and practice in social work. However, a minority reported a less frequent link, which may indicate areas where curriculum development could be focused to improve practice relevance.

In summary, the study suggests that the educational experiences of most participants are effectively preparing them for their professional roles as social workers. The high rate of positive responses reflects well on the educational programme's ability to link theory and practice.

The conclusion that can be drawn from this study is that the competencies required of professional social workers are generally being met by current educational provision. This is evidenced by the high number of respondents who see a clear link between what they are learning and their professional practice.

A significant majority of respondents report that their learning is often focused on issues of personal interest and is important for their professional practice. In addition, a significant number of participants report that their learning activities effectively contribute to the improvement of their professional practice and are well connected to it.

Descriptive statistics of the statements.

Table 1 shows the descriptive statistics of four statements about the relevance of the study process in relation to learners' perceptions of their learning. The statements are rated on a 5-point Likert scale, where 1 means strongly disagree and 5 means strongly agree. The table shows the minimum, maximum, mean, standard deviation, skewness, and kurtosis of each statement.

TABLE 1: DESCRIPTIVE STATISTICS FOR STATEMENTS ABOUT RELEVANCE OF SOCIAL WORK STUDIES (N=97)

	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
My learning focuses on issues that interest me.	3	5	4,45	,559	-,361	,245	-,880	,485
What I learn is important for my professional practice.	1	5	4,26	,781	-1,026	,245	1,690	,485
I learn how to improve my professional practice.	1	5	4,10	,872	-1,070	,245	1,756	,485
What I learn connects well with my professional practice.	1	5	4,03	1,104	-1,297	,245	1,155	,485

Analysis of social work students' attitudes towards the relevance of their studies reveals a generally positive outlook. The mean scores, all above 4, indicate agreement or strong agreement with the statements presented. In particular, the statement 'My learning focuses on topics that interest me' received the highest mean (4.45) and the lowest standard deviation (0.559), suggesting a consistent and enthusiastic response reflecting students' high level of interest and motivation in their learning topics.

In contrast, 'What I am learning is well connected to my professional practice' received the lowest mean (4.03) and the highest standard deviation (1.104), suggesting varied responses and a perceived lower relevance of course content to professional practice among students. This divergence suggests an area for curriculum development to improve practice relevance.

The negative skewness values for all statements indicate a rightward shift in responses, with more students agreeing than disagreeing - a trend that was most pronounced in responses to the statement relating to professional practice, which had the most negative skewness value (-1.297). This asymmetry suggests a subset of students who may not find their studies applicable to their professional roles.

When these findings are compared with similar studies, such as that of [20], the effectiveness of field education in social work education is observed. However, there remains a call for better alignment of research with professional practice, a sentiment echoed in the research by [10] which highlighted a gap between research and practice in social work.

The Kruskal-Wallis test was used to compare the responses of funded and unfunded students to four statements (see Table 2) relating to their learning and professional practice.

TABLE 2 INFERENCE STATISTICS (KRUSKAL-WALLIS) FOR STATEMENTS ABOUT THE RELEVANCE OF SOCIAL WORK STUDY BY STATE FUNDING (N = 97)

	My learning focuses on issues that interest me	What I learn is important for my professional practice	I learn how to improve my professional practice	What I learn connects well with my professional practice
Chi-Square	1,399	5,920	2,564	,584
df	1	1	1	1
Asymp. Sig.	,237	,015	,109	,445

Analysis of students' attitudes towards the relevance of their social work studies reveals notable differences, particularly in the perceived importance of their education for professional practice. There is a significant difference between funded and unfunded students, as shown in Table 2. The chi-squared value is 5.920 with 1 degree of freedom and an asymptotic significance of 0.015. This value is below the alpha level of 0.05, which allows us to reject the null hypothesis that there is no difference between the groups on this statement.

Looking more closely at the Ranks section, we can see that the median rank of state-funded students is 55.20, which is higher than the median rank of non-state-funded students, which is 42.40. This suggests greater agreement with the statement among state-funded students, a finding confirmed by the Mann-Whitney criterion, which deems the difference statistically significant ($U = 865.000$, $Z = -2.433$, $p = 0.015$, $r = -0.247$). However, the effect size (r) is small, indicating that the difference, although statistically significant, may not be substantial in practical scenarios.

Conversely, no significant differences were found between funded and non-funded students on the other three statements: "My learning focuses on topics that interest me", "I learn how to improve my professional practice" and "What I learn is well connected to my professional practice". The corresponding chi-squared values are 1.399, 2.564 and 0.584 with asymptotic significances of 0.237, 0.109 and 0.445 - all exceeding the alpha level of 0.05 - so we maintain the null hypothesis for these statements.

In summary, Table 2 shows that state-funded students are more likely than non-state-funded students to believe that what they are learning is important for their professional practice, but there are no differences between the groups in other aspects of their learning and professional practice. Comparison of these findings with similar studies reveals a consistent pattern; for example, [27] found that financial support mechanisms can influence students' perceptions of the relevance of their educational experience to their future careers.

Table 3 shows the correlations between relevance and reflective thinking, based on a survey of 97 participants.

TABLE 3 SPEARMAN'S CORRELATION BETWEEN THE RELEVANCE OF THE SOCIAL WORK STUDY PROCESS AND REFLECTIVE THINKING STATEMENTS (N = 97)

Statements about the relevance of the study process		**Statement of reflective thinking**
		I think critically about how I learn
My learning focuses on issues that interest me.	Correlation Coefficient	0,253*
	Sig. (2-tailed)	0,012
	N	97
What I learn is important for my professional practice.	Correlation Coefficient	0,277**
	Sig. (2-tailed)	0,006
	N	97
I learn how to improve my professional practice.	Correlation Coefficient	0,323**
	Sig. (2-tailed)	0,001
	N	97

Analysis of social work students' attitudes towards the relevance of their studies reveals a positive correlation between the learning process and reflective thinking (see Table 3). The data indicate that students who critically engage with their learning material, focusing on topics of personal interest, show a significant correlation ($r = .253$, $p = .012$, $N = 97$), suggesting that interest-driven learning is associated with deeper engagement and reflection.

Furthermore, the importance of what students learn in relation to their professional practice also shows a positive correlation ($r = .277$, $p = .006$, $N = 97$), suggesting that relevance to professional practice is a key factor in students' perceptions of the value of their education. This is further supported by the strong correlation between learning to improve professional practice and reflective thinking ($r = .323$, $p = .001$, $N = 97$), highlighting the importance of practical application in educational settings.

These findings are consistent with those of [28], who focused on reflective learning from both academic and practice in social work. Similarly, [29] reported that practical application of learned skills was highly valued by social work students, reinforcing the importance of tailoring educational content to professional needs.

Table 4 below shows the Spearman's correlation between the relevance of the study process and the statements about the interpretation of the study process, based on a survey of 97 participants.

Table 4 SPEARMAN'S CORRELATION BETWEEN STUDY PROCESS RELEVANCE AND STUDY PROCESS INTERPRETATION STATEMENTS (N = 97)

		I make good sense of other learners' messages	Other learners make good sense of my messages	I make good sense of the tutor's messages	The tutor makes good sense of my messages
My learning focuses on issues that interest me	Correlation Coefficient	0,333**	0,397**	0,370**	0,432**
	Sig. (2-tailed)	0,001	0,000	0,000	0,000
	N	97	97	97	97
What I learn is important for my professional practice	Correlation Coefficient	0,274**	0,279**	0,337**	0,341**
	Sig. (2-tailed)	0,007	0,006	0,001	0,001
	N	97	97	97	97
**. Correlation is significant at the 0.01 level (2-tailed).					

The Spearman correlation analysis presented in Table 4 shows a positive relationship between students' interest in the subject matter and their ability to make sense of messages from peers and tutors. Specifically, the correlation coefficients range from 0.274 to 0.432, all of which are significant at the 0.01 level, suggesting that as students find the learning material more relevant to their interests and professional practice, their understanding of communication within the learning environment improves.

This finding is consistent with the work of [30], who found that engagement with course content significantly improved students' academic performance and interaction quality. Similarly, [31] reported that the learning environment of course material is a strong predictor of student satisfaction and perceived learning.

In conclusion, the current study supports the existing literature, which highlights the importance of aligning educational content with students' career aspirations and interests to foster a more effective learning experience.

Table 5 shows the correlations between different statements about the relevance and interactivity of the study process.

Table 5 SPEARMAN'S CORRELATION BETWEEN STATEMENTS ABOUT THE RELEVANCE AND INTERACTIVITY OF THE STUDY PROCESS (N = 97)

		I explain my ideas to other learners	I ask other learners to explain their ideas	Other learners ask me to explain my ideas
I learn how to improve my professional practice	Correlation Coefficient	0,329**	0,308**	0,268**
	Sig. (2-tailed)	0,001	0,002	0,008
	N	97	97	97
**. Correlation is significant at the 0.01 level (2-tailed).				

The analysis presented in Table 5 indicates a positive relationship between the relevance of the learning process and the interactivity of the learning process among social work students. Specifically, the Spearman's correlation coefficients (.329**, .308**, .268**) suggest a moderate relationship between students' learning to improve their professional practice and their engagement in explaining ideas to others, asking for explanations, and being asked to explain ideas. These results are significant at the 0.01 level (2-tailed), indicating a reliable relationship between these variables.

Comparatively, these findings are consistent with those of [32] who reported similar positive correlations between the impact of interactive teaching methods on student learning outcomes at university level. Similarly, [33] found that increasing students' involvement in their learning processes and building relationships with students through teaching sessions can facilitate improvements in students' motivation and academic success.

The study shows moderate positive and significant correlations between learners' explanations of their ideas and their learning outcomes in terms of improving professional practice.

Table 6 shows the correlations between the relevance study process and tutor support in a study.

TABLE 6. SPEARMAN'S CORRELATION BETWEEN STUDY PROCESS RELEVANCE AND TUTOR SUPPORT STATEMENTS (N = 97)

		The tutor stimulates my thinking	The tutor encourages me to participate	The tutor models good discourse	The tutor models critical self-reflection
My learning focuses on issues that interest me	Correlation Coefficient	,265**	,019	,305**	,329**
	Sig. (2-tailed)	,009	,855	,002	,001
	N	97	97	97	97
What I learn is important for my professional practice	Correlation Coefficient	,528**	,383**	,423**	,345**
	Sig. (2-tailed)	,000	,000	,000	,001
	N	97	97	97	97
I learn how to improve my professional practice	Correlation Coefficient	,421**	,338**	,407**	,316**
	Sig. (2-tailed)	,000	,001	,000	,002
	N	97	97	97	97
What I learn connects well with my professional practice	Correlation Coefficient	,411**	,219*	,370**	,227*
	Sig. (2-tailed)	,000	,031	,000	,025
	N	97	97	97	97
**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).					

The analysis of Spearman's correlations presented in Table 6 shows a varying degree of association between the relevance of the learning process and the supportive statements made by the tutors. In particular, 'My learning focuses on topics that interest me' shows a significant positive correlation with 'The tutor stimulates my thinking' (r=.265, p=.009) and 'The tutor models good discourse' (r=.305, p=.002), suggesting that when tutors stimulate students' thinking and model effective discourse, students find the learning material more relevant to their interests.

Furthermore, the strongest correlation is observed in 'What I am learning is important for my professional practice', specifically with 'The tutor encourages me to participate' (r=.528, p<.001), suggesting that tutor encouragement has a significant impact on students' perceptions of the importance of their learning for professional practice. This finding is consistent with the work of [34] who explored how teachers can encourage student engagement in the classroom.

In terms of improving professional practice, 'I am learning how to improve my professional practice' correlates strongly with 'The tutor models critical self-reflection' (r=.421, p<.001).This echoes the findings of [35] that critical reflection on the critical incident studied was effective in improving social work practice, and that additional critical analysis of the wider issues raised by the research findings may enhance social work as a values-based, client-centred and social change profession.

Finally, 'What I learn is well connected to my professional practice' shows a moderate correlation with 'The tutor model good discourse' (r=.370, p<.001), supporting the notion that good discourse modelling by tutors helps to bridge theoretical knowledge with practical application, as discussed by [36].

Table 7 below shows the results of a correlation analysis between two statements related to the relevance of the study process and two statements related to peer support.

TABLE 7. SPEARMAN'S CORRELATION BETWEEN THE RELEVANCE OF THE STUDY PROCESS AND THE STUDY PROCESS PEER SUPPORT STATEMENTS (N = 97)

		Other learners encourage my participation	Other learners empathise with my struggle to learn
My learning focuses on issues that interest me	Correlation Coefficient	,164	,294**
	Sig. (2-tailed)	,109	,003
	N	97	97
I learn how to improve my professional practice	Correlation Coefficient	,266**	,051
	Sig. (2-tailed)	,009	,623
	N	97	97
**. Correlation is significant at the 0.01 level (2-tailed).			

The analysis of Spearman's correlation presented in Table 7 indicates a positive relationship between the relevance of the study process and the statements about peer support among social work students. Specifically, when students focus on topics that interest them, there is a significant correlation with the encouragement they receive from other students ($r = .164$, $p = .109$), although this result is not statistically significant. However, there is a stronger and significant correlation with the empathy they perceive from peers in their learning difficulties ($r = .294$, $p = .003$).

Furthermore, the data shows a significant correlation between improving professional practice through learning and peer support ($r = .266$, $p = .009$), while no significant correlation is found with peer empathy ($r = .051$, $p = .623$). These findings suggest that peer support plays a role in enhancing the educational experience, particularly through encouragement and shared interest in learning topics.

Comparing these findings with similar studies such as [37] and [38], we find congruence in the positive impact of peer support on student engagement and learning outcomes. [37] highlight that peer and teacher interaction, social presence and social media use have a positive impact on active collaborative learning and student engagement, thereby influencing their learning outcomes. While [38] emphasise the contribution of empathy to a supportive educational atmosphere.

Discussion.

The study confirmed the hypothesis that social work students have positive attitudes towards their learning process. Students showed high levels of interest, motivation, and relevance in their learning and high levels of application of their learning to their professional practice.

The study showed that social work study programmes are effective in providing students with learning opportunities that meet their interests and needs as professionals. The programmes also help students to improve and enhance their professional practice by linking theory and practice.

The study showed that learners have different patterns of response to different statements, with some statements having more asymmetric and peaked distributions than others. This suggests that there may be some variability in how learners perceive and experience their learning process, depending on their personal and contextual factors.

The study suggests that state funding may have an impact on how students perceive the relevance of their learning to their profession, but not on how they engage with their learning or how they apply it to their practice. This implies that state funding may influence learners' expectations and satisfaction with their learning, but not their actual learning outcomes or behaviours.

The study highlighted that reflective thinking is an important factor in increasing the relevance of learning to professional practice. Students who engaged in reflective thinking reported higher levels of relevance and application of their learning than those who did not. This suggests that learning should develop learners' reflective thinking skills to help them make meaningful connections between their learning and their professional practice.

The study showed that learning should increase learners' interest and relevance in order to improve their communication and understanding. Students who reported higher levels of interest and relevance also reported higher levels of communication and understanding with other learners and tutors. This suggests that learning should provide opportunities for learners to interact and collaborate with others and to receive feedback and guidance from tutors.

The study showed that explaining ideas to other learners is an important aspect of the learning process that improves learners' professional practice. Students who explained their ideas to other learners reported higher levels of application of their learning than those who did not. This suggests that learning should encourage learners to share and discuss their ideas with others and to learn from the perspectives and experiences of others.

The study showed that tutor support was an important factor in increasing the relevance of learning. Students who received more tutor support reported higher levels of relevance and application of their learning than those who received less tutor support. This suggests that learners should be provided with adequate and timely tutor support and that their progress and performance should be monitored and assessed.

Study limitations

The study does not provide information on the demographic or professional background of the participants, which could influence the interpretation of the results. The survey also appears to lack a neutral option, potentially forcing participants to choose a more positive or negative response than they might otherwise. In addition, the data do not indicate the specific nature or context of the learning activities, which limits the ability to generalise the findings to wider populations.

The study has some limitations that should be acknowledged. First, the sample size was relatively small and may not be representative of the population of social work students in online courses. Second, the data collection method was based on self-report questionnaires, which may be subject to bias and social desirability effects. Thirdly, the study did not measure students' actual learning outcomes or behaviours, but only their attitudes and perceptions. Therefore, further research is needed to validate and extend the findings of this study and to explore the causal relationships between the variables.

In conclusion, this study contributes to the literature on learning in social work education by providing insights into social work students' attitudes towards their learning process. The study suggests that learning can be an effective and engaging way of delivering social work education if it is designed and delivered in a way that promotes learner interest, motivation, relevance, communication, understanding, reflection, application and support from tutors and peers.

CONCLUSIONS

- The study suggests that participants' learning experiences are highly relevant to their professional interests and needs. The strong positive responses indicate that the learning is perceived as relevant and useful, which can enhance motivation and the application of new knowledge in professional settings.
- Learning experiences with professional interests and needs are strongly positive, suggesting that relevance in training is key to increasing motivation and practical application in professional contexts.
- The impact of government funding on perceptions of educational relevance is notable, but does not directly correlate with student engagement or practical application of learned knowledge.
- The development of reflective thinking skills is crucial for bridging the gap between academic learning and social work practice, indicating a need for curricula that foster such skills.
- An engaging learning environment plays a significant role in improving communication and understanding, indicating the importance of interactive and stimulating educational environments.
- Collaborative environments that encourage interaction and the exchange of ideas are fundamental to the learning process, emphasising the value of teamwork and communication in educational strategies.
- Peer-to-peer teaching methods are shown to be effective in reinforcing the application of knowledge in professional settings, highlighting the benefits of peer learning models.
- The need for effective tutor support is clear, as it makes learning more relevant and applicable; this underlines the importance of tutor accessibility and responsiveness.
- The preliminary nature of the study's findings, due to the small sample size and the potential for self-report bias, calls for further research to confirm and extend these findings. This suggests that a broader investigation could provide more definitive insights into the educational strategies discussed.

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Assessment of Factors in the Performance of the Manufacturing Industry

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Abstract. **Any success or failure of the manufacturing industry, according to scientists, indicates the processes that are going to occur in the entire national economy in the future as well as the overall current state of the national economy. In Latvia, small and medium enterprises engaged in the manufacturing industry make up the largest proportion of market sector economically active statistical units, and the value added generated by small and medium manufacturing enterprises represents the largest proportion of total value added generated by the manufacturing industry. The research aims to identify and assess factors in the performance and development of the manufacturing industry and small and medium manufacturing enterprises in Latvia. The research employed general scientific research methods: monographic, descriptive and graphic as well as analysis and synthesis. The Cobb-Douglas model was used to assess the situation in the manufacturing industry and identify the effects of factors on economic growth. The research identified and assessed the factors in the performance and development of the manufacturing industry and small and medium manufacturing enterprises in Latvia.**
Keywords: assessment, manufacturing industry, productivity, small and medium enterprises

I. INTRODUCTION

Manufacturing is an industry that manufactures finished products from raw materials and other inputs [1], [2], typically represents a global network that uses local and global (material and energy) resources [3], [4] and is one of the most resource-intensive (e.g. material, energy and water) industries with economies of scale, lower labour costs and larger employment potential. The manufacturing industry (Section C), according to the Statistical classification of economic

activities in the European Community (NACE Rev. 2), includes 24 divisions (divisions10-33).

Increased attention is paid to the manufacturing industry because, according to scientists, this industry indicates the overall state of the economy with sufficient precision, and any success or failure of the manufacturing industry indicates the processes that are going to occur in the entire economy in the future [5], [6].

Nowadays manufacturing enterprises face an increasingly complex environment, affected by a lack of natural resources, legal regulation and a growing consumer demand for sustainable products [7], as well as complex global challenges, e.g. increasing competition, volatile commodity prices, increasing consumer expectations and unstable economic conditions [8], [9]. Manufacturing enterprises constantly reassess and modify their competition strategies as well as adapt their supply chains and technologies to increase their performance, and compete and survive in the long term [8].

The international scientific literature uses the term performance to describe an enterprise's operational results, which is widely used in all areas of management science to explain phenomena, diagnose causes, identify causal associations, as well as make forecasts and comparisons [10]. Performance is the result of achieving an enterprise's goals, a measure of success [11], an ability to present results in certain dimensions relative to the target [12], a way to identify the progress, an ability to successfully implement future actions to achieve goals and objectives [13]. Performance could be viewed as a multifaceted phenomenon that involves various perspectives (e.g. shareholder and employee), periods (e.g. long- and short-term) and criteria (e.g. market share and profit) [14].

The terms performance management, performance measurement and performance assessment could be distinguished in relation to performance [15]. An effective performance measurement system aligned with the characteristics of the external environment could help a manager to make better decisions to increase the

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enterprise's performance [16], [17]. The field of performance measurement has evolved from measurement, i.e. what to measure, how to measure and how to report the results, to management, i.e. how to use indicators in managing enterprise performance [18], considering technological, economic and social trends [19]. Performance assessment at an enterprise is an integral part of the management process [20], [21], which allows the enterprise to identify the effects of managerial decisions on the performance, as well as the progress made and the decisions necessary for an enhancement thereof.

Small and medium manufacturing enterprises (SMEs) could be characterized as the main contributors to industrial economic growth worldwide in several aspects, including innovation, output and employment [22]. For example, European SMEs employ two thirds of the workforce and account for more than half of the total output of the manufacturing industry [23].

In 2021 in Latvia, according to data from the Official Statistics Portal [24], there were 10855 SMEs, which accounted for 99.46% of the total market sector economically active statistical units operating in the manufacturing industry. The value added generated by manufacturing SMEs represented 59.7% of the total value added of the manufacturing industry in Latvia in 2021 [25].

In the period from 2006 to 2019, 80% research papers available in the Scopus and Web of Science databases focused on the requirements, design and development of performance measurement systems for SMEs in the manufacturing industry and only 20% on performance measurement as a means of improving performance management or a possibility of performing a comparative assessment [26].

The authors believe that both foreign and national scientists have insufficiently focused on measurement and assessment of performance of the manufacturing industry and manufacturing SMEs, as well as factors in the performance thereof.

The research aims to identify and assess factors in the performance and development of the manufacturing industry and small and medium manufacturing enterprises in Latvia.

II. MATERIALS AND METHODS

Data from the Central Statistical Bureau and the Cobb-Douglas model, which is one of the most commonly used models for identifying the effects of factors on economic growth, were employed to assess the situation in the manufacturing industry. The Cobb-Douglas production function is characterized by the following mathematical relationship [27] (equation 1):

$$Y_t = A_t F(K_t, L_t) \qquad (1)$$

where

- Y_t – output or value added in time period t, EUR;
- A_tF – multifactor productivity index in time period t;
- K_t – investment in equity or fixed assets in time period t, EUR;
- L_t – labour input in time period t, hours

The Cobb-Douglas model is based on an assumption that output is affected by the main factors of production, which are labour and fixed assets or capital, as well as multifactor productivity, or the efficiency of the factors of production. Multifactor productivity considers changes in the quality of technology and the efficiency of the use, the efficiency of factor management, as well as other factors. An additional model uses indexes or changes in shares. In similar research studies in European Union (EU) Member States and Latvia, it has been established that the average share of income generated by fixed assets was 35%, while the share of income generated by labour was 65% [28].

The Official Statistics Portal provides data on three of the four indicators used by the Cobb-Douglas model for manufacturing enterprises not classified by size: "value added", "number of hours worked by employees" and "value of fixed assets". The Official Statistics Portal does not provide publicly available data on the assets of manufacturing SMEs or, in this particular case, the indicator "value of fixed assets"; therefore, the authors submitted a request to the Central Statistical Bureau, which is one of the statistical institutions of the Official Statistics Portal and which, at the request of the authors, collected the necessary data on manufacturing SMEs [29].

III. RESULTS AND DISCUSSION

The manufacturing industry plays an important role in contributing to economic growth in Latvia. In 2020, the manufacturing industry accounted for 12.7% of the total value added, 14.2% in 2021 and 17.7% in 2022 [30].

The 20% target for investment as a share of GDP set by the National Development Plan of Latvia 2014-2020 for the manufacturing industry for 2020 [31] was not achieved in 2020 and also in 2021 and 2022. The Operational Strategy for 2020-2022 designed by the Ministry of Economics of the Republic of Latvia [32], based on 2018 data, set a 12.5% target investment as a share of GDP for 2022. It could be concluded that the target set for 2022 was achieved in 2020.

The authors believe that the target set by the National Development Plan of Latvia 2014-2020 for 2018 was not achieved because the output of high value-added products that would be competitive in export markets was not sufficiently developed by manufacturing enterprises.

Productivity is the most important criterion that determines the international competitiveness of the manufacturing industry. By increasing investment in equipment and training by the manufacturing industry, it is possible to significantly increase the productivity of labour, as well as to increase the competitiveness of the products manufactured, not affecting the other factors of production [31].

The authors performed a comparative analysis of manufacturing enterprises and manufacturing SMEs.

Data from the Official Statistics Portal on productivity in the manufacturing industry, expressed as a ratio of value added to the number of employees, show that the productivity increased in Latvia in 2010-2021. In Latvia in 2021 compared with 2010, productivity growth in the manufacturing industry reached 114.07% and 85.44% in manufacturing SMEs [25].

Productivity in manufacturing enterprises and changes therein are determined by the value added generated by the manufacturing industry and the number of employees (see Table 1).

TABLE 1. CHANGES IN THE VALUE ADDED, NUMBER OF EMPLOYED PERSONS AND PRODUCTIVITY OF MANUFACTURING ENTERPRISES IN LATVIA, 2010–2021, % COMPARED WITH THE PREVIOUS YEAR* (AUTHORS' CALCULATIONS BASED ON [25])

Year	Manufacturing enterprises			Manufacturing SMEs		
	Value added	Number of persons employed	Productivity	Value added	Number of persons employed	Productivity
2010	25.70	-0.32	26.11	21.19	0.17	20.98
2011	5.25	3.24	1.94	0.51	0.39	0.11
2012	13.97	5.39	8.15	12,32	7.55	4.43
2013	1.08	2.09	-0.99	5.00	1.31	3.64
2014	4.00	0.82	3.16	6.57	3.41	3.06
2015	5.87	-1.92	7.94	5.15	0.17	4.96
2016	3.99	0.11	3.88	2.20	-0.07	2.28
2017	8.24	-0.07	8.31	4.29	-0.02	4.31
2018	10.93	0.92	9.93	4.83	-0.64	5.51
2019	7.91	-2.08	10.20	2.77	-4.58	7.71
2020	4.15	-0.76	4.96	6.87	-0.59	7.50
2021	28.40	4.30	23.11	26.08	3.87	21.38

* *indicator values that decreased, compared with the previous year, are highlighted in green.*

As shown in Table 1, the value added by manufacturing enterprises and manufacturing SMEs increased in the analysed period compared with the previous year.

Compared with the previous year, the number of persons employed by manufacturing enterprises tended to both increase and decrease (highlighted in green in Table 1). It should be emphasized that the number of persons employed by manufacturing SMEs gradually decreased in the period 2016-2020. In the period 2010-2021, compared with the previous year, in Latvia, productivity in manufacturing enterprises and manufacturing SMEs, in percentage terms, tended to increase overall. However, it could be concluded that the increase in productivity in manufacturing SMEs was lower than that in manufacturing enterprises, except in 2013 and 2020.

In the period analysed, the year 2021 should be emphasised because the economy recovered from the pandemic, and 17 out of 22 manufacturing industries showed an increase in output, which contributed to an increase in both the number of employees and productivity, compared with 2020 [33], [34].

The level of productivity in the manufacturing industry was lower than the average in the national economy. The experience of several countries shows that the manufacturing industry plays an important role in increasing overall productivity. This could mainly be explained by the potentially higher innovation capacity of the manufacturing industry. Manufacturing is an industry that is largely oriented towards foreign markets and has a higher degree of integration in global value chains. The low level of productivity in the entire national economy is largely determined by low productivity in the manufacturing industry. In 2021, it was almost 45.7% of the EU average [33].

Growth in the manufacturing industry is determined by innovation capacity, incl. the share of high-tech segments in the manufacturing industry. In terms of technological intensity, the share of high-tech segments in the manufacturing industry increased by 4.13 percentage points in 2021 compared with 2010 [35]. The relatively low level of productivity and moderate changes in the manufacturing industry in Latvia are significantly affected by structural factors. The national manufacturing industry is strongly dominated by low-tech segments. This could be explained by the significant share of traditional industries (food and woodworking), which together make up almost half of the total value added generated by the manufacturing industry and which is almost one and a half times higher than the EU average [33].

Based on data from the Official Statistics Portal on the value added by manufacturing enterprises, the number of hours worked by employees and the value of fixed assets in Latvia in 2010-2021, the authors calculated the share of fixed assets in value added and the multifactor productivity index, using an equation of the Cobb-Douglas model. Change indices (CI) for Cobb-Douglas model indicators for manufacturing enterprises, expressed as a ratio of the indicator for the reporting period to that for the previous period, and changes in percentage terms, i.e. deviation, are shown in Table 2.

TABLE 2. COBB-DOUGLAS MODEL INDICATORS OF MANUFACTURING ENTERPRISES IN LATVIA, 2011–2021 (AUTHORS' CALCULATIONS BASED ON [36], [37])

Year	Value added Y_t		Number of hours worked by employees L_t		Share of fixed assets in value added K_t		Multifactor productivity index A_tF*	
	DI	Changes, %	DI	Changes, %	DI	Changes, %	DI	Changes, %
2011	1.05	5.25	1.04	3.77	0.97	-2.81	1.04	3.78
2012	1.14	13.97	1.04	3.85	0.90	-9.87	1.15	15.33
2013	1.01	1.08	1.01	1.34	0.92	-7,72	1.03	3.06
2014	1.04	4.00	1.01	0.91	0.99	-0,98	1.04	3.75
2015	1.06	5.87	1.08	7.77	0.99	-0.65	1.01	1.08
2016	1.04	3.99	0.88	-12.42	0.92	-7.99	1.17	16.71
2017	1.08	8.24	1.01	1.36	0.92	-8.12	1.11	10.52
2018	1.11	10.93	0.96	-4.04	0.91	-8.54	1.18	17.57
2019	1.08	7.91	1.02	1.82	0.98	-1.89	1.07	7.37
2020	1.04	4.15	0.99	-1.29	1.00	0.49	1.05	4.85
2021	1.28	28.40	1.08	7.61	0.84	-16.17	1.30	30.22

* *authors' calculations based on the Cobb-Douglas model equation.*

After analysing the performance of manufacturing enterprises in terms of percentage change in the CI and changes in the value added by manufacturing enterprises in Latvia (see Table 2), the authors concluded that the performance of manufacturing enterprises gradually improved in 2011-2021. Employment in manufacturing enterprises in Latvia, expressed as an index of the number of hours worked, has overall remained unchanged from 2011 to 2021, returning to the level of 2015 in 2021 and confirming that the production process has become more efficient. The multifactor productivity index for the period 2011-2021 confirms increases in the performance of national manufacturing enterprises.

The factors affecting the performance of manufacturing SMEs (see Table 3) show similar trends as those for manufacturing enterprises (see Table 2).

TABLE 3. COBB-DOUGLAS MODEL INDICATORS OF MANUFACTURING SMES IN LATVIA, 2011–2021 (AUTHORS' CALCULATIONS BASED ON [25], [29])

Year	Value added Y_t		Number of hours worked by employees L_t		Share of fixed assets in value added K_t		Multifactor productivity index A_tF*	
	DI	Changes, %	DI	Changes, %	DI	Changes, %	DI	Changes, %
2011	1.01	0.51	1.01	1.13	1.01	0.36	1.00	-0.35
2012	1.12	12.32	1.08	7.75	0.91	-9.30	1.11	10.72
2013	1.05	5.00	1.00	0.46	0.94	-6.10	1.07	7.02
2014	1.07	6.57	1.03	3.00	0.98	-2.31	1.05	5.40
2015	1.05	5.15	1.09	9.04	0.95	-4.91	1.01	1.16
2016	1.02	2.20	0.88	-12.28	0.94	-6.11	1.14	13.77
2017	1.04	4.29	1.00	-0.17	0.93	-7.18	1.07	7.17
2018	1.05	4.83	0.93	-7.23	0.94	-6.53	1.13	12.70
2019	1.03	2.77	1.01	1.01	1.02	2.45	1.01	1.24
2020	1.07	6.87	0.98	-1.60	0.98	-1.96	1.09	8.74
2021	1.26	26.08	1.08	8.08	0.879	-12.11	1.25	25.41

* *authors' calculations based on the Cobb-Douglas model equation.*

The number of hours worked by employees, the share of fixed assets in value added and multifactor productivity accounted for 100% of the value added. Based on the changes in Cobb-Douglas model indicator values expressed in percentage terms, the authors constructed Figure 1, which shows the number of hours worked by employees employed by national manufacturing enterprises, the share of fixed assets in value added and the effect of multifactor productivity on the value added by manufacturing enterprises in Latvia in 2011-2021.

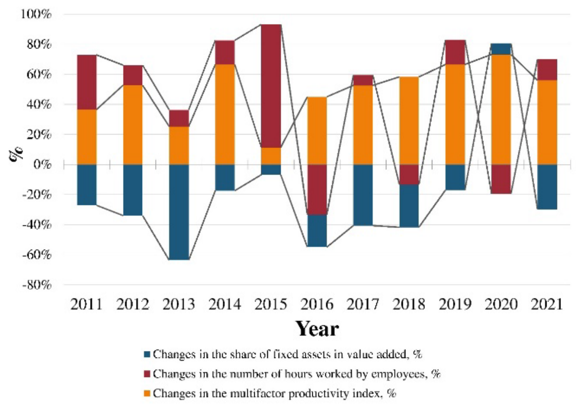

Fig. 1. Effects of the factors "Share of fixed assets in value added", "Number of hours worked by employees", "Multifactor productivity index" on the performance of manufacturing enterprises in Latvia in 2011.–2021, % (authors' calculations based on [36], [37])

The calculation results showed that the value added by or performance of manufacturing enterprises was most significantly affected by multifactor productivity, which, on average, accounted for 49.45% of the overall performance of the manufacturing industry in the period 2011-2021. Changes in the number of hours worked by employees accounted for, on average, 11.78% of the performance of manufacturing enterprises, and the effect of changes in the share of fixed assets in value added on the performance of manufacturing enterprises was negative and, on average, accounted for 25.37% of the change in the value added by manufacturing enterprises. The authors could conclude that investments in fixed assets, i.e. an increase in the value of fixed assets was insufficient to contribute to an increase in the value added by or performance of manufacturing enterprises.

It should be emphasized that in 2021 compared with 2020, the effect of the number of hours worked by employees, the share of fixed assets in value added and multifactor productivity on the performance of manufacturing enterprises changed in Latvia. The effect of an increase in the number of hours worked in manufacturing enterprises on the performance of manufacturing enterprises was positive at 14.09%, whereas the effect of a decrease in the share of fixed assets in value added on the performance of manufacturing enterprises was negative at 29.95%, while the effect of multifactor productivity was 55.96%. The authors believe that labour availability is an important factor that contributes to the manufacturing industry; however, it is not at all the main factor that affects the growth and performance of the manufacturing industry in Latvia. It is necessary to increase investments in technologies, as well as implement measures that could positively affect output efficiency or multifactor productivity.

An analysis of the effects of the number of hours worked by employees, the share of fixed assets in value added and multifactor productivity on the performance of manufacturing SMEs in the period 2011-2021 (Fig. 2) revealed that the performance of manufacturing SMEs was most significantly affected by multifactor productivity, which, on average, accounted for 38.43% of the total performance of manufacturing SMEs.

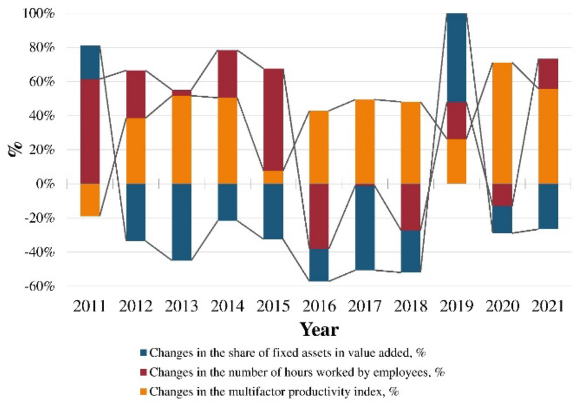

Fig. 2. Effects of the factors "Share of fixed assets in value added", "Number of hours worked by employees", "Multifactor productivity index" on the performance of manufacturing SMEs in Latvia, 2011–2021, % (authors' calculations based on [25], [29]).

Changes in the number of hours worked by employees accounted for, on average, 17.72% of the performance of manufacturing SMEs, and changes in the share of fixed assets in value added had a negative effect on the performance of manufacturing SMEs and accounted for an average of 17.85% of the change in the value added generated by the manufacturing industry.

In the period 2011-2021 in Latvia, the effect of factors on the performance of manufacturing SMEs, compared with that of manufacturing enterprises, differed significantly in 2019. In 2019 in Latvia, however, the effect of the number of hours worked by employees, the share of fixed assets in value added and multifactor productivity on the performance of manufacturing SMEs was positive, and the largest positive effect was a 52.09% change in the share of fixed assets in value added. The authors believe that in order to sustain increases in the performance of manufacturing SMEs, it is necessary to increase investments in fixed assets, incl. technologies.

The Report on Productivity in Latvia [38] has examined the possibility of granting government support to increase productivity at enterprises. The report proposed three criteria (one basic criterion and two additional ones) to be met to grant government support to an enterprise:

1. The basic criterion: in the medium term, the enterprise was able to achieve higher productivity than other similar enterprises (in the same size and age group, industry and location (distance from Riga and other cities));
2. An additional criterion (1): the enterprise belongs to a group of enterprises having a higher probability of continuing their economic activity;
3. An additional criterion (2): a significant share of economic activity is performed by the enterprise in areas with a high unemployment rate.

The authors concluded that the productivity of manufacturing enterprises increased in 2010-2021. The Report on Productivity in Latvia [38] concluded that manufacturing enterprises had a higher probability of continuing their economic activity; however, an analysis of the probability of stopping economic activity by enterprise size and age group revealed that it was higher for micro and new enterprises.

In the manufacturing industry, SMEs made up the majority of enterprises operating in the industry. Data from the Official Statistics Portal [24] show that in 2021, there were 10855 SMEs, which accounted for 99.46% of the total number of enterprises operating in the manufacturing industry, and micro-enterprises accounted for 81.71% of total number of manufacturing SMEs.

The authors believe that when considering granting government support to manufacturing enterprises, it is also necessary to assess an opportunity for manufacturing micro-enterprises to receive government support for increasing their productivity by incorporating additional criteria for evaluation of a manufacturing micro-enterprise into the eligibility criteria for granting government support, e.g. the growth of the relevant segment of the manufacturing industry, as well as investments by manufacturing micro-enterprises in modernization and innovation.

IV. CONCLUSIONS

After analysing the performance of manufacturing enterprises in terms of change in the value added by manufacturing enterprises, which includes the number of hours worked by employees, the share of fixed assets in value added and changes in multifactor productivity, it should be concluded that the performance of manufacturing enterprises gradually improved in the period 2011-2021. The performance of the manufacturing industry in 2011-2021 was most significantly affected by multifactor productivity, which, on average, accounted for 49.45% of the overall performance of the manufacturing industry, while in the case of manufacturing SMEs it was 38.43%.

Multifactor productivity involves changes in the quality and use efficiency of technology, factor management efficiency as well as other factors, and the effect of the multifactor productivity factor on changes in value added in the manufacturing industry confirms that the production process has nevertheless become more efficient.

Growth in the manufacturing industry is affected by innovation capacity, incl. the share of high-tech segments in the manufacturing industry. In terms of technological intensity, the share of high-tech segments in the manufacturing industry increased by 4.13 percentage points in 2021 compared with 2010. The relatively small increase in the period analysed explains the relatively low level of productivity not only in the manufacturing industry but also in the entire national economy of Latvia.

The recommendations for granting government support to increase the productivity of enterprises limit an opportunity for manufacturing micro-enterprises to receive government support, which make up the majority of SMEs operating in the manufacturing industry.

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Is the principle of justice respected in the implementation of conventional beekeeping support?

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Abstract. **From 2023, conventional beekeepers will receive support for pollination of land areas. The amount depends on the land area and the number of hives. Hives must be registered and veterinary requirements must be met. In addition, the beekeeper must certify that the relevant landowner will allow the beekeeper's bees to pollinate the landowner's cultivated areas for five consecutive years. It sounds quite absurd.In addition, the amount of support in material terms is so small that the beekeeper must seriously consider whether the relevant areas will be available for five years before asking to allow the bees to pollinate the neighbor's crops. If not, the aid received will have to be repaid. In general, support measures for conventional beekeeping are currently implemented in such a way and to such an extent that it can be said that there is no support at all.Therefore, in order to preserve beekeeping as an industry, it is immediately necessary to: 1) radically change the procedure for granting support, 2) increase the amount of support to at least cover the costs of the pollination service provided to the farmer.**

Keywords: beekeeping, beekeeper, bees, conventional beekeeping, pollination.

I. Introduction

"Honeybee" is an animal belonging to the species Apis mellifera.[1] "Beekeeping is recognised to be an activity, which has an essential significance in the sustainable development of the rural areas, in the job-creation, the conservation of the ecosystem's biological diversity, and in the maintenance of ecological balance."[2] In addition to producing bee products for consumption, bees maintain biodiversity and provide food to society with polliation. The honey bee is a key managed species worldwide for both crop pollination and honey production [3] [4], a highly valued resource worldwide.[5] "84% of plant species and 76% of Europe's food production are directly dependent on pollination. The estimated economic value of this process is 14.2 billion euros per year".[6] So, the activity of beekeepers is associated with a significant contribution to the economy in the form of produced products and the maintenance of the ecosystem as a whole. In order to evaluate the current situation in the beekeeping industry, surveys were conducted with organizations and beekeepers involved in the industry. As a result, 81% of the respondents recognized that beekeepers need support to ensure operations, mainly for updating the number of bees in hives, that measures are needed to prevent damage caused by adverse climatic conditions and to develop and promote the use of management practices suitable for changing climatic conditions.[7] Until 2023, support for conventional beekeepers was provided for the number of inhabited hives. The purpose of the study is to identify and analyze the main problems of conventional beekeeping from 2023, when the receipt of support is determined for the areas to be pollinated, based on the experience of beekeepers obtained by summarizing the conclusions of the first year of the implementation of this procedure.

II. Materials and Methods

Research methods are based on the analysis of data, documents, available information, beekeepers' experience and regulatory acts. The importance of honey bees as a globally important resource is assessed. The study uses an analytical method to investigate the current situation in the conventional beekeeping industry and specifically the possibility for a beekeeper to receive support based on pollination of areas, rather than support for bee colonies only. With the help of the comparative method, the proportion of conventional beekeepers in the total number of beekeepers has been updated, support for beekeepers in

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some European countries has been examined. The requirements set forth in the regulations for beekeepers and the problems of fulfilling the set requirements are summarized, based on the practical experience expressed by beekeepers about the experience accumulated in 2023. Using the analytical and comparative method, problems in the implementation of support measures were identified. It has been established that with the year 2023, completely new requirements for receiving support for conventional beekeepers have been introduced, which obliges beekeepers to request that grain farmers give written permission for the conventional beekeeper's bees to pollinate his fields, this is absurd. With the help of the analytical method, proposals have been put forward to change the conditions of the normative act, which determine the analyzed support conditions.

III. Results and Discussion

Society is interested in developing conventional beekeeping to ensure the efficiency of honey production and ensure the irreplaceable influence of bees on environmental conservation. The number of bee colonies is characterized by the information that on May 1, 2020, 102,019 bee colonies were registered in Latvia. In 2021, at the beginning of May - 87,465 bee colonies, which is 14.3% less than in the corresponding period a year earlier.[8]

All over the world, beekeepers report that bee colonies are dying, for example France, Belgium, Germany, Great Britain, Italy, Spain and the Netherlands, USA, Brazil.[9] In addition, the death of bee colonies to such an extent that announcements are made about the risk of extinction of pollinators.

Of course, slowly world trends in this area also affect Latvia. Various information can be found on the number of bee colonies, but conventional beekeepers must be recognized as producers who can influence the market for bee products, which must be distinguished in this respect from "hobby" beekeepers.

A beekeeper must first of all count on the purchase of bee colonies, the purchase of bee keeping equipment, hives, cells, inventory. As an unpredictable and uninfluenced able condition to be reckoned with, there is a very long wintering period of bees in the conditions of Latvia. Approximately from September to April, a total of seven to eight months, when the viability of bees can be negatively affected until they die: 1) drastic changes in weather conditions, 2) diseases, 3) problems with food (perhaps it is not usable, lack of food, etc.) and other circumstances. So, for example, a bee keeper with 40 years of experience says that "out of 240 winterized bee colonies this year, I have lost more than half"[10]. This vividly describes the special dependence of beekeeping on weather conditions, chemical agents used by other farmers, etc.

In order for a beekeeper engaged in conventional beekeeping to qualify for any state or European Union support, a whole series of requirements must be fulfilled, which consume time and require money. Below is an overview of the key conditions that qualify as tiered requirements. In addition, the excessive requirements are of course expressed in direct annual costs[11], which the beekeeper has to cover.

1. The owner or keeper of bee colonies, after the first registration in the state institution at the Agricultural Data Center, must submit information about the bee colonies (hives) according to the state on May 1 and November 1 of the respective year by the end of May and November every year, stating the registration number of the colony and hive, review date and number of bee colonies.[12] It is possible to submit information via electronic registration (after concluding a contract with the institution) or in paper form, for example by submitting an application to an employee of the relevant institution, who is available in a specific county on a specific day and time.[12]
2. If during the working season of bees, that is, in the period from April 1 to September 30, bee colonies are moved to the field to be pollinated outside the shelter to a temporary location for pollination of plants, the owner or keeper of the holdings, using the electronic notification system, must provide information about the performed relocation to the Agricultural Data Center within seven days after the said relocation. The Ministry of Agriculture has indicated that as of April 1, 2021, five regulations are applicable with regard to the traceability (registration and marking) of animals, including bee colonies: Regulation (EU) 2016/429 of the European Parliament and of the Council on transmissible animal diseases and which is amended and repealed by specific acts in the field of animal health ("Animal Health Act"); Komisijas deleģētā Regula 2019/2035 (ES) Commission Delegated Regulation 2019/2035 (EU) supplementing Regulation (EU) 2016/429 of the European Parliament and of the Council with regard to the rules applicable to facilities for keeping terrestrial animals and hatcheries, and regarding the traceability of certain terrestrial animals and hatching eggs; The Commission's Implementing Regulation (EU) 2021/520, ark o, lays down rules on how to apply Regulation (EU) 2016/429 of the European Parliament and of the Council with regard to the traceability of certain kept terrestrial animals; Commission Implementing Regulation (EU) 2021/963, the framework provisions for the application of Regulation (EU) 2016/429 of the European Parliament and of the Council (EU) 2016/1012 and 2019/6 with regard to the identification and registration of horses and creates models of identification documents for these animals; Commission Implementing Regulation (EU) 2022/1345 laying down rules on the application of Regulation 2016/429 of the European Parliament and of the Council with regard to the registration and approval of facilities where terrestrial animals are kept and reproductive products are collected, obtained, processed or stored.

3. In the food circulation with bee products, it is allowed to engage (that is, sell) only if the activity is registered with the Food and Veterinary Service. Of course, it is necessary to ensure that the necessary hygiene requirements are met for honey processing rooms, used devices, and containers.[12]
4. Quality, classification and additional labeling requirements for honey must be observed.[13]
5. The beekeeper must keep records of treatment and prevention measures for bee colonies, samples taken for diagnosis and analyzes performed. Laboratory tests of drinking water should be performed regularly, that is, at least once a year.[14]
6. Beehive labeling requirements must be met.[12]

It can be concluded that the bureaucratic burden on the beekeeper has been ensured, because the goal of legal norms is not achieved in the best possible way to protect the values [15], which in the case of beekeeping are based on historical experience, life knowledge, and the existence of an industry based on rural development as a whole.

The main problems that conventional beekeepers face are as follows.

1. Bee products, first of all, the yield of honey depends on weather conditions. For example, a cold spring prevents bees from collecting honey in the spring season, the so-called "spring" honey. Prolonged rain can generally cause the death of bees.
2. Damage caused by forest animals to bee colonies. For example, the damage caused by bears, most often completely eliminating bee colonies.
3. Use of pesticides in the cultivation of agricultural plants, such as rape. The effect of various chemicals on bees is sometimes identified as a phenomenon when a beekeeper put down winters bee colonies for hibernation, but in the spring, when you open the hive after wintering, there are no bees in the hive and you cannot tell where they have disappeared.[16] It turns out that the bees' organism was weakened possible by the influence of chemicals and was not able to survive the winter months in the hive.
4. Bees exposed to substances harmful to bees are more susceptible to disease.
5. The spread of monocultures greatly limits the ability of bees to fight various threats against to bees, such as mites, other parasites.

So, bees and beekeeping as a whole are the industry most dependent on nature, the surrounding environment, weather conditions, chemicals, threats from other forest animals. Therefore, if the state recognizes that beekeeping as an industry is necessary, it should be given adequate support that sufficiently minimizes the listed threats. In 2011, "hobby" beekeeping [17] dominated in Bulgaria and Europe, in 2021, when conducting a study on beekeeping activities in seven European countries (Estonia, Croatia, Finland, Italy, Norway, Portugal and Spain), two thirds of the surveyed beekeepers described themselves as conventional beekeepers [18], it confirms that beekeeping is perceived as an important agricultural sector.

As of 2023, beekeepers can no longer receive support for the number of bee colonies to be maintained, but the beekeeper is obliged to register the areas on which bees will provide pollination. At the same time, for example, in Sweden already in 2019, depending on the number of colonies, beekeepers received subsidies for pollination of cherry, apple and clover fields - 50-80 € per colony of bees.[19] So, from 2023, payment can be received for a hectare where the beekeeper's bees provide the pollination service.[20]

The main requirements for support payments for the "provision of pollination service" are as follows:

1. Multi-year commitments are made for five years. Beekeepers must undertake that the number of bee colonies declared in the support year, in the first year of the particular beekeeper will pollinate exactly the same area as in the first year for all the years.
2. The support applicant must have at least two beehives/colonies per hectare in order to receive support for one pollinated hectare.
3. No less than fifteen hectares, which the beekeeper to apply to pollinate, can be applied for support.
4. No less than thirty hives/flocks in the conventional farming system must be registered in the agricultural data center during the grazing season (May 15-September 15).
5. When moving beehives/flocks to pastures, the minimum distance from the beehive shelter is three kilometers.
6. During the grazing period, the support applicant must notify the Agricultural database (within 7 days after the relocation) of the temporary relocation of beehives, indicating the number of beehives, the start and end date and location of the relocation (cadastre number).
7. Hives must be marked with the herd number assigned by the Agricultural Data Center.[21]
8. Must take qualification courses in agriculture and food production in the amount of 40 hours by May 31, 2027.

Without analysis of requirements, the implementation of such a support system shows that in the season of 2023, the number of applicants for support funding in the event "Management of beekeeping units for pollination needs" decreased by 25%. [22] The question is justified, whether it is really necessary to create a new, comprehensive regulatory act [23], when it is obvious that the authors do not understand the implementation of these provisions. "The notion of legal reason" [24] has disappeared when formulating the obligations that, starting from 2023, conventional beekeepers must fulfill.

This is not surprising, because with the launch of the new support system, conventional beekeepers have faced several problems that cannot be solved without losing human dignity:

1. Difficulties in obtaining approval from other land managers for land units that the beekeeper wants to apply for support. In practice, it was found that in 67% of cases, beekeepers could not find the manager of the land units and contact information to coordinate the land units that the beekeeper's bees "want" to pollinate and apply for support, in 58% of cases, the land managers indicated that they wanted to receive payment for coordination and consent pollination cases. In 69% of cases, other farmers did not want to give approval and consent to receive pollination services.[21]
2. In the event that the beekeeper needs to obtain information about the owners of agricultural lands adjacent to the apiary, this creates ethical problems. Taking into account the laws of logic [25], the conditions should be exactly the opposite. Farmland owners should ask the beekeeper to let his bees go to the field and pollinate, not the other way around. For example, you will not be able to get a crop from unpollinated canola.[26]
3. Obtaining contact information about land owners and users from the Cadastre information system is a paid service.[27]
4. Bees can fly only a certain distance, so "traveling apiaries" without an appropriate economic base cannot exist at all, because moving a beehive requires either additional workers, which the beekeeper cannot afford to hire, or technical equipment (special loaders, trailers), which purchase requires significant investment.

The mentioned conditions put the beekeeper in the role of a humiliating supplicant in relation to the owners of neighboring lands that grow rapeseed, other crops, because the beekeeper must beg: will you let my beesfly to pollinate your crops? Beekeepers do not have the appropriate equipment to be able to actually implement "travelling beekeeping", because one or two people cannot even lift a beehive with bees, let alone take the many where. It needs for klifts, trailers. Not to mention that in the summer season such work can only be done at night, because even with the slightest light the bees are outside the hive. Moreover, the amount of aid is so small that it does not cover even the basic costs. There is no doubt that the set conditions are overly bureaucratic and do not contribute to the development of beekeeping as an industry. If we want to preserve conventional bee keeping in Latvia, not just amateur beekeeping with one or two bee colonies, the support requirements must be changed immediately and beekeepers must begiven support that issustainable in terms of economic, nature protection and social aspects.[28] Beekeepers must be given fair, proportionate support for the development of beekeeping.

The fact that conventional beekeeping can be preserved as an important agricultural sector is proven, for example, by the experience of France. France has allocated 5 million euros to support beekeepers in 2024. Beekeepers insist that the work is hampered by high costs, bureaucracy, increase in unsold production, unregulated foreign competition, production losses related to climate change. [29] African countries have a different view, where beekeeping is valued as an industry that can make a very large contribution to the family budget. [30]

The assessment of proportionality has disappeared, but before the implementation of the regulation the essential interests [31], [32] should be identified and weight or value should be assigned to these interests, it is obvious that this principle has been forgotten in the creation of the analyzed regulation. At the same time, justice "Like a hidden treasure" [33],[34], which derives from the basic norm that Latvia is a democratic republic, has disappeared from this regulation. Only the above-mentioned principles indicate that beekeepers must be given fair, proportionate support for the development of conventional beekeeping, therefore the regulations of the Cabinet of Ministers, where requirements for conventional beekeepers have been set since 2023, must be changed.

IV. Conclusions

In order to preserve beekeeping as an agricultural industry, there is an immediate need to:

1. It is necessaru to radically change the procedure for granting support. The main stakeholder in field pollination is the field owner. A beekeeper does not have to plead with a neighboring landowner to allow the beekeeper's bees to pollinate his fields. Therefore, the number of bee colonies managed by the beekeeper should be the main criterion for granting support. Therefore, the regulations of the Cabinet of Ministers of April 18, 2023 No. 197 and 2.1.5. In point "Requirements for the implementation of the intervention "Management of beekeeping units for pollination", support for conventional beekeepers should be provided based on the number of bee colonies maintained by the beekeeper.
2. There is an immediate need to increase the amount of support so that it at least covers the costs of beekeepers. The amount of support at the moment is too small even for bee hibernation measures. The size of the aid should be analogous to the aid received by cereal growers. Therefore, the regulations of the Cabinet of Ministers of April 18, 2023 No. 197 and 2.1.5. the condition of the

requirement intervention "Management of beekeeping units for pollination" for conventional beekeepers, whose care is at least 30 bee colonies, the amount of support to be granted, giving the agricultural sector - beekeeping the opportunity to maintain this occupation.

The research uses an analytical method to investigate the requirements in the work of conventional beekeepers. With the help of the analytical and comparative method, problems have been identified when applying for state support since 2023. In order to study the problems of the practice of conventional beekeepers, the following methods of interpretation of legal norms were used: grammatical, systemic, teleological and historical. Inductive and deductive research methods were used to draw conclusions about existing requirements and conditions and suggest possible solutions.

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Management of the solar power development in households of Ukraine

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***Abstract.** Solar power is one of the fast-growing promising areas of renewable energy use. The article is devoted to the use of solar radiation energy in private households of Ukraine. It is noted that the amount of solar radiation is high enough to create solar power facilities throughout Ukraine.*

Based on the results of the research, it was found that households that have installed photovoltaic power station are fully self-sufficient in electricity and are the most energy efficient, as the surplus of environmentally clean electricity produced is sold at a "green" tariff. Based on the data of the study of the state of installation of solar power plant in private households, has been made a forecast of the development potential of this electricity sector for the period up to 2024.

On the basis of the conducted research, it can be stated that the use of solar power in private households has a sufficiently large perspective to ensure which it is advisable to introduce a net-metering system in Ukraine, which includes the free sale of surplus energy produced on the market with the possibility of "taking" it from this market later.

***Keywords:** solar power, photovoltaic power station households, financial model, "green" tariff*

I. INTRODUCTION

In recent decades, there has been a trend in the world to abandon traditional energy sources and switch to alternative ones, where an important place is given to solar power. This is the most promising source of electricity, since solar power can be obtained constantly, for free, and anywhere on the globe. In particular, solar power has been extremely popular in Ukraine in recent years. The advantages of this type of energy are its availability, as Ukraine has the possibility of its free use due to its geographical location. Modern technologies make it possible to use the potential of the sun's energy with sufficiently high efficiency. However, in contrast to the large amount of literature and research conducted on solar power, less attention has been paid to qualitative assessments of the strengths and weaknesses of its use in private households.

The purpose of the article is to study aspects of solar power development in Ukraine in the context of providing private households with electricity and legislative regulation of this process.

A review of the literature.

A number of scientists' works are devoted to the aspects of effective development of solar power in private households.

Y. Dzyadykevych, M. Buryak and I. Lyubezna point out that the use of solar power in everyday life provides an opportunity to meet the needs of electricity and at the same time become independent of generating companies and external conditions. Electric energy produced in the country from solar power is of particular importance for Ukraine's energy security [1].

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S. Matyakh, T. Surzhik, and V. Ryeztsov claim that the power indicators of incoming solar radiation are high enough for the creation of solar power facilities throughout the territory of Ukraine. The thermal energy of solar radiation can be effectively used in private households for hot water supply and heating [2].

V. Bodunov believes that one of the ways to stimulate the development of renewable energy is preferential electricity tariffs for business entities, consumers of electricity, including energy cooperatives and private households, whose generating plants produce electricity from alternative energy sources. Such a state policy exists in Ukraine as a "green" tariff [3].

Some research authors pay attention to the fact that on the basis of solar power it is possible to easily build distributed systems of the future - disconnected from the central network, independent clusters within communities. It is in this direction that the development of the energy industry is moving. Today, at the current tariff, home solar stations are paid for in 4-5 years. After 9-10 years, they should be occupied due to the net-metering system, which Ukraine should implement and which includes the free sale of surpluses to the market with the possibility of "taking" energy from this market later [4].

The report on the solar electricity market in Western Europe [5] notes that the Western European solar electricity production market consists of its sale and related services. As the cost of using solar power to generate electricity falls every year, many users are increasingly switching to solar power. Some of the major additional benefits of going solar include cost savings that depend on electricity usage, the size of the solar electric system, and a number of other factors.

II. Materials and methods

This study is included in the general subject of the research laboratory "DAK GPS" of the Higher Education Institution "Podilskyi State University", whose activity is based on the study of the potential of effective use of renewable energy sources [6-11]. The theoretical and methodological basis for the article were the scientific works of scientists, which became the basis for researching the development of solar power in private households. Data from official sources were used for the analysis. The information base of the study was the materials of the State Agency for Energy Efficiency and Energy Saving of Ukraine, analytical materials, reviews and calculations of domestic experts and companies in the field of solar power and its use in private households.

To achieve the goal, the article uses the method of statistical observation for collecting primary statistical material and its analysis. Tabular and graphical methods were used to present the results of the study, which made it possible to analyze the dynamics of the installation of photovoltaic power station in private households, their capacity and the amount of energy they realized under the "green" tariff in the period 2014-2021. A modeling method is used to build a financial model of a solar power plant of a private household. The forecasting method made it possible, with the help of correlation analysis, to calculate the forecast indicators of the installation of photovoltaic power stations and their capacity in private households, and the volume of energy sales under the "green" tariff for the future

III. Results and discussion

Solar power is a relatively new industry in Ukraine. The entire area here is suitable for the location of photovoltaic power stations. The rate of its development is extremely high compared to other sectors of the domestic economy. Thus, according to the results of 2021, solar power accounted for more than 5% of the total electricity production in Ukraine [12].

Some research authors indicate that the thermal energy of solar radiation can be effectively used in private households for hot water supply and heating. From an environmental point of view, solar electricity may have very few limitations in its implementation as there is no significant negative impact on the environment. Social characteristics include the creation of additional jobs [13].

Y. Dzyadykevych, M. Buryak and I. Lyubezna believe that the development of solar power in Ukraine will make Ukrainian energy more competitive. The International Renewable Energy Agency (IRENA) has concluded that the increased use of solar power in the period up to 2030 will reduce the total costs of the Ukrainian energy system. With this in mind, there will be a positive impact on the environment and the health of the population, as the level of smog decreases and the volume of emissions of harmful substances decreases [1].

S. Matyakh, T. Surzhik, and V. Ryeztsov note that with the help of solar power, it is possible to provide electricity to residents of the private sector, which is also possible in parallel with the operation of the electrical network. The most common are photovoltaic power stations located on the roof of buildings. [2].

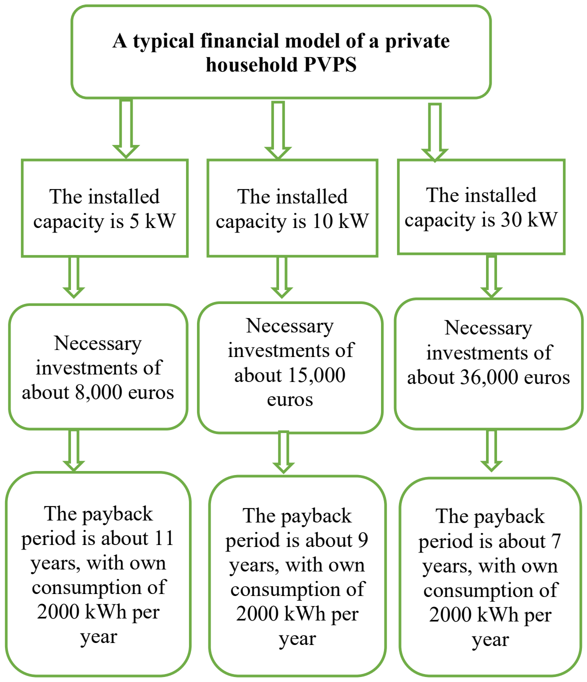

Fig. 1. A typical financial model of a private household photovoltaic power stations [14]

For the installation of solar power in the private sector, typical financial models of photovoltaic power stations for private households (PVPSh) have been developed, which, based on a given volume of energy consumption, determine the required installed capacity, payback period and necessary investments, taking into account the size of the "green" tariff (Fig. 1) [14, 15].

It is worth noting that the vast majority of households install solar plants with a capacity of 30 kW, since they are more efficient from the point of view of investment return. For comparison: the payback period of a 5 kW PVPSh is 11 years with an investment of 8 thousand euros, and the most popular 30 kW roof PVPS is 7 years with an investment of 36 thousand euros [16].

The main benefit for households in the Western European solar market is cost savings, which depends on electricity consumption, the size of the solar electric system, whether users buy or lease solar systems, hours of direct sunlight, roof size and angle, and local electricity tariffs. Some of the other benefits include increased housing costs. A study by Lawrence Berkeley National Laboratory found that, on average, solar added about $15,000 to the value of a home [5]

The legislation of Ukraine [17] clearly regulates who, where exactly and under what conditions can set up the PVPSh. A household consumer has the right to install in his private household a generating plant intended for the production of electricity from the energy of solar radiation. The size of such an installation should not exceed 50 kW. Production of electricity from such an installation is possible without a corresponding license. Households that have installed PVPSh are fully self-sufficient in electrical energy and are the most power efficient, as the surplus of environmentally clean electricity produced is sold at a "green" tariff [17], [18].

V. Bodunov draws attention to the fact that according to Article 63 of the Law of Ukraine "On the Electric Energy Market", the universal service provider is obliged to purchase electric energy produced by the generating units of private households, the installed capacity of which does not exceed 50 kW, according to the "green" tariff in the amount exceeding the monthly consumption of electric energy by such private households. However, in accordance with Article 58 of this law, the connection of generating plants of consumers, including private households, should not lead to a deterioration of the regulatory parameters of the quality of electric energy in the network and the security of supply. [3],

More and more private households are choosing solar power. Installed photovoltaic power stations in households provide an opportunity to independently meet their power needs, reduce dependence on the import of traditional energy resources, save on electricity bills, be autonomous, and stimulate the local economy [19].

In 2021, Ukrainians set a new record for the number of domestic PVPSh, during which nearly 15,000 Ukrainian families installed solar panels, which is twice as many as in 2020. This is a record number of installed home heating systems for a year, informs the press service of the State Agency for Energy Efficiency and Energy Saving of Ukraine with reference to the results of quarterly monitoring. In total, as of the end of 2021, there were approximately 45,000 households in Ukraine that had installed photovoltaic power stations. (fig. 2) [20], [21].

It should be noted that the active rate of development of domestic PVPSh in 2021 allowed to increase their capacity by 426.1 MW, which is 36.4% of the new renewable energy sources capacities put into operation last year. Thus, the total installed capacity of all household solar systems reached 1,205.1 MW at the end of the year. (Fig. 2). Home solar stations make up only 11% of the total installed capacities of PVPSh (Fig. 2). [4], [22].

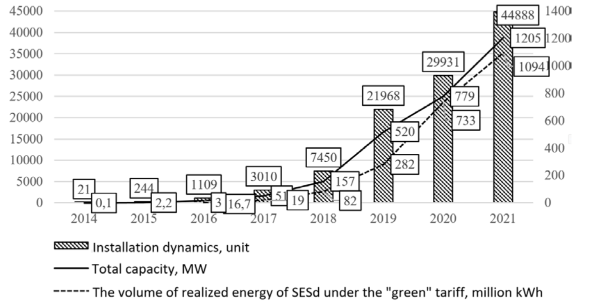

Fig. 2. The dynamics of the installation of photovoltaic power stations in private households [14]

Based on the materials of State Energy Efficiency of Ukraine, one can notice that the development of photovoltaic power stations in private households has positive dynamics. Over the period 2016-2021, the rates of sales of electricity sold to the European Union under the “green” tariff are characterized by stable growth. The highest numbers were achieved in the period 2019-2021. During this period, the sales volume increased by 4 times from 282 million kW*year in 2019. up to 1094 million kW*year in 2021 It is important to note that private households favor the transition to natural electricity (Fig. 2) [14].

The State Agency for Energy Efficiency and Energy Saving assessed the regions of Ukraine and established a rating for the number of installations of ESSD as of 01/01/2021. The top three regional leaders, due to the number of establishments by the EU PVPS, have increased: Dnipropetrovsk - 4184 PVPS, Ternopilska - 2512 PVPS, Zakarpattia - 2082 PVPS regions. (Table 1) [23].

The decision to install a solar installation is influenced by the economic factor, which allows selling excess electricity to the grid. Since 2008, the "Green Tariff" has been in effect in Ukraine, which is a policy of stimulating the production of electricity from alternative sources by the state. The basis of the system is the purchase of excess produced alternative electricity from private households. "Green" tariff for electric energy produced from the power of solar radiation by generating units of private households, the installed capacity of which does not exceed 50 kW, provided they are located on the roofs and/or facades of buildings and other capital structures [24], [25].

TABLE 1. RATING OF REGIONS REGARDING THE NUMBER OF INSTALLED PVPSH AS OF 01.01.2021

№	Region	Number of PVPSh	Number of population, persons	number of PVPSh per 1,000 people
1	Ternopil	2512	1081418	2,32
2	Zakarpattia	2082	1256802	1,66
3	Kirovohrad	1550	945549	1,64
4	Ivano-Frankivsk	2149	1373252	1,56
5	Khmelnytska	1508	1037640	1,45
6	Kyiv	2350	1767940	1,33
7	Dnipropetrovsk	4184	3206477	1,30
8	Odesa	1273	1131096	1,13
9	Chernivtsi	1231	1206351	1,02
10	Volyn	754	1035330	0,73
11	Vinnytsia	1094	1560394	0,70
12	Cherkasy	811	1264705	0,64
13	Kherson	1693	2675598	0,63
14	Kharkiv	652	1045879	0,62
15	Zhytomyr	758	1220193	0,62
16	Sumy	628	1157301	0,54
17	Lviv	1175	2522021	0,47
18	Rivne	519	1400439	0,37
19	Chernihiv	256	904374	0,28
20	Mykolayiv	805	2950819	0,27
21	Poltava	606	2380308	0,25
22	Zaporizhzhia	397	1705836	0,23
23	city of Kyiv	222	1005745	0,22
24	Donetsk	637	4165901	0,15
25	Luhansk	85	2151833	0,04

According to the specialists of the Solar System installer company, relying on the statistical data of the State Agency for Energy Efficiency and Energy Saving of Ukraine, the interest of Ukrainian households in "clean" sources of energy is growing. In order to further promote the development of this direction, the State Agency for Energy Efficiency and Energy Saving of Ukraine wants to start a trend and mechanism that is already popular in Europe - #NetEnergyMetering. In addition, as more and more households use "clean" energy, the market for solar installation materials and services is growing. To date, photovoltaic power stations installed by families are primarily investments in the amount of about 640 million euros in the development of the Ukrainian energy industry [16]

TABLE 2. DYNAMICS OF INSTALLATION OF PHOTOVOLTAIC POWER STATIONS BY PRIVATE HOUSEHOLDS

Indicators	2017	2018	2019	2020	2021	2022	2023	2024
Number of PVPS, units	3010	7450	21968	29931	44888	x	x	x
Trend line	202	10826	21450	32074	42698	53322	63946	74570

Based on the data from the conducted research, I will establish the installation of photovoltaic power stations in private households for the period 2017-2021. (Fig. 2), a forecast of the development potential of this electricity sector for the period up to 2024 has been compiled. Using the Excel spreadsheet editor, a graph of a linear trend was drawn, which illustrates the duration between periods and the number of installations of photovoltaic power stations and the coefficient of determination (R^2), which is calculated automatically. In the presented graph, R^2 = 0.975, which classifies the relationship between values as high, so that the model generated is adequate to the real data (Fig. 3).

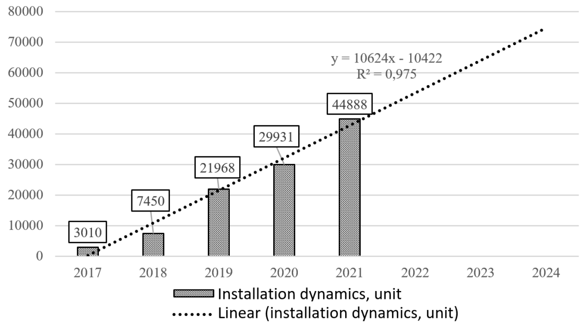

Fig. 3. Trend model for forecasting the development of solar power in private households (Covered by the authors)/

Taking into account the received trend equation y= 10624x-10422, the forecast indicators of the installation of photovoltaic power stations in private households for 2022-2024 were calculated, according to which the state of their coverage in 2024 will be at the level of 74,570 units. Compared to the actual indicators of 2021, the projected growth in 2024 will be 66%.

Research shows that the potential for the development of solar power is provided by our own scientific and industrial bases, design bureaus that design solar collectors, production of mono- and polysilicon, nanotechnology, the availability of necessary metal products, etc. Photoenergy projects have been actively implemented in Ukraine since 2010. The advantages of solar power are the general availability and inexhaustibility of the energy source.

At present, solar power is used mainly for household lighting and private use by households. By extending the hours of available light, it creates additional time for productive activities. Now, many different devices have appeared in the private use of the population, which consume a large amount of energy. Therefore, electricity consumption in Ukraine is growing, and every household needs a reliable and modern source of energy. Therefore, energy independence and reliability in the fact that there will always be a current are important above all. There are also environmental benefits, each kilowatt-hour of solar power generated will significantly reduce greenhouse gas emissions such as CO_2 as well as other dangerous pollutants. Solar power also reduces water consumption and abstraction

Further expansion of the scale of use of solar power for the production of electricity and thermal energy in the private sector of Ukraine will contribute to raising the standard of living, especially in rural areas. Inexhaustibility and ecological purity, as the main properties of solar power, are expected to provide greater stability of the energy sector of households and improve the state of the environment than is possible when using traditional fuel resources.

IV. Conclusions

During the studied period, the development of photovoltaic power stations in private households has a positive dynamic, and the active rate of installation of domestic PVPSh by the end of 2021. allowed to increase their number and power, and the amount of electricity sold by them under the "green" tariff is characterized by stable growth. Based on the research conducted on the state of installation of photovoltaic power stations in private households, a forecast of the development potential of this electricity sector was made.

On the basis of the conducted research, it can be stated that the use of solar power in private households has a sufficiently large perspective to ensure which it is advisable to implement a net-metering system in Ukraine, which includes the free sale of surplus energy produced on the market with the possibility of "taking" it from this market later.

V. Acknowledgments

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Organization of participatory budget (PB) development in Latvian municipalities

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***Abstract.* In recent years, negative trends have been observed in Latvia in connection with society's reluctance to get involved in political processes and, therefore, also in state and local government administration. The number of voters who voted in the 2017 local government elections in the amount of 50.39% was assessed as an alarming indicator. In the municipal elections of 2021, when only 34.01% of eligible voters voted, the result causes alarm. The results of the elections and studies show that there is alienation of the population from the government and the current trust in the state administration is very low. Citizens do not believe that they can influence the development and management processes of the state and local governments. One of the reasons for distrust is the lack of feedback from the municipality or the inability or unwillingness of the municipality to solve the problems raised by the residents. The need to ensure public participation is defined in several regulatory acts of the Republic of Latvia. Residents' involvement is a long-term process, in which the prerequisite is the building of trust between the municipality and the residents. If citizens have the opportunity to determine how a part of the municipal budget will be spent, municipalities will promote democratic values and the opportunity to participate in the decision-making process. Participatory budget in local governments is one of the ways to try to bring citizens closer to local government. By 2025 in Latvia, it must be included in the municipal budget.**

The aim of the work is to find out the readiness of Latvian local governments to plan a participation budget in 2025 in the amount specified in the Law on Local Governments.

The tasks of the work are to study the findings of various authors on public participation and the participatory budget, to analyse the normative documents on the participatory budget adopted in Latvia and to conduct a situational study of the experience of local governments and their readiness to implement a participatory budget by 2025. Methods used in the work - monographic method, analysis of various theoretical sources, regulatory acts, sociological research method - interview, - for finding out the opinion of experts and logically constructive method - for forming judgments and recommendations.

Keywords:* *activity, democracy, participation budget, municipality, residents, activity.

I. Introduction

Public involvement in decision-making processes in the municipality is an integral part of ensuring effective administration and services to citizens. In practice, it has been observed that society does not understand what its role is in the planning process. It mainly reacts only when the decision of the municipality affects the private property of society representatives [1]. Good municipal development planning is unthinkable without purposeful public involvement in all stages of planning - needs and interests are identified at the beginning. Then they are prioritized and reconciled with the interests of other persons and the goals of sustainable development, discuss the best development solution, as well as monitor the implementation [2].

In recent years, negative trends have been observed in Latvia, as in many other countries, in connection with society's reluctance to get involved in political processes and, therefore, also in state and local government administration [3]. The results of the elections and studies show that there is alienation of the population from the government and the current trust in the state administration is very low. Citizens do not believe that they could influence the development and management processes of the state and local governments. At the end of 2021, a survey conducted by the OECD showed that only a little more than 13% of Latvian citizens believe that the political system provides them with the opportunity to influence government decisions and only 26% of OECD survey participants in Latvia believe that their expressed opinion in public discussion will be

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considered [4]. Public discussion is only one of the ways of public involvement in municipal administration. The participation process is diverse and also changing. Participation is also made a complex mechanism by the objective contradictions that exist between the principles of democracy and bureaucracy [5]. In general, the degree of participation and involvement of many people has changed, representatives of middle and higher education and income strata are involved in politics significantly more often. With the creation of social networks, the communication habits of citizens have also changed - with their help, you can organize spontaneous protests or shitstorms, which can criticize politics and politicians in an aggressive-demagogical way [6].

As one of the forms of public involvement in decision-making, the creation of a participatory budget (hereafter - PB) in local governments is proposed. From the year 2025, Latvian municipalities will have to implement the LB compulsorily. Several municipalities (Riga, Gulbene) have already chosen to voluntarily organize a participation budget, allocating certain funding for this purpose. The problem exists because the majority of local governments in Latvia do not voluntarily want to implement the LB process. Therefore, the author puts forward a hypothesis - Latvian municipalities and residents have little experience in implementing LB, so they have difficulties in implementing LB. The aim of the work is to find out the readiness of Latvian local governments to organize LB in 2025 in accordance with the provisions of the current Local Government Law. The tasks of the work are to study the experiences of other countries and the findings of various authors on participatory budgeting, to analyse the regulatory documents of the Republic of Latvia on participatory budgeting, and to conduct a situational study of the experience of local governments in creating LB. Methods used in the work - monographic method, analysis of various theoretical sources, regulatory acts, sociological research method - survey using a questionnaire to find out the experience of the municipality so far, and logically constructive method - making judgments and recommendations.

Justification of the need for the participatory process. From ancient times to the present day, the interpretation of democracy has been a controversial issue, and the political systems of countries that call themselves democratic vary greatly. Historically, the first form of direct democracy developed in Ancient Greece, where the statesman Pericles (circa 500 - 429 BC) said that his state system is called democracy, because state power does not belong to a few citizens, but to the majority. The fact that democracy is a form of government in which the majority rules seems to be relatively indisputable. However, the question of how this majority should exercise power raises a different understanding of democracy and its types. Should majority rule be exercised directly - in meetings and votes, or indirectly - by appointing representatives?

Modern democracy is representative democracy. It is based on holding office for a certain period of time, representatives are elected in representative associations of the people, so that they discuss and make political decisions, and thus the will of the people is manifested mainly in elections. But this is how the sovereignty of the people is limited. The manifestation of direct democracy is the right of citizens to express their opinion. One of the tools is the popular poll or referendum, where the government can poll citizens on important topics. In the case of representative democracy, politicians and civil servants take responsibility for making the right decisions on behalf of the people, because the issues to be decided are complicated enough for non-specialists. The methods of direct democracy expand the possibilities of citizen participation, increase the integration capabilities and contribute to the legitimacy of the democratic system [7].

However, instruments of direct citizen participation at the central level exist in Italy, France, Ireland, Australia, New Zealand, Denmark as well as other countries. Switzerland is an example of implementing the methods of direct democracy mainly in a consensual democratic system, where all important decisions are made by consensus of almost all important political groups. An indisputable advantage of direct democracy is the fact that citizens directly make decisions and thus take responsibility for their consequences [8]. Participation can be at the level of local government, state administration or international institutions. If civic participation at the municipal level can be formally regulated in regulatory enactments or even not at all, then the formal types of civic participation at the national and international level are defined in regulatory enactments [9]. Informal participation can be the organization of various manifestations and participation in non-governmental organization networks. Public participation increases the government's responsibility to society and strengthens citizens' right to participate, strengthens society's influence on decisions [10]. Participation is the way to trust. The list of forms of civic participation cannot be exhaustive, because the most active and creative part of society is in search of new forms and methods of participation. The forms of public participation can be different - participation in elections, referendums, citizens' meetings (forums, hackathons, and think tanks), collective submissions, participation in innovation laboratories, and so on, as well as participation in participatory budget projects [11].

Participatory budgeting is one of the ways of public involvement in state or local government administration. It is a democratic process that gives citizens the opportunity to determine how part of the municipal or state budget is spent. Participatory budgeting is a set of structured measures for citizens to make direct decisions about spending state or local government money, which must be implemented by the organizer of the participatory budget [12]. Participatory budgeting activities are proposed by citizens and not the ideas of officials, however, there are concerns that due to limited resources and state policies, it may not develop democratically [13].

Participatory budgeting is implemented in more than 2700 municipalities in different countries of the world [14]. The costs of the largest projects are measured in millions of euros, while the most modest state investment is measured in thousands of euros [15]. The forms of participatory budget implementation can be different - in some places, the participatory budget is implemented on a national scale, in some places it is implemented on the scale of small villages or neighbourhoods. The involvement of the public in the planning of even a small part of the budget is a recognized benefit both for the citizens themselves, for the municipality and for the political system, because it is often observed that the citizens are dissatisfied with the work of the public administration and the public's involvement in the political processes is low. The most important thing is that the PB ensures that the participant's contribution will have an impact results [16].

II. MATERIALS AND METHODS

Participatory budgeting as a process as we know it now - when citizens present ideas, vote on them themselves and the municipality implements them, started already in 1989 in the city of Porto Alegre in Brazil. Under the leadership of Mayor Olivio Dutra, a participatory budget was introduced with the aim of promoting public participation in governance and channeling state resources to the poor. This example was a successful example of community mobilization, small-scale infrastructure and improving access to services. The participation budget in Porto Alegre was used until 2017. Over time, political support for participatory budgeting has declined, and Porto Alegre's current leadership has stalled the process, questioning the long-term impact [17]. Despite this, LB has become popular all over the world - thousands of participatory budget options have been introduced in America, Africa, Asia and Europe as well [18].

The USA created it for the first time in 2009. New York has been creating LB since 2011. Allocating one million dollars to four city council members and in 2016 more than 30 million dollars were already allocated [19]. Seattle and Boston have LB initiatives that focus on youth engagement [20]. It turns out that budget priorities change if citizens are also involved in the municipal budget process, and not only officials decide on it [21].

In Poland, since 2019, the implementation of the LB has been determined as mandatory for all municipalities (6 cities with county rights) and 0.5% of the last budget execution expenses must be allocated. The LB process is not mandatory for Latvia's neighbour Estonia, but it has been implemented by more than 20 municipalities. For the city of Tartu, the goals of LB are to improve understanding of the municipal budget and its formation process, to promote cooperation at the community level and to find solutions to practical problems in the city by implementing ideas [22].

In Europe, the example of Portugal is worth noting, because in this country LB has been implemented both at the national level and at the municipal level in the capital Lisbon, LB was introduced already in 2008 in accordance with the Lisbon LB principles charter. The charter guarantees that local residents are involved in the decision-making process, determining the areas in which a part of the municipal budget will be invested and, in general, this process teaches citizens to integrate individual problems into broader issues of common interest [23]. Meanwhile, the implementation of LB on a national scale is regulated by the resolution of the Portuguese Council of Ministers, which defines the implementation of LB model, which includes five principles - interconnection of thematic and territorial scopes, compliance of the project with the criteria, the period of funding, the amount owed, the principle of transparency of the procedure and the principle of execution of decisions. From the above, it can be said that the implementation of LB requires the following factors - well-structured participatory measures to ensure broad public participation, adequate financial resources and the support of a strong local government leader, political commitment and flexibility to adapt to the changing environment and the government's commitment to implementing the proposals generated in the process. As well as a civil society willing and able to contribute to the ongoing policy debate [24].

The successful implementation of participatory budgeting in municipalities requires a clear definition of the process and ensuring transparency, which consists of 5 stages (see Fig. 1)

Fig. 1 Stages of the participatory budgeting process [25]

In the first stage, the participation budget regulations are prepared and approved, which determine the financing available for the projects and the rules of project implementation. At this stage, it is recommended to involve society - associations, non-governmental organizations, foundations and residents of the specific municipality. In the second stage, citizens should be given the opportunity to vote on project ideas both in person and online by creating a national-level platform or a section on the municipal website. In Brazil, already in 2001, in the city of Ipatinga, for the first time, residents were offered the opportunity to vote on projects using the Internet. Online voting was later integrated into other Brazilian municipalities [26]. Since then, the number of cities around the world - Paris, New York, Lisbon, Mexico City, Madrid - that have used online voting has increased. Thirdly, the municipality must ensure the evaluation of the submitted ideas. The more precisely everything about project preparation, submission and evaluation of ideas will be described in the regulations, the fewer misunderstandings there will be. In the fourth stage, project ideas are put to a vote, so it would be important to ensure that the voting results are collected in a transparent manner. If the project is not forwarded for voting, the municipality must contact the project submitter and explain the reason. In the fifth stage, it is necessary to ensure the implementation of the winning projects and, if necessary, the maintenance of the created objects [27].

Researchers of the LB process allow themselves to say that no modern LB process is perfect, but it is attractive for philosophical reflection because it questions assumptions about democratic participation and budget prioritization [28].

III. RESULTS AND DISCUSSION

Public involvement in the state planning process in Latvia is defined in the Development Planning Law of the Republic of Latvia, Territorial Development in the Planning Law and in the Cabinet of Ministers regulations "Public Participation procedure in the development planning process". However, studies show that Latvia faces a significant problem of passivity of the population. In 2018, the survey conducted by the State Chancellery in cooperation with NGOs showed that the citizens do not believe in the ability to influence social and political processes, because they do not receive sufficient feedback from state and local government institutions. It was also concluded that the greatest desire of the public is to report on their own initiative to the state or local government institutions about their ideas and proposals for a specific problem that still has no solution [29]; [30].

The situation in municipal elections is very worrying. The low turnout in the 2021 local government elections can be explained not only by the disbelief to influence the situation, but also by the administrative territorial reform implemented in 2021, which was not supported by the population and imposed in many places, the difficult course of which once again confirmed the gap between the government and the society. The number of municipalities was reduced from 119 to 43. After the reform, in many places, the central administration is no longer easily accessible to residents - it has moved away both in terms of location and availability of services [32]. You have to get used to the fact that there are far fewer specialists in some parishes. During the reform, several municipalities contested the administrative-territorial reform in the Constitutional Court. Even in 2024, the mutual disputes about the existence of the forcibly united territories have not settled [32].

At the national level of Latvia, the issue of participatory budgeting became particularly relevant in 2020, when the Cabinet of Ministers' order "On the Conceptual Report "On the Implementation of Participatory Budgeting in Latvia" was adopted, in which the task of the Regional Policy Guidelines for 2021-2027 "Involvement of wider society in regional in achieving policy goals"[33]. For its implementation, the government planned and made changes in the regulatory acts for the implementation of the participatory budget in Latvia, defining the basic conditions for the participatory budget mechanism and methodical support for municipalities and local communities in the implementation of the participatory budget. In order to stimulate the involvement of Latvian municipalities and the public in the participatory budgeting process, the newly adopted Law on Municipalities included a chapter "Public involvement in the work of local governments", which describes the recommended methods of public involvement - public deliberations, collective submission, residents' councils, municipal referendum and the essence and principles of LB are presented. Based on this law, the participation budget for local governments in Latvia has been established as a mandatory procedure from 2025. What can Latvian municipalities expect in relation to the participatory budget? When implementing the participatory budgeting process, it is expected that it will promote the involvement of the residents of the administrative territory of the municipality in deciding the development issues of the territory [34]. The municipality will have to provide financing for the participation budget in the amount of at least 0.5 percent of the municipality's average one-year personal income tax and real estate tax actual revenues, which are calculated for the last three years. This amount can be considered relatively large, especially if the municipality has no experience of participation in budgeting. Based on the calculations made by the Ministry of Environmental Protection and Regional Development in 2020, when the amount of one percent was used in the modelling, the LB amounts in various municipalities amounted to 51,000 euros to 645,000 euros, except for Riga. After the merger of the municipalities as a result of the administrative territorial reform in 2021, the budgets of the municipalities have become larger and the planned financing of the LB may provisionally be larger (see Table 2)

There are 7 state cities and 36 counties in Latvia, which also include urban and rural areas, so in 2025 Latvia will have 43 municipal participation budgets. The answer to the question - whether Latvian municipalities have experience in organizing project tenders for February 2024, could be answered in the affirmative, because many municipalities have organized project grant tenders for creative, socially significant projects in the territory of the respective county, which promote culture, education, sports, leisure and the environment popularization of cleaning activities (as is the case in Livani county) or with the aim of promoting entrepreneurship, paying special attention to socially responsible merchants and economic operators (for example, the city of Jelgava). Also, since 1991 [35], Latvian local governments have had the opportunity to implement European Union projects with the LEADER approach to improve rural development potential. The main elements of LEADER are a partnership or a local action group, a strategy for the development of a local territory and a certain territory, but a "bottom-up" approach - when the initiative comes from local residents, getting involved in identifying and solving the problems of their territory.

Information on the websites of municipalities shows that out of all 43 municipalities in Latvia, 13 municipalities (30%) have voluntarily organized LB in the period from 2018 to 2024. Taking into account the fact that LB will be mandatory to be organized by 2025, it should be said that relatively less than 30% of the total number have gained experience in this not quite simple process, there is a risk that most municipalities will face difficulties in the LB process. Municipalities can voluntarily implement LB. The first municipality in Latvia that started implementing a participatory budget was the state city of Riga. Since 2018, it has organized a participation budget every year. The employees of the Riga municipality, in consultation with the PROVIDUS think tank researchers, learned from other countries and their own experience. This has also been done by Gulbene municipality [36].

In terms of money, very different funding has been allocated to the participation budget - the largest amount has been allocated by the state city of Riga - 700,000 euros [36], and the least - by Cesis County, 20,000 euros, [37]. In 2024, Riga will have its sixth attempt to create participation budget, but for Cesis County - first experience.

The author collected data on some local governments of Latvia, which voluntarily organized a participation budget in 2023, a comparison of the amount of the voluntarily determined participation budget was made with the expected amount determined by law (see Table 1). According to the author, the size of the amount is not decisive if one wants to try the LB process from the development of the regulations to the announcement of the winners.

TABLE 1 The 2023 participation budget of individual local governments of Latvia and Comparison of the expected participation budget in 2025 (thousands of euros)

Creating a budget	**Some Latvian counties**						
	Riga state city	*Gulbene county*	*Olaines county*	*Cesis county*	*Marupe county*	*Balvi county*	*Sigulda county*
The amount of the voluntarily created participation budget for 2023	700	110	150	20	250	60	160
The projected participation budget in the amount prescribed by law for 2024	3 891.9	65.5	116.3	157.6	248.4	51.5	163.8

The source was created by the author using Analysis of municipal financial indicators

From the data in Table 2, it can be seen that the voluntarily allocated size of the participation budget for four municipalities out of seven is greater than the legally determined, provisionally calculated amount. For only one municipality - Sigulda County, the current LB amount is 2% less than what it could be tentatively next year. In general, these numbers can be evaluated positively, because these municipalities will have the experience of financial administration of a relevant size with a participatory budget. However, the largest part of municipalities - about 30 municipalities that have never tried the LB process - is causing concern.

The local governments that voluntarily implemented LB have provided the voting system themselves, each autonomously. State support is promised for 2025, when the information system currently at the disposal of local governments - the Territorial Development Planning Information System - will be improved, thus providing an opportunity for local government development planning specialists to implement development planning processes in one place. At the same time, it is planned to create the public part of the LB information system in the form of an e-service on the Latvija.lv portal. This system will give citizens the opportunity to participate in the participatory budget initiative by submitting project applications or voting for other projects, and to view other examples of the implementation of territory development projects submitted in participatory budget tenders [38].

IV. RESULTS AND DISCUSSION

The research on the past experience of Latvian municipalities in not creating or creating LB was held in February 2024. An individual electronic questionnaire was sent to the heads of all municipal development departments. All 43 municipalities of Latvia were included in the general survey. Since in different municipalities, LB issues are coordinated by persons of different positions, a request was made in the questionnaire to forward the questionnaire to the most knowledgeable specialist about LB in the specific municipality.

A total of 33 questions were included in the questionnaire, including 29 questions about the experience of implementing a participatory budget and one question about the reasons why the municipality did not dare to implement a participatory budget and 3 questions for identifying the respondent. 15 questions were open-ended, 11 questions were closed-ended and 3 questions had to be rated on a Likert scale.

A study on the experience of Latvian municipalities in participatory budgeting. Out of 43 Latvian municipalities, 24 municipalities submitted answers. Out of 24 municipalities, six municipalities or 25% have had experience in organizing LB. These are Sigulda, Cesis, Smiltene, Valmiera, Gulbene and Olaine counties, whose specialists' answers are the basis for a study of existing experience and readiness for the next budget year.

To the question - why local governments have not organized a project competition, several answers were received - the vast majority (59%) answered that the law did not define LB as a mandatory measure, there was a lack of human resources (35%) to coordinate the process, a voting system was not provided (35%), there was a lack of funding for this purpose (30%). Other excuses were mentioned that other citizens' initiative projects are being implemented and the regulation on LB is in the process of being developed. The fact that none of the municipalities mentioned that there was a lack of understanding of the need for LB is a positive thing.

As the most important goal in the organization of LB, municipalities mentioned the involvement of residents in the development of the county and in deciding territorial issues. Smiltene County also mentioned promoting the recognition of the county as a goal, as well as developing creative forms of joint cooperation.

The amounts that the municipalities allocated to LB were different - from 20,000 to 160,000 euros, but during the trial period it did not play a significant role. The maximum funding allocated by the municipalities for one project depended on the total amount of the participation budget - the larger the total funding, the more money allocated for one project (see Table 3), it was 15,000 euros to 50,000 euros. Project applicants could submit their initiatives to LB within one or two months.

The duration of the participatory budgeting process, from the announcement of the tender or the publication of the regulations to the announcement of the project winners, took three, six, seven or eight months for municipalities. During this time, municipal employees, in addition to their direct work duties, had an additional burden, providing advice to project applicants and then moving the projects to a vote. It took an average of 2 to 4 hours a day or even 3 to 6 hours a day.

The number of project applications characterizes the activity of the population. In municipalities where LB was held for the first time (Cesis, Sigulda, Smiltene), a higher number of submitted projects has been observed (Table 2). This can be explained by the residents' expectations and the fact that there are restrictions in the regulations for project applicants if their project won and was implemented in the previous period, as is the case in Gulbene county.

TABLE 2 PB project submissions and voting results (created by the authors)

Indicators	**Some Latvian counties**			
	Sigulda county	*Gulbene county*	*Smiltene county*	*Cesis county*
The allocated participation budget in euros	160 000	110 000	30 000	20 000
Number of submitted projects	21	9	13	20
Qualified projects	12	9	12	17
Projects that received full funding	3	3	3	1
The number of citizens who voted	~10%	1400	2541	2000
Number of inhabitants on 01.01.2024.	32507	19592	18408	43438

Usually, not all submitted projects are developed in sufficiently good quality and therefore are not put to the vote, but in one municipality, all the submitted projects qualified for the vote. It should be noted that this municipality (Gulbene district) has more than 3 years of experience in working with project applicants and formulating requirements.

Most often (5 answers), municipalities cited non-compliance with the requirements of the regulations and too high costs or an increase in facility maintenance expenses after project implementation as the reason for not qualifying projects for voting. Out of six municipalities, four allowed in the by-laws that the implementation of the project could result in facility maintenance expenses, but two municipalities did not allow it. The creation of new facilities requires additional funding for maintenance. Municipalities may be dissatisfied with this, however, it must be said that any object needs care, inspection, and repair in order to serve perfectly. In the author's opinion, municipalities are doing the right thing by including restrictions on the project's future expenses in the bylaws, so that they are not endless.

An important part of the participation process is the provision of a vote. Here, municipalities have to take into account both their own capabilities and the digital skills and capabilities of local residents. The voting process is a competition between local communities and you have to expect that people are ready to cheat in order to win. Out of all the counties, only the Cesis County allowed that the declared and non-declared residents of the territory can vote on the projects. If only residents declared in the county can vote on the projects, then a method to verify this must be provided. Only one county ensured voting only online, the other counties organized voting both electronically and allowed voting on paper or in person in the municipality. In general, the number of voters varied from 500 to 33,000 (see Table 3), depending on the population of the municipality. In the best case, the voters make up about 10% of the declared population, but there is also a smaller proportion of voters (Olaine County).

Voting on projects could take from two weeks to one month. All municipalities allowed that the projects could be realized in the property of the municipality, two municipalities - in the property of the municipality and the state. The 2024 budget includes 1-3 projects that can be fully implemented, but two municipalities will start the partial implementation of one project. What have been the residents' wishes? Residents voted the most for projects related to the arrangement of recreation areas, environmental improvement, tourism promotion, youth activities, and one project dedicated to senior citizens' activities.

In a five-point Likert scale, municipalities assessed cooperation with colleagues, giving it 4.33 points. Despite the fact that the municipalities are beginners and the initiative submitters have little experience, the quality of the received project applications was assessed by the municipal specialists with 3.5 points. When asked to assess the complexity of the LB process, it was assessed with 3 points, which is an average assessment and a confirmation that there is still something to learn and improve.

Challenges for the LB projects implemented so far for municipalities have been - relevant funding allocation to LB, increase in costs during the implementation of LB projects, planning of project implementation deadlines, understanding of the need for LB among municipal employees, ensuring the operation of the voting platform, public understanding of LB goals and the ability of project submitters to qualitatively develop project applications, planning correct costs.

Challenges in the future in connection with LB, when it will be a mandatory process, according to local government specialists, are:

- Limited financial resources of municipalities;
- The uniformity of the submitted projects and the increase in the cost of the projects during their implementation;

- The capacity of the municipality to implement projects in terms of human resources and other non-financial resources;
- Development of an effective mechanism of regulation and activities for dividing the budget in planning units (territories) and so that the initiatives proposed by citizens are within the autonomous functions of the municipality;
- Determine optimal financing for one project. If it is set incorrectly (a small amount of funding for one project can lead to many supported projects), the municipality may lack the human resources to implement the projects within two years;
- Investment of the participation budget in property owned by another public person or a private person, which is permitted by law, is a challenge that municipalities cannot meet if the appropriate legal regulations are not developed;
- Creation of a unified voting system delegated to the Ministry of Environment and Regional Development is a concern. The local government participation budget regulations (binding regulations) may be different and it would be necessary for the ministry to consult with the local governments on the development of the voting system.

V. CONCLUSIONS

In the future, Latvian municipalities will have a challenge:

- Accept that it is necessary to take into account the opinion of the citizens and to form cooperation. If necessary, educate by teaching how to write project applications;
- Develop a high-quality participation budget regulation, so that there are clearly understandable rules both for citizens to submit projects and for the municipality to evaluate projects and organize voting. The regulations can be changed every year, according to the needs;
- Balance the current year's budget and necessarily plan a relatively large amount of funding in it for the financing of participation budget projects;
- In parallel with your direct job duties, undertake to perform additional tasks - consulting citizens in project writing and implementation of the projects that won the vote, from the development of the procurement specification to the successful conclusion. It would be important to receive support from the management of the municipality and colleagues of all those who will be involved in the participatory budgeting process.

Residents will have the opportunity to obtain financing for their initiatives, provided that the project application is prepared in accordance with the requirements of the regulations of the relevant municipality. Citizens should expect that the preparation of high-quality project applications takes a lot of time and there could be disappointment after an unqualified project or a project not voted by the public. Those project authors who definitely want to win the vote will have to spend a lot of energy on organizing the voting campaign. I would like to believe that the citizens' understanding of the work of the municipality will increase and, therefore, civic involvement in the next municipal elections in the summer of 2025.

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Sustainable solutions: Advancing in Tech-based ESG reporting platforms

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Abstract. **Sustainability reporting plays a crucial role in promoting ethical conduct, managing risks, and enhancing stakeholder engagement for businesses aiming for long-term success. Recent changes in European legislation, particularly the Corporate Sustainability Reporting Directive (CSRD), signal a significant shift towards aligning sustainability reporting with financial reporting to meet Sustainable Development Goals. Concurrently, advancements in Environmental, Social, and Governance (ESG) reporting processes have led to the emergence of tech-based platforms, leveraging artificial intelligence (AI), to streamline data gathering and compliance efforts among EU companies. This paper examines the potential impacts of such platforms, focusing on their role in facilitating ESG information collection for regulatory compliance. Utilizing secondary sources such as European legislative acts and relevant literature, the study also presents a case study of "Ecomate ESG platform" as an illustrative example. In addition to regulatory compliance, these platforms offer benefits such as improved efficiency and enhanced stakeholder engagement. The conclusion draws upon key findings to propose general recommendations for the future development of the ESG sector and the effective utilization of AI within it.**

Keywords: sustainability; eco-innovation, net-zero economy, Tech-based solutions, corporate governance.

I. Introduction

The accelerated dynamics of global economic, social, and ecological processes, influencing and causing changes in the policies and consequently in the legislation of the European Union (EU) which busts innovation and affects businesses. A number of events of the last decade such as the war in Ukraine, Covid-19 and the health crisis (Kumar, Srivastava, 2022), the shortage of energy resources etc. pose strategic questions to the European community and highlighted the debate in terms of functions and responsibilities of businesses [1]. The literature on Corporate Social Responsibility (CSR) has been a subject of study for over seven decades since its inception in the 1950s. Kumar and Srivastava have observed a remarkable surge in research in this area and today ESG reporting is considered as one of the most researched topics when it comes to business ethics [1]. No-financial reporting becomes an obligatory prerequisite for increasing a company's reputation which leads to better economic performance and increased competitiveness on the market, furthermore "protecting the planet and meeting social needs" [2].

As societal expectations evolve, sustainability reporting has emerged as a pivotal practice, guiding companies toward ethical conduct, risk management, and long-term viability. The landscape of Environmental, Social, and Governance (ESG) reporting is undergoing significant transformation, driven both by the requirements of the latest EU legislation, as well as by technological innovation. The proliferation of tech-based platforms, empowered by artificial intelligence (AI), offers new avenues for companies to navigate the complexities of ESG reporting. These platforms promise to streamline data collection, enhance regulatory compliance, and facilitate stakeholder engagement. Against this backdrop, this paper explores the potential impacts of tech-based ESG reporting platforms in the EU, with a focus on their role in facilitating ESG information gathering for regulatory compliance. The primary objective of this study is to analyse the potential impacts of tech-based ESG reporting platforms in the EU,

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particularly in facilitating companies' compliance with regulatory frameworks and enhancing their sustainability efforts. This study adopts a methodology of utilizing a comprehensive review of European legislative acts and an analysis of relevant scholarly literature, also incorporating a case study of the 'Ecomate ESG platform' to provide practical insights into the functioning and effectiveness of such platforms. By delving into the nuances of this evolving landscape, the paper aims to offer valuable insights and recommendations for the future development of the ESG sector and the effective integration of AI technologies.

II. Materials and methods,

A. Literature review and data collection

For the purposes of the paper secondary sources of information and analysis are conducted, including scientific research articles of established authors and official publications in key databases such as Scopus, and Web of Science. In addition, the research examines an European legislative acts such as the Corporate Sustainability Reporting Directive (CSRD) and relevant literature on sustainability reporting frameworks. Upon the literature review, compiling evidence suggest that this scientific domain remains nascent and inadequately matured. For this reason, the paper presents a case study of an applicable reporting ESG Platform, called Ecomate. The data is analysed in order to evaluate the features and of tech-based ESG reporting platforms. The rapidly evolving nature of technology and regulatory frameworks could be considered as a limitation.

B. Theoretical framework

Sustainability reporting serves as a crucial tool for organisations to communicate their environmental, social, and governance (ESG) performance to stakeholders [3]. Various frameworks and guidelines have been developed to standardise the reporting process and ensure the disclosure of relevant information. One prominent framework is the Global Reporting Initiative (GRI), which provides comprehensive guidelines for reporting on economic, environmental, and social impacts. The GRI framework emphasises the importance of materiality, stakeholder engagement, and transparency in reporting, guiding companies in identifying and prioritizing ESG issues relevant to their business operations [4].

The integration of technology into ESG reporting processes has transformed the way companies collect, analyse, and disclose sustainability data. Tech-based ESG reporting platforms leverage advanced technologies such as artificial intelligence (AI), machine learning, and big data analytics to automate data collection, identify trends, and generate actionable insights. These platforms enable companies to streamline the reporting process, enhance data accuracy, and improve stakeholder engagement by providing timely and transparent information [5].

From a theoretical standpoint, the adoption of tech-based ESG reporting platforms can be understood through several lenses. Institutional theory suggests that organisations adopt new practices, such as tech-based reporting platforms, to conform to institutional norms and expectations. The legitimacy gained through ESG reporting enhances the organisation's reputation and reduces institutional pressures. Additionally, resource-based theory posits that companies invest in technology to gain competitive advantages, such as improved efficiency and decision-making capabilities. By leveraging tech-based reporting platforms, companies can better manage their ESG risks and opportunities, leading to long-term sustainability and profitability [6].

Despite the potential benefits, the adoption of tech-based ESG reporting platforms is not without challenges. Technical barriers, such as data integration and system compatibility, may hinder the implementation process. Moreover, concerns about data privacy, security, and algorithm bias raise ethical considerations that must be addressed [7]. However, these challenges also present opportunities for innovation and collaboration among stakeholders. By addressing technical and ethical concerns, companies can harness the full potential of technology to advance their sustainability goals and create value for society.

III. Results and discussion

A. Regulatory landscape

The introduction of tech-based ESG reporting platforms is dictated not only by global trends and improving the company's reputation, but also with the evolving legislative landscape, particularly within the European Union (EU). Therefore, before analysing the case study, an overview of the European legislation framework is needed. The EU recognizes that environmental issues are not isolated and affect all other spheres, including at the supranational level.

The beginning of the common European environmental policy was set in 1972 during a meeting of a low Council in the city of Paris, France. The Single European Act of 1987 introduces an entirely new section "Environment" which aims to provide the first legal basis for a common policy in the field of the environment, with the aim of preserving the efficiency of the environment, protecting clean health and to ensure the rational use of natural resources [8].

In terms of environmental, transport, energy efficiency and competitiveness policies, the Green Deal is the first European legislative act to set the goal of climate neutrality by 2050. The goals are ambitious, with the document stating that by 2030 carbon emissions should decrease by 55%, and by 2050 the net emissions of greenhouse gases on the territory of the Union should be completely eliminated and a transition to clean energy should be ensured [9].

As a part of the tendency and according to the innovations in the European legislation from 2023, changes to CSRD came into force, which includes mandatory reporting of information on the sustainability of a business, according to the European Sustainability Reporting Standards (ESRS) framework. This means that from 2024 it will be phased in as mandatory for large companies to comply with ESG standards and to report non-financial reports regarding ESG. As of this year The

Directive (EU) 2022/2464 of the European Parliament and of the Council applies to all State Members as it affects the organisations with the public-interest entities with an average number of employees over 500 and net turnover over EUR 40 million [10]. It is envisaged that the non-financial ESG reports will gradually evolve towards greater comprehensiveness for medium and small enterprises.

The changes to the CSR Directive are required for several reasons, the first of which is related to the conditions laid down in the European Green Deal. For example, the following documents are prepared: Action plan for financing for sustainable growth; System for classification of ecologically sustainable economic activities; "Guidance on the disclosure of non-financial information: Supplement on the disclosure of climate-related information" and others that need to be considered when preparing the corporate sustainability report.

The second group of factors relates to the increased interest on the part of investors regarding corporate information on sustainability. Climate change, loss of biodiversity, changes in soil, water, air, etc. are an objective prerequisite for increased financial risk. In this context, before starting the research and subsequently the realisation of an investment intention, ESG data is also needed. This would provide a comprehensive and credible assessment to investors, based on which they could successfully eliminate any of the potential financial threats. In practice, it turns out that non-financial reporting has an indirect financial result and impact, which further increases the need for reporting.

According to a KPMG study conducted in 2015, the world's largest 250 companies (from the Fortune Global 500 ranking) perceive reporting as an important chat from company management, and for the same year, 92% of them developed and communicated a corporate social report [11]. In addition to the need for compliance with regulatory requirements, the consideration of corporate sustainability leads to the improvement of the ESG rating and to positives for the organisation, improving its reputation with customers and investors.

Due to the emerging regulatory changes in European legislation, the topic of corporate ESG reporting in 2023 is gaining wide relevance. The specification of documentation and additional administrative work directs companies to seek external companies for creating an ESG strategy and reports. This tendency is a prerequisite for advancing in Tech-based ESG reporting platforms. This, in turn, creates a demand for new competencies in the market and allows a number of consulting and auditing companies to specialise in the subject and build a competitive advantage.

In summary, the implications of regulatory changes on ESG reporting practices are far-reaching and impact the way companies manage risks and position themselves in the marketplace, while sustainability becomes a must-have element in the management of companies that wish to compete in the market. Based on the described effects, at the current stage there is a tendency to introduce new software developments and tech-based ESG platforms on the market, designed to ease reporting processes in the corporate sphere and provide a technological base for these activities.

B. Tech-based ESG reporting platforms: features, functionality and impact.

Tech-based ESG reporting platforms are designed to offer a comprehensive suite of features and functionalities that enable organisations to effectively manage and report their environmental, social, and governance (ESG) performance. These platforms leverage advanced technologies such as artificial intelligence (AI), machine learning, and big data analytics to automate data collection, analysis, and reporting processes, thereby enhancing efficiency, accuracy, and transparency in sustainability reporting. Some of the main features and capabilities of AI-driven ESG reporting platforms include, but are not limited to [12]:

Data collection and aggregation. Tech-based ESG reporting platforms facilitate the collection and aggregation of ESG data from various internal and external sources. They integrate with existing systems such as enterprise resource planning (ERP) systems, supply chain management software, and sustainability management tools to gather data on key performance indicators (KPIs), environmental impact metrics, social responsibility initiatives, and governance practices. Advanced data aggregation techniques ensure the seamless integration of disparate data sets, enabling companies to generate comprehensive reports that reflect their overall sustainability performance.

Data analysis and visualisation. These platforms employ AI algorithms and machine learning techniques to analyse ESG data and extract meaningful insights. They use advanced analytics tools to identify trends, patterns, and correlations within the data, allowing companies to gain deeper insights into their sustainability performance and identify areas for improvement. Visualisation features such as interactive dashboards, charts, and graphs help users to visualise and communicate complex data in a clear and compelling manner, making it easier to understand and interpret.

Customizable reporting templates. Tech-based ESG reporting platforms offer customizable reporting templates that enable companies to tailor their ESG reports to meet the needs of different stakeholders. These templates provide a framework for organizing and presenting ESG data in a standardized format, ensuring consistency and comparability across reports. Companies can choose from a range of predefined templates or create their own, incorporating relevant metrics, indicators, and benchmarks to effectively communicate their sustainability performance to stakeholders.

Stakeholder engagement tools. Many tech-based ESG reporting platforms include stakeholder engagement tools that facilitate communication and collaboration with investors, customers, employees, and other stakeholders. These tools enable companies to gather feedback, respond to inquiries, and demonstrate transparency in their sustainability efforts. Features such as online forums, surveys, and feedback mechanisms allow stakeholders to engage directly with companies, providing valuable insights and fostering a culture of openness and dialogue.

The adoption of tech-based ESG reporting platforms has significant implications for companies, investors, and other stakeholders, shaping decision-making processes and driving positive social and environmental impact [5].

Tech-based platforms improve transparency and accountability by providing stakeholders with timely and accurate information about companies' sustainability performance. This increased transparency fosters trust and credibility, enhancing companies' reputation and brand value [13].

By providing companies and investors with access to comprehensive ESG data and insights, tech-based platforms support informed decision-making processes. Companies can identify emerging risks and opportunities, allocate resources more effectively, and align their business strategies with sustainability goals.

Of course, there are also some challenges, limitations and risks associated with the use of Tech-based platforms for ESG reporting [5].

One of the primary challenges associated with tech-based ESG reporting platforms is ensuring the quality and reliability of the data used for reporting. Companies often rely on a variety of internal and external data sources, each with its own level of accuracy and completeness. Ensuring data quality requires robust data validation processes, data cleansing techniques, and ongoing monitoring to identify and correct errors or inconsistencies.

Integrating tech-based ESG reporting platforms with existing systems and processes can be complex and time-consuming. Companies may encounter compatibility issues, data interoperability challenges, and resistance to change from employees accustomed to traditional reporting methods. Achieving seamless integration requires careful planning, stakeholder engagement, and investment in training and organizational change management.

Keeping pace with evolving regulatory requirements and standards presents a significant challenge for companies using tech-based ESG reporting platforms. Regulatory frameworks such as the Global Reporting Initiative (GRI), the Sustainability Accounting Standards Board (SASB), and the Task Force on Climate-related Financial Disclosures (TCFD) continue to evolve, introducing new reporting requirements and guidelines [4]. Ensuring compliance with these regulations requires ongoing monitoring, updates to reporting templates, and alignment with industry best practices.

Tech-based ESG reporting platforms often involve the collection, storage, and processing of sensitive data, including financial information, employee data, and environmental performance metrics. This raises concerns about data privacy and security, particularly in light of increased regulatory scrutiny and the growing threat of cyberattacks. Companies must implement robust data protection measures, such as encryption, access controls, and regular security audits, to mitigate the risk of data breaches and unauthorised access.

The use of AI algorithms and machine learning techniques in tech-based ESG reporting platforms introduces the risk of algorithm bias and interpretation errors. Biases in data selection, modelling assumptions, and algorithmic decision-making can lead to inaccurate or misleading results, undermining the credibility and reliability of ESG reports. Companies must carefully assess the validity and robustness of AI algorithms, conduct sensitivity analyses, and provide transparent disclosures about the limitations and assumptions underlying their models [13].

While tech-based ESG reporting platforms offer many benefits, there is a risk of overreliance on technology and automation, leading to a reduction in human oversight and judgement. Automated data collection and analysis processes may overlook nuanced or context-specific factors that require human judgement and interpretation. Companies must strike a balance between automation and human intervention, ensuring that technology complements rather than replaces human expertise in ESG reporting and decision-making processes.

To summarise, tech-based ESG reporting platforms offer promising solutions to enhance sustainability reporting practices, providing companies with advanced tools and functionalities to streamline data collection, analysis, and reporting processes. These platforms enable companies to improve transparency, accountability, and stakeholder engagement, driving positive social, environmental, and economic outcomes. However, their adoption is not without challenges and potential risks, including data quality issues, integration complexities, regulatory compliance burdens, as well as concerns about data privacy, algorithm bias, and overreliance on technology. Addressing these challenges and mitigating risks will be crucial to realizing the full potential of tech-based ESG reporting platforms and ensuring their effectiveness in supporting sustainable business practices and decision-making.

C. Case Study: Ecomate ESG Platform

This section of the article presents a case study of an applicable reporting ESG Platform SaaS (Software as a service), called Ecomate, presented by the Italian company Ecomate S.R.L. The investigated platform is one of the first ESG software suites of all products needed to integrate sustainability in a company, whose alpha version was released first in 2020. Furthermore, the platform is pertinent to be researched due to the fact that it integrates all 4 investigated features and capabilities of AI-driven ESG reporting platforms. Its algorithms guide the company through the implementation of sustainability, with straightforward language and instant timing.

The process starts from the data acquisition through either self-assessment or risk analysis. Subsequently, an ESG rating is obtained, leading to the generation of a customised improvement report and continuing through to the stage of non-financial disclosure. One of the positives is that the Platform offers solutions designed for monitoring a multitude of companies to create personalized audits and ratings using the world's first RaaS (Rating As A Service), which is considered as a competitive advantage of this product.

Through a fully guided assessment, Ecomate's algorithm calculates the environmental, social, and governance (ESG) performance of a company using 11 impact modules and over 70 sustainability topics. The scope of the algorithm supports all existing industrial sectors and multiple national and international compliance frameworks and detects the criticalities of the company. Platform advantage is that it automatically generates a fully personalised report, based on the client's answers, whose aim is to enhance and solve sustainability related problems. The platform is designed to facilitate portfolio monitoring, incorporating tailored audit trails personalised to individual requirements, which ensures control and documentation in accordance with scientific standards.

Another positives of the researched platform is the ESG open standard approach, which means that the entire process, related to sustainability ranking, is designed to be transparent, clear and accountable, which enhances visibility and facilitates the decision-making process

In order to ensure transparency and compliance with the legal framework the process is overseen and verified by a decentralised technical-scientific committee. This committee operates under an open-science licence, emphasising the importance of collaboration and sharing within the scientific community. This type of crowdsourcing, involving external experts in shaping the rating's logic and content, should ensure transparency and fairness. Currently, 8 consulting firms and nearly 50 experts across various domains have volunteered their time, contributing over 20,000 hours of work. Ecomate claims that the approach allowed them to create a reporting algorithm, able to produce nearly 300,000 unique improvement and impact comments, along with a benchmarking system that offers substantial depth of analysis and flexibility [14].

In tech-based platforms the duality is considered crucial, especially in the context of the business model aimed at institutional clients (e.g. banks) or companies with extensive supply chains. In connection with that Ecomate's framework is established based on self-reporting, with the dual purpose of preventing fraud, as a basis for the truthfulness of platform's results and assisting users through a process inherently reliant on uncertain and potentially not clear-understood data. To be competitive in the market, the platform needs to incentivize the adoption of the framework among their clients and suppliers to gain traction, making the platform a useful instrument that could reduce monitoring overburden. In response to marker Ecomate has created an extensive approach, combining different techniques and logic, which showed that the use of AI (especially machine learning algorithms) was a last resort, more supporting than enforcing fraud prevention. Multiple layers (tiers) of engagements are applied as follows:

- Psychological. The platform provides valuable insights and business improvement suggestions, which rely entirely on correct data, in case of fraud data the user is explicitly warned, added to a grey list and network is informed and users are aware of sample checks of the received data, including visits;
- Stakeholder involvement - Each profile has its public url address at Ecomate, where stakeholders could report discrepancies or detected problems;
- Internal logical supervision – The platform uses its proprietary mapping algorithm, using an expert system of unusual or contradicting user trails, basically asserting that claimed data is not expected by certain types of client profile.
- External data cross checking - proprietary multilevel algorithm for cross-checking with data from databases e.g. Creditsafe and from publicly available data e.g. Eurostat;
- Machine learning algorithms – Use to detect anomalies, later assigned for review to the support team.

In summary of the provided information about the Ecomate ESG platform, the tool could be considered only as an intermediate stage before actually Ecomate takes steps into implementing deepening AI integration. Looking at the core service model of Ecomate platform the value of AI could be extracted, considering scalability as a data flow and connectivity and a client servicing. The increase of diversified clients will put pressure on the servicing and maintaining client satisfaction. With the increase of data and global data flow, machine learning is increasing its ability to be useful instruments in providing more by fraught detection, smarter decisions, and improved look over the future.

The newest AI advance under the label of LLMs (Large language models) is setting a new bar of expectations. The current implementation, providing users with advice and connecting them with consultants is not enough within the world of AI agents, especially those trained for specific tasks. Writing reports could be easily also "outsourced" to AI.

In order to be competitive in the rapidly growing market of reporting technologies, Ecomate has created a plan for the forthcoming 2025 to integrate AI in the entire set of services and processes such as:

- AI for robo-advisory to guide better customer experience/support
- Forecasting ESG engine with ML / deep learning
- GPT-LLM large language model for improvement reports
- Fraud detection improvement with AI-Analyst
- Strategy/tactical AI to create revenues paths
- Filling the gaps between products with AI

It is essential to make a distinction between the market expectations, especially the venture investors, in such a way that the AI is obligatory included in the future backlog against the necessity to implement it. Challenges are mostly related to gaining traction with the customers, making reporting easy and useful for the final respondents.

Probably the most direct benefit in the backlog will be gained from the connection with LLM. Understanding LLM only as an advisory function is showing some limitations, where the full potential could be realised only in fine-tuning and in the future integration of the scientific committee as specific LLM agents, with the ability to adapt to the increasing legal framework.

IV. CONCLUSION

In conclusion, the rise of tech-based ESG reporting platforms represents a significant milestone in the evolution of sustainability reporting practices. These platforms leverage advanced technologies such as artificial intelligence and machine learning to automate data collection, analysis, and reporting processes, offering companies a powerful tool to enhance transparency, accountability, and stakeholder engagement. By streamlining reporting processes and providing timely and accurate information, tech-based platforms enable companies to meet evolving regulatory requirements, identify emerging risks and opportunities, and align their business strategies with sustainability goals. However, the adoption of these platforms is not without challenges and risks, including data quality issues, integration complexities, and concerns about data privacy and algorithm bias. Addressing these challenges requires a concerted effort from companies, regulators, and other stakeholders to ensure the effective implementation and responsible use of technology in ESG reporting.

The case study of the Ecomate ESG platform provides a practical illustration of how tech-based platforms are implemented and utilized in real-world scenarios. Ecomate's innovative approach combines self-reporting with AI-driven algorithms to facilitate data collection, analysis, and reporting processes, while also addressing concerns related to fraud prevention and stakeholder engagement. By leveraging AI technologies, Ecomate enables companies to assess their ESG performance, identify areas for improvement, and generate actionable insights to drive sustainability initiatives. The platform's transparent and collaborative approach, coupled with its commitment to data integrity and security, underscores the potential of tech-based ESG reporting platforms to drive positive change and enhance corporate sustainability practices.

By analysing the case study, an important outcome is that due to the new technologies and legislation, there occurs a need for data availability and collection, which is an essential part of the ESG reports optimization and analyses. Furthermore, reflection on the significance of tech-based ESG reporting platforms is that the companies should incentivize data collection which also will reflect positively on fraud, and probably also reduce self-reporting through automated data analysis. By applying comprehensive ESG tools and ensuring the quality and reliability of the data used for reporting, companies increase their competitiveness in the market and improve their efficiency and decision-making capabilities, reputation, and overall performance.

As we continue to navigate the complex landscape of sustainability reporting, it is essential to embrace innovation, collaboration, and transparency to build a more sustainable future for all. By harnessing the power of technology and adopting best practices in ESG reporting, companies can not only meet regulatory requirements but also create value for society, investors, and other stakeholders, driving positive social, environmental, and economic outcomes in the process.

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Evaluation of aspen (Populus tremula) wood structure infected by fungi (Phellinus tremulae) and opportunities for wider use of timber in structural elements

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Abstract. **The external characteristics of aspen (*Populus tremula*) tree give the only clue to the quality of logs, packing case timber, pulpwood and other roundwood assortments obtained in harvesting. When the tree is bucked into roundwood assortments, the cross sections at the butt and top ends of these assortments may provide additional indicators of the quality such as heart colouring, wetwood, heartwood hard rot and heartwood soft wood. Thus, it becomes important when correlating the occurrence of these imperfections with the quality of sawn timber that is produced from the aspen logs and packing case timber. Although aspen has a wide distribution throughout Europe, there are no unified quality requirements for roundwood assortments due to lack of scientifically approved information related to wood structure.**
To identify the fungi caused aspen decay and describe the main anatomical changes generated by the fungi *(Phellinus tremulae)* Polymerase Chain Reaction laboratory technique were used in the investigation.

The main goal of the study is to work out the aspen roundwood, harvested in final felling sites timber strength parameters depending on timber quality characterized data based on the testing methods: moisture content - according to *ISO13061-1:2014*; density - according to *ISO13061-2:2014*; compression strength paralel to the grain- according to *ISO 13061-17:2017*; modulus of elasticity- according to *ISO 13061- 4:2014*; three point bending strength - according to *ISO 13061- 3:2014.*
The results of the study might help for practical applications so that this wood specie can be processed more efficiently for the value - added products and thorough knowledge of decay patterns of *Phellinus tremulae* are likely to assist to establish more accurate quality requirements for roundwood assortments and provide useful information for optimizing tree management programs.

Keywords: Populus tremula, Phellinus tremulae, **timber strength parameters.**

1. INTRODUCTION

European aspen (Populus tremula L.) is one of the most widely spread species in the world, with a natural range stretching from the Arctic Circle in Scandinavia to north Africa, and from Britain across most of Europe and north Asia to China and Japan. In Latvian aspen is the second most common hardwood species forming 3.68 % of the total wood supply [9; 10]. Only 27% in the year 2022 of the Latvian aspen supply goes to the sawmill industry for processing and since there are no Latvia grading rules and design values for aspen timber nothing of the timber is used for structural purposes.

Aspen heart rot decays the heartwood of infected trees. In early stages of disease development, the heartwood begins to show patterns of discoloration, but remains hard and firm. As the decay advances, the heartwood decomposes and the tree loses structural strength. Although heart rot does not affect all uses of aspen, decayed wood has undesirable pulping qualities and

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stained wood is not suitable for veneers [1; 6; 11; 28; 43]. Aspen heart rot caused by fungus *Phellinus tremulae.* This pathogen occurs only on living aspen [1; 2; 3; 32; 33].

The pathogen infects branch stubs or small dead branches, eventually growing into the inner wood along the branch trace. It begins to grow out to the surface along branch traces to produce conks. Microscopic spores produced in conks are airborne and travel long distances. Spores can cause infection if they land on a suitable point. Defected trees lose an average of 70 % of wood volume in cull [4; 5; 19; 38].

Compared to other decays, conks are reliably produced and are useful indicators for detecting and estimating heart rot.75-85% of trees with cull due to aspen heart rot have conks [31; 34]. Average cull for trees with conks is 82%, but only 40% for infected trees without conks. On a linear basis, decay generally extends 2.4-3.7m in each direction from conks. Aspen causes white trunk rot, the most important heart rot of Aspen. Although white trunk rot occurs throughout the tree's range, the disease varies in incidence and severity [40]. Damage has been related to tree age, diameter, site quality and genotypic variation [32]. Studies show that 21- to 50- year old stands found that 80% of trees had at least some advanced decay, trees with conks (14% of all trees) accounted for 64% of the decay found in the study.

The early stage of decay is characterized by a soft cream color, often with distinct dark zone (demarcation line) [6] separating it from the surrounding healthy wood. In later stages of decay the wood becomes spongy or punky, yellowish in color and the decayed wood contains a number of irregular concentric black zone lines [1; 8; 13; 21; 43].

Although aspen heartwood is normally not distinct in appearance from sapwood, discoloration or staining is common of aspen stems. It may originate as a response to wounds, frost cracks, branch stubs, insect or ani mal damage, incrementbore holes. In addition, discolored zones often are associated with cankers, decay columns and other microorganism activity. Discoloration may result from the reaction of living cells of the xylem to various agents or directly from color imparted by microbial tissues or products.

Many stains occur in the heartwood before or during the development of decay. In the initial stages, the strength of affected tissues is not greatly reduced, but later these tissues may be weakened [6; 15; 16; 17; 21; 22; 23; 41]. However, because of the many fungi and bacteria associated with stain in aspen and the vagaries of stain color and other features, it is difficult to be sure of the causes of particular stains. For example stains caused by wetwood [16; 41].

Wetwood appears wet and discolored and has a high mineral content and variable bacterial populations. It is not necessarily associated with decay. In fact the anaerobic conditions and organic acids in wetwood inhibit fungal growth. Although the discoloration in aspen largely disappears when dried, the wood is brash and subject to splitting and cracking and has reduced strength. Because the color fades, it is difficult to detect and cull out these affected zones early in the manufacturing process.

The requirements of wood for matches are exacting in that the wood must combine straightness of grain, ease of splitting, easy of working, and taughtness, To meet such rigid requirements, a wood must be suitable for other uses as well. The fact that aspen is not used more widely for other purposes lies not in the wood itself but in other factors, such as distribution of stands and availability in desired sizes and grades. Cost, demand, and harvesting and marketing practices change as conditions change. The fact that in the past some of these factors have been adverse to the utilization of aspen stands does not mean that the wood cannot be used more widely now and in the future at a reasonable cost and without sacrifice of the quality of the product.

General description of *Populus tremula* physico-mechanical properties on the basis of different literature sources [14; 40] are given (Table 1).

TABLE 1. PHYSICAL AND MECHANICAL PROPERTIES OF EUROPEAN ASPEN AT THE ABSOLUTE HUMIDITY 12% ON THE BASIS OF DIFFERENT LITERATURE SOURCES

Country, region	**Density kg/m^3**	**Compressing strength N/mm^2**	**Hardness, N/mm^2**			**Compression strength paralel to the grain, N/mm^2**		**Bending strength, N/mm^2**	**Modulus of elasticity, N/mm^2**	**Swelling ratio, %**		
			ends	**radial**	**tangential**	**pressure**	**stretch**			**radial**	**tangential**	**volume**
Central Russia	485	12,4	27,7	19	19,9	44,7	133	77,4		0,2	0,32	0,54
Latvia	475					42,8	97,1	71		0,13	0,32	0,47
Belarus	495	9,76	25,2	17,7	18,8	42,3		71,7		0,18	0,3	0,5
Ukraine	525	11,3			19,6	46,1	134	91		0,13	0,32	0,47
Armenia	515		24,5	19,8	20	39,5		71,4		0,11	0,26	0,39
Eastern Russia	416					35,7		65		0,17	0,24	0,43
Swedern	434	11,93						55,1				
Central Europe	450								9750			
North America	380		27						8100			

The purpose of this study was to investigate the aspen wood infected by fungi *Phellinus tremulae* using fungal identification molecular methods and according to the investigation results and taking into account the knowledge about the strength properties of aspen obtained in references (Table 1.) to determine the strength properties of aspen timber originating from Latvia sound timber, timber coloured caused by fungi when strenght parameters aren't significantly affected, early stage of rot, characterized by discoloured fibres and patches in the wood, where the general texture and strength properties only start being affected. The investigations were carried out in Latvia State Forest Research Institute "Silava" and in Latvia University of Life Sciences and Technologies at the Forest and Wood Product Research and Development Institute Testing Laboratory "MEKA". The goal of this study was to supplement and synthesize the existing experience and knowledge about *Populus tremula* timber physico-mechanical properties and to work out the recomendations to improve the commercial value of roundwood assortments, to find out the possibilities of using visual and machine grading and to determine some of the mechanical properties of the material in bending and compressing.

The following objectives were set to achieve the study goal:

1. To investigate the aspen wood infected by fungi *Phellinus tremulae* using fungal identification molecular methods [6], sampling methods and general requirements for physical and mechanical testing of small clear wood specimens [21; 36], moisture content for bending specimens [17; 25], density for bending specimens [26], wood -sampling methods and general requirements for physical and mechanical tests [27], compression strength paralel to the grain [29], three point bending strength and modulus of elasticity [30]
2. To offer the quality recomendations of aspen roundwood assortment toward heart coloration and hard rot stage identification in relation to the quality requirements not only of traditionally manufactured products (furniture manufacturing, sauna, cladding, indoor doors, wood work, core material, veneer and plywood production) but also requirements of building construction elements and glued laminated timber (GLT) [7; 12; 29; 30; 35; 44; 45].

II. MATERIALS AND METHODS

In order to investigate an aspen wood infected by fungi *Phellinus tremulae* (Fig. 1) using fungal identification molecular methods, the aspen stem quality characterized 45 wood pieces were prepared for fungal identification (Fig. 2)

Fig. 1. Phellinus tremulae.

Fig. 2. Preparation of selected aspen stems quality characterized wood pieces for fungal identification.

For fungal identification molecular methods (PCR) were used. One to three representatives from the unidentified fungal morphotypes were subjected to molecular identification using the universal fungal primers ITS1F and ITS4 [7]. Molecular work (DNA extraction, PCR amplification and PVR product purification) was performed in the Latvian State Forest Research Institute Silava Genetic Resources Centre. Sanger sequencing (in one direction) was performed by Macrogen Europe using the ITS4 primer. All sequences were manually edited using the Lasergene software package SeqMan (DNASTAR, Madison, Wisconsin). BLAST searches were performed using GenBank (https://blast.ncbi.nlm.nih.gov/Blast.cgi). The Internal Transcribed Spacer (ITS) sequence homology was set at 98 – 100 % for delimiting fungal taxon and at 95-98% for delimiting at the genus level.

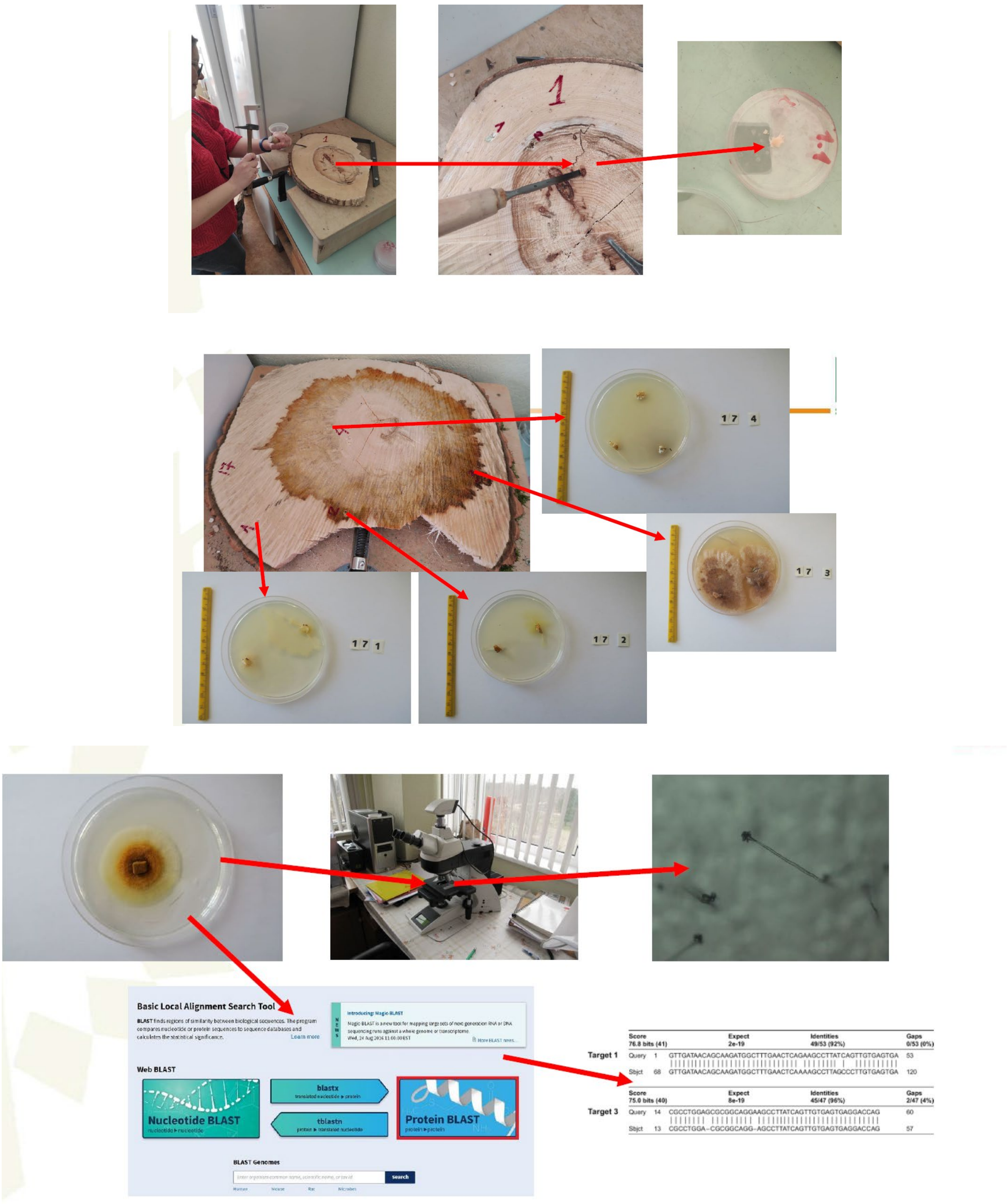

Fig. 3. Molecular research method (PCR).

In order to investigate the possibility of using sawn timber of European aspen (Populus tremula L.) as a structural material, 26 pieces unedged aspen boards were prepared in the sawmill "4 Plus" in the north of Latvia according to the scheme (Fig. 4).

According to the [24] principles unedged aspen boards were longitudinally cutting into edged boards of the dimension 32x1300mm). Boards were chosen to represent sound wood, heartwood colouring and hard rot stage zones [24]. Boards were dried at room temperature until the moisture content equilibrium of the indoor air which was detected by the successive weightings until reaching the constant mass.

After samples were logitudinally sawn, planed and calibrated to the actual size 22 mm x 22mm and cut in 350 mm long pieces for bending strenght and modulus of elasticity testing [30], for compression strength paralel to the grain testing samples were prepared into dimensions 25x25x40mm [30]. All of the testing samples were conditioned at the standard environment of 20±2 °C and 65±5 % relative humidity [25] (Fig. 4).

All of the samples were selected into 3 groups; sound timber, heartwood coloured timber, heartwood hard rot stage timber (Fig. 5).

Fig. 4. Selection of the laboratory tested aspen wood samples.

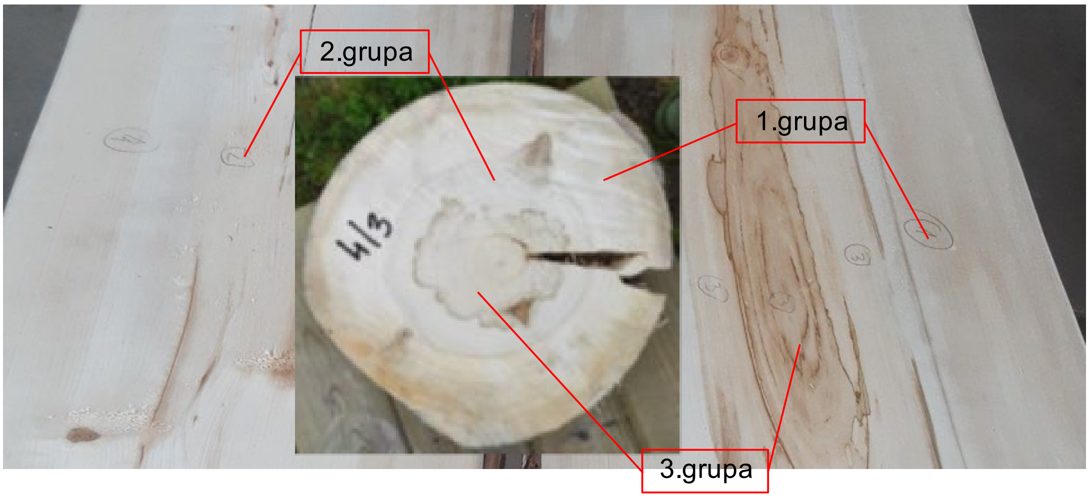

Fig. 5. Selecting of the testing samples according to the quality, where 1 grupa- sound timber, 2 grupa- heartwood coloured timber, 3 grupa- heartwood hard rot stage timber.

Before testing moisture content according to standard [25] and density of test specimens according to standard [265] was determined. Test specimens were dried and weighed until the weight of dried timber didn't change in 2 hours more than 0.1%. The scheme of the test arrangement is given (Fig.6) .

I II III

Fig. 6. The laboratory investigation process, where:
(I)- 3. point bending strength and modulus of elasticity ISO 13061-3(4)-2014; (II)-testing samples; (III)- compression strenght paralel to the grain ISO 13061-17-2017.

III. RESULTS AND DISCUSSION

The investigation results are given (Table 2) where the colouring contains 100% of the cross-sectional area of the tested samples. Timber damaged by fungi contains 92% of the cross-sectional area of the tested samples.

TABLE 2. THE RESULTS OF THE LABORATORY INVESTIGATION PROCESS

Mean values (STDEV)

Testing samples according to the quality	Moisture content,% %	Density, kg/m^3	3. point bending: Strength, N/mm^2	3. point bending: Modulus of elasticity, N/mm^2	Compression strength: Strength, N/mm^2
1.group (sound timber)	14.2 (0.256)	491.6 (45.4)	74.036 (9.56)	10536 (1529)	37.5 (4.70)
2.group (heartwood coloured timber)	14.4 (0.341)	484.6 (55.4)	66.0 (10.9)	9198 (1724)	35.2 (5.11)
3.group (heartwood hard rot stage timber)	14.8 (0.683)	429.0 (64.4)	50.3 (15.4)	6989 (1918)	29.6 (7.94)

Deviation of the mean value compared to 1. group (sound timber), %

Testing samples according to the quality	Moisture content,% %	Density, kg/m^3	3. point bending: Strength, N/mm^2	3. point bending: Modulus of elasticity, N/mm^2	Compression strength: Strength, N/mm^2
2.group (heartwood coloured timber)	-	-1.4**	-10.8*	-12.7*	-6.1*
3.group (heartwood hard rot stage timber)	-	-12.7*	-32.1*	-33.7*	-20.9*

* - significant impact ($p<0.05$)
** - no significant effect ($p\geq0.05$)

IV. CONCLUSIONS

1. Aspen mechanical properties in bending and compression are being significantly reduced if timber is cloured and/or damaged by fungi *Phellinus tremulae*
2. Heartwood colouring reduces aspen timber strength in radial bending by 11%, modulus of elasticity by 13%, compression strength in fiber direction by 6% compared to sound timber strength parameters.
3. Heartwood hard rot reduces aspen timber strength in radial bending by 32%, modulus of elasticity by 34%, compression strength in fiber direction by 21% compared to sound timber strength parameters.
4. Stemwood density values of aspen on the basis of different literature sources are given 380- 525kg/m^3. In Latvia aspen timber has the average density -475 kg/m^3. Heartwood hard rot reduces aspen timber density by 13%.
5. The study indicates that sawn timber of European aspen growth in Latvia can be visually graded and theoretically are suitable for manufacturing construction materials f.e.g. glued laminated beams (GLT).

Based on the investigational results there are advised:

- to evaluate an aspen roundwood assortment as heartwood hard rot stage timber if the demarcation line is forming a continuous closed line at least 180 degrees.
- to evaluate an aspen roundwood assortment as heartwood coloured timber or heartwood hard rot stage timber according to the visual features [35] if the demarcation line do not forming a continuous closed line till 180 degrees

Fig. 7. The identification of the heartwood hard rot, where:1- demarcation line; 2- the heartwood hard rot stage timber.

Fig. 8. The identification of the heartwood coloured timber, where:1- demarcation line; 2- the heartwood coloured timber

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Opportunities of improving harvesting technologies for wider use of Scots pine (Pinus sylvestris L.) in construction elements

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Abstract. **Although *Pinus sylvestris* has a wide distribution throughout Europe, there are lack of scientifically approved information related to the sapwood timber strength parameters impregnated with natural resins comparing to the strenth parameters of non-resinous wood and industrially impregnated roundwood assortments using as the elements of wooden constructions such as wood poles for power lines. The main goal of the study is to work out the *Pinus sylvestris* stems which were previously treated using resin tapping technologies and harvested in final felling sites, timber strength parameters depending on timber quality characterized data based on the testing methods: moisture content - according to *ISO13061-1:2014*; density - according to *ISO13061-2:2014*; compression strength paralel to the grain- according to *ISO 13061-17:2017*; modulus of elasticity- according to *ISO 13061- 4:2014*; three point bending strength - according to *ISO 13061- 3:2014*. The results of the study might help for practical applications so that this wood specie can be processed more efficiently for the value - added products whose timber quality indicators would allow it to be used in wooden structures without additional chemical and thermal treatment, to establish more accurate quality requirements for roundwood assortments and to provide useful information for optimizing Scots pine harvesting management programs**.

Keywords: Pinus sylvestris, resin taping, timber strength parameters.

I. Introduction

Wood is one of the popular building materials at all times. In the era of steel and concrete, wood structure has a special charm. However, wood products are vulnerable to microbial damage during storage and cause a serious waste of resources, affecting their service life. It is reported that 40% of the planned wood used in the world every year is vulnerable to decay and damage by insects, with a loss of billions of US dollars. Therefore, the preservative, anti-mildew and anti-insect treatment for wood plays a key role in prolonging the service life of wood products and protecting forests. Common wood preservatives are divided into fumigant type, tar type, oil-soluble type and water-soluble type. At present, water-soluble preservatives are one of the most widely used preservatives with various types in the world, accounting for 75% of the total amount of preservatives used. Commonly used water-soluble preservatives include chromium-copper-arsenic (CCA), ammoniacal copper quats (ACQ-B, ACQ-D), copper citrate (CC) and copper azole (CopperTriazole, RNCuAz). Although CCA preservatives have a good preservative effect, they contain heavy metals such as chromium and arsenic, which affect human health and ecological environment. (Fig. 1)

At present, the research on wood preservatives in the world still mainly focuses on the application of chemical wood preservatives. However, with the increasing awareness of environmental protection worldwide, natural wood preservatives with non-toxicity, harmlessness, good durability, no impact on bonding properties, wide range of raw materials and low price will be paid increasing attention.

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Fig. 1. *Pinus sylvestris* roundwood preservation with CCA when heartwood cannot be pressure impregnated

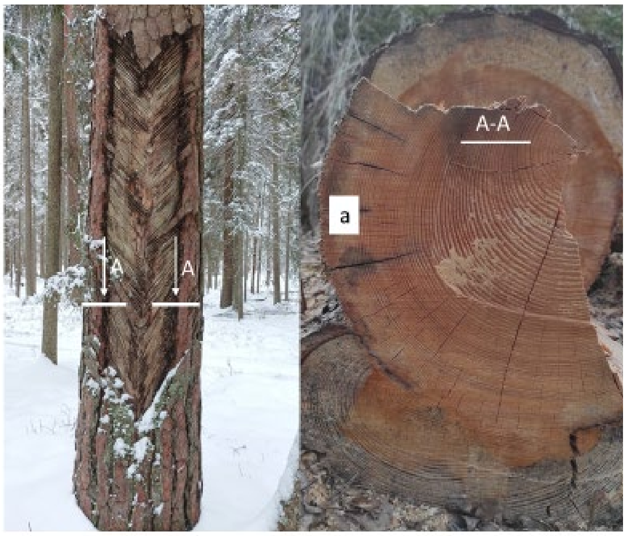

Fig. 2. Overmature stand of *P. sylvestris*. Resin-tapped in 1970 Felled by wind in 2020 year-51 years after it was resin tapped. For 2 years it was left on the ground. Resin tapped side protected the tree from rot and pioneer fungi (Fig.2a)

Therefore, it is advisible to return to knowledge related to resin tapped firewood preparing before harvesting in Latvia [16]; [25] (Fig.3) investigations made in this area by foreign researchers [5], [6], [7], [8], [9] [26], [28] and Scandinavian wood preservations traditions based on high degree of social responsibility not only in relation to materials and resources but also in regards to community-created spaces. Scandinavian tradition is based on systematically injuring growing *Pinus sylvestris* trees. In this process the sapwood is being impregnated with natural resins with a high consentration of Pinosylvin which is the most rot resistant contant that can be produced.

If the high quality roundwood with high concentration of resin are used in engineering constructions, that constructions will last for many hundred years. The barking must be done in the springtime. After barking the growing tree woodcells are impregnated with resins and other rot resistant substances. The sapwood formed as the formstable and hydrofobic material with avery high resistance against rot. The barked trees have been standing for 5 years after the barking started before eventually felled.

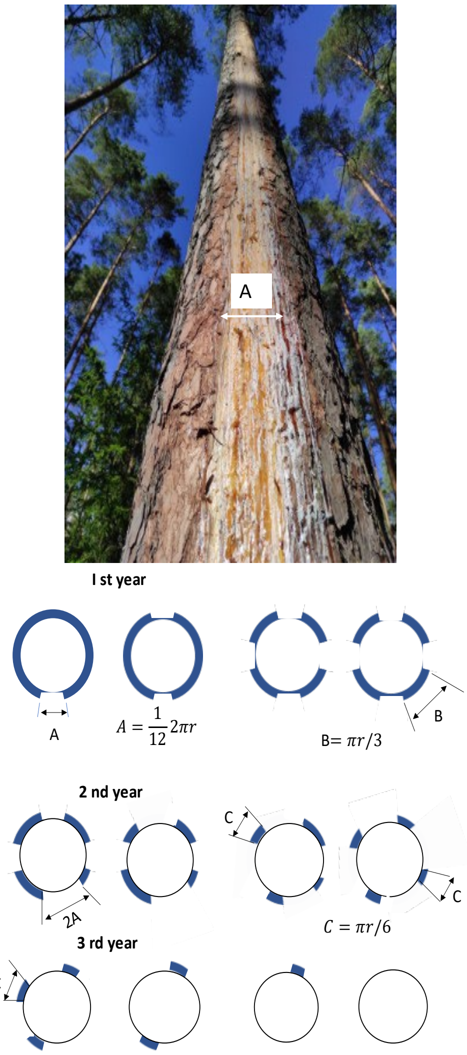

Fig. 3. Resin tapped firewood preparing scheme, when in just 3 years before tree harvesting sapwood is completly resin penetrated.

As an approvement of the durability of resin taped trees wood is the fact that overmature trees of *Pinus sylvestris* bearing large wounds made by resin tapping decades ago are still present in woodlands of south-eastern Baltic Sea region (Fig.2). Investigations [29] reveal that, even on the long term, resin tapping has little influence on health condition and vitality of *P. sylvestris*, even at the very old age.

The wood of resin taping area is highly resinous, making machining difficult. However, the increased resin content in the wood as a result of tapping causes a major change in the physical properties of the wood, such as an increase in density, as well as changes in the chemical properties [27]; [24] including improving the tree's natural protection from xylophagous agents [4]; [18]; [17]; [26]. The accessory substances of the cell wall can modify the mechanical behavior of wood in two ways: by acting as an inert mass in relation to the cell wall matrix structure, or by affecting hygroscopicity and therefore swelling [9]. Some studies have associated wood extractives and their influence with fracture parameters. In addition, resin incrustation in the cell lumen may act as a transmitter of efforts from one tracheid to another, helping the wood achieve a higher mechanical response, as occurs with synthetic polymers artificially included inside the cell lumen [17].

According to the investigation [24] the obtained results showed that the higher density of resinous wood compared with non-resinous wood is a result of the tree's defense processes. The repeated wounding of the tree during the 25 years of tapping causes the permanent activation of its defense mechanisms. While wounding generates both axial and radial traumatic resin canals, it also increases resin production through the metabolic route from the ray parenchyma cells to the axial tracheid lumen through the cross-field pits. The combination of these two processes results in the artificial resinification of the wood, increasing the wood density [3].

Tapping cause changes in the chemical composition of the cell wall, and this affected the physical and mechanical properties of the wood.

All the mechanical properties are strongly correlated with wood density [19], [23], [8], [9] showed that extractives strengthen the wood structure and therefore the mechanical properties, whereas investigations [1] had the opposite opinion. According to investigations [2] an increase in extractives had no effect on the mechanical properties, but according to other authors, these properties decreased [1].

The results for resistance to compressive strength parallel to the grain in the resinous wood compared with the non-resinous wood concurred with those obtained by investigations [9] for hardwoods, indicating that density is associated with increased accessory substances of the cell wall and that these substances positively affect the compressive properties of wood. However, these results differ from investigations [2] that confirmed the lack of correlation between extractives and compressive strength parallel to the grain, In a later study researcher [2] found no relationship between extractives and compressive strength parallel to the grain in *Tectona grandis L.f.* Although *Pinus sylvestris* has a wide distribution throughout Europe, there are lack of scientifically approved information related to the sapwood timber strength parameters impregnated with natural resins comparing to the strenth parameters of non-resinous wood and industrially impregnated roundwood assortments using as the elements of wooden constructions such as wood poles for power lines.

Taking into account the knowledge of Swedish technologies in the use of *Pinus sylvestris* resinous logs in engineering constructions and the investigations carried out in Latvia State Forest Research Institute "Silava" [29] related to evaluation of standing tree quality after the resin tapping, State Stock Company "Latvijas Valsts Meži" (Latvia's State Forests) started the project on the use of resinous wood in engineering constructions without providing the chemical treatment of timber during the period of operation of engineering structures, as the resin tapped sapwood will be naturally preserved.

In Latvia there have been no research on strenth of resin tapped wood, so it is important to ensure the determination of wood strength parameters for the designing the building structures.

The main goal of the study is to work out the Pinus sylvestris stems strength parameters of resinous and non - resinous sapwood zone in the third year after the start of the resin tapping project.

The tests were carried out in Latvia University of Life Sciences and Technologies at the Forest and Wood Product Research and Development Institute Testing Laboratory "MEKA".

The goal of this study was to supplement and synthesize the existing experience and knowledge about *Pinus sylvestris* timber physico- mechanical properties and to work out the recomendations to improve the commercial value of resin tapped roundwood assortments.

The following objectives were set to achieve the study goal:

1. To investigate properties of *Pinus sylvestris* resinous and non-resinous timber using laboratory testing methods:

1.1. Moisture content according to ISO-13061-1:2014

1.2. Density according to ISO-13061-2-2014

1.3. Compression strength paralel to the grain according to ISO 13061-17-2017

1.4. Three-point bending strength and modulus of elasticity according to ISO 13061-3(4)-2014

2. To compare the strength parameters of resinous sapwood to non-resinous sapwoods and to offer the requirements of building construction elementsd using resinous *Pinus Sylvestris* roundwood.

II. MATERIALS AND METHODS

To accomplish detailed examination, on harvesting site 505-301-13 (Table 1) one pine was felled on 3rd year after resin tapping in year 2023. 550 trees were selected to resin tapping in all harvesting sites.

TABLE 1 CHARACTERISTICS OF INVESTIGATED FOREST SITE TYPES AND RESIN TAPPED PINUS SYLVESTRIS TREES

Parameter	Harvesting sites		
Block area-Forest block-Forest compartment	505-469-31	505-301-13	505-320-17
Area (ha)	3.39	1.57	3.87
County	Bārbele		
Parish	Vecumnieki		
Forest type	Hylocomniosa	Myrtillosa	Hylocomniosa
Age class	Overmature stand		
Age decade	11	11	13
Species composition	8 Pinus sylvestris103 2 P.Abies 83	10 Pinus sylvestris108	9 Pinus sylvestris123 1 P.Abies98
Specie	01-*Pinus sylvestris*		
Age (years)	103	108	123
Height (m)	30	28	31
Diameter (cm)	34	30	34
Basal area (m^2)	9	32	33
Stock (m^3/ha)	373	418	468
Specie	03-P.Abies		
Age (years)	83		98
Height (m)	27		28
Diameter (cm)	29		28
Basal area (m^2)	9		5
Stock (m^3/ha)	109		62

Pine was 135 years old (Fig. 4). The first resin tapping injury was made in year 2020 second injury was made in 2021 according to the sheme (Fig. 5).

Fig. 4. Overmature stand (Biological age-135 years) of Pinus sylvestris (DBH=43.6 cm). Resin-tapped in 2021.

The tree was felled in 2022 to prepare samples for investigation properties of *Pinus sylvestris* resinous and non-resinous timber using laboratory testing methods.

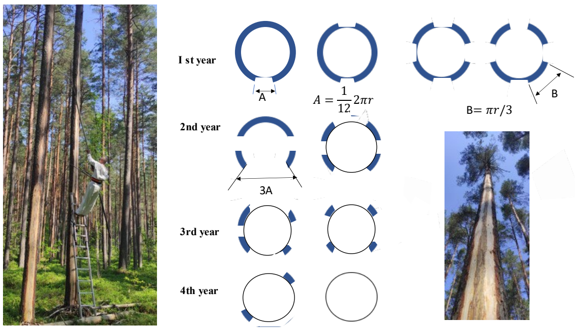

Fig. 5. Overmature stands of *Pinus sylvestris.* Resin-tapped in 2023 (2nd year). One side of the tree after second year of barking (Fig.5a). Here it is barked on both sides with 7-8cm wide stripes that are approximately 7 meters high. The barked trees will be standing for 5 years after the barking started before eventually felled.

Samples for investigation were taken from the trunk sapwood resinous zone and non -resinous zone according to the scheme (Fig.6).

The trunk sapwood was tangentially sawn in to edged boards 30 mm thick, which were air-dried to 16% moisture content (Fig.7) to prepare samples with a cross-section of 22×22mm for investigation of compression strength paralel to the grain- according to *ISO 13061-17:2017* (Fig. 7); modulus of elasticity- according to *ISO 13061- 4:2014* (Fig. 7); three point bending strength - according to *ISO 13061- 3:2014*. (Fig. 7). Testing samples were prepared according to the requirements of the standards [10], [11], [12], [13], [13], [14], [15], [16], [20].

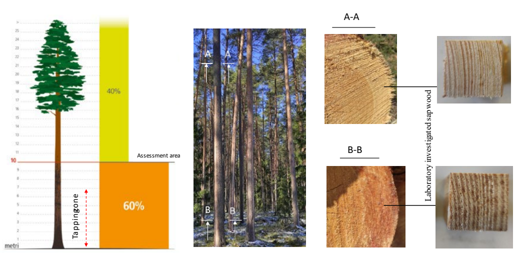

Fig. 6. The scheme of prepared samples from the trunk sapwood resinous zone and non -resinous zone.

Fig. 7. Samples from the trunk sapwood resinous zone (Fig.7a) and non -resinous zone (Fig.7b).

Samples were dried at room temperature until the moisture content equilibrium of the indoor air which was detected by the successive weightings until reaching the constant mass.

After samples were logitudinally sawn, planed and calibrated to actual size 20 mm x 20 mm and cut in 320 mm long pieces for bending test [4] and in 30 mm long pieces for compression test [15]. Test pieces were conditioned at the standard environment of 20±2 °C and 65±5 % relative humidity [13], [14].

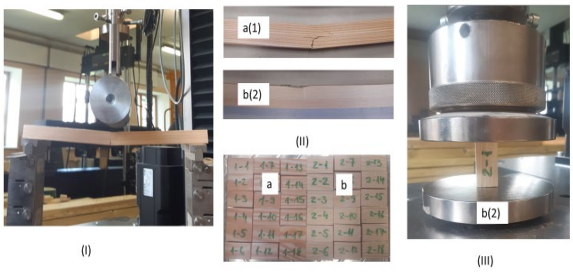

Fig. 8. The laboratory investigation process, where: **(I)**- 3. point bending strength and modulus of elasticity ISO 13061-3(4)-2014; (**II**)-testing samples; **(III)**- compression strenght paralel to the grain ISO 13061-17-2017; **a (1)**- specimens from resin tapping sapwood zone devastated in the stretch zone; **b (1)**- specimens from non-resinous sapwood zone devastated in the stretch zone; **b (2)-** compression of the reference sapwood specimens paralel to the grain.

For each test 50 pcs. of laboratory samples were prepared. All test pieces were identified with a number. Test specimens were measured with an electronic caliper to 0.01 mm and weighed to 0.01 g. Test specimens were conditioned. Before testing moisture content according to standard [11] and density of test specimens according to standard [12] was determined. Test specimens were dried and weighed until the weight of dried timber didn't change in 2 hours more than 0.1%. The scheme of the test arrangement is given (Fig. 8). The results of laboratory analyses are given (Table 2).

III. RESULTS AND DISCUSSIONS

The investigation results are given (Table 2).

TABLE 2 THE RESULTS OF THE LABORATORY INVESTIGATION PROCESS

Testing samples	Mean values (STDEV)				
	Moisture content, %	Density, Kg/m3	3. point bending		Compression strength
			Strength, N/mm^2	Modulus of elasticity, N/mm^2	Strength, N/mm^2
Specimens from resin tapping sapwood zone	16,4	671 (21.4)	89.2 (4.2)	8750 (370)	46.47 (1.58)
Specimens from reference zone	13,7	530 (12.9)	83.5 (6.42)	11200 (388)	47.04 (5.11)
Deviation of the mean value compared to specimens from reference sapwood, %					
Specimens from resin tapping sapwood zone	-	26,70%	6.8*	-22.0*	-0.8*

*- significant impact ($p<0.05$)

p.s, according to the standard [2] the density of timber is calculated if the moisture content of the timber is 12%. All strength properties were recalculated because the moisture content of the specimens in testing was about 15%. If the moisture content of timber increases 1% all strength properties of the timber decrease, for example the modulus of elasticity decreases about 1% and the compression strength parallel to grain decreases about 3% [9]. Decreasing value of moisture increases the values of stiffness and strength in the same range.

IV. CONCLUSIONS

The results of the study indicated the following:

1. Resin tapping of *Pinus sylvestris* has a significant effect on the wood density and mechanical properties in bending, while the compression strength paralel to the grain parameters are not significantly affected.

2. The average density of *Pinus sylvestris* sapwood in resinous zone is 671 kg/m^3 and the average density of sapwood in *non -resinous zone* average density is 530kg/m^3. Sapwood resinous zone density parameter is 27% higher compared to sapwood in non -resinous zone. STDEV parameters characterized mechanical properties (density, kg/m^3) for sapwood resinous zone is 21.4 kg/m^3, for non -resinous zone is 12.9kg/m^3.

3. The average modulus of elasticity for *Pinus sylvestris* sapwood resinous zone is 8750N/mm^2. The average modulus of elasticity for *Pinus sylvestris* sapwood sapwood non – resinous zone is11217 N/mm^2 . The parameter of average modulus of elasticity for sapwood non -resinous zone is 22% higher compared to resinous zone. STDEV parameters characterized mechanical properties (modulus of elasticity EM, N/mm^2) for sapwood resinous zone is 370N/mm^2, for non -resinous zone is 388N/mm^2.

4. Three-point bending strength in the radial direction of *Pinus sylvestris* sapwood resinous zone is 89.2 N/mm^2. In the radial direction of *Pinus sylvestris* sapwood *non - resinous zone* is 83.5 N/mm^2. The parameter of bending strength for sapwood resinous zone is 7% higher compared to non-resinous zone. STDEV parameters characterized mechanical properties (three point bending strength, N/mm^2) for sapwood resinous zone is 4.2N/mm^2, for non -resinous zone is 5.4N/mm^2. Compression strength paralel to the grain for *Pinus sylvestris* sapwood resinous zone is 46.7 N/mm^2. Compression strength paralel to the grain for *Pinus sylvestris* sapwood non -resinous zone is 47.0 N/mm^2. STDEV parameters characterized mechanical properties (compression strength paralel to the grain, N/mm^2) for sapwood resinous zone is 1.58N/mm^2, for non -resinous zone is 1.79/mm^2.

5. According to the investigation [24] there are restrictions to use resin tapped *Pinus sylvestris* roundwood in wooden engineering constructions such as wood poles for power lines because of low strength parameters of modulus of elasticity (EM). The strength parameters of wood poles for power lines determined by standard BS 1990; ANSI/ASTM D 1036 -58 are the sequential:

- Three point bending strength (σ_l)and modulus of elasticity (EM).By standard σ_l =53.8 N/mm^2 ; EM=10480 N/mm^2
- Three-point bending strength (σ_l) and modulus of elasticity (EM) of resin tapped *Pinus sylvestris* roundwood. By investigations σ_l =89.2 N/mm^2 ; EM=8750 N/mm^2

6. There is advisible to use the resinous logs into the roof structures and in the first rows of the log houses (Fig. 9).

Fig. 9. The structural elements of the log house

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Formalization Of Tasks To Ensure The Safety Of Emergency And Explosive Operations In The Mining Industry

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Abstract. **The development of quarries and underground mines is characterized by the need to expand their borders and resume the work of temporarily non-working sections of the countries, as well as maintain the capacity for ore production, the reduction of which is associated with a reduction in the active area of ore bodies. At the same time, work intensification is necessary, which is complicated by the limited size of the working area. Such complications can be largely compensated for by increasing the height of the exploding sill. At the same time, work intensification is necessary, which is complicated by the limited size of the working area. Such complications can be largely compensated for by increasing the height of the exploding sill. This is precisely the purpose of the present research, which was carried out by processing arrays of information that allows us to optimize this process. The study was carried out with machine processing of the information and change of the studied parameters.**

Keywords: coulomb criteria, gas, explosion, hydrodynamics, poisson's ratio, simulation, ventilation

I. Introduction

The purpose of the present work is how to make a choice of preventive measures and means of labor protection. This is done on the basis of a machine survey and all the chosen solutions must be justified, taking into account the occupational risk as well as the blasting in the mining industry. The existing approaches for objective reasons do not provide an opportunity to justify the choice of the necessary measures to maximally reduce the level of occupational risk in case of explosions in mining. Therefore, an effective methodological approach is needed to justify preventive measures, since the level of risk in mining enterprises is still high. The present study is devoted to solving this urgent scientific problem and finding optimal solutions under the many different combinations of factors that influence the performance of this laborious work.

Various methods and combinations of factors that influence the performance of raw material extraction were used in the research.

II. Materials and methods,

The intensity of work is largely determined by the stock of blasted rock mass, which should be sufficient to ensure the effective operation of the required number of excavation, loading and transport equipment. Naturally, in the conditions of deep open pits, as well as when working on temporarily non-working sides, this possibility is significantly reduced due to a significant reduction, mainly in the width of working sites. This reduction can be compensated for by increasing the height of the ledge, as a result of which the stockpiles of blasted rock mass move from the horizontal to the vertical plane. For example, if the working area width is reduced by a factor of 2, the stockpiles of blasted rock mass are practically preserved if the ledge height is increased by a factor of 2 [1-2].

Blasting using standard industrial explosives in the tunnelling of underground mine development results in the release of noxious vapours such as carbon monoxide (CO), nitrogen dioxide (NO_2) and ammonia (NH_3). These noxious gases must be cleaned up in a reasonable time before miners re-enter the work area. Poor procedures for determining the optimum re-entry time after an explosion can result in several injuries, fatalities and production losses. Injuries and fatalities are associated with workers returning to work areas too soon after blasting or workers being in restricted areas immediately

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after blasting. Determining the optimal re-entry time after blasting is vital because overestimation of re- entry time causes production losses, while underestimation causes health and safety problems [3]. Moreover, underground mining operations schedule explosions at the end of the work shift to allow sufficient time for the explosive gases to escape.

The disadvantages of this are:

1. concentrations of harmful gases may not fall below the threshold values before the next shift resumes operation;

2. fans operate at an uncontrolled speed, resulting in relatively high ventilation costs.

Thus, it is necessary to provide the optimum amount of air based on the desired re-entry time after the explosion to eliminate the disadvantages described above.

Dilution with fresh air is one of the best ways to control explosive gases in underground mines. This involves removing contaminated air within reasonable limits. It must be temporarily contained before workers re-enter the work area. An important factor related to dilution and purification of flue gases, which has been neglected, is the optimum location of the exhaust duct[4-5].

On creating safe, productive and cost-effective underground mining operations using a computational fluid dynamics approach. must be achieved by determining:

- blast exclusion zones;
- optimal discharge locations;
- suitable re-entry time after blasting and optimum air quantity based on commonly used ventilation and blasting conditions.

All subsequent crash reviews have demonstrated vital aspects of previous research, viz:

- flue gases and their constituent gases;
- Mathematical modelling of flue gas dispersion;
- determination of re-entry time after the explosion;
- Study of explosive gas propagation in underground mines using computational fluid dynamics.

III. Results and discussion,

Scientific research shows that:

1. a comprehensive 4-dimensional analysis of the flow dynamics of underground mine smoke concentrations and clean-up is needed;

2. a detailed study is needed to understand the effect of the supply air outlet location on dilution and smoke removal;

3. there is currently no means of estimating safe blast distances, i.e. blast exclusion zones,

4. There is no comprehensive relationship for estimating re-entry times after an explosion in underground mines.

Mathematical models describing the dispersion of flue gases in the underground mine workings can be used to solve the set problems. The corresponding basic equations and the obtained boundary conditions were complex and coupled nonlinear partial derivative equations.

In those cases when it is impossible to obtain an exact analytical solution of a geomechanical problem, modelling (optical, modelling on equivalent materials, and recently computer modelling) is used as a research method. The main stages of modelling are: construction of a formal model, software simulation process, computational experiments. Software variants allow to obtain elastic-plastic solution under plane deformation conditions, and only elastic solution under plane stress state conditions in homogeneous and inhomogeneous medium [6-8].

The elastic model is a linearly deformable medium, stresses and strains are subject to Hooke's physical law. The elastic problem is solved by the finite element method in the following sequence:

1) input of information about the geometry of the finite element network, its properties and the specified nodal forces and displacements;

2) formation of the vector of nodal and mass forces;

3) direct preparation of information that refers to the next element, in particular the numbers of surrounding nodes, their coordinates, element properties;

4) compilation of the element stiffness matrix (ESM);

5) formation of the system stiffness matrix by sending the MLE coefficients to the appropriate addresses;

6) introducing the given nodal displacements by multiplying them by the corresponding columns of the system stiffness matrix and transferring the results to the nodal force vector;

7) solving a system of equations;

8) printing of nodal displacements;

9) cleaning the field of the nodal force vector from the primary values;

10) calculation and printing of deformations and stresses in elements;

11) calculation of nodal forces from the found stresses and their accumulation in the field of the nodal force vector;

12) printing of nodal forces.

The simplest, most versatile, but most extensive information includes the coordinates of all nodes, the given nodal forces, the given nodal displacements, the numbers of the three nodes surrounding each element, the type number of each element, the modulus of elasticity, the Poisson's ratio, and the volume weight of the elements of each type. The natural stress field is determined by recalculating the load into given nodal forces.

The load can be applied at once or in several steps to observe the deformation process step by step. For example, if the number of steps is set to three, the given nodal force is first divided by three and solved, then doubled, and finally the force will be taken equal to its full value, while the result of the solution does not depend on the number of loading steps. The gravity forces of the elements are automatically taken into account. The introduced volumetric weight is multiplied by the area of the element, equally divided among the three nodes and applied in the direction of the vertical axis. The cutout in the area is simulated by giving values of elastic modulus E=0 and volume weight γ=0 to the group of elements filling this area.

A medium that deforms elastically up to the moment of reaching the limit state and does not change its resistance during its further deformation is elastoplastic. The realisation of such a medium is achieved by combining the FEM and the modified Newton-Raphson (initial stress) method proposed by O. Zenkiewicz, which consists in the following. The elements of the medium are initially endowed with initial elastic properties, and a constant stiffness matrix of the system is compiled. Then the full specified load is applied, the elastic problem is solved and the theoretical stresses and strains are calculated. The difference between the elastic and calculated stresses is considered as the initial stress increment. The initial stress increment of the element is converted into initial nodal forces, which are added to the force vector of the system. The following elastic solution is carried out with the same stiffness matrix but with a new set of nodal forces. The addition of the initial forces increases the elastic stresses in the element, but by an amount smaller than the initial stresses because the added nodal forces are distributed to all elements. Iterations are repeated until the found elastic stresses correspond to the given geomechanical model of the rock mass; in principle, the medium can have any law of plastic flow [9-14].

Under conditions of hydrostatic compression, rocks can be in any magnitude of stress state. However, when the stress-strain state is not equal, the magnitude of tangential stresses is limited by the strength properties of the medium. Deformations of rocks under the action of tensile stresses are typical for the upper zones of slope sliding, as well as for the rock strata settling above the excavated space during underground excavation of minerals for the development system with complete roof collapse. Therefore, it is of interest to predict the expected tensile strains and to determine the beginning of element failure, i.e. - the beginning of cracking or delamination process at the contact of layers [15-26]. The ultimate stresses in the tensile region in the "Geomechanics" program are limited by the tensile strength limit, and they are automatically assumed to be equal to C/5 for elements that do not go into the plastic, and equal to zero for elements that go into the plastic at the previous iteration cycles. In the compression region, the Coulomb criterion is applied, and the ultimate stresses are limited by the compressive strength, which is determined automatically by this criterion, based on the physical and mechanical properties of the rock mass given layer by layer:

$$\sigma_{1=2C_{ctg}\left(45-\frac{\varphi}{2}\right)+\frac{1+sin\varphi}{1-sin\varphi}\sigma_3} \qquad (1)$$

where *C* - adhesion and angle of internal friction.

The elastic-plastic model of the medium with unstrengthening beyond the strength limit is of the greatest interest in the study of physical processes of rock mass failure around geomechanical objects and possible limiting geotechnical situations. The main points of the numerical implementation of this model are as follows. The algorithm combines two theories - the theory of elasticity and the theory of limit state. The concept of residual strength (resilience) is introduced. σ_1^{ocm} formula (1), where *C* - are parameters of the medium with residual strength. Formally, the only difference from the model with ideal plasticity is the definition of σ1 :

$$. \ \sigma_1 = \sigma_1^{ocm} + \frac{\sigma_1^{np} - \sigma_1^{ocm}}{2\varepsilon_1^{y}}(3\varepsilon_1^{np} - \varepsilon_1) \qquad (2)$$

where σ_1^{np} –is the ultimate maximum stress (ultimate strength): ε_1^{y}-ultimate elastic strain.

The ultimate stress in the compressive region is limited by the compressive strength, the ultimate

Strength is determined by formula (2) at $\varepsilon_1^{y} \leq \varepsilon_1 \leq 3_1^{y}$, residual strength $\sigma_1^{ocm} = \sigma_1/3$, the ultimate strength is determined by equation(1).

Stable elastic-plastic solutions, taking into account the residual strength, are usually achieved in10-15 iteration cycles. The number of iteration cycles is indicated in the output. If the iteration process has not converged within 100 cycles, there is no hope for convergence in the future and the programme is terminated. To describe the physical and mechanical properties it is necessary to determine the modulus of elasticity E, Poisson's ratio ν, volume weight γ, cohesion C and angle of internal friction of each type of element.

IV. CONCLUSIONS

The input information makes up seven conditional arrays and is prepared in accordance with the programme description. The use of unified design schemes and programs for automated uniform breakdown of design schemes with pre-selected parameters sharply reduces the volume of prepared information, as it is already known in advance, so only adjustments are required for the introduction of a new object or for changes in mining and geological conditions, loading conditions, etc. The output information is presented in the same system of units as the input information, it consists of control information and results of the problem solution. As the control information the following information is printed out: specified characteristics of all types of elements; areas of all elements from the first to the last by ten numbers in a line; total area of the considered area; if the number of specified non-zero forces and displacements does not coincide with the number of corresponding signs, the instruction "check the signs" is issued. If the sum of the specified forces and displacements does not match the control values, the following instructions are issued: "check forces" or "check displacements". If the information check does not reveal any errors, the programme continues to run. From the results of the solution, the following are printed by elements and nodes: element serial number; element state (if sign "0" is indicated for the given element, the element is deformed elastically, if sign "1" - it is deformed plastically, sign "-1" means that the element is torn in at least one direction); principal stresses σ , σ^{12} and angle α between the direction σ1 and the x-axis; principal strains ε , ε12 and angle β; theoretical values of principal stresses σ1m and σ m ; node sequence number; displacements of each node in the x and y axis directions; node forces including gravity forces, including nodes with specified displacements. If necessary, axial values of stresses σ_x , σ_y , σ_{xy} and strains ε_x , ε_y , ε_{xy} are printed.

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Smart cities as a tool for environmental sustainability: opportunities and challenges

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Abstract. **The article's research focus is to investigate the impact of technologies used in smart cities to achieve environmental sustainability. The research methods used to review scientific studies worldwide on the problem under consideration, analysis and synthesis, comparative analysis, and logical approach. The information and communication technologies in smart cities aim to promote sustainability and provide adequate services to citizens, thereby improving their quality of life. Specific characteristics of smart cities are the extensive use of technology, real-time monitoring, innovation, and citizen empowerment, with a constant focus on sustainability. Analysis of the cited examples shows that technologies are being deployed in smart cities to improve transportation systems, deal with traffic jams and waiting times at traffic lights, and more with real-time data analysis. In most examples, information and communication technologies create a smart grid to achieve optimal energy use and improve the efficiency, reliability, and economy of the provided utility services. Self-monitoring and control of smart grids are realized using intelligent sensors and smart meters for energy transmission and distribution for real-time analysis of current consumption. An intelligent energy system involves using technologies for efficient energy production and distribution. The conducted case study on the effectiveness of the smart city in terms of environmental sustainability establishes that the sustainable management of resources and reducing the harmful impact on climate change and the environment requires optimizing the use of energy and resources and increasing the use of renewable energy sources. Analysis shows how technology can achieve environmental sustainability by reducing carbon emissions from cities, improving air quality, and optimizing the use of natural resources. Implementing intelligent systems and applications can reduce greenhouse gas emissions by an average of 20%, water consumption by up to 30%, and the amount of non-recyclable solid waste by around 15-20%, depending on the city's specific characteristics.**

Keywords: environment, efficiency, smart, technology.

I. INTRODUCTION

In recent years, climate change has acquired the significance of a global emergency and affects human well-being and the sustainability of other forms of life. Climate change is a significant threat to human health, affecting the physical environment and all aspects of both natural and human systems – including social and economic conditions and the functioning of health systems. The world's population lives in cities, consuming many natural resources, including energy, raw materials, fuels, and water. The environmental sustainability of cities is increasingly challenged by air pollution, traffic and waste management issues, ageing infrastructure, and over-urbanisation. One of the possible solutions for achieving environmental sustainability is the smart city. The smart city concept is related to a sustainable city based on the use of innovation and information and communication technologies to reduce pollution, provide better services to citizens, and use natural resources wisely. The article presents smart cities' main characteristics and possibilities for achieving environmental sustainability. The article provides up-to-date and detailed information related to environmental sustainability issues and smart cities' role in reducing greenhouse gas emissions, integrating technology into urban infrastructure, resource management, and possible technological limitations and challenges.

II. MATERIALS AND METHODS

The material includes a review of scientific research worldwide on the problem at hand to identify the opportunities and challenges of using smart cities for environmental sustainability. The following scientific methods were used in the research process - analysis and synthesis, comparative analysis, and logical approach.

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III. RESULT AND DISCUSSION

A. Key features of smart cities – evolution of the concept, technological innovation, examples of successful smart city projects

There are many definitions deriving the concept of the smart city. The key features of a smart city are computer technology to manage critical infrastructures and components, achieve intelligent transportation, intelligent traffic and waste management, intelligent health system and education, and more efficient and fair living conditions [22]. Information and communication technologies are fundamental in making cities smart, providing real-time data, and making intelligent decisions. Integrating information and communication technologies offers the opportunity to improve the management and use of available resources and infrastructure in cities, simultaneously improving the quality of life [7]. Although interest in smart cities has increased in recent years, historically, the concept was born in the 1980s during a discussion of ideas about the possibilities of changing the management of cities and making them more flexible for adapting to global markets. The concept of a smart city began to be used in the 1990s to introduce a new urban planning policy. After 2000, high-tech companies such as Siemens and IBM began to use the term to describe the possibilities of integrating information and communication systems in urban infrastructure [4]. The development of the concept of smart cities is also associated with the use of interchangeable terms, such as "intelligent city" and "digital city". Most definitions associate the smart city with intelligence, improved quality of life and efficiency. Information and communication technologies in smart cities aim to promote sustainability and provide adequate services to citizens, thereby improving their quality of life. Specific characteristics of smart cities are the extensive use of technology, real-time monitoring, innovation, and citizen empowerment, with a constant focus on sustainability [19]. Computers, computer networks, smartphones, television, and the Internet are essential components of the smart city architecture to ensure the connectivity of the services provided with the infrastructure. Distinctive features of smart cities are [9]:

- Positive attitude towards business – a sense of cooperation is created between the local government and companies to promote the development of their activities.
- Openness – regarding the introduction of innovations that benefit citizens.
- Real-time monitoring and control – city authorities effectively use surveillance cameras to regulate traffic, reduce crime, and more.
- Improving the well-being of citizens – by using various technologies, such as biometric identification, GPS, data mining software, etc., as well as developing solutions for emerging problems in the management of cities.
- Sustainability (social and environmental) to reduce greenhouse gas emissions through technologies.

The latest technological advances in smart cities are the Internet of Things (IoT), big data, machine learning, fifth generation (5G) networks, various robotic and automated systems, electric vehicles, etc. [1]. The smart city's infrastructure consists of the road network, traffic management systems, traffic lights, water supply, power supply, fire safety, hospital system, residential and public buildings, etc. Technology transforms the physical infrastructure of cities into a smart one that is more efficient, secure, and safe. Smart city infrastructure includes software, sensors, firmware, and more that provide information about carbon footprint and sustainability [10]. An example of a smart city grid can be given with the power transmission system, which consists of various conventional and renewable energy sources. These meters allow load balancing and quick elimination of errors that occur, reliable energy delivery to consumers, and real-time reporting of consumption. Smart buildings, which use various sensors, hardware and software, smart meters, access control, video surveillance, and power and lighting management, are part of the infrastructure. In recent years, smart cities have started to include more and more "green" buildings, where optimal energy efficiency and environmental control are achieved to reduce the carbon footprint. IoT enables processing of large databases, thereby achieving maximum energy and operational efficiency of the building, more optimal use of resources and reduced operating costs [22]. The three key characteristics of smart cities are intelligence, connectivity, and technology (tools). IoT enables the use and connection of smartphones, sensors, smart meters, networks, software and firmware, buildings, vehicles, and energy systems. With the help of IoT, the implementation of communication between all specified devices and structures, exchange of information and data and achievement of connectivity are achieved. Smart cities use various sensors in transportation, buildings, networks, and communication services, performing different tasks such as location determination, recognition, monitoring, pollution control, etc. [5]. On the other hand, big data is inherently about large data sets that are complex and difficult to manage using traditional tools. In smart cities, big data is generated from sensors, smart devices, media, medical information, transactions, institutional archives, and others, which creates challenges for their management, sharing, search and storage [12].

Examples of successful smart city projects are presented in Table 1.

TABLE 1 SUCCESSFUL SMART CITY PROJECTS [3; 13]

City	Smart city projects
London	The London Development Database enables citizen access to building permit management and real-time stage tracking implemented for smart meters for energy and water use. Heathrow Pods is a unique form of transport using driverless, intelligent vehicles to transport passengers from the airport to the city.
New York	A LinkNYC network has been implemented to replace phone booths with free Wi-Fi hotspots that are widely distributed throughout cities. Midtown in Motion technology has been implemented to manage traffic and reduce congestion during peak hours, using speed sensors and a data centre. The water supply has an intelligent system allowing real-time monitoring of readings and online bill payment.

City	Smart city projects
Tokyo	Systems have been installed to control and coordinate the various renewable energy sources and use intelligent metering devices.
Copenhagen	A system has been implemented to control air quality, waste management and energy consumption to reduce emissions. In one of the districts (Nordhavn) a test system (EnergyLab) is used to achieve sustainable transport, electricity, and heating.
Amsterdam	An automated system has been built for sharing bicycles, paying for parking by phone and intelligent waste collection by paying a fee only for garbage thrown away.
Singapore	The city is one of the most technological. The innovations introduced include the first innovative hospital that uses Big Data in the provision of health services, the use of unmanned taxis, as well as the Digital Twin application, which is a virtual model of the city, allowing citizens and tourists to easily navigate and discover sites and services, with using real-time information.
Dubai	The city uses artificial intelligence in digitizing services provided to citizens and city lighting, transport, and communication systems.

Analysis of the cited examples shows that technologies are being deployed in smart cities to improve transportation systems, deal with traffic jams and waiting times at traffic lights, and more with real-time data analysis. In most of the examples mentioned, information and communication technologies are used to create a smart grid to achieve more optimal use of energy and improve the efficiency, reliability, and economy of the provided utility services. Self-monitoring and control of smart grids are realized using intelligent sensors and smart meters for energy transmission and distribution for real-time analysis of current consumption [6]. Although information and communication technologies are at the heart of smart cities, cooperation with local government and citizens is crucial in achieving environmental sustainability and economic development [19].

B. Environmental sustainability in smart cities

The positive impacts of making cities smart are numerous. In terms of environmental sustainability, the positive effects are related to more efficient use of energy, reduction of CO2 emissions, creation of energy-efficient buildings (green buildings) and a change in the behaviour of end-users of utility services [21]. An intelligent energy system involves using technologies for efficient energy production and distribution. An essential part of the intelligent energy system is using green energy, photovoltaic energy, wind energy, etc. Achieving efficiency from the intelligent energy system is possible through smart infrastructure, grid, and meters. Information and communication technologies are at the core of the intelligent energy system that collects consumer information and data and shares it with energy providers. Technologies also control energy consumption for ventilation, air conditioning and heating. Critical factors for efficient use of energy are innovative management and intelligent management, achieving low energy loss, safety and security of the system, and integration of different types of energy – from biofuels to wind and solar panels. Smart meters measure energy usage and report data in real-time, facilitating payment reliability and limiting opportunities for human error [18].

The applications used in smart cities must deal with several challenges related to environmental degradation and climate change. Examples of such applications are technologies for precision agriculture, waste management, use of sensors to manage energy use, etc. Smart (precision) agriculture uses drones and sensors based on artificial intelligence to optimize the use of fertilizers and pesticides. Smart waste management is about using sensors to observe and monitor the disposal of waste to reduce the harmful impact on the environment [8]. The conducted analysis found that sensors, mobile applications, and warning systems are needed to achieve a sustainable and green environment in smart cities. The intelligent sensors that are integrated into the waste collection bins allow for 24-hour monitoring and sending information about the current state of the garbage to the responsible institutions [20]. Public disclosure of information also encourages citizens to collect their garbage separately to take care of the environment. Using such intelligent sensors also reduces the fuel costs of the cleaning companies because the trash is collected as needed, reducing carbon emissions. Another advantage is that citizens receive real-time information on the best place to dispose of their junk to keep the environment clean. Using an intelligent waste management system solves the problems related to the separate collection and sorting of waste in most residential areas [18]. The main benefits of using an intelligent waste management system are related to [17]:

- Reducing the level of pollution - using a 24-hour monitoring system providing information from sensors allows optimal waste management with the lowest possible costs for the city budget.
- Increasing community engagement - in addition to reducing the level of pollution, the smart system encourages citizen engagement in achieving environmental sustainability.
- Using a free application by citizens encourages them to dispose of their garbage in the appropriate place and participate in cleaning the environment.
- Achieving a sustainable environment - during normal waste collection, trucks pass through residential neighborhoods along a predetermined route without information on whether it is essential, which, in addition to high economic costs, also leads to the release of a large amount of carbon monoxide. Innovative applications enable the reduction of unnecessary journeys, saving fuel costs and combustion and reducing the harmful impact on the environment.

To achieve ecological stability, it is necessary to implement strategies for planning and managing urban green spaces, including parks, gardens, and green spaces, to reduce noise and pollution and maintain ecosystems.

C. Opportunities and challenges

The possibilities for smart cities are many. First, increasing the effectiveness of the policies implemented by local authorities and improving services for citizens (such as electronic services) increase the possibilities of responding to emergencies, improving security, reducing crime, etc. In this regard, smart cities' focus is improving citizens' quality of life, including mobility, healthcare, and access to services. Secondly, smart cities promote economic development by investing financial resources and implementing innovations in various sectors of the economy. Thirdly, smart cities improve environmental protection by reducing pollution, increasing renewable energy sources, and achieving sustainable water supply. To achieve environmental sustainability, smart cities invest resources to implement smart infrastructure, including that of a sewage system [19]. Smart infrastructure comprises multiple devices enabling connectivity, real-time data collection and analysis. The benefits of so-called green infrastructure are numerous, including addressing environmental challenges such as pollution, flooding, carbon emissions, etc. Most cities that want to be smart focus on activities related to solving energy problems and achieving environmental sustainability to improve the quality of life of their citizens. Smart cities are using technologies to address the many challenges of natural resource management. One of the significant challenges is related to the dependence on data and information, as well as their management and analysis, which gives rise to the need for substantial investments in infrastructure and technology. Another challenge is the efficient allocation of resources to achieve long-term sustainable development goals. The management of renewable energy systems and other natural resources requires, on the one hand, significant financial resources to be invested and, on the other hand, the implementation of effective communication strategies to achieve citizen engagement. Dealing with the mentioned challenges requires coordinating the actions of the local authority and all interested parties [2].

Despite the undeniable advantages, smart cities face various challenges. First, the technological dependence of towns should be pointed out, which leads to an increase in the need for financial investments and various materials for building infrastructure and electricity. Suppose even just one part of the necessary materials (e.g. semiconductors) is delayed. In that case, it disrupts the supply chain and the inability of smart cities to provide energy to their citizens. Secondly, the volume of collected data and information increases the risk to personal data privacy due to the use of multiple intelligent sensors. Similarly, constant connectivity requires companies to significantly increase their spending on maintaining the security of their information systems and on cybersecurity to protect their sensitive data and information. Thirdly, the difficulty of achieving connectivity in cities with millions of people of all ages, some of whom may refuse to use modern technology daily, should be pointed out [16].

D. Case study Analysis

In environmental sustainability, key indicators to measure the results achieved by smart cities are reduced greenhouse gas emissions, reduction of non-recycled waste, and more efficient use of water resources. New York is one of the cities with actual initiatives to achieve sustainability, including through legislative change to reduce harmful emissions. The use of modern technologies is essential to achieve economic growth in the city, as well as to attract investment and provide multiple services to make the local economy competitive. One of the city's first areas of improvement is energy use. In 2013, the local government introduced an efficiency program that retrofitted lighting with LED technology, helping reduce greenhouse gas emissions by 900 metric tons and saving over $800,000 annually. The city's priority is reducing water consumption and wastewater generation. For this purpose, an intelligent system for automatically reading water meters has been introduced to the town, which warns users in real time about water leaks and provides information on opportunities to reduce consumption. On an annual basis, the intelligent system is estimated to have reduced water consumption by over 1 billion gallons, saving citizens over $74 million. In terms of waste, smart trash and recycling bins have been introduced throughout the city. The bins are powered by solar energy and equipped with a chip that shows when the container is full and prompts cleaning companies to process it. After the implementation of the system, the efficiency of garbage collection in the city has improved by up to 80%, and due to the reduced time for the trucks to move, greenhouse gas emissions have also decreased. New York is a city that is constantly investing in technology to become innovative. After 2020, a program will begin to install intelligent technologies and sensors in individual neighborhoods of the city, aimed at improving the services provided, including traffic management, water leak detection, street lighting and air quality monitoring [14].

Singapore is another example of an intelligent city that has achieved high environmental sustainability. The city has invested a lot of resources in using electric vehicles and implementing innovations in transport. Emissions in the town are incredibly high, with greenhouse gases mainly from the increased use of air conditioners, which are a significant source of energy use given the specific tropical temperatures. Numerous parks, a centralized system for cooling and regulating the temperature in business buildings and citizens' homes, and numerous green areas have been built in the city to limit harmful emissions. The digitization of the city also includes many innovations for building smart homes, providing health services, education, etc. For more optimal energy use, Singapore is switching to using natural gas and covering the roofs of public buildings with solar panels to harness solar energy. Introducing intelligent LED lights in the city reduces power by 15% [11]. The town is gradually moving to the use of electric cars. These efforts minimise energy use by 8 million megawatt-hours per year, combined by households and businesses, reducing 3 million tons of greenhouse gases. The city's activities in the field of Environmental Sustainability are also aimed at achieving a circular economy by increasing recycling for a more efficient use of resources. One of the activities undertaken is the recycling of the used water, as well as the use of part of the incinerated waste in construction. In just one year, waste has been reduced by 30%, and water consumption has been reduced by 10% to 130 liters per capita, through the use of smart meters. Environmental sustainability is also achieved by banning the movement of cars in the central part of the city, freeing up spaces for green areas. In addition to the use of green energy and buildings, to promote Environmental Sustainability, initiatives are being implemented in the city to change the way of life and established values of citizens, such as using more bicycles, awareness of opportunities to reduce the carbon footprint, etc. [15].

The Norwegian capital, Oslo, is one of the remarkable examples of resilience. The city is distinguished by its large green areas (47% of the territory) and low carbon emissions. Oslo uses 60% of its total energy consumption from renewable energy sources (mainly hydropower). The city centre is car-free, with many resources invested in environmental projects, including electric transport and bicycles. An interesting fact is that the city uses biogas as a source of energy for city transport and heavy-duty vehicles (such as waste trucks), which is produced locally. About 60% of all cars are electric, with ownership and use encouraged with tax cuts and plenty of charging stations. A regulatory restriction has been introduced for construction without the use of fossil fuels, as well as the use of machines with zero emissions [23]. In comparison, data on greenhouse gas emission reductions show that after transforming cities into smart cities, greenhouse gas emissions decreased by 900 metric tons/year in New York, 3,000 in Singapore, and 4,500 in Oslo (Fig. 1).

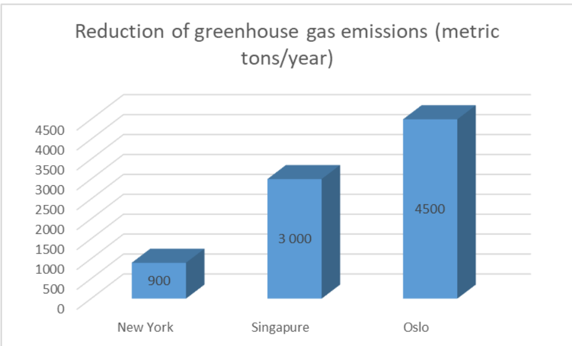

Fig. 1. Reduction of greenhouse gas emissions (metric tons/year)

Water use was also reduced, from 30 to 45% in the three analysed cities (Fig. 2).

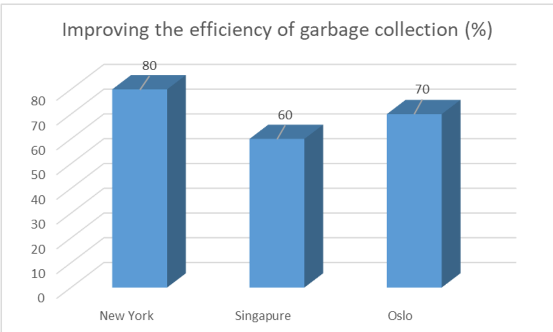

Fig. 2. Reduction of water consumption (%)

An improvement in waste management efficiency is reported - between 60 and 80%, with the most significant improvement in New York (Fig. 3)

The conducted research on the effectiveness of the smart city in terms of environmental sustainability establishes that the sustainable management of resources and reducing the harmful impact on climate change and the environment requires optimizing the use of energy and resources and increasing the use of renewable energy sources.

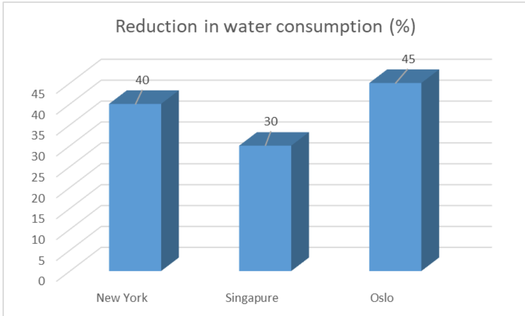

Fig. 3. Improving the efficiency of garbage collection (%)

I. CONCLUTION

Rapid urbanization leads to air and water pollution, deteriorating citizens' well-being and social inequality. Smart cities are defined as reliable solutions for the mentioned problems, in which, using information and communication technologies, urban sustainability can be achieved. The analysis shows how technology can lead to achieving environmental sustainability by reducing carbon emissions from cities, improving air quality, and optimising the use of natural resources. Implementing intelligent systems and applications can reduce greenhouse gas emissions by an average of 20%, water consumption by up to 30%, and the amount of non-recyclable solid waste by around 15-20%, depending on the city's specific characteristics. The future development of towns requires technology to be accepted as a mandatory part of the tools used to solve various environmental problems. A change in the behaviour of citizens is also recommended, which should be achieved by raising awareness.

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The estimation of spatial genetic diversity of vendace (Coregonus albula L.) populations in Baltic Lakeland

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Abstract. **The vendace (*Coregonus albula*) is native widespread to lakes in northern Eurasia. In the Baltic Lakeland region, populations of local whitefish are the remnants of the Arctic freshwater faunal complex and often regarded as an example of a glacial relict and indicator species of the state of the lake ecosystem. Together with other whitefishes vendace belongs to economically valuable fish species.**

The territory of the Baltic Lakeland region is located on the territory of three countries (Latvia, Lithuania and Belarus). The range of the vendace population is declining in waterbodies in Latvia and Belarus, the catch is insignificant and unstable, and this species is included in the list of specially protected fish species. However, in Lithuania this species is widespread and not protected.

The understanding fish population genetic diversity is very important for protection of rare communities and conservation of unique native populations. The estimation of the genetic structure of populations and determining the causes of genetic differentiation and the factors that promote variation between and within populations is fundamental for understanding adaptation and is, therefore, a primary goal of population and conservation genetics. Little is known about the genetic structure of vendace populations in waterbodies in Baltic Lakeland.

In this study eight microsatellite loci were used to investigate the genetic structure within and between populations in six vendace populations from Baltic Lakeland, namely Drivyaty, Rudakova, Strusto, Snudi, Naroch and Drūkšiai. Allelic variation was different in all investigated vendace populations; the observed and expected heterozygosity level was quite high. Bayesian-based STRUCTURE analysis suggested that there are two main genetic groups within our study area, separating Rudakova, Naroch and Strusto into one and others studied populations into the other cluster. These populations would be differentiated due to drift, reduced gene flow and possibly selection that promoting divergence.

Keywords: anthropogenic impact, Baltic Lakeland, genetic differentiation, indigenous population, population decline, population genetics, translocation

I. INTRODUCTION

The vendace (*Coregonus albula*) is native widespread to lakes in northern Eurasia around the Baltic Sea, from Germany and Denmark in the west, through Poland to Estonia, Lithuania, Latvia and Russia in the east, and is also found in the slightly brackish waters of the Baltic Sea [1]. In North–eastern Europe populations of local whitefish are the remnants of the Arctic freshwater faunal complex and can be considered as glacial relics [2], [3], [4].

Vendace's ecological importance stems from its position in the food chain of European lakes. As a planktivorous fish, vendace primarily feeds on zooplankton and benthic invertebrates, playing a crucial

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role in regulating the abundance and distribution of these lower trophic level organisms [5]. Beyond its role in trophic interactions, vendace is a very plastic species of freshwater whitefish and also serves as a valuable bioindicator species for assessing the health of freshwater ecosystems in Europe. Vendace inhabit in lakes with relatively low trophic conditions and high oxygen levels, so this species also serves as a bioindicator of water quality [6], [7]. Due to its sensitivity to environmental stressors such as pollution, habitat degradation, and climate change in vendace populations can provide early warnings of ecosystem disturbances. Besides this, vendace, together with other whitefishes, belongs to economically valuable fish species. Moreover, *Coregonus albula* is a valuable commercial fish species in Europe [8], [9].

Historically, the territory of the Baltic Lakeland region is located on the territory of three countries (Latvia, Lithuania and Belarus). The management in the past and present, state in nowadays and the factors affecting vendace in different waterbodies differ. So, for example the range of the vendace population is declining in waterbodies in Latvia and Belarus, the catch is insignificant and unstable [10], [11], and this species is included in the list of specially protected fish species. Coregonidae fish species in Latvian lakes has diminished, and vendace have been found only in 13 lakes after 1990 [12]. The habitat of vendace in Belarus is catastrophically declining also. Over the past 50-70 years, the number of lakes inhabited by vendace has decreased from 40-50 to 17 [5], [13]. However, in Lithuania this species is widespread and not protected; vendace was found in 76 lakes [14].

The understanding fish population genetic diversity is very important for protection of rare communities and conservation of unique native populations. The estimation of the genetic structure of populations and determining the causes of genetic differentiation and the factors that promote variation between and within populations is fundamental for understanding adaptation and is, therefore, a primary goal of population and conservation genetics. Little is known about the genetic structure of vendace populations in waterbodies in Baltic Lakeland [15], [16], [17]. That is why genetic diversity was studied in six vendace populations from Baltic Lakeland, namely Drivyaty, Rudakova, Strusto, Snudi, Naroch and Drūkšiai.

Microsatellites are successfully used for genetic studies of different Coregonus species, as well as for the monitoring, protection and management of these species [18], [19], [20], [21], [22]. In this study eight microsatellite loci were used to investigate the genetic structure within and between populations.

The aim of research was to reveal genetic variability and genetic structure of vendace populations in different waterbodies in Baltic Lakeland and to detect whether the management in the past and present and the factors affecting vendace in different waterbodies had an impact on its genetic variability and genetic structure in present.

II. Materials and Methods

A. Sampling

Vendace samples were collected in Baltic Lakeland in 2006 – 2015. The material was collected from seven lakes, namely Lake (further L.) Naroch, L. Snudy, L. Rudakova, L. Strusto, L. Drivyaty, L. Drūkšiai and L. Rāznas (see location, surface area and depth of lakes in Fig. 1, Table 1). Classification of the lakes' morphologies was done according to Ancāne [23]. All studied lakes are eutrophic or meso-eutrophic and support commercial and recreational fishing, although commercial activities are currently insignificant and not profitable. Vendace were fished with 20 mm mesh size bottom-set gill nets, each measuring 70 m in length and 6 m in height. As the contribution of vendace to the fishery is not big and the catch is insignificant and unstable, the size samples taken for research purposes differed in each lake (Table 1).

Samples of fish tissue (skeletal muscles) were taken and stored at -80ºC to await DNA extraction.

Table 1 The data of sampling and the main characteristics of lakes in which the material was collected.

Lake	Location	Water drainage	Area (km^2)	Average depth (Max depth),m	Sampling date	N
Naroch	54˚86`N, 26˚75`E	Viliya River	79.6	8.9(24.8)	11.2014	20
Drivyaty	55˚6`N, 27˚03`E	Daugava River	459	6.1(12)	11.2014	3
Rāznas	56˚19`N, 27˚26`E	Daugava River	57.56	7(17)	2006	4
Snudy	55˚75`N, 27˚06`E	Daugava River	22.0	4.9(16.5)	11.2014	19
Rudakovo	54˚89`N, 26˚89`E	Daugava River	0.24	11.3(28.6)	11.2014	5
Strusto	55˚70`N, 27˚04`E	Daugava River	13	7.3(23)	11.2014	4
Drūkšiai	55˚64`N, 26˚58`E	Daugava River	44.79	7.6(33.3)	07.2015	48

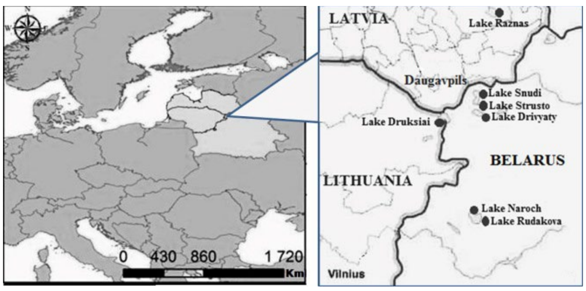

Fig. 1. Map showing sampling locations of seven samples.

B. Microsatellite analysis

DNA was purified from skeletal muscle tissue according to the salt-extraction method of [24], which earlier was used, in genetic researches of water animals [17], [25]. The quality and quantity of DNA samples was determined using spectrophotometer BioSpec-nano (Shimadzu). The extracted DNA was then stored at -20 ºC to await analysis.

For the analysis, the DNA was diluted to a concentration of 20 ng/µL. Microsatellite amplification was performed using the ABI 9700 thermocycler. PCR was performed with fluorescently marked primers (NED, HEX, FAM) in a volume of 12 µL. PCR mixture components were: 100 ng of DNA sample, 10mM Tris-HCl buffer with 50mM KCl, 1.5 mM MgCl2, 2mM dNTP mix, 0.06 U/µL Taq DNA polymerase, 0.4 µmol/µL of each primer. The individuals were genotyped at eight microsatellite loci altogether: five of them were dinucleotide repeat loci (*Cisco90*, *Cisco126*, *Cisco157*, *Cisco200*, *BWF1*) [26], [27] and three tetranucleotide repeat loci (*Clatet6*, *Clatet9*, *Clatet13*) [28]. PCR was performed using the thermal cycling program, following an initial denaturation at 94°C for 5 min, 25 cycles were run with denaturation at 94°C for 30 s, annealing at 58°C (for *Cisco126*, *Cisco157*, *Cisco200*, *Cisco90*, *BWF1*), at 61°C (for *Clatet6*, *Clatet9*), at 57°C (*Clatet13*) for 30 s, and extension at 72° C for 60 s followed by 7 min extension at 72°C and cooling at 4°C. Amplification was performed three times including a positive and negative control.

The PCR products were separated on ABI 310 automated analyser (Applied Biosystem) using Genescan ROX 500 size standard (Applied Biosystem), alleles were scored in GeneMapper 3.7 software (Applied Biosystem). The given data was verified in the software Micro-Checker 2.2.3 [29]. The Micro-Checker program was used to check out the data for typographic errors, to identify the null allele and genotyping errors: short allele dominance (large allele dropout) and scoring of stutter peaks.

The standard indices of genetic variation were measured: number and frequency of alleles at a locus, occurrence of private alleles in each population, observed and expected heterozygosity level at each locus. Their differences and significance were calculated with the help of $\chi2$ criteria using POPGENE 1.32 [30] and GeneAlex 6.41 software [31]. Richness of alleles and private alleles in each population were determined, accounting for differences in the size of samples. The rarefaction procedure was used for the smallest sample size as implemented in the software HP-RARE 1.0 [32].

In order to estimate and visualize the genetic structure and differentiation of the studied vendace populations and possible relatedness, the computer programs STRUCTURE 2.3 [33] and POPHELPER Structure Web App v 1.0.10. [34] were used. A model assuming admixture and correlated allele frequencies between K populations (Burn-ins of 100.000 replications and 300.000 Markov chain Monte Carlo (MCMC) replicates) were used. Sampling locations were used as a priori information to assist the structuring (the LOCPRIOR model) as recommended for weak signals of structuring [33]. Values of K between one and seven were tested, running STRUCTURE ten times for each K and using Evanno's ΔK method to determine the most suitable number of clusters [35]. The most likely (highest ln Pr(X|K)) grouping was visualized using POPHELPER Structure Web App v 1.0.10 [34]. The genetic relatedness of the populations was estimated with the help of Nei's [36] index of genetic distance (D) using the computer program Populations 1.2.32 [37]. The dendrogram was created according to the UPGMA method using the computer program TREVIEW [38]. Genetic divergence was estimated by pair-wise F_{ST} values [39] using GeneAlex 6.41 software [31]. The P-values for the pair-wise F_{ST} values was corrected for multiple comparisons by Bonferroni corrections (BFCs) following Rice [40]. Using the computer program Bottleneck 1.2.02 [41] populations were examined for evidence of a bottleneck effect.

III. RESULTS AND DISCUSSION

A. Genetic variation

The standard parameters of genetic variation in studied Latvian populations of European vendace are shown in TABLE 2. A total of 135 alleles from among eight microsatellite loci were determined in seven studied samples. Allele number in different samples varied from 24 to 98.

TABLE 2 SUMMARY OF GENETIC STATISTICS OF THE STUDIED VENDACE POPULATIONS INCLUDED IN THE STUDY

Populations	N_A	N_{RA}	N_{RPA}	H_O	H_E
Naroch	56	3.34	0.61	0.602	0.657
Snudy	70	3.77	0.63	0.635	0.719
Rudakovo	24	2.54	0.36	0.400	0.440
Strusto	29	3.13	0.36	0.500	0.543
Drivyaty	25	5.13	1.33	0.625	0.514
Drukšiai	98	3.72	0.86	0.589	0.721
Rāznas (*C. lavaretus*)	34	3.67	1.62	0.708	0.672

N_A – total number of detected alleles, N_{RA} - mean allelic richness, N_{RPA} – private allelic richness, H_O – observed heterozygosity, H_E - expected heterozygosity

TABLE 3 F_{ST} VALUES OBTAINED DURING THE PAIR COMPARISON OF EUROPEAN VENDACE SAMPLES FROM THE STUDIED LAKES

Sample	**Naroch**	**Snudy**	**Rudakova**	**Strusto**	**Drivyaty**	**Drūkšiai**	**Rāznas**
Naroch		0.001/*	0.001/*	0.005/ns	0.001/*	0.001/*	0.001/*
Snudy	0.082		0.001/*	0.297/ns	0.001/*	0.001/*	0.001/*
Rudakova	0.091	0.119		0.227/ns	0.002/ns	0.001/*	0.001/*
Strusto	0.060	0.007	0.024		0.002/ns	0.001/*	0.001/*
Drivyaty	0.154	0.132	**0.309**	0.191		0.001/*	0.001/*
Drūkšiai	0.115	**0.050**	0.193	0.078	0.138		0.001/*
Rāznas	0.232	0.166	0.329	0.239	0.241	0.175	

ns - not significant, * P<0.05, ** P<0.01, *** P<0.001; underlined– significance level after BFCs corrections. The smallest and the highest F_{ST}–values are shown in bold; a value lying in the range between 0 and 0.05 indicates little genetic differentiation; a value between 0.05 and indicates 0.15, moderate differentiation; a value between 0.15 and 0.25. high differentiation; and values above 0.25, very high genetic differentiation [43], [44]

The mean number of alleles per locus or allelic richness (N_{RA}) varied from 2.54 (L. Rudakovo) to 5.13 (L. Drivyaty). The mean number of private alleles (N_{RPA}) varied from 0.36 (L. Rudakovo and L. Strusto) to 1.62 (L. Rāznas).

In recent vendace population research [17] in nine waterbodies from Baltic Lakeland was shown that the allelic richness ranged from 4.24 to 6.22 and mean number of private alleles varied from 0.29 to 0.87, there was assumed, that waterbodies where was revealed the highest number of private alleles have native vendace population. In our case the highest number of private alleles in L. Rāznas associated with another species in that sample, L. Rāznas sample with *C. lavaretus* indivuduals was taken as outgroup for present research.

The observed and expected heterozygosity for all samples over the eight microsatellite loci varied from 0.400 (Lake Rudakovo) to 0.708 (Lake Rāznas) and from 0.440 (Lake Rudakovo) to 0.721 (Lake Drūkšiai), respectively (TABLE 2). The individual locus tests (for each sample) displayed that eight cases out of 56 had significant deviations of genotype frequencies from Hardy - Weinberg equilibrium (HWE) before BFCs. A significant deviation from HWE was revealed at locus *Clatet6* for L. Naroch, at loci *Cisco200*, *BWF1*, *Cisco90* and *Clatet13* for Lake Snudy, at loci *Cisco200*, *BWF1* and *Clatet9* for Lake Drūkšiai. Significant deviations of genotype frequencies from HWE after BFCs were revealed in two loci in samples from two different lakes. That is, heterozygosity deficits were detected at L. Naroch population in locus *Clatet6* and in L. Drūkšiai in locus *Cisco200*, which was indicated by Micro-Checker as caused by possible presence of null alleles.

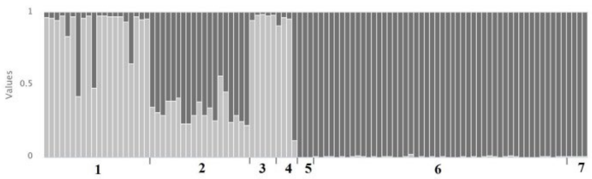

Fig. 2. Bayesian clustering of all individuals using STRUCTURE (1 –L. Naroch, 2 – L. Snudy, 3 – L. Rudakova, 4 – L. Strusto, 5 – L. Drivyaty, 6 – L. Drūkšiai, 7 - L. Rāznas).

The heterozygosity deficit in locus *Clatet6* as caused by the presence of null alleles was observed also in other *Coregonus albula* population study in northern and central Finland [20], central and southeast Finland [8]. The heterozygosity deficit in both loci, as *Cisco200* as *Clatet6*, caused by the presence of null alleles, was mentioned also for *Coregonus albula* populations in different waterbodies in Baltic Lakeland [17]. In present study it was revealed in only one waterbodies for each locus (*Cisco200*, *Clatet6*). Altogether the level of heterozygosity was quite high. So, quite similar heterozygosity levels have been reported for whitefish populations in Poland and Scotland waterbodies (0.485–0.553, [42]; 0.433–0.455, [46], respectively). There were revealed quite high level of heterozygosity. It was shown, that relatively high levels of heterozygosity could also be recovered long after translocations (at least 16 years; [45]). In studied samples there was not been revealed any evidence of a bottleneck effect, which was established by the allele frequency distribution.

In the waterbodies in Baltic Lakeland the number of detected allele fluctuates. For instance, in previous research there were detected 44 alleles in locus *Cisco200* [17], whereas in present research there were detected only 31 alleles in the same locus. However, in some other locus there were revealed more alleles. For instance, there were revealed two more alleles in locus *Clatet13*, five more alleles in locus *Clatet9* and one more in loci *Cisco126* and *Cisco90*. Despite this, it is one and a half and two times less than in vendace samples from economically valuable fishing areas in central and southeast Finland [8]. The possible reason of it may be that, vendace populations in Baltic Lakeland possibly went through the bottleneck in the past [13], [17], [42].

B. Population structure and spatial variation

The F_{ST} values of genetic differentiation between the studied vendace populations in Baltic Lakeland are shown in TABLE 3. The pair L. Strusto - L. Snudy displayed the smallest differentiation (0.007, $p > 0.05$), whereas the pairs L. Rudakova - Lake Drivyaty and L. Rudakova - Lake Drūkšiai had the highest F_{ST} values (0.309, $p \leq 0.01$; 0.193, $p \leq 0.01$ respectively).

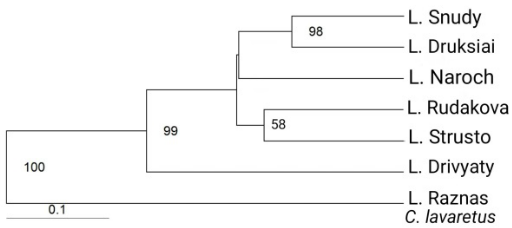

Fig.3. Genetic differentiation of seven studied samples from waterbodies in Baltic Lakeland as revealed by UPGMA tree using Nei et al., (1983) genetic distance (Da).

Besides *C. lavaretus* samples from L. Rāznas, high genetic differentiation shows also pair L. Drivyaty – L. Strusto (0.191, $p > 0.05$). For all other pairs, moderate genetic differentiation was shown, the FST values varied from 0.05 to 0.154 ($p \leq 0.001$) (TABLE 3). The sequential BFC slightly change the significance level (P value) from the pairwise F_{ST} comparisons. Moderate level of genetic differentiation is reported for native whitefish populations in Scotland also have been shown [46]; the same recently was shown for some vendace populations in Baltic Lakeland [17]. So, we can assume, that lakes Naroch, Snudy-Strusto, Rudakova and Drūkšiai are isolated from each other; there is no migration and gene flow.

Little genetic differentiation between L. Strusto and L. Snudy is the smallest, which was revealed between vendace populations in Baltic Lakeland. These two lakes are connected by a channel and little genetic differentiation of vendace samples from these lakes confirms that there is active vendace migration between lakes. Similar little genetic differentiation was reported also for vendace populations after recent invasion in waterbodies in Finland [20]. So we can conclude, that little genetic differentiation between populations is revealed if there is gene flow between. However, Bayesian clustering does not assemble L. Strusto and L. Snudy into one genetic group (Fig. 2.). Earlier was shown also that genetic differentiation between vendace samples from waterbodies which is from different drainage systems is higher than between samples from waterbodies within the same drainage system [9], [17]. However we did not revealed such patterns in present research.

Bayesian clustering partitioned populations into two genetic groups (K=2; Fig. 2), placing lakes Naroch, Strusto and Rudakova in one group; and lakes Rāznas, Drūkšiai, Drivyaty and Snudy in the second group. The

UPGMA tree (Fig. 3) shows following grouping: L. Rāznas and L. Drivyaty were separated as two different branches, other five lakes branch out into separate group. L. Rāznas separated into different branch because it sample constitute of *C. lavaretus* individuals, which was taken as outgroup. Lake Drivyaty separation into different group is unclear; however it may be caused by the small sample size from this lake.

There are five samples from waterbodies which are placed on Belarus area and one from lake, which is placed on Belarus - Lithuanian area. Genetic variability and structure of them do not differ significantly, however all these have different management in the past and present, and the factors affected vendace in past. So, as it has been published earlier [17], [47], due to its economic importance European vendace has been artificially propagated in Latvia. Unfortunately its actions had not been successful, the stocks of vendace decreased and, now, it has protection status. Similarly, European vendace has been artificially propagated in Belarus to increase stocks of this valuable species. However these actions had not been successful [13], vendace's stocks reduced, and it has protection status now [5].

L. Drūkšiai has absolutely different history in this case. It is situated in north-eastern Lithuania. "From 1984, the water of L. Drūkšiai has been used for cooling reactor units of the Ignalina nuclear power plant (INPP). Before the beginning of the construction of the INPP (1950–1975), the fish community of Lake Drūkšiai had been dominated by stenothermal fish species: lake smelt *Osmerus eperlanus* (L.) and vendace *Coregonus albula* (L.), the biomass of which accounted for ca. 40% of the total fish biomass of the lake."[48]. In the first years of exploitation of the INPP (1984–1986) the biomass of vendaces decreased 58.8-fold [49]. During 5 years after the closure of the INPP vendace present one of the core species in the lake fish community [50]. Nowadays, Lake Drūkšiai is a water body of high productivity where both intensive amateur fishing and limited commercial fishing is allowed. The stocks in lake are rather high. So, there is successfully recovered vendace population in L. Drūkšiai. Now, about so substantial fluctuations in population`s size, possibly, indicate only number of alleles in population. Possibly such genetic properties could be formed much earlier.

Taking into account, given genetic diversity in studied vendace samples, can assume that there are various vendace populations in each of studied waterbodies. Vendace populations partially adapted to the changed environmental conditions, but in some of them it is quite fragile. So, it can assume that L. Snudy and L. Strusto vendace populations may be considered as one management unit, taking into account low genetic differentiation between these lakes. However, the Bayesian clustering do not reveals such grouping; so, there is need in additional studies (monitoring). As other studied vendace samples are isolated from each other, it could be considered as different management units to develop optimal strategy for their effective conservation and management.

CONCLUSION

The level of genetic variability was different in studied populations in Baltic Lakeland. The differences may be caused by genetic drift, which influence allele frequencies in various ways. Changes may be observed on the level of population genetic variability and genetic structure as a result of thermal regime changes and the impact of intensive anthropogenic eutrophication.

Present research could be useful in the design and monitoring of conservation programs of *Coregonus albula* populations in Baltic Lakeland.

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Air pollution engineering for accidents with hazardous substances

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Abstract. **One of the challenges facing modern society is related to the dangers of industrial accidents and terrorist attacks related to the spread of fires and dangerous substances. In the present article, a systematic approach is proposed for organizing monitoring, creating possible development scenarios, modeling the spread of potential toxic-element pollution, comprehensive analysis and creating an adequate response to such severe situations. The assessment of the scale of pollution transport, dispersion, chemical transformation and the degree of danger is directly related to the correct registration of the basic accident, weather and environment characteristics and thoroughly monitoring of the dynamics of their change. The collection of the necessary data is carried out on the basis of heterogeneous sensor networks. The application of modern methods for the unification of disparate information scattered in space and time allows the accurate evaluation of the current state. Different development scenarios are generated on the basis of methodologies and corresponding mathematical models are applied. The risk assessment framework feeds these models with the unified sensor information and comprehensively examines them to provide a quantitative estimate of the possible critical levels of harmful pollution and predict the consequences. The paper's relevance is heightened by the growing threat of terrorism that targets industrial infrastructure and climate change that increase the frequency and severity of natural disasters, compounding the challenges of predicting and managing air pollution events. It contributes to the discourse on environmental engineering and disaster management by proposing a systematic methodology for real-time data collection, risk assessment, and the application of predictive models to inform effective response strategies. By tackling these issues, the paper aligns with contemporary priorities in environmental protection, public health, and safety regulations, making it highly topical for stakeholders in academia, industry, and government seeking to enhance resilience against air pollution disasters.**

Keywords: Air pollution engineering, accident modeling, dispersion of toxic substances.

I. Introduction

Air pollution is a dangerous phenomenon that threatens the lives of people and the planet as a whole by disrupting its eco-systems. Air pollution occurs most often as a by-product of industrial or other human activity, as a result of natural disasters (volcanoes for example) or as a result of industrial accidents or acts of terrorism. The last two ways of occurrence of air pollution are characterized by their sudden occurrence, in many cases impossibility of advance forecasting and monitoring, absence of a control strategy. The location of air pollution also cannot be easily predicted. In addition to the places of storage and pollutant production, such incidents can also occur during the transportation of dangerous substances, in the places of their application/use. This uncertainty about the realization of dangerous air pollution in time and space necessitates the creation of a new organization to reduce or eliminate the negative consequences of such accidents. In classic industrial air pollution, stationary stations usually monitor accurately the current state of air cleanliness closely. In contrast, pollution resulting from accidents requires rapid and large-scale deployment of sensor networks to collect data on the distribution and concentration of pollutants, collect local meteorological data on air currents and changes in the air environment that can affect the spread of the pollutants. This large

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volume of data must be normalized, tied geographically to the specific location of the accident, and carried out to a point in time. The general pollutant transport models must be also localized to the specific accident at the specific site.

The article is written to present a global picture of the most important components in air pollution engineering for accidents with hazardous substances. Secondly, the organization of effective information exchange and the choice and localization of the pollutant transport models are of major concern. The clear and concise understanding of these mandatory system attributes gives us the indispensable means to assess the magnitude of the disaster, predict its impact on people and the environment and plan the most effective actions to reduce or neutralize its harmful effects.

The paper is organized as follows: Section 2 reviews the current state of research for air pollution engineering. In the third section the main tasks of disaster management are revealed and the crisis headquarters information system is proposed. Section 4 presents the methodology of modeling and data analysis. A short review of mathematical models is given in Chapter 5 and a chosen model is described in details. In the last part of the text the most important conclusions and contributions are summarized.

II. Materials and Methods

Related works: When some substances in the air at concentrations higher than their normal ambient levels lead to significant effects on humans, animals, vegetation or materials we are talking for air pollution [1]. The main source of toxic air pollutants is the economic, industrial and population growth, although there are also various natural disasters (wind-blown dust, volcanic eruptions and fires, for example) that also contribute to air pollution. Different technical disciplines deal with the study of air pollution. They are usually combined into more general one – air pollution engineering. In the scientific literature on air pollution issues, there is no consensus on what is meant by air pollution engineering. Some authors understand by this concept the study of the generation and control of air pollutants [2]. Other authors consider within this terminology only preventive measures and air pollution control techniques for removing or reducing harmful gases, vapors and particulates from industrial process emissions [3]. In this article, the emphasis in air pollution engineering falls on the organization of monitoring and establishing the specific values of air pollution in the disaster/accident area, the construction of a realistic mathematical model for the pollution spreading over time and the taking of appropriate measures to reduce the adverse consequences resulting of pollution. Issues of preventive control, which are extremely important for stationary sources of air pollutants, are of secondary importance here. In most cases, they are regulated by various state legislative acts for control the handling of dangerous substances, their transportation and the prevention of terrorist acts.

In [4], the authors examine air pollution for various disasters, citing specific examples of such situations. Among those considered as consequences of natural disasters are floods [5], drought [6], wild fire [7], [8], earthquake [9], [12] tsunami [10] - [12], volcanic eruption [14] - [17], epidemics [18], [19], extreme temperature [20], insect pest infestation [21], mass movement (landslide, avalanches, earthquake) [22].

Air pollutions due to anthropogenic disasters are listed separately and include those resulting from wars, conflicts and fire accidents. Anthropogenic disasters can be initiated by careless treatment of the working environment or poor organization of work or be purposefully carried out in the case of terrorist acts and civil conflicts with the aim of causing significant physical damage, loss of life or impact on the environment. Risk assessment [23] and optimum risk management is usually sought to reduce the consequences of such disasters. Risk assessment includes (1) hazard identification; (2) exposure assessment; (3) dose-response assessment and (4) risk characterization. Optimal risk management deals with the actions that must be taken within the framework of laws and regulations in place to minimize the possibility of hazardous air pollution in accidents and to respond as quickly as possible to such accidents in order to reduce damage and preserving the life and health of people [24], [25].

Disaster management: The disaster management activity is diverse and has the main purpose of: 1) Identifying potential hazards and assessing the risks associated with them and selecting appropriate organizational actions to prevent such accidents or reducing the possibility of occurrence to an acceptable level; 2) Organization of the activities of various services and bodies to establish the extent of the accident, create teams to assist the victims and restore the critical infrastructure, predict the possible future impacts on people, the environment and the infrastructure and guarantee their safety; 3) Planning and organization of activities for full recovery from the impact of the accident (Fig. 1).

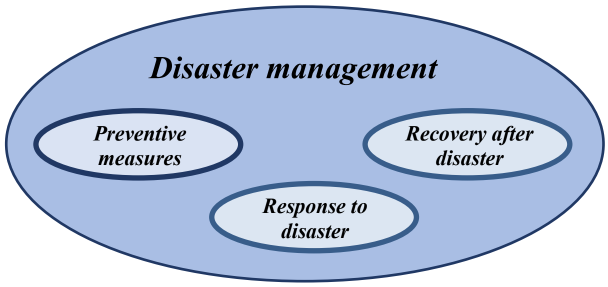

Fig. 1. Main disaster management components.

In 2005, the first international (agreement of 168 governments) framework program for building the resilience of nations and communities to disasters (2005-2015) was created in Hyogo [26]. Later in Sendai, this framework program was further developed for the period 2015-2030 as the Framework for Disaster Risk Reduction 2015-2030. The main goal remains the same - reducing existing risk and preventing the creation of new risk [27].

The preliminary preparation of society to deal with disasters and accidents is a complex and multidimensional process related to the relevant legislative and regulatory activity, creation of specialized bodies, services and commissions, material provision for action, determination of areas that are subject to increased risk for such disasters and accidents, creating action plans for various disasters.

These activities cannot always prevent disasters from occurring, but they can certainly reduce economic loss, damage to critical infrastructure, prevent or minimize human casualties, and enable recovery in a short period of time.

The consequences of disasters and accidents often remain for years to hamper the population and the countries that suffered them. One such telling example is the consequences of the Fukushima earthquake, which up to this day, 13 years later, remain very serious. In such severe disasters, the main focus of remediation is on health care and rehabilitation of victims and repair of damage to infrastructure. Although not paramount, disaster analysis is needed to plan and implement better policies and practices to avoid or mitigate similar events in the future.

The third component of disaster management differs from the other two in the need for all actions to be performed in a very short period of time and coherently in time and space. This can only be accomplished in the conditions of a highly organized society, equipped with the necessary services, provided with sufficient equipment and opportunities for quick orientation in the situation, establishing the main parameters of the disaster and making adequate informed decisions.

Accidents related to air pollution are somewhat more insidious than other destructive incidents because they may go unnoticed by people initially at their impact. The activities of rescue, relocation, provision of decontaminated food and water depend to a large extent on the precise identification of hazardous substances and the extent of their spread. The type of airborne contamination also determines the way of providing emergency medical assistance and quality protection of the medical teams in action. The above-mentioned features of accidents related to air pollution require to a greater extent the development of an information subsystem to deal with such situations.

In Fig. 2, the architecture of such a system is proposed, the main purpose of which is to support the informational work of the crisis headquarters.

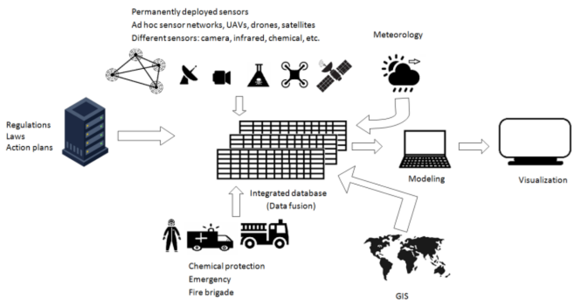

Fig. 2. Crisis headquarters information system.

Two elements are particularly critical in the crisis information flow diagram shown above. The first of these concerns the unification of information from multiple sensors and documents. Some of the information is permanent, but another part is tied to a specific place and refers to a specific moment in time. Bringing the information to a given time and obtaining dense coverage of the data in a given area requires not just interpolation/extrapolation of the data but also taking into account the topography of the area and the nature of the objects, air currents, the type of hazardous substances from the point of view of the process of their diffusion and many other factors. For this purpose, it is necessary to localize the available mathematical models, validate the obtained results with the help of the continuously arriving data. All of this must be accomplished in a critically short time dictated by the danger of the situation and the impossibility of postponing decisions.

The second critical element is modeling the progress of the contamination. Depending on the forecast, the problems related to the evacuation of the population in the threatened areas must be solved as quickly as possible, the provision of temporary shelters, water and food, the provision of effective emergency health care to the victims, the taking of measures for the decontamination of the polluted areas, the provision of vital services such as telecommunications, transport, prevention of the spread of infections and many others.

III. RESULTS AND DISCUSSION

Data analysis and methodology for modeling: Identification of powerful energy and pollution sources is the first step of our methodology. In the context of air pollution, the various energy and pollution sources contributing to the release of pollutants need to be identified. These sources can include combustion processes (such as explosions, industrial accidents, or vehicle emissions), chemical anthropogenic sources (such as releases from chemical plants), or natural physical processes (such as dust storms, volcanic eruptions, forest fires, etc.).

The next step is related to partitioning of the released energy. The total energy released during the disaster is partitioned into different components based on the identified sources. For example, in a wildfire scenario, the energy released from the combustion of biomass, the energy required for ignition, and the energy released from the combustion of structures can be considered as separate components.

Modeling of the pollutants' dispersion and transport in the air comes next. Once the energy components are identified, a model should be used to simulate the dispersion of pollutants released into the atmosphere. This model must take into account factors such as meteorological conditions (wind speed and direction, atmospheric humidity, precipitations), terrain characteristics of the affected area, as well as the physical and chemical properties of the most dangerous pollutants. At the same time, calculation of pollutant concentrations should be carried out by using proper chemical reactions model. As a result, the method should be able to estimate the concentrations of these pollutants at various locations around and downwind of the disaster site. This is rather big, complicated and tuff mathematical and computational problem, some simplifications should be done in order to solve it successfully [30, 31].

Validation and calibration is another important issue. As usual for any modeling approach, the accuracy of the multi-energy method for air pollution assessment relies on validation against observational data from past disasters (if available) and calibration to account for uncertainties in model parameters and input data.

Assessment of safety, healthcare and environmental impacts should be the final result and the most socially important application of our work. The calculated pollutant concentrations can be compared with regulatory standards or health-based guidelines to assess potential health risks to exposed populations and environmental impacts on ecosystems. This information is crucial for emergency response planning, public health interventions, and environmental management strategies.

Mathematical models: The dispersion of gases within the atmosphere can be analyzed through a diverse array of models. These models are differentiated by several factors, including the nature of the pollutant's release (either instantaneous or continuous), the geometric characteristics of the source (point, linear, areal, or volumetric), the topographical and atmospheric conditions, the pollutants' composition (chemical, radioactive, and so on), their physical state (solid, liquid, or gas), and the scale of the dispersion (local, regional, or global). From a scientific standpoint, the most systematic method for classifying these models is based on their mathematical approach, dividing them into three main categories [32]:

Empirical models - These models are entirely based on experimental observations and data, without applying deep mathematical analysis.

Lagrangian models - In these models, the movement of pollutants is tracked individually, treating them as individual particles that move along with the air currents.

Eulerian models - Here, pollutants are analyzed within a fixed control volume unit, considering changes in concentration and distribution over time and space. An example of such model (the Danish Eulerian Model) is described in [33].

In item 15 of the introductory notes of Directive 2012/18/EU (Seveso III) [28], the obligation of operators of high-risk enterprises to prepare and submit a safety report to the competent authorities is regulated.

This report should include details of the enterprise, the hazardous substances present, the installation or storage facilities, potential scenarios for major accidents, risk analysis, prevention and intervention measures, and available management systems. Its objective is to prevent and mitigate the risk of major accidents, as well as to ensure the ability to take necessary steps to limit their consequences.'

Quantitative risk assessment involves identifying and analyzing all possible accident scenarios to provide a comprehensive description of the risk level. The Safety Report should contain a list of scenarios used in the risk assessment, along with the following details for each scenario:

- Information about the substance (type, quantity, method of storage, processing or production, physicochemical and toxicological characteristics, etc.)
- Amount of substance involved in the accident (released substance)
- Duration of the discharge
- Discharge conditions (pressure, temperature, phase)
- Release location and situation (indoor/outdoor, presence of shells, etc.)
- Accident frequency (expressed as frequency of occurrence).

Hazard analysis and accident cause analysis should result in the identification of several major accident scenarios with comparable characteristics related to the 'content loss event' (extent, location, physical conditions). Scenarios with an expected frequency lower than 10^{-8} per year are considered to have negligible risk and can be excluded from consequence analysis and risk assessment.

The following hypotheses are considered for the occurrence of adverse events:

- Leakage of a substance (gas, vapors, liquids, solids)
- Sudden ignition (jet fire, puddle fire)
- BLEVE (Boiling Liquid Expanding Vapor Explosion)
- Explosion
- Collapse
- Formation of a toxic spill
- Formation of a toxic cloud
- Formation of a flammable liquid spill
- Formation of a flammable cloud
- Ignition of a flammable cloud.

This study will consider scenarios involving the formation of a toxic cloud. The following gas release options are possible and the key factors are as described:

1. Local depressurization (hole) in the wall of a gas pipeline.
2. Rupture of a pressurized gas pipeline.
3. Local depressurization of a pressurized gas vessel.
4. Complete depressurization of a pressurized gas vessel.

Stability of the atmosphere

The stability of the atmosphere is crucial for the dispersion of toxic substances in the environment. It depends on the wind speed and the temperature difference between the air at the Earth's surface and higher altitudes. Stability levels are classified into six stability classes based on five wind speed categories, three types of daytime sunshine, and two types of nighttime cloudiness. These stability classes are known as Pasquill - Gifford stability classes.

Models to describe dispersion

The chosen models specifically address instantaneous gas releases, differentiating based on gas density. The Gaussian plume model applies broadly, while the Britter and McQuaid model is tailored for heavy gases, reflecting distinct dispersion behaviors influenced by gas properties.

Gaussian plume model

Passive dispersion depends mainly on atmospheric turbulence. Turbulence, in turn, is determined by the stability of the atmosphere and height above the surface.

The dependence of the passive dispersion can be represented by the Gaussian plume method for instantaneous release [29]:

$$c(x,y,z,t) = \frac{Q}{(2\pi)^{3/2}\sigma_x\sigma_y\sigma_z} e^{-\frac{(x-u_a t)^2}{2\sigma_x^2}} e^{-\frac{y^2}{2\sigma_y^2}} e^{-\frac{(h-z)^2}{2\sigma_z^2}}$$
(1)

where:

$C_{(x,y,z)}$ – concentration at a point with coordinates x, y, and z [g/m³];

Q – total released mass [g/s];

u_a – ambient velocity at which the plume or puff is advected by the wind [m];

$\sigma_x, \sigma_y, \sigma_z$ – dispersion parameters [m];

h – height of the plume centre-line [m].

The terms σ_x, σ_y, and σ_z refer to the standard deviations of the concentration distribution in the respective x (along-wind), y (cross-wind), and z (vertical) directions. Two approaches for modeling dispersion parameters can be followed: one based on statistical theory and the other on empirical data fits.

Statistical Theory Approach:

σ_x (along-wind dispersion): Measures the spread of a plume along the wind due to turbulence, based on the intensity of along-wind velocity fluctuations and the time the plume has been traveling.

σ_y (cross-wind dispersion): Indicates the plume spread perpendicular to the wind, also depending on the intensity of cross-wind velocity fluctuations and time, usually resulting in a wider dispersion than σ_x.

σ_z (vertical dispersion): Represents how the plume spreads vertically, affected by vertical velocity fluctuations and time, influenced by factors like atmospheric stability.

Empirical Data Fit Approach:

σ_x (along-wind dispersion): Calculated using empirical data on how the plume spreads with distance from the source, without a direct theoretical basis in turbulence.

σ_y (cross-wind dispersion): Estimated using observed data and empirical formulas based on the distance from the source, commonly using the Pasquill-Gifford method.

σ_z (vertical dispersion): Like σ_x and σ_y, it's based on empirical data, with different formulas applied depending on atmospheric conditions and source height.

The Gaussian dispersion model would visually convey the complex behavior of pollutant dispersion in the environment, emphasizing the need for both theoretical understanding and empirical data to predict the impact of emissions accurately.

Britter and McQuaid method for dense gas dispersion

The Britter and McQuaid methodology is a rigorously formulated approach for the simulation of dense gas dispersion, frequently cited in scholarly articles concerning the dispersion phenomena of heavier-than-air gases. This methodology employs a series of empirical functional relationships to elucidate the temporal and spatial evolution of pollutant dispersion under the influence of wind currents. It establishes a mathematical framework to relate the peak concentration C_{max} to the initial concentration C_0, within a range of 0.001 to 0.1, is through a dependency on $\left(x/V_i\right)^{1/3}$ and $\sqrt{\frac{g_0 V_i^{1/3}}{u^2}}$ where the equation is given as:

$$\left(\frac{x}{V_i}\right)^{1/3} = f_i\left[\left(\frac{g_0 V_i^{1/3}}{u^2}\right)^2\right] \quad (2)$$

In this context:

x – denotes the downwind distance from the source;

V_i – represents the initial volumetric release;

g_0 – is a modified gravitational acceleration factor;

u – is the ambient wind velocity.

The modified gravitational acceleration g_0 is defined as $g\frac{(\rho-\rho_{air})}{\rho_{air}}$ where ρ and ρ_{air} are the density of the gas and ambient air respectively.

Upon determining the values of $\left(\frac{g_0 V_i^{1/3}}{u^2{}_{ref}}\right)^{1/2}$ and C_{max}/C_0 empirical curves, one can deduce x/V_i. Given known values for C_0, V_i and u, either from sensor readings or as part of the initial conditions $C_{max} = f(x)$ can be plotted to represent the maximum concentration varying with x.

To ascertain the temporal evolution and radial expansion of the gas plume, the methodology employs empirical relations to solve for the puff radius $b_{(t)}$, and the time variable t:

$$b_{(t)} = \sqrt{b_0{}^2 + 1{,}2t\sqrt{g_0 V_i}} \quad (3)$$

$$x = 0{,}4u_{ref}t + b_{(t)} \quad (4)$$

Furthermore, the average vertical extent of the dispersed pollutant (b_z) for each distance x is computed as:

$$b_z = \frac{C_0 V_i}{\pi b^2 C_{max}} \quad (5)$$

The Britter and McQuaid model thus provides a robust framework for the assessment of dense gas dispersion following instantaneous releases, integrating empirical correlations with theoretical underpinnings to facilitate detailed analysis of dispersion patterns. This model is indispensable for the formulation of risk mitigation strategies in the event of industrial incidents, offering precise insights into the atmospheric dispersion and potential environmental impact of hazardous pollutants.

Impact assessment

The assessment of the consequences for individuals exposed to ambient spaces contaminated with hazardous gases or vapors is based on the concentration of the hazardous substance and the duration of exposure. A widely used system worldwide for assessing the consequences of accidental releases of gases or vapors is known by the abbreviation AEGL.

AEGL – (Acute Exposure Guideline Levels – indicative values of exposition).

AEGL 1 - concentration of the substance above which it is predicted that the population, including some sensitive individuals, may experience notable discomfort or irritation; however, symptoms are transient and reversible after discontinuation of exposure.

AEGL 2 - concentration of the substance above which it is predicted that the population, including some susceptible individuals, may develop irreversible serious and long-term adverse health effects or may be unable to leave the area of the accident.

AEGL 3 - concentration of the substance above which it is predicted that the population, including some sensitive individuals, may experience life-threatening effects and death.

IV. Conclusions

The study has refined the Gaussian plume and Britter and McQuaid models for dense gas dispersion, enhancing theoretical frameworks that underpin the understanding of hazardous substance dispersion in the atmosphere. This advancement contributes to the theoretical domain by providing a more nuanced understanding of the variables and dynamics involved in air pollution spread following industrial accidents.

A significant theoretical contribution of this research is the development of an integrated risk assessment framework that leverages data from heterogeneous sensor networks. This framework enriches the theoretical underpinnings of environmental risk analysis, particularly in the context of air pollution events stemming from accidental releases of hazardous substances.

On the practical front, the enhanced predictive capabilities afforded by the improved models directly inform the development of emergency management protocols. These protocols can now be more effectively tailored to address the specific characteristics and risks of hazardous substance releases, leading to more efficient and targeted emergency responses.

The insights gained from this study provide a robust foundation for informing policy decisions and regulatory guidelines concerning industrial safety and environmental protection. By elucidating the potential impacts of accidental air pollution events, regulatory bodies can implement more stringent safety standards and monitoring protocols for industries handling hazardous substances.

The research findings have practical implications for public health strategies, particularly in preparing for and mitigating the adverse health effects of air pollution from industrial accidents. Healthcare systems can utilize the study's risk assessment data to develop targeted medical response plans and public health advisories to protect communities in the event of hazardous substance releases.

In conclusion, this article examines the main problems related to air pollution engineering for accidents with hazardous substances. The main components of disaster management are described. A scheme of the crisis headquarters information system is proposed. The critical points in this system are outlined – the unification/fusion of disparate information from heterogeneous sensors and modeling of the pollutant distribution process.

The methodology for modeling and analyzing data is outlined, with a classification of the primary types of models utilized in air pollutant modeling, chosen for their minimal computational demands.

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Proving Optimization by Comparison of Business Processes

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Abstract. **One of the biggest problems in the practice of any business process analyst is how to prove the process optimization they have performed to the management and/or the management of the company/organization, who are neither specialists in business process analysis (at least in most cases) nor specialists in higher mathematics (even more rarely).**

The problem is further complicated by:

- the fact that the introduction of changes in a business process can also change the related business processes (the so-called "process chain reactions"), which could lead to a change in the functioning of the entire business process system of the firm/company under consideration (and in the whole spectrum from "extremely positive development" to "total degradation" and even bankruptcy/closure) if not taken into account;

- the right-proportional "objectivity-complexity" ratio of the methods that could be used for the purpose (i.e. the more objective and accurate a method is, the more complex it is);

- overly complex (especially from a mathematical point of view) methods look unconvincing in the eyes of the management/management of the company/organisation;

- overly simple (especially from a mathematical point of view) methods look unconvincing in the eyes of the more mathematically and/or more analytically oriented leadership/management of the company/organization;

It is therefore necessary to find a method (or more than one) that meets the following conditions:

- allows the objective evaluation of business processes;

- allows the comparison of business processes before ("as-is") and after ("to-be") optimization;

- allows the consideration of business process changes that are related to the optimized business process - i.e. evaluates and analyzes process chain reactions;

- compares similar business processes - for example, the stocking processes of two different firms/companies.et.

Keywords: ***business process analysis, business process optimization, business process optimization proof.***

I. Introduction

The process approach to managing companies/organizations is emerging as a result of the ever accelerating and increasingly dynamic world around us - changes in it are becoming more and more intrusive, the reactions of companies/organizations have to be many times faster and more adequate as compared to the end of the 20th century and many times faster as compared to the beginning of the 20th century.

The process approach to managing companies/organizations consists of continuously optimizing the business processes of the company/organization. A correct association would be the famous Long Life Learning approach to personal professional development - both are based on:

- constant monitoring;
- continuous state/process evaluation "as-is";
- developing a "to-be" state/process;
- change;
- comparison of both "as-is" and "to-be";
- Correction;
- a new cycle starting with observation.

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The conclusion - both approaches obey Aristotle's rule "Life requires movement", i.e. to survive in the modern world of increasingly fierce competition, continuous development and improvement is necessary.

The methodology for the practical application of the process approach is business process analysis, the purpose of which is the continuous monitoring and optimization of the business process system of the company/organization.

There are a large number of definitions of business process analysis, but the authors of the article define it as "a cyclical set of activities to improve the business process system of the firm/organization".

Theoretically, business process analysis consists of the following activities (each of them is a separate stage of business process analysis):

- Observation;
- Description;
- analysis (including evaluation);
- Optimization.

In practice, there is a fifth stage - proving the optimization. There are several reasons why it is not described in the professional literature:

- First, it partially overlaps with the analysis phase, during which the optimization is prepared and proven through analyses, clarifications, flowcharts, business process maps, etc.
- Second, this stage is skipped in many firms due to lack of motivation and/or specialized knowledge (both process and mathematical) among management;
- Thirdly, this stage is also skipped in companies where the business process is the owner and/or senior manager of the company;
- Fourth, this stage is often skipped in order to save time and money;
- Fifth, this stage is skipped when management places very high trust in business process analytics.

Despite these reasons, this fifth stage poses a serious problem for business process analytics, especially if there is a lack of professionals with specialized business process and/or mathematical knowledge among the firm's senior management, as is very often the case, especially in developing countries. But what is the problem and why is it a problem specifically for senior management without specialized business process and/or mathematical knowledge?

The answer is - the problem lies in the complexity of proving the quality of business process optimization performed by business process analytics to senior management without specialized business process and/or mathematical knowledge.

Based on the analysis and optimization of the processes through the MUSCA method, business process analysts will be given the opportunity to present the results of their optimization activity to managers without specialized knowledge in BPA and higher mathematics.

II. Materials and Methods

In this article the following optimization tools are discussed and classified:

- removing or adding an element from the business process;
- changing the sequence of business process elements;
- replacing a separate element of the business process;
- technical optimization - improvement/replacement of technical equipment to increase productivity
- staff training;
- miscellaneous.

In the given paper, the following methods for business process description and analysis are discussed and classified:

- Textual and tabular-textual apparatuses - such a method of description is, for example, the book-play type description;
- Graphical/symbolic language - such are UML (Unified Modeling Language), ARIS, BPMN (Business Process Model and Notation);
- Complex tabular methods - a representative of this type of methods is "BSC" (Balanced Scorecard)
- Complex mathematical methods - systems analysis, MUSCA, etc. at the time of writing this paper.

The criteria for proving business optimization are also discussed:

- financial measures - price, value, etc;
- time measures - periods of time (day, hour, minute, second, etc.);
- qualitative measures - what mistakes can be made and with what damage to the company/organisation, what waste is produced, etc;
- Risk - what risks can occur and with what consequences for the company/organisation ?;
- quantitative measures - quantity of output, etc.

III. Results and Discussion

Company problems/reasons for process optimization

A common practice among business process analysts is to view problems in an individual business process, as well as in a business process system, as process (or business process system) diseases whose symptoms and source need to be identified.

The problems (i.e. diseases) that may lead to the need for optimization of a process, the authors of the article classify into the following groups:

- Excessively high resource costs (symptom) due to a process imperfection (source);
- Excessively high resource costs (symptom) for technical reasons (source);
- Presence of viral business processes (source);

- Presence of a bottleneck (symptom of one problem and source at the same time) in a related process or in the process itself;
- Excessive losses caused by errors (symptom);
- Excessive losses caused by risks (symptom);
- Changes in a process brought about by through process chain reactions (symptom) that result from changes in another process (source);
- miscellaneous.

Cases reviewed:

For the purposes of the study, real cases from the practice of the authors were used. In order to preserve trade secrets, no data that would allow the identification of the companies will be disclosed.

First case - a logistics company operating in Bulgaria. The following company issues were identified:

- excessively high resource costs (symptom) due to a process imperfection (source);
- excessively high resource costs (symptom) for technical reasons (source).

Second case - company-distributor of parts. The following company issues were identified:

- Presence of viral business processes (source);
- Presence of a bottleneck (symptom of one problem and source at the same time) in a related process or in the process itself;

Third case - software developer company. The following company issues were identified:

- excessively high resource costs (symptom) for technical reasons (source).
- Presence of viral business processes (source);
- Changes in a process brought about by through process chain reactions (symptom) that result from changes in another process (source);

Process optimization tools

The tools for the optimization/improvement of a process can be categorized (in terms of a mechanistic approach) conventionally into several categories:

- removing or adding an element from the business process;
- changing the sequence of business process elements;
- replacing a separate element of the business process;
- Technical optimisation - improving/replacing technical equipment to increase productivity;
- staff training;
- other optimization methods - they are numerous, but they are rare and do not occupy a significant share among the tools used for business process optimization.

To solve/eliminate each of the categories of problems considered, there is a corresponding arsenal of tools from those listed above that is used to solve them.

Cases reviewed:

First case - a logistics company operating in Bulgaria.

In this case, the following methods are used:

- changing the sequence of business process elements;
- replacing a separate element of the business process;
- improving/replacing technical equipment to increase productivity;
- staff training.

Second case - company-distributor of parts. The problem of viral business processes is unique because there is no single solution. In this case, the following methods are used:

- removing or adding an element from the business process;
- changing the sequence of business process elements;
- staff training.

Third case - software developer company. In this case, the following methods are used:

- removing or adding an element from the business process;
- changing the sequence of business process elements;
- improving/replacing technical equipment to increase productivity;
- staff training.

Business process description and analysis tools

The toolkit for description and analysis is relatively limited - it can be classified by the presence of certain "apparatus" in a given analytical instrument:

- Textual and tabular-textual apparatuses - such a method of description is, for example, the book-play type description;
- Graphical/symbolic language - such are UML (Unified Modeling Language), ARIS, BPMN (Business Process Model and Notation);
- Complex tabular methods - a representative of this type of methods is "BSC" (Balanced Scorecard)
- Complex mathematical methods - system analysis, etc.) at the time of writing this paper.

Textual apparatuses are a limited set of rules for describing the business processes under consideration. The advantages of this type of apparatus are:

- are simultaneously the easiest both from a technical point of view and to learn;

- least preparation time before use - only a piece of paper and a pen or computer and a text document are needed;
- accessible to individuals without specialized business process skills.

Text-table apparatuses use a more extensive set of rules to describe the business process under consideration in a preprepared tabular apparatus, which is a set of tables in which information about business processes and their features is entered and synthesized.

The advantages of this type of apparatus are:

- a bit more complicated both from a technical point of view and to be learnt;
- require a bit more preparation - pre-prepared tables, usually electronic spreadsheets;
- accessible to individuals without specialized business process skills.

Graphical apparatuses are a set of graphical symbols, each of which address a particular element/aspect of business processes. The graphical apparatuses are diverse enough, which is the reason we had to limit ourselves to Unified Modeling Language (UML), ARIS, Business Process Modeling Notation (BPMN). The reasons the authors choose them are:

- they are the most applied graphical notations by business process analysts;
- UML is the most widely used graphical notation in the IT industry;
- ARIS is the most preferred graphics notation among business users;
- Each of the three notations has its own concept that differs significantly from that of the other two graphic notations.

UML defines a notation and a meta-model. Notation are the graphical symbols used in diagrams, and meta-model are the 14 types of diagrams that define the concept of the language and are specialized in particular aspects. The advantages of UML are:

- It is universal;
- Extremely easy to learn, incl. by staff without specialized knowledge of business process analysis
- It requires no special technical preparation - just a pen and a piece of paper;
- do not require specialized knowledge of business process analysis to read already made flowcharts/business process maps.

BPMN has a rich set of different graphical symbols based on the principle of hieroglyphics - a separate symbol for each individual need that may arise when describing a business process and a hierarchical business process system. Additional elements that carry information, such as colors, etc. are also included.

The main disadvantages of BPMN are:

- BPMN process maps are huge in size;
- the huge amount of highly specialized symbols make BPMN unintuitive and harder to learn;
- the use of BPMN is done only through software because of the huge amount of symbols and the huge size of the process maps

The advantages of BPMN are:

- It is universal;
- Reflects clearly the hierarchy of processes in business process systems
- It describes the processes in great detail.

ARIS is based on the event-process chain methodology The business process is viewed as a single, integral element of the organization's system. The logic of "event/fact - action/process - event/fact" is followed, where actions can be viewed as "the initial event or fact for a given process or action" and "the final event/fact that results from the action/process".

ARIS uses a limited number of symbols (similar to UML), each of which is responsible for a specific element of the process. ARIS addresses each process element in detail, but without going to the extremes of BPMN with highly specialized symbols based on the hieroglyphic principle. It also takes an extremely qualitative and intuitive look at the hierarchy of processes in a business process system.

The main disadvantages of ARIS are two:

- The main one consists in the necessary technical preparation for the use of BPMN - it is done only through software;
- ARIS process maps are large in size (though significantly smaller than BPMN).

The advantages of ARIS are:

- It is universal;
- Reflects clearly the hierarchy of processes in business process systems
- It describes the processes in great detail;
- Intuitive and easy to learn, including by businesses;
- Attractive in appearance.

The most prominent and recognizable representative of complex scorecard methods is the "BSC" (Balanced Scorecard), which was developed in 1996 by Harvard professor Robert Kaplan and the business consultant. The idea of a system of balanced scorecard measures that look at the firm/company in a comprehensive way. It defines 4 whole aspects of the firm - Financial, Organizational, Customer, Learning and Growth Perspective, i.e. financial measures are only one of the aspects.

The BSC method includes:

- several different types of tables that are arranged hierarchically from top to bottom - aspects, indices (KPIs), values;
- for each of the aspects, measures/indices are defined, the value of which is calculated on the

basis of formulas involving values/parameters that are objective and verifiable.

The Balanced Scorecard has no serious drawbacks that need to be commented on, apart from the need for technical training, i.e. spreadsheet software is needed.

However, its advantages are serious:

- the method is objective because it is based on provable quantities and predefined formulas;
- the method is complex and does not rely solely on financial measures;

The most recognizable representative of complex mathematical methods is systems analysis. It is a sophisticated and complex method for mathematically describing systems of business processes and individual processes using formulas from higher mathematics. An entirely mathematically based engineering approach, systems analysis is an extremely objective and versatile method for business process analysis. Its only drawback - it appears to be accessible only to people with specialized knowledge of higher mathematics, i.e. to a relatively limited contingent of users.

A relatively new method is MUSCA, which is simultaneously a complex mathematical and tabular textual method for the description and analysis of business processes. It describes textually and mathematically in tables business processes and business process systems, including hierarchically at all levels - business process element, business process, process group, system-wide level.

Its mathematical apparatus is complex and relatively simple, and examines business processes and business process systems in detail through provable quantities and mathematical formulae.

MUSCA has no serious shortcomings that need to be commented on, except:

- the need for technical training, i.e. spreadsheet software is needed;
- Training in business process analysis is needed to be used effectively but it is not necessary to rely on the results obtained from its use.

Each of these tools has its uses and advantages, but what is their evidential power, (i.e. can they be used and if so how effectively?) to prove optimizations.

Cases reviewed:

First case - a logistics company operating in Bulgaria.In this case, Unified Modeling Language (UML) was used for process description.

Second case - company-distributor of parts. In this case, the Table-Textual method was used for process description.

Third case - software developer company. In this case, Architecture of integrated information systems (ARIS) was used for process description.

Proving optimizations

Both the business process optimization toolkit and the business process description and analysis toolkit were briefly discussed above. At the intersection of the two toolkits lies the question - "How to prove the optimization performed?" Current practice is by comparing business processes „as-is“ (before optimization) and “to-be” (after optimization).

To substantiate our conclusions, this section will discuss the applications of the different options.

When used methods are removing or adding a business process element, changing the sequence of business process elements or replacing a single business process element, two options are most valid:

- the use of graphical methods (ARIS, UML, BPMN) to map the process before and after optimization as illustratively as possible;
- the use of mathematical methods (BSC, system analysis, MUSCA) to analyse the specific characteristics of the process before and after optimisation, and to monitor for the presence of a business process chain reaction;
- the combination of these methods.

The option of using only graphical methods is only advisable in cases where management, for one reason or another, does not want to go into detail and unnecessary numbers (or has very high confidence in business process analytics).

When technical optimization or staff training methods are most valid are methods with mathematical apparatus (BSC, system analysis, MUSCA) to analyse the specific characteristics of the process before and after optimization, as well as to monitor for the presence of a business-process chain reaction.

When the problem is presence of viral business processes or presence of bottleneck, it is best to use the methods to with mathematical apparatus (BSC, system analysis, MUSCA) to analyse the specific characteristics of the process before and after optimization, as well as to monitor for the presence of a business-process chain reaction.

Cases reviewed:

First case - a logistics company operating in Bulgaria.

In this case, Balanced Scorecard was used for process assessment and analysis (was made special type of specialized for the logistics industry Balanced scorecard).

Second case - company-distributor of parts. In this case, the MUSCA was used for process assessment and analysis.

Third case - software developer company. In this case, system analysis was used for process assessment and analysis.

Criteria for proving optimizations

As discussed in the exposition above, the most up-to-date and applicable methods for proving process optimization are those with complex mathematical apparatus. Which leads to the following question - "What criteria for comparison of processes before and after optimization should these methods use to be as correct as possible in proving the optimization performed ?".

The qualities these criteria need to possess are as follows:

- be measurable;
- be provable;
- be objective, i.e. not ambiguous.

Such criteria may be:

- financial measures - price, value, etc;
- time measures - periods of time (day, hour, minute, second, etc.);
- qualitative measures - what mistakes can be made and with what damage to the company/organisation, what waste is produced, etc;
- Risk - what risks can occur and with what consequences for the company/organisation ?;
- quantitative measures - quantity of output, etc.

Financial metrics have some very serious advantages:

- they have the greatest proof for business and management - "Whatever they tell you, it's always about money";
- all the other criteria listed can be reduced to financial measures (e.g.: the process takes 1 hour, the only cost is the worker's wage, there are no possible risks and errors, the hourly wage of the worker is 10 euros, therefore the cost of the process is 10 euros).

Also, financial metrics have some very serious drawbacks - they can be extremely misleading in several cases:

- when they are linked to exchange rates and their values change, which subsequently lead to a change in the value of the process;
- when they are linked to the prices of consumables and their prices change, subsequently leading to a change in the value of the process;
- when they are linked to wages and their values change, which subsequently lead to a change in the value of the process;
- etc. beyond process changes that subsequently result in a change in process value.

In these cases, it is possible that fluctuations in the value of the process under consideration arise that have nothing to do with optimization and can lead to misleading.

Time metrics are some of the most preferred, both by business process analysts and by businesses in general. The reasons for this are:

- they are a very accurate optimization metric when accurately measured;
- the time criterion can be reduced to a financial criterion (e.g. the process took 1 hour before optimization, after optimization it takes half an hour, the only cost is the worker's salary, there are no possible risks and errors, the hourly pay of the worker is 10 euros, therefore the cost of the process is 10 euros before optimization and 5 euros after optimization, i.e. the process is optimized by this measure by 50%).

Also, time measures have one serious drawback - they can hardly be accurate enough for the following reasons:

- It is difficult to prove the exact value of the time spent for an action/process before and after optimization - multiple measurements are needed to be able to claim a real measured average, even then 100% reliability cannot be guaranteed;
- It is difficult to prove the exact value of time spent on an action/process when it is performed by staff - values can vary considerably depending on their temperament, chronotype, stress level, fatigue level, motivation, experience, knowledge and skills etc.
- also the risks and errors affect the execution time of the action/process.

Risks and errors can hardly be a stand-alone measure without being bundled with other measures, but are an extremely strong corrective to financial and time measures. The methods for measuring them, and calculating their impact on financial and time measures, are the subject of separate analyses (risk analysis and error analysis, respectively).

The only more serious disadvantage - it is almost impossible to foresee all possible risks and errors that may affect the implementation of an action/process, because some unforeseen may appear later (after the analyses).

Quantitative measures (e.g. output) are extremely accurate and demonstrable. They can be correlated with other measures:

- with financial measures - unit value;
- with time measures - time to produce a unit of output
- with risks and errors - what risks and errors can impact the production of a unit of output.

Quantitative measures have two drawbacks:

- they are not always applicable;
- they are not a sufficiently accurate stand-alone criterion.

Results from cases reviewed:

First case – Logistics Balanced Scorecard was designed specially for logistics process assessment and analysis. Result: processes was evaluated and analyzed successfully at a user-understandable level.The problem is that it only reflects the final results of the processes and changes in them, but without looking into their details/elements.

Second case - company-distributor of parts. In this case, the MUSCA examined the entire system of business processes in detail at all levels at a user-understandable level.

Third case - software developer company. In this case, system analysis examined the entire system of business processes in detail at all levels, but not on a user-understandable level - results were only available to users with a specialized education in higher mathematics.

IV. Conclusion

The serious problem of proving the performed process optimizations to managers who do not have specialized knowledge of business process analysis and higher mathematics is solved best through the application of the complex mathematical method MUSCA.

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Factors Influencing the Implementation of Digitalization in the Livestock Industry 4.0

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Abstract. **The current era is characterized by a digital revolution, and businesses and industries are undergoing accelerated transformation. Now, terms like "Industry 4.0," "digitalization," and "smart" are frequently employed to describe these adjustments. To thrive in the current era, even Livestock Farms must adapt to this transition and employ digitalization. However, Livestock Farmers may delay associating their industry with digitalization and AI. To aid them in this transition, a scientific study was conducted to determine which livestock processes are useful for digitalization and their industry-wide advantages. In addition, it examines the viability of emerging technologies such as blockchain, IoT, Big Data, and AI in animal husbandry. By understanding each process and its digital solution, the various periods of digitalization can be defined.**

Keywords: Digitalization, Livestock Farms, Industry 4.0, AI, digital transition, efficiency.

I. INTRODUCTION

The food sector today is interfacing with two main changes: the implementation of industry 4.0 technologies and the need for sustainability [1].

Mohd Javaid et al. (2022) recognized and explored important uses of Agriculture 4.0 technologies, suggesting concepts like "smart farming," "several critical technologies," and the "Exploring Agriculture 4.0 Domain" in depth [2]. A variety of artificial intelligence technologies can be incorporated into the process of livestock production and management, such as machine vision, voice recognition, virtual reality, and wearable devices, to transform traditional feed management, increase production efficiency, and reduce labour costs [3]. The convergence of blockchain-based IoT infrastructure is anticipated to provide another foundation for the livestock sector dependent on the devices used, the services provided, and the overall architecture of the integrated system. It would allow integrated systems to function ecologically and sustainably without compromising animal welfare standards, resource management, or livestock output. In the livestock domain, technologies are developed to raise animal production sustainably [4].

Production has evolved into smart farms with numerous sensors and actuators that generate vast amounts of data, requiring processing and reasoning to avoid unfortunate situations. All these requirements and technologies have made the agriculture environments highly dynamic and complex [4]. In this context, Artificial Neural Networks (ANNs) excel at learning from experience [5] and sophisticated self-adaptive scientific software ecosystems - SSECO [6], [7].

Livestock farming is one of the 21st century's less digitalized domains, but it can benefit from adopting digital tools. Improvements in animal welfare and long-term sustainability in livestock farming may be achieved using cutting-edge technology like big data analytics, machine learning, the Internet of Things, sensors, etc [8]. Farmers will be able to take better care of their animals sooner if IoT can assess the probability of sickness based on general information, such as a rise in temperature and a reduction in movement, and then alert them. Doing so increases manufacturing efficiency while manual labour and associated costs are decreased [9]. Livestock based on the Internet of Things can have their health monitored and controlled, and their surroundings and field supervised for the best feeding practices [10].

However, this process is hampered by various factors such as the remoteness of pastures from farms and settlements; difficult access to high mountain pastures; insufficient internet and network connectivity in these areas; the need for continuous monitoring of large hard-to-reach areas; the need to process and analyse dynamically

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incoming information related to the status of animals as well as that of pastures and many others. A topical issue in research is the use of different approaches to monitoring the state of cattle and pasture breeding [11]. On the other hand, not many studies until now have reported an evaluation of the social and environmental impact of solutions that substantially reduce the workforce [12]. Also the requirements of smart livestock husbandry for practice are very high [13].

There have been bottlenecks in developing smart livestock husbandry, and the problems are mostly related to the immaturity of related technologies, imperfection of related equipment, and a lack of product supply chains [14]. Designers of large Agriculture 4.0 research and development programs need to ensure that the focus goes beyond the development of the latest sensor or device. Such programs need to take a more holistic perspective to include consideration of supporting regulatory, business model, advisory, and capability development to enable uptake and ensure the benefits of Agriculture 4.0 are shared [15]. We also are willing to underline the challenges and opportunities of Agriculture 4.0 in cattle husbandry.

II. Methods and Research Design

This research aims to provide Livestock Farmers with a guide to understanding the concepts of digitization, digitalizing, and digital transformation in their context. This research question seeks to determine which digital tools and platforms are most successful for enhancing farm management and decision-making and how they may be integrated with current systems and processes.

This study examined the factors that influence the digitalization of livestock operations. Using a Google Forms-created online survey, data for this study were gathered for this investigation among five countries—Argentina, Bolivia, Brazil, Germany, and Paraguay. The questionnaire comprised ten closed-ended questions designed to collect data on the attitudes and experiences of livestock producers regarding the use of digital technology in livestock operations. The chi-square test was utilized in this study as a statistical method for further data analysis.

Limitation of the study - the study does not examine the attitudes of other actors in the cattle business and is limited to a specific locale, which may impact the generalizability of the results. Finally, self-reporting through a survey also introduces the possibility of response bias, in which participants may provide socially desirable answers or do not accurately reflect their actual experiences or opinions. The study's findings will be analysed while considering these limitations, and future research can address these limits by employing different sampling methodologies, open-ended questions, and increasing geographic coverage.

By evaluating these aspects, the research may provide light on the obstacles and possibilities related to using digital technology in livestock operations. Also, the study may aid in identifying best practices and strategies for increasing the use and utilization of digital technologies in the cattle business.

A. Methods

Using descriptive and inferential statistics, one hundred livestock producers from Argentina, Bolivia, Brazil, Germany, and Paraguay participated in an online questionnaire. The questionnaire was made available in four languages: English, Spanish, Portuguese, and German, to assure accessibility and inclusivity. This multilingual approach was intended to increase the diversity of perspectives captured by the survey by facilitating participation among farmers who spoke these languages. These countries were chosen to provide a variegated representation of livestock producers from various regions, each with distinctive characteristics and contexts about digitization in livestock operations. By including participants from multiple countries, the study sought to capture a variety of perspectives and experiences, thereby enhancing knowledge of the factors that influence the adoption of digital technology in cattle husbandry. This study will use the chi-square test as a statistical method for further data analysis.

B. Research design

This quantitative study employed a survey-based methodology and a quantitative research design. The authors were using the following research design "Fig.1".

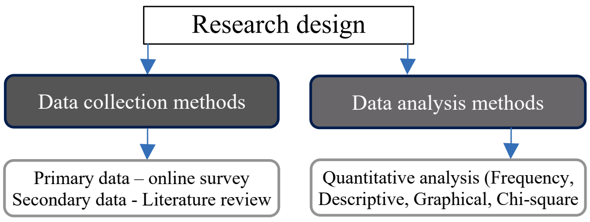

Fig. 1. Research design.

The sampling technique utilized in this investigation was convenience sampling. Given the practical constraints and limited resources, convenience sampling was an appropriate method for efficiently recruiting participants. Livestock producers were solicited through various livestock-related groups and organizations, such as industry associations, agricultural cooperatives, and online forums. This strategy enabled access to a large pool of willing and easily accessible potential participants.

III. Data Analysis

65 percent of the sample's 100 livestock producers reported using digital technology. These participants were categorized as "technology adopters" and provided insightful information regarding their experiences, obstacles, and benefits of digitization in livestock agriculture. The "non-adopters" comprised 35 participants who did not use digital technology. Their perspectives and reasons for not implementing digital technology were crucial to comprehending the obstacles and limitations associated with digitization in the livestock industry.

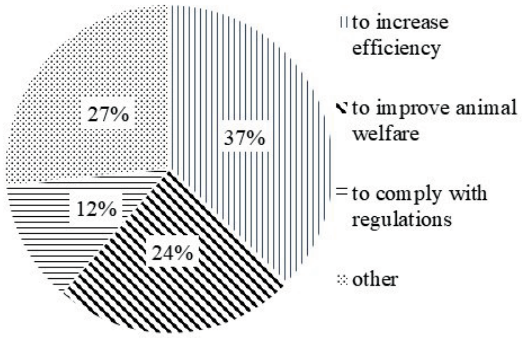

Fig. 2. Q2.What is the primary reason why you have implemented digital technologies in your livestock enterprise?

“Fig.2” indicates that the key motivations for deploying digital technology in livestock operations are to boost efficiency and improve animal welfare. Regulatory compliance was a lesser priority but was nonetheless mentioned by several respondents. It also implies that cattle industry owners may have other, non-question-specific motivations to embrace digital technology. Efficiency and animal welfare are the most often mentioned reasons for deploying digital technology in the cattle business.

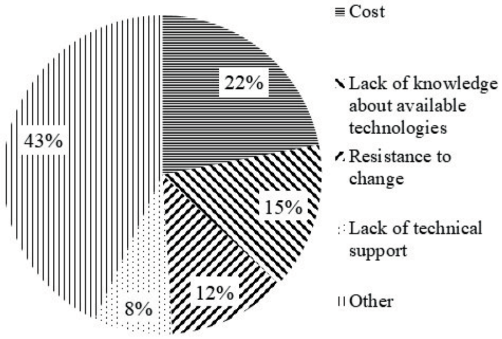

Fig. 3. Q3.What are your biggest challenges when implementing digital technologies in your livestock enterprise?

The survey also inquired about the most significant obstacles to utilizing digital technology in livestock agriculture “Fig. 3”. The cost was the most often cited obstacle (22%), followed by lack of awareness about current technologies (15%), unwillingness to change (12%), and lack of technical assistance (8%). In addition, 43% of respondents also noted other obstacles.

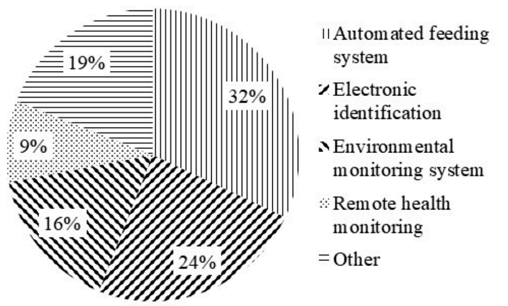

Fig. 4. Q4.Which digital technologies you have implemented in your livestock enterprise?

In addition, respondents were questioned on the digital technology they had deployed in their cattle operation. Automated feeding systems were the most generally installed technology (32%), followed by electronic identification (e.g., ear tags) (24%), environmental monitoring systems (16%), and remote health monitoring (9%). 19% of respondents also cited other technology “Fig. 4”.

The survey also inquired about the implications of digital technology implementation on livestock farming. The most often reported positive benefits were better animal health (28%), greater output (26%), and decreased labour expenses (18%). Some responders (12%) also noted a rise in profitability, while others (16%) highlighted additional impacts “Fig.5”.

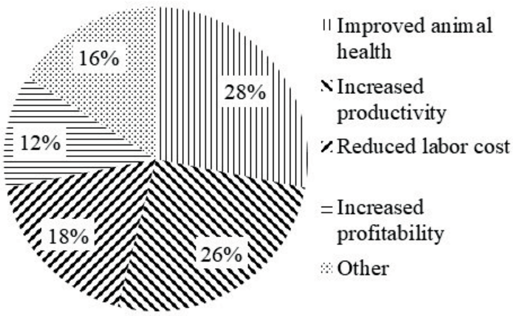

Fig. 5. Q5.How has the implementation of digital technologies affected your livestock enterprise?

According to the data, a substantial proportion of respondents acknowledged the positive effects of digital technology on animal health and production. This indicates that digital solutions have enhanced animal welfare and productivity in livestock operations. In addition, the results validate digital technology's potential as a valuable instrument for optimizing livestock husbandry practices. Diverse perspectives were expressed by respondents regarding the future of digital technology in livestock agriculture. Forty percent of those surveyed believed digital technologies would become even more important. This demonstrates a positive outlook and highlights the perceived value and potential innovations that digital solutions may bring to the livestock industry. In contrast, 28% of respondents indicated that digital technologies would continue to be significant, but not to the same degree as today. This perspective implies a degree of stability and acknowledges that digital technology has already had a significant impact on livestock operations, with the expectation that its significance will likely plateau or reach a saturation point.

Intriguingly, 12% of respondents predicted that the significance of digital technology would diminish in the future. This viewpoint may reflect concerns or doubts regarding digital solutions' long-term viability or efficacy in livestock agriculture. In addition, 20% of respondents were doubtful about the significance of digital technology in the future, highlighting the need for additional research and analysis to completely comprehend the potential trajectory of technological advancements in the livestock industry “Fig.6”.

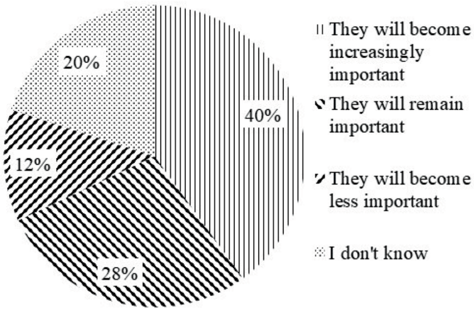

Fig. 6. Q6.How do you see the role of digital technologies evolving in livestock farming in the future?

In order to determine which elements would increase the likelihood that farmers would adopt digital technology, the study queried respondents about the aspects that would affect their choice. The most often reported reason was lower cost (24%), followed by improved technical assistance (18%), a greater understanding of existing technologies (15%), and proof of their usefulness (11%). In addition, 32% of respondents also noted other issues “Fig.7”.

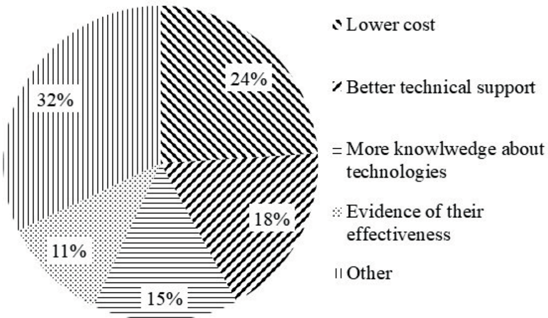

Fig. 7. Q7.What factors would make you more likely to implement digital technologies in your livestock enterprise?

Cost and technical assistance are significant variables in influencing the possibility of integrating digital technology in a livestock operation, according to “Fig. 7”. In order to stimulate deployment, the findings also underscore the need for a better understanding of current technologies and proof of their efficacy. This information sheds light on the elements that may impact the adoption of digital technology in the livestock business. Finally, it implies that cost and technical assistance are important factors and that there is a need for further information and data to support technology adoption decision-making.

Respondents were asked how they maintain their knowledge of digital technology in livestock agriculture (Q8). Trade periodicals (29%) and internet resources (27%) were the most prevalent information sources, followed by conferences or workshops (18%). 26% of respondents additionally indicated other sources of information.

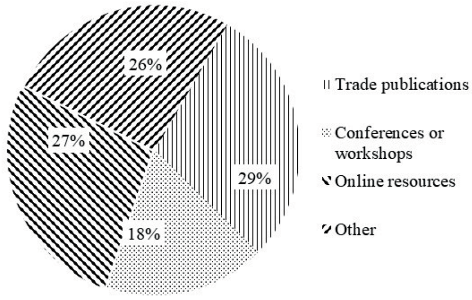

Fig. 8. Q8. How do you stay informed about digital technologies in livestock farming?

The survey also gathered information about farmers' familiarity with digital technology in livestock operations. For example, 36% of respondents reported being very comfortable, 28% reported being comfortable, 14% were indifferent, 12% reported being unpleasant, and 10% reported being uncomfortable. It indicates that most respondents are comfortable using digital technology in livestock operations, with just a tiny fraction indicating discomfort (Q9).

There may be some ambiguity or lack of expertise with digital technology in the business, judging by the relatively high percentage of respondents who reported feeling indifferent. This information sheds light on how familiar cattle firm owners are with digital technology. Most respondents seem comfortable utilizing these technologies, although there may be some confusion or lack of expertise that must be addressed to promote wider uptake and use. “Fig.9” reveals that the majority of the respondents feel that the future of cattle farming will become more technology-driven, reflecting a belief in the expanding use of digital technologies within the business. Twenty-two respondents feel that the future of livestock farming will stay mostly unchanged, indicating a more conservative or cautious view of technology's role in the business. In addition, 18 respondents feel that animal farming will become more environmentally and socially sustainable in the future, focusing on environmental and social sustainability in the business. For example, 15 respondents specified "other" opinions on the future of cattle farming, but we have no information regarding their opinions.

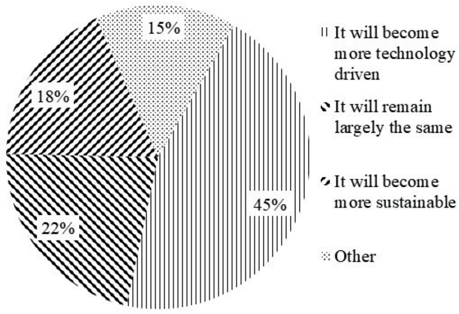

Fig. 9. Q10.How do you see the future of livestock farming in general?

In conclusion, most respondents have incorporated digital technology in their livestock operations to enhance efficiency and animal welfare. The technologies most often utilized were automated feeding systems and electronic identification. Cost and a lack of information on accessible technology were the primary obstacles to deploying digital technologies. Respondents reported several beneficial outcomes, including enhanced animal health and enhanced output. Others were dubious as to whether digital technology would become more significant. Cheaper costs and improved technical assistance would influence the choice of farmers to use digital technology. The most prevalent knowledge sources on digital technology were trade periodicals and internet sites. In general, farmers' familiarity with digital technology varied.

A. Chi-Square test

According to the study findings, the key motivations for employing digital technology in livestock farming were to boost efficiency (28%) and improve animal welfare (18%). Cost (22%) and lack of information about available technology (15%) were the greatest barriers to using digital technologies. Automated feeding systems (32%) and electronic identification (such as ear tags) (24%) were the most typically installed digital technology.

TABLE 1 SURVEY SUMMARY

Survey Question	Category 1	Category 2	Category 3	Category 4	Category 5
1	65	35	-	-	-
2	28	18	9	20	-
3	22	15	12	8	43
4	32	24	16	9	19
5	28	26	18	12	16
6	40	28	12	20	-
7	24	18	15	11	32
8	29	18	27	26	-
9	36	28	14	12	10
10	45	22	18	15	-

28% of respondents noted that digital technologies improve animal health, 26% of respondents said that they increase output and 18% of respondents noted that digital technologies reduce labour costs - "Table 1".

Respondents that have adopted digital technology in their cattle operation claim various advantages, as shown in "Table 2". Most respondents claimed that the deployment of digital technology had enhanced animal health (32%) and production (25%). These findings are consistent with the principal motivations for deploying digital technology: to enhance efficiency and animal welfare. The data also shows that respondents who have used digital technology have reported lower labour expenses (23%) and higher profitability (11%). Although they are not the most often cited advantages, they are important and show that digital technology may improve the financial viability of cattle operations. 9% of respondents who have used digital technology claimed "Other" advantages, which is interesting. However, it is impossible to establish these benefits without more information, but it shows that integrating digital technology in cattle farming may provide various benefits beyond those identified in the survey.

TABLE 2 CHI-SQUARE TABLE

	Animal Health	Increased productiv.	Reduced labour costs	Increased profitabil.	Other	Total
Implement. digital technologies	21 (32%)	16 (25%)	15 (23%)	7 (11%)	6 (9%)	65 100%
Not implement.	7 (20%)	10 (29%)	3 (9%)	5 (14%)	10 (29%)	35 100%
Total	28	26	18	12	16	100

The chi-square test assessed the association between digital technology installation and the stated efficiency levels, animal welfare, and profitability. There was a substantial relationship between the use of digital technology and reported levels of efficiency ($\chi 2$ = 9.58 (9,48 minimum for p=0,05), p= 0.05, degree of freedom = 4).

Therefore, it can be concluded that there is a significant relationship between the implementation of digital technologies and the reported effects on livestock enterprises, supporting the hypothesis that livestock farmers who have implemented digital technologies report higher levels of efficiency, animal welfare, and profitability than those who have not.

The data also reveals that respondents who have yet to incorporate digital technology did not report any improvements in animal health, productivity, labour expenses, or profitability. This shows that digital technology may be crucial for reaching these gains and that cattle producers who have to adopt them may be losing out on possible advantages. However, it is crucial to highlight that the reasons for not integrating digital technology may be diverse and complicated, and one chart can only capture some of them.

TABLE 3 CHI-SQUARE FOR GREATEST OBSTACLES

	Cost	Lack of knowledge	Resistance to change	Lack of technical support	Other	Total
Implemented digital technologies	20 31%	14 22%	8 12%	7 11%	16 25%	65 **100%**
Not implemented	2 3%	1 2%	4 6%	1 2%	27 42%	35 **100%**
Total	22	15	12	8	43	100

A chi-square test may also be used to evaluate the hypothesis that livestock producers' greatest obstacles for digital technology integration are different for those who already adopted digital technologies and for others who are planning to implement it in the future. To do this, a contingency table will be produced, including the frequencies of the two variables: "Largest obstacles livestock producers face when applying digital technology" and expectation of none-implementers "Not implemented".

"Table 3" shows that 20 out of 65 respondents who implemented reported cost as their biggest challenge, while 14 out of 65 reported lack of knowledge as their biggest challenge.

"Table 3" displays the worst problems respondents encountered while using digital technology in their cattle operation, divided by implementation category.

As seen in the "Table 3", 43% of respondents cited "Other" as their major issue. This shows that cattle producers may encounter additional obstacles when deploying digital technology beyond those stated in the study. The particular category of "Cost" was the most often reported problem, with 22% of respondents citing it as their greatest obstacle. This is not unexpected, given that integrating new technology may be costly, and smaller livestock operations may have limited funds for such expenditures. This is further confirmed by the fact that when respondents were asked to name their greatest issue, implementation costs and a lack of knowledge and technical help/support were the most often reported obstacles. 15% of respondents reported a "Lack of understanding about accessible technology" as their key issue, making it the second most often stated obstacle. This emphasizes the significance of education and training for livestock producers to stay up with the continuously expanding technological environment. 12 % and 8% of respondents named "Resistance to Change" and "Lack of Technical Support" reasons for their organizations' failure to adapt to new technologies. These obstacles imply that more assistance and resources may be required to assist livestock producers in understanding and using digital technology. Cost and lack of understanding are two major obstacles cattle producers face when utilizing digital technology. This underscores the necessity of providing livestock farmers with inexpensive and accessible technological solutions and education and training programs to keep them aware of the advantages of various technologies.

For this study ("Table 3"), the chi-square statistic is computed as follows: $\chi 2 = 28.17$. A chi-square distribution table with 4 degrees of freedom and a probability p of 0.001 can be consulted to find the critical value of chi-square, which is 18.47. Given that the calculated chi-square statistic (28.17) is higher than the critical value (18.47).

IV. Conclusions

The findings of this study provide compelling evidence that incorporating digital technology in livestock husbandry positively affects productivity, animal welfare, and profitability. According to the study's findings, automated feeding systems and electronic identification, such as ear tags, were the most widely used digital technologies on the surveyed livestock ranches. Compared to those who did not adopt digital technology, livestock producers who did so reported greater efficiency, enhanced animal care, and increased profitability. This finding suggests that integrating digital technologies can substantially improve livestock farming's key performance indicators. Statistical analyses, such as the chi-square test, were administered to examine the correlation between digital technology adoption and outcomes. The chi-square test results supported the hypothesis that there is a significant correlation between the use of digital technology and levels of productivity, animal care, and profitability. This finding supports the notion that adopting digital technology is associated with favourable outcomes in livestock husbandry which is not new. In addition, it was conducted to evaluate the possibility that livestock producers' greatest obstacles are emerging when integrating digital technology, so real situation experience with technology adoption is arises during implementation. Respondents cited cost as the primary impediment to adoption, and there was a significant correlation between the obstacles cited and the implementation cost and lack of technical support. This finding emphasizes the significance of resolving cost-related obstacles and providing sufficient support to facilitate the adoption of digital technology in the livestock industry. The research findings indicate that livestock producers can improve their operations by adopting digital technologies through technology transfer. The results indicate that adopting digital technology is associated with productivity, animal welfare, and profitability gains. Nonetheless, it is essential to recognize and resolve the obstacles that impede the widespread adoption of digital technology, specifically the implementation cost and the availability of expert assistance. To encourage the widespread adoption of digital technology in livestock husbandry, efforts should focus on reducing implementation costs, providing financial incentives, and enhancing access to knowledge and technical support. By addressing these obstacles, the livestock industry can maximize the benefits of digital technology, resulting in more efficient and sustainable agricultural practices.

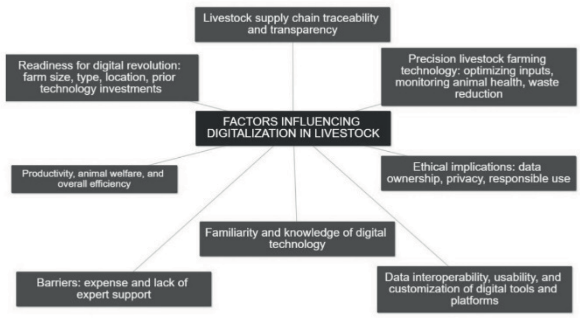

Fig. 10. Factors influencing digitalization in livestock

Also, the findings of this study highlight the need for sustained research and collaboration among stakeholders to surmount obstacles and facilitate the widespread adoption of digital technology in livestock husbandry. As a result, the industry can realize its maximum potential and attain enhanced productivity, animal welfare, and financial outcomes. We present a small model based on the survey which could help to visualize our findings "Fig.10".

The livestock farming industry's readiness for the digital revolution varies depending on factors such as the farm's size, type, location, and investment in technology. While some farms have made significant investments in digital technology and are reaping its benefits, others may require thorough preparation to catch up. The cost is a major barrier to adopting digital technology, which affects small-scale producers with limited resources the most. Furthermore, data ownership, privacy, and ethical use of digital technology in livestock farming need addressing. Despite these challenges, more livestock farms recognize digital technology's potential benefits and are preparing for the digital revolution. Precision livestock farming technology has received substantial investment in recent years, and it aims to use data and analytics to optimize inputs like feed and water, monitor animal health, and reduce waste. There is also a growing awareness of traceability and transparency in the livestock supply chain, which can be facilitated by digital technologies such as blockchain. Three of the most widely accepted forms of digital technology amongst farmers were automated feeding systems, electronic identification, and environmental monitoring. These tools may improve feeding precision, animal tracking, and herd management while reducing the need for human labour. The survey found that many farmers have seen an uptick in animal health and output after adopting digital technologies for use in livestock care. As a result, there may be more room for cost savings and optimization of digital technology since just a minority of respondents indicated increased profitability. Additionally, the research highlights the ethical considerations associated with using digital technology in livestock husbandry especially in respect to new standards of Industry 5.0.

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Phytochemical Study of Comfrey (*Symphylus officinale* L.) Root Extracts

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Abstract. The purpose of the present study was to determinate the biologically active substance in 95% ethanol and subsequent water extracts from Bulgarian comfrey (Symphylus officinale L.) roots and to evaluate their antioxidant potential. The antioxidant activity was evaluated by several reliable methods such as DPPH-, ABTS-, FRAP-, CUPRAC-, ORAC and HORAC-assays, as well as the total phenolic content. In addition, the total organic, fructose and sugar content were determined by spectrophotomeric and HPLC-RID methods. The level of fructans in ethanol extracts was 25.2 g/100g dry weight, as nystose and 1-kestose were only 0.1g/100g dry weight, and 0.3g/100g dry weight, respectively. The absence of fructooligosacharides in water extracts after the ethanol pretreatment was established. Inulin content was evaluated to be 25.2 g/100 g dry weight. In addition, total uronic content was established to be 2.0 g/100 g dw as its level dominated in water extracts – 1.7 g/100 g dw, respectively. The metabolite profile of roots revealed their potential application as radical scavengers due to the presence of polyphenols. Phenolic acids (neochlorogenic, p-coumaric and gallic acids) and flavonoids (quecetin, myrecitin and naringin) were the dominant polyphenols in comfrey extracts. Therefore, the root extracts of Symphylus officinale L. could be assumed as a rich source of biologically active substance, in particular dietary fiber with potential prebiotic effect, due to the presence of polysaccharide inulin and fructooligosacharides.

Keywords: antioxidant, comfrey, inulin, roots

I. Introduction

Comfrey (*Symphytum officinale* L.) is a medicinal plant that belongs to Boraginaceae family. It is perennial herb widely spread across Europe, but it can also be found in some parts of Asia and South America and North America [1], [2]. It can grow as weed in moist, low meadows, or along ponds and river banks where it may reach to a height of 20±150 cm, (usually 0.3-1.2 m) with long, hairy leaves with narrowing ends, and yellowish to red-violet flowers [3] –[5]. In Bulgaria is distributed from 0 to 1500 [5] and can be also found in forest throughout the country. Comfrey root is large up to 30 cm (typically 8-12 cm), branching, and black on the outside with a creamy white interior containing slimy mucilage [3, 5]. It is collected during spring (March), at the end of summer (August) and during autumn (November) [3]. In traditional medicine, comfrey roots are used from century for the treatment of wounds, joint disorders, and musculoskeletal injuries [1]-[3]. In Bulgaria tea has an expectorant, diuretic and anti-inflammatory effect. It is recommended as an aid in the treatment of duodenal and stomach ulcers, gastric bleeding, cough, inflammation of the upper respiratory tract, periodontitis, sprains, pleurisy, contusions, bone inflammations, difficult-to-heal wounds, conditions after amputation and purulent processes.

Compounds that were identified in comfrey root as active in the treatment of sprains, arthritis, fractures, and hematoma include allantoin, rosmarinic acid, and other hydroxycinnamic acid derivatives, as well as muco-polysaccharides, A, B and C vitamins, triterpenoid saponins, tannins, calcium, potassium, and selenium [1]. Other compounds found in comfrey root include abundant mucilage polysaccharides (about 29%) composed of fructose and glucose units [2], starch, inulin, resins, aspargine (1-3%), choline [3], phenolic acids such as rosmarinic acid (up to 0.2%), chlorogenic acid (0.012%)

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as well as caffeic acid (0.004%) and α-hydroxy caffeic acid, glycopeptides and amino acids and triterpene saponins in the form of monodesmosidic and bidesmosidic glycosides based on the aglycones hederagenin (e.g. symphytoxide A), oleanolic and lithospermic acids [2].

Comfrey roots or their extracts is scarcely investigated as a source of bioactive compounds with potentially beneficial biological effects. The information about the presence of carbohydrate content as a potential source of dietary fibers is limited. No detailed information about carbohydrate composition, especially sugars, fructan and uronic acid content in the comfrey roots growth in Bulgaria were found.

Therefore, the objective of the present study was to evaluate carbohydrate composition, the total phenolic content and antioxidant potential of comfrey roots extracts and to enrich the knowledge about this medicinal plant.

II. Materials and methods

All reagents and solvents were of analytical grade scale. Dried roots of comfrey (*Radix Symphyti*) were produced by Bilki.bg (Bulgaria). The plant material was finely ground and passed through a 0.5 mm sieve. The moisture content analyzed by AOAC 945.32 [6] was established to be 8.8%. The ground roots were kept in a screwed capped container at room temperature for further analysis.

A. Preparation of root extracts

The extraction was performed by previously described method by Olennikov et al. [7] with slight modification [8]. Comfrey roots (0.8 g) were extracted with 20 mL boiling 95% ethanol under a reflux for duration 60 min. The extraction process was repeated twice with 20 mL and 10 mL solvents, respectively. The residue was dried and then it was extracted successively three times with distilled water - 20 mL, 20 mL and 10 mL under reflux for 60 min . The obtained extracts were analysed in terms of antioxidant activity, total phenolic and carbohydrate content. Each sample was extracted in duplicate.

B. Carbohydrate analysis

The content of low molecules and high molecules fractions of fructans were presented as fructose equivalent was determined by spectrophotometric -method at 480 nm. The content of mono-, di-, oligosaccharides and inulin was analysed by HPLC-RID method [9].The uronic acid content in the extracts was assayed by m-hydroxybiphenyl method [10]. Galacturonic acid (5-100 μg/mL) was used for the calibration curve.

C. Determination of total saponin content

Total saponin content was determined colorimetrically by vanillin-sulfuric acid method [11]. The analysis was performed as described by Pasaribu et al. [12]. Diosgenin (200-500 μg/mL) was used as a standard and the analysis was performed in duplicate.

D. Determination of total phenolic content (TPC)

A modified Kujala et al. [13] method with Folin – Ciocalteu`s reagent was used for the determination of the total polyphenolic content (TPC). Gallic acid was employed as a calibration standard and the results were expressed as mg gallic acid equivalents (mg GAE) per gram of plant dry weight (dw).

E. Determination of antioxidant activity (AOA)

DPPH radical scavenging assay

Antioxidant activity was established toward the stable form of the synthetic product DPPH (2,2-diphenyl-1-picrylhydrazil radical) by the method of Brand-Williams et al. [14] with slight modifications. A freshly prepared 4.10-4 M solution of DPPH (in methanol) was mixed with the sample in a ratio of 2:0.5. The unit of Trolox equivalent antioxidant capacity (TEAC) defined the concentration of Trolox having equivalent antioxidant activity expressed as μM TE/g dw.

ABTS radical scavenging assay

The radicals scavenging activity of the studied extracts against radical cation (ABTS•+) was estimated according to a previously reported procedure with some modifications [15]. The antioxidant value was defined as the concentration of Trolox having equivalent antioxidant activity expressed as μM TE per gram dry weight (μM TE/g dw).

Ferric-reducing antioxidant power (FRAP) assay

The FRAP assay was carried out according to [16] BenzieFerric-reducing antioxidant power (FRAP) assay. Tthe absorbance of the reaction mixture was recorded at 593 nm. The results were expressed as μM TE/g dw.

CUPRAC assay

The CUPRAC assay was carried out according to the procedure [17]. Absorbance against a reagent blank was measured at 450 nm after 30 min. Trolox was used as standard and total antioxidant capacity of herbal extracts was measured as μM TE/g dw.

Oxygen Radical Absorbance Capacity (ORAC)

This assay was measured according to the method [18]. The method measures the antioxidant scavenging activity against peroxyl radical induced by 2,2'-azobis (2-amidinopropane) dihydrochloride (AAPH) at 37°C. Fluorescein (FL) was used as the fluorescent probe. The final ORAC values were calculated using a regression equation between the Trolox concentration and the net area under the curve. Results were expressed as micromole Trolox equivalents per litre.

Hydroxyl Radical Averting Capacity (HORAC) assay

HORAC measures the metal-chelating activity of antioxidants under the conditions of Fenton-like reactions employing a Co(II) complex and hence the protecting ability against formation of hydroxyl radical [18]. HORAC values were calculated using a regression equation between gallic acid concentration and the net area under the curve. One HORAC unit was assigned to the net protection area provided by 1μmol/l gallic acid and the activity of the sample is expressed as μmol gallic acid equivalents (GAE) per litre. ORAC and HORAC analyses were carried out using a FLUOstar OPTIMA plate reader (BMG LABTECH, Offenburg, Germany), excitation wavelength of 485 nm and emission wavelength of 520 nm were used.

F. HPLC analysis of phenolic compounds

High Performance Liquid Chromatography (HPLC) analyses of phenolic components was performed on an Agilent 1220 HPLC system (Agilent Technology, USA), equipped with a binary pump and UV–vis detector. A wavelength of k = 280 nm was used. Separation of phenolic compounds was performed using an Agilent TC-C18 column (5 µm, 4.6×250 mm) at 25 C. Mobile phases constitute of 0.5% acetic acid (A) and 100% acetonitrile (B) at a flow rate of 0.8 ml/min. A gradient was used with 14% B, between 6 min and linearly increased to 25% B and then 50% B at 40 min. The standard compounds gallic acid, 3,4-dihydroxy benzoic acid, chlorogenic acid, caffeic acid, p-coumaric acid, ferulic acid, ellagic acid, catechin, epicatechin, quecetin, quercetin 3-β-glucoside, myricetin, kaemferol and naringin were used [19].

G. Statistical analysis.

All analyses were performed in triplicate (n=3). The data were presented as mean values ± standard deviation (SD). Statistical analysis was performed using using ANOVA, with the Tukey's range. A difference was considered statistically significant, when $p < 0.05$.

III. Results and discussion

A. Carbohydrate content

The carbohydrate content in 95% ethanol and subsequently aqueous extract of comfrey root was presented (Table 1). Individual sugars and inulin content were detected on HPLC-RID (Fig.1). It was found that in 95% ethanol fraction dominated sugars and fructooligosacchrides (Fig.1a), while in subsequent water fraction only high content of inulin and minor conent of sucrose and fructose were found (Fig.1b). It was the first detailed about presence of inulin and fructooligosaccharides in comfrey roots. Inulin content reached 24.9 g/100 g dry weight. The total fructan content reached 32.5 g/100 g dw. Nystose and 1-kestose were detected only in 95% fraction in small amount (0.1 and 0.3 g/100 g dw, respectively). Sucrose and fructose were found in both fraction, while glucose were found only in 95% ethanol comfrey root extract. In addition small ammount uronic acid content found mainly in water fraction -1.7 g/100 g dw. This study demonstrate inulin as the main reserved carbohydrate in comfrey roots. In previous study Van Laere and Van Den Ende [20] only mentioned *Symphytum officinale* L. as source of inulin. Vasfilova and Vorob'eva [21] reported for presence of glucofructan in roots of *Symphytum officinale* with low molecular weight in the beginning of vegetation period and for high molecular in the end of vegetation in the roots-45-47%. In their study low molecular fructans wer detected to be 11%, while high molecular 29.5%. In our case the result s for high molecular fructan fraction 27.6 g/100 g was close to their findings, while low molecular fraction (in ethanol extract) was more than 3 times lower. This coud be expailned with harvest and climate conditions. Moreover, the total fructan content was higher in subsequent water extract, where their content reached to 27 g/100g, which was in accordance with previous reported values of 15-30% [22].

TABLE I. CARBOHYDRATES CONTENT IN EXTRACTS OF COMFREY ROOTS, G/100 G DW (MEAN ± SD, N=3)

Carbohydrates	Comfrey Extracts		
	95% Ethanol	***Water***	***Total***
Uronic acid content	0.3±0.1b	1.7±0.2a	2.0±0.2a
Total fructans	4.9±0.5b	27.6±1.0a	32.5±0.5a
Inulin	0.3± 0.1b	24.9±2.2a	25.2± 2.2a
Nystose	0.1± 0.0a	n.d.	0.1± 0.0a
1-Kestose	0.3± 0.1a	n.d.	0.3± 0.1a
Sucrose	1.8± 0.5a,b	1.5± 0.5a	3.3± 0.5a
Glucose	2.3± 0.5a	n.d.	2.3± 0.5a
Fructose	5.1±0.2a	1.0± 0.4b	6.1± 0.3a

Values are mean ± standard deviation of three separate experiments. Different letters within each column indicate significant differences betweentreatments according to Tukey's test at $p < 0.05$; n.d. – not detected, ns - not significant

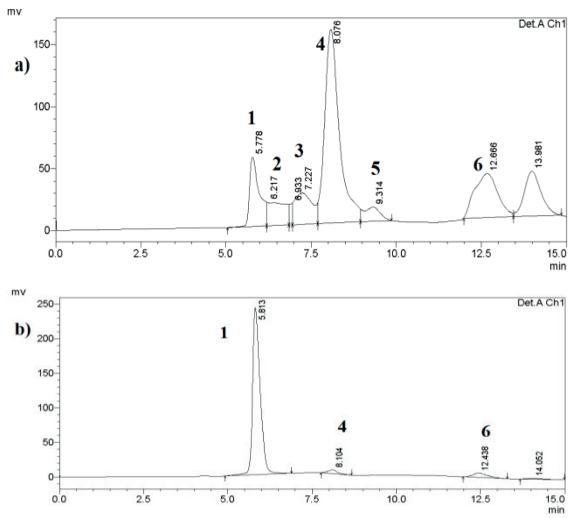

Fig. 1. HPLC chromatograms of the extracts obtained from comfrey (*Symphylus officinale* L.) root, a) 95 % etahnol and b) water extracts, where 1. inulin; 2. nystose, 3. 1-kestose 4. sucrose, 5. glucose and 6. fructose.

B. Total saponins, total phenolic content and antioxidant activities

Total saponins, total phenolic content (TPC) and antioxidant activities (µm Trolox equivalent/g dw) in root extracts of comfrey (*Symphytum officinale*) were summarized in Table 2. It was found that saponins dominated in water fraction – 17.4 µg/g dw, while its content in 95% ethanol fraction was more than half times lower. Total phenolic content in both fraction was approximately equal – 4 mg GAE/g dw.Six method based on different mecanisms were used to evte antioxidant potential of the comfrey root extracts (Table 2). Water extracts demonstrated higher results for antioxidant potential by methods based on electron transfere – FRAP and CUPRAC methods. The methods based on hydrogen transfere or mixed mechanism (DPPH and ABTS) demonstrated higher antioxidant potential of the subsequient water extract. The highest antioxidant potential was observed by ORAC method for 95% ethanol extract -355.5 µmol TE/g dw. The highest antioxidant potential for the subsequent water extract was found by CUPRAC method – 129.0 µmol TE/g dw. The lowest values was observed by HORAC method for the water extract and DPPH assay for 95% ethanol fraction. In general the subsequent water extracts from comfrey roots exhibited stronger radical scavenging activity, methal reducing ability in comparison with ethanol extract. Ethanol fraction showed the highest potential for oxygen radical absorbance capacity.

Our results for antioxidant ponential DPPH and ABTS methods were closed to these reported by Neagu, et al. [23]. Anlas et al. [24] reported higher than our results for the total phenolic contents of ethanolic and aqueous extracts of *S. officinale* - 116.93 mg GAE/g and 99.49 mg GAE/g, respectively and they also explained that the greater amount of phenolic compounds leads to more potent radical scavenging effect.

TABLE 2. TOTAL SAPONINS,TOTAL PHENOLIC CONTENT (TPC) AND ANTIOXIDANT ACTIVITIES IN ROOT EXTRACTS OF COMFREY (*SYMPHYTUM OFFICINALE* L.)

Analysis	Extracts	
	95% ethanol	***Water***
Total saponins, µg/g dw	7.2 ± 1.6b	17.4 ± 3.9a
TPC, mg GAE/g dw	4.4 ± 0.1a	3.9 ± 0.1ns
FRAP, µmol TE/g dw	62.2 ± 0.6b	99.9 ± 1.0a
CUPRAC, µmol TE	122.0 ± 2.4a	129.0 ± 1.5ns
ABTS, µmol TE/g dw	71.4 ± 0.6b	84.6 ± 0.6a
DPPH, µmol TE/g dw	60.9 ± 0.6b	79.5 ± 0.4a
ORAC, µmol TE/g dw	355.5 ± 7.1a	78.1 ± 0.6b
HORAC, µmol GAE/g dw	67.6 ± 1.0a	41.8 ± 3.3b

Values are mean ± standard deviation of three separate experiments. Different letters within each column indicate significant differences between treatments according to Tukey's test at $p < 0.05$; ns - not significant

Therefore, water extracts contained much more active biocompounds than an ethanol extract that were relatively strong scavengers of free radicals, as it was shown in Table 3.

C. Phenolic acids and flavonoids

The contents of phenolic acids (mg/100 g) and flavonoids extracts in comfrey root were summerized in Table 3. Ten phenolic acids and eight flavonoids were detected mainly in the subsequent water fraction, whereas 95% ethanol contained only eight phenolic acids and six flavonoids. In general neochlorogenic acid dominated in 95% ethanol comfrey extract (26.0 mg/100 g), while in the subsequent water extract *p*-coumaric acid was in the highest amount (38.3 mg/100 g). Chlorogenic and vanilic acids, as well as flavonoids quercetin 3-β-glucoside and epicatechin were not detected in 95% ethanol, while these four phenolic compounds presented in the subsequent water extract of comfrey roots. Quercetin and catechin dominated in 95% ethanol comfey root extract, while there content in the subsequent water extract was two times lower. Myricetin, kaemferol, naringin and naringenin dominated in water fraction.

In agreement with some previous reports [24]-[27] the phenolic acid and flavonoids in comfrey roots including chlorogenic acid, cafeic acid, ferulic acid, coumaric acid, ellagic acid, epicatechin, myricetin, quercetin, kaempferol were detected. Besides these bioactive compounds, the presence of neochlorogenic acid acid was also detected. In the water extract of comfrey root, the content of ellagic acid is 1.5 g/100 g dw.

TABLE 3. CONTENTS OF PHENOLIC ACIDS (MG/100 G) AND FLAVONOIDS IN *S. OFFICINALE* EXTRACTS

Phenolic compounds		Comfrey Extracts		
		95% Ethanol	***Water***	***Total***
Phenolic acids	Chlorogenic acid	n.d.	0.7±0.4a	0.7±0.4a
	Neochlorogenic acid	26.0±3.1 a	6.8±1.4b	32.8±2.5a
	Vanilic acid	n.d.	1.5±0.2a	1.5±0.2a
	Cafeic acid	2.5±0.3b	3.6±0.5a	6.0±0.3b
	p-Coumaric acid	18.2±2.1 b	38.3±5.8 a	56.5±3.7a
	Ferulic acid	0.4±0.1b	1.5±0.2a	1.9±0.3a
	Ellagic acid	0.5±0.1b	1.5±0.2a	2.0±0.3a
	Cinnamic acid	4.0±1.0b	5.7±0.5a	9.7±0.6a
	3,4-dihydroxy benzoic acid	1.2±0.1b	2.5±0.1a	3.7±0.1a
	Gallic acid	7.3±3.0a	4.5±0.4b	11.8±2.6a, b
Flavonoids	Quecetin	73.4±1.4 a	42.7±0.2 b	116.0±0.8 a,b
	Quercetin 3-β-glucoside	n.d.	19.8±0.1 a	19.8±0.1a
	Myricetin	21.5±1.1 a,b	39.0±0.1 a,b	60.5±5.3a, b
	Kaemferol	8.6±1.1b	10.4±3.0 a	18.9±0.9a
	Naringin	21.4±3.0 b	30.0±3.1 a	51.3±3.1a, b
	Naringenin	6.6±1.1b	8.2±2.6a	14.8±3.9a
	Catechin	26.8±0.7 a	13.3±3.1 b	40.1±1.5a
	Epicatechin	n.d.	4.2±0.3a	4.0±0.3a

Values are mean ± standard deviation of three separate experiments. Different letters within each column indicate significant differences between treatments according to Tukey's test at $p < 0.05$; n.d. – not detected.

The high content of ellagic acid in comfrey root can be responsible for its biological and antioxidant activity. In general, the roots of confrey contained in the highest amount p-coumaric, neochlorogenic and gallic acids and quecetin, myricetin, catechin and naringin. The comfrey root extracts showed higher content of flavonoids in comparision the phenolic acids.

IV. CONCLUSIONS

The current research revealed the main carbohydrate content in 95% ethanol and subsequent water extracts from comfrey roots. Therefore, the obtained results demonstrated that the plant material is potential source of fructans, especially the prebiotic inulin. Due to the antioxidant potentials, the polyphenol and flavonoids content, both extracts of comfrey root could be considered as a source of bioactive components with potential application in pharmacy and cosmetics.

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Thermodynamic Empirism for Describing Atmospheric Pollutants

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Abstract. **Humanity is currently subject to excessive pollution of the Biosphere and the atmosphere that comes from anthropogenic activity. The global warming is the most acute problem that has a negative impact on the state of the biosphere as a whole. The long empirical analysis on the state of the atmosphere makes it possible to develop quantitative expressions that give a dependence of the atmospheric temperature variation depending on the accumulation of anthropogenic polluting gases with greenhouse effect. One of the gases with a greenhouse effect is carbon dioxide, which has a major contribution to global warming. The method suggested in the paper focuses on the empirical analysis with the application of the thermodynamic laws describing the state of the atmosphere and gives the results of the validation within certain limits of the variation of the atmospheric temperature as the dependence of the accumulated concentration of the polluting gases with greenhouse effect. The relational connection between variations of concentrations and of the temperature is found by the equation of state of the ideal gas, assuming that the atmosphere can be described by this equation and the combination with the adiabatic thermodynamical equation leads to the expression which contains those variations. Annually, the monitoring stations record variations of concentrations and temperatures. The last 40 years the average temperature of the atmosphere is elevated up to 1^{0}C. The respective calculations by the application of thermodynamic expressions lead to the same order of 1 ^{0}C. It is explained by the application of thermodynamic physico-chemical laws that the rate of photosynthesis is comparatively low compared to the rate of additional excessive accumulation of carbon dioxide that comes from anthropogenic activity. The importance of the suggested method allows us to conclude about the validation of the method with the direct application of analytical expressions of the state of the atmosphere. Statistical analysis is very widely applied in general for data analysis, but it would be recommendable physico-chemical laws to be applied directly with a wider retrospective and the most important thing is that it allows the control of both the real recorded values and to be compared with those calculated by the thermodynamic method. The practical importance of this expression is based on the fact that the anthropogenic accumulation of carbon dioxide is followed by the accumulation of heat excess in the atmosphere, and in its turn to the increasing of the average global temperature of the atmosphere. One thing it is important to mention that the effect which takes place must be explained and this explanation is given by physical-chemical methods based on thermodynamic phenomena for the atmosphere.**

Keywords: adiabatical constant, biosphere, greenhouse gases, pollutants.

I. INTRODUCTION

The acute problem of contemporary humanity is the solving of the acute state of the atmospheric pollution. High levels of anthropogenic pollutant gases lead to high values of atmospheric temperatures. Global warming and all effects in the atmosphere could be described by classical physical laws. The presence of the pollutants in both gas and aerosols has a negative effect on the evolution of the biosphere and further on the state of the atmosphere. Modern anthropogenic activity is characterized by the increasing of the concentrations of green house pollutant gases. One of the major green house components is carbon dioxide which has a ratio of

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75% in comparison to other pollutants and therefore the effect could be considered only on the base of carbon dioxide and the other components are of minor importance and almost have no influence. The empirical suggested method in this study is based on deeply analysis that applies in general the model of ideal gas. One of the empirical analyzes based on prolonged observations is the application of the laws of thermodynamics that describes the state of physical models of gases with the application of macroscopic parameters of the state of gases. The application of this suggested model of ideal gas for atmospheric air allows checking the calculated values with the real ones such as the effective molar mass of the air and the adiabatic constant. The validity of the suggested method is confirmed by re-calculation of the important parameters such as the molar mass and the adiabatic constant and which are coincident with the real ones.

The priority of the direct application of the known physical models to the atmospheric phenomena consists in the checking of the respective values which allow us to validate the suggested method for the direct application of the description of the state of the atmosphere.

II. Material and Methods

The composition of the dry air is complex and it contains 78,08 % nitrogen, 20,95% oxygen, 0,93% argon, 0,04% carbon dioxide and small amounts of other gases. [1] The state of the atmosphere can be described by macroscopic thermodynamic parameters such as temperature, pressure, volume. To some extent it can be considered that the state of the atmosphere can be described by the equation of ideal gas. [2], [3] For dry air is valid the adiabatic equation of the ideal gas [3]:

$$P(h)\cdot[T(h)]^{-\frac{\gamma}{\gamma-1}} = const \tag{1}$$

where γ is the adiabatic constant of the air (γ ≈ 7/5).

The pressure of the atmosphere is maximal at sea level and decreases with altitude [4]. This is because the atmosphere is very nearly in hydrostatic equilibrium so that the pressure is equal to the weight of air above a given point. The change in pressure with altitude can be expressed by the density as [5]:

$$\frac{dP}{dh} = -\rho\cdot g = -\frac{M\cdot P\cdot g}{R\cdot T} \tag{2}$$

where g is the gravitational acceleration; ρ is the density of air; h is the altitude; P is the pressure; R is the gas constant; T is the thermodynamic temperature; M is the molar mass. This change in pressure "2" originates from the barometric formula of troposphere [6]:

$$P(h) = P_o\cdot e^{-\frac{M\cdot g\cdot h}{R.T(h)}} \tag{3}$$

The substitution of "3" into "1" gives the following result:

$$P_o\cdot e^{-\frac{M\cdot g\cdot h}{R.T}}\cdot[T(h)]^{-\frac{\gamma}{\gamma-1}} = const \tag{4}$$

If the temperature depends on height, it would be better to obtain such expression of the value of temperature that depends on height by the application of "4":

$$[T(h)]^{-\frac{\gamma}{\gamma-1}} = \frac{const}{P_o}\cdot e^{\frac{Mgh}{RT(h)}} \tag{5}$$

$$[T(h)]^{\frac{\gamma}{\gamma-1}} = \frac{P_o}{const\cdot e^{\frac{Mgh}{RT(h)}}} \tag{6}$$

The process of logarithmization of "6" by natural logarithm gives the following result:

$$\frac{\gamma}{\gamma-1}\cdot\ln[T(h)] = \ln P_o - \ln(const) - \frac{Mgh}{RT(h)} \tag{7}$$

$$T(h)\cdot\ln[T(h)] = \frac{T(h)\cdot(\gamma-1)}{\gamma}\cdot(\ln P_o - \ln(const)) - \frac{Mg\cdot(\gamma-1)h}{R\cdot\gamma} \tag{8}$$

$$\ln[T(h)] = \frac{(\gamma-1)}{\gamma}\cdot(\ln P_o - \ln(const)) - \frac{Mg\cdot(\gamma-1)\cdot h}{R\cdot\gamma\cdot T(h)} \tag{9}$$

The graphic of the dependence $\ln[T(h)] = f\left(\frac{h}{T}\right)$ is represented on the "Fig.1". For the case when *h=0*, then *h/T=0* and "9" is written as:

$$\ln[T(0)] = \frac{(\gamma-1)}{\gamma}\cdot(\ln P_o - \ln(const)) \tag{10}$$

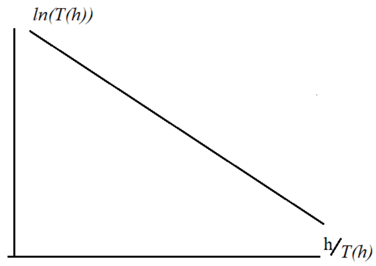

Fig.1 The dependence of $\ln[T(h)] = f\left(\frac{h}{T}\right)$

Such a way, it would be possible to recalculate the temperature at the null level *T(0)* and also the molar mass *M* by the slope of this graphic. The "10" could be applied for the small altitudes. Then:

$$\ln T = \frac{(\gamma-1)}{\gamma}\cdot(\ln P - \ln(const)) \tag{11}$$

In order to describe the increasing of the temperature due to of the greenhouse effect, it would be better to differentiate "11":

$$\frac{\Delta T}{T} = \left(\frac{\gamma-1}{\gamma}\right)\cdot\frac{\Delta P}{P} \tag{12}$$

The respective expression of the equation of the state of ideal gas: $P.V = \nu.R.T$; $P = C.R.T$; C is the molar concentration of the mixture of gas of the atmospheric air. The respective variation of pressure is:

$$\Delta P = R\cdot(\Delta T.C + \Delta C.T) \tag{13}$$

The substitution of "13" into "12" gives:

$$\frac{\Delta T}{T}=\left(\frac{\gamma-1}{\gamma}\right)\cdot\frac{R(\Delta T\cdot C+\Delta C\cdot T)}{P}=\left(\frac{\gamma-1}{\gamma}\right)\cdot\frac{\Delta T.C+\Delta C.T}{C.T}$$

$$\Delta T=(\gamma-1)\cdot\frac{\Delta C\cdot T}{C} \qquad (14)$$

The "14" shows quantitatively the increasing of the temperature of the atmosphere with the increasing of the molar concentration of greenhouse gases by the value ΔC.
The density of air at sea level is about 1,2 kg/m^3. The molar concentration of the atmospheric air is calculated as:

$$C=\frac{\rho}{M}=\frac{1{,}2(kg/m^3)}{0{,}029(kg/mol)}=41{,}37(mol/m^3)=0{,}04137(mol/l)$$

The average mass of the atmosphere is about 5 quadrillion (5,13×10^{15}) tones or 1/1,200,000 the mass of Earth [6]. The mass of the atmosphere that is 5,13.10^{18} kg allows to calculate the full volume of the atmosphere - $V_{atm.}$:

$$V_{atm}=\frac{m_{atm}}{M\cdot C}=\frac{5{,}13.10^{18}(kg)}{0{,}029(kg/mol)\cdot 0{,}04137(mol/l)}=$$
$$=4275{,}96.10^{18}(l)=4275{,}96.10^{15}(m^3)=4{,}28.10^{18}(m^3)$$

Then, easily we can calculate the height of troposphere - *h*:

$$h=\frac{V_{atm}}{S_{Earth}}=\frac{4{,}28.10^{18}}{4.3{,}14.(6371.10^3)^2}=$$
$$8{,}39.10^{-9}.10^{18}.10^{-6}=8{,}39.10^3(m)\cong 8{,}5(km)$$

The calculated value of molar concentration of air will be used to appreciate the change of the temperature as the result of increasing of greenhouse gases by the value ΔC. In general the average temperature of the atmospheric air is increasing almost linearly the last 50 years. [8] The graph is represented on the "Fig. 2".

The opinions about the reason of the increasing of the temperatures are various, but the most observation is on the focusing of the increasing of the concentration of carbon dioxide that is one major greenhouse gas and the carbon dioxide has 75% effect from all others green house gases [9]. The registration of the concentrations of carbon dioxide [9] is represented by the diagram on the "Fig. 3".

The changes of the values of temperatures and concentrations which are described by the "Fig. 2" and "Fig. 3" could be included into the "15" and the final result is the representation of the graphic $\Delta T=f(\Delta C)$ that in general is a linear dependence on the "Fig. 4".

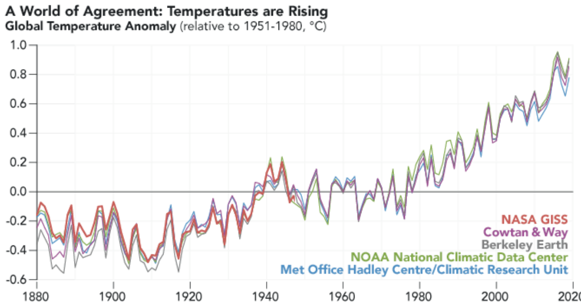

Fig. 2. The history of global change of the temperature [13]

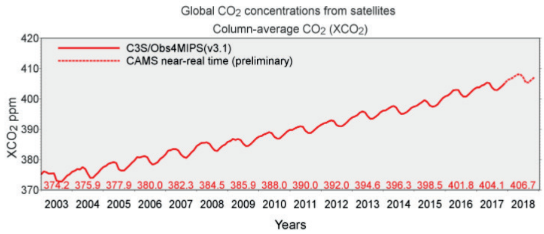

Fig. 3 The dynamics of the change of the concentration of CO_2 [14]

Such a way, the slope of the dependence of $\Delta T=f(\Delta C)$ allows to re-calculate the value of adiabatic constant γ. The numerical value of γ confirms the validity of the suggested quantitative expression of the temperature variation.

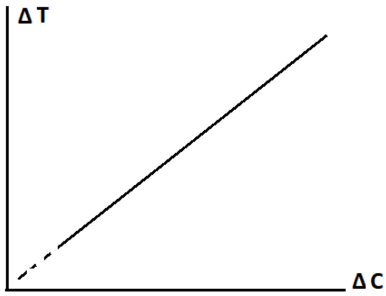

Fig. 4 The form of the dependence of $\Delta T=f(\Delta C)$

III. RESULTS AND DISCUSSION

The values of temperatures and of the pressure are changeable with the altitude. The following Table 1 shows the results [7] of the measurements of these values.

Table 1 The important parameters of the atmosphere as the function of altitude [7]

Height h; m	Temperature t; (^{0}C)	Pressure; P; (10^4 ; Pa)	Density; ρ; kg/m3
0	15	10.13	1.225
1000	8.5	8.988	1.112
2000	2	7.95	1.007
3000	-4.49	7.012	0.9093
4000	-10.98	6.166	0.8194
5000	-17.47	5.405	0.7364
6000	-23.96	4.722	0.6601
7000	-30.45	4.111	0.59
8000	-36.94	3.565	0.5258

9000	-43.42	3.08	0.4671
10000	-49.9	2.65	0.4235

In order to validate "1" by the application of real values of the source [11], the following graphic $\ln[P(h)] = f(\ln[T(h)]$ is represented on the "Fig. 5". The procedure of natural logarithm of "1" is:

$$\ln\left[P(h)\cdot[T(h)]^{-\frac{\gamma}{\gamma-1}}\right] = \ln[const] \quad ;$$

$$\ln[P(h)] = \frac{\gamma}{\gamma-1}\cdot\ln[T(h)] + \ln[const]$$

The slope of this linear dependence allows finding the adiabatic constant γ of air.

The correlation calculation of the linear dependence shows that $\frac{\gamma}{\gamma-1} = 5{,}2521 \Rightarrow \gamma = \frac{5{,}2521}{4{,}2521} \approx 1{,}23$

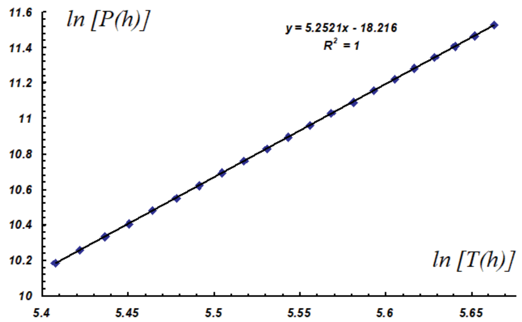

Fig.5 The functional dependence $\ln[P(h)] = f(\ln[T(h)]$

The obtained result of the adiabatic constant of the atmospheric air is of the same order of the results of the papers [10], [11]. In order to check the barometric formula written by "3" for the troposphere air it would be better to represent this expression by the logarithm of this expression. The linear dependence will validate the expression of the barometric formula: $\ln[P(h)] = \ln[P_o] - \frac{M.g}{R.T}.h\cdot$

The graphic of $\ln[P(h)] = f(h)$ is represented on the "Fig. 6".

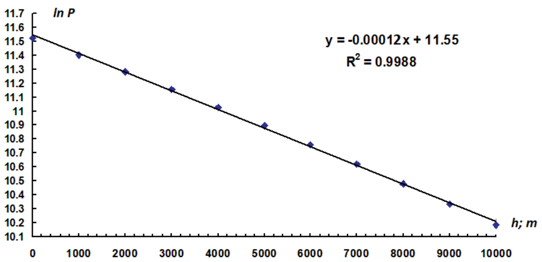

Fig. 6 The graphic of the dependence $\ln[P(h)] = f(h)$

The respective slope is: $\frac{M.g}{R.T} = 0{,}00012$

Then, the calculation of the molar mass of troposphere air is:

$$M = \frac{0{,}00012\cdot 8{,}31\cdot 288}{9{,}83} = 0{,}02921(kg/mol)$$

The calculated value of the molar mass of the troposphere air is of the same order like in [7].

$$\ln P_0 = 11{,}55 \;\Rightarrow\; P_0 = 103777(Pa) \approx 1{,}04\cdot 10^5(Pa)$$

The obtained value of the pressure of the troposphere air at the null level is of the same order of the value from the Table 1 [7]. The graphic of $\ln[T(h)] = f(h/T)$ is represented on the "Fig.7".

The correlational calculations show that:

$$\ln[T(0)] = \frac{(\gamma-1)}{\gamma}\cdot(\ln P_o - \ln(const)) = 5{,}6581$$

$$\ln[T(0)] = 5{,}6581; \quad T(0) = e^{5{,}6581} = 286{,}6(K);$$

The respective slope of the graphic is:

$$-\frac{Mg\cdot(\gamma-1)}{R\cdot\gamma} = -0{,}0057$$

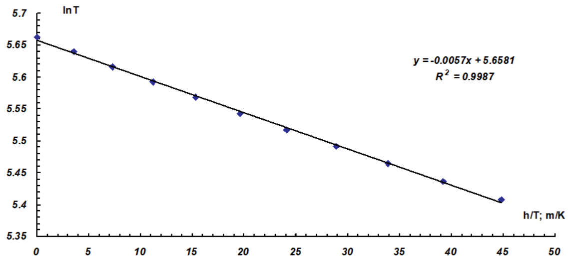

Fig. 7 The graphic of the dependence $\ln[T(h)] = f(h/T)$

Then, easily we can recalculate the molar mass of the troposphere air:

$$M = \frac{0{,}0057.R.\gamma}{g.(\gamma-1)} = \frac{0{,}0057\cdot 8{,}31\cdot 1{,}2}{9{,}83\cdot 0{,}2} = 0{,}0289(kg/mol)$$

The suggested method of the quantitative description of the variation of the atmospheric temperature ΔT with the increasing of the concentration of greenhouse gas CO_2 can be checked by the following Table 2 that is based on the results of the sources [9]. [12],

Table 2. The variation of temperature as the function of the increasing of the concentration of CO_2

N°	Year	ΔT; °C	C (CO_2); ppm	ΔC (CO_2); ppm	ΔC (CO_2); mg/m³
0	1980	0	338	0	0
1	1981	0,03	340	2	3,61
2	1982	0,05	341	3	5,41
3	1983	0,07	343	5	9,01
4	1984	0,09	345	7	12,63
5	1985	0,11	347	9	16,23
6	1986	0,13	348	10	18,03
7	1987	0,15	349	11	19,84
8	1988	0,18	350	12	21,64
9	1989	0,19	350.5	12,5	22,54
10	1990	0,22	351	13	23,44

11	1991	0,26	352	14	25,25
12	1992	0,32	353	15	27,05
13	1993	0,34	355	17	30,66
14	1994	0,36	357	19	34,26
15	1995	0,37	359	21	37,87
16	1996	0,39	360	22	39,67
17	1997	0,41	361	23	41,48
18	1998	0,42	362	24	43,28
19	1999	0,43	363	25	45,08
20	2000	0,45	365	27	48,69
21	2001	0,46	369	31	55,90
22	2002	0,47	373	35	63,12
23	2003	0,5	375	37	66,72
24	2004	0,54	376	38	68,52
25	2005	0,58	378	40	72,13
26	2006	0,59	379	41	73,93
27	2007	0,6	380	42	75,74
28	2008	0,61	381	43	77,54
29	2009	0,62	382	44	79,34
30	2010	0,63	383	45	81,15
31	2011	0,65	385	47	84,75
32	2012	0,68	393	55	99,18
33	2013	0,7	398	60	108,20
34	2014	0,74	401	63	113,61
35	2015	0,78	402	64	115,41
36	2016	0,8	406	68	122,63
37	2017	0,81	410	72	129,84
38	2018	0,82	412	74	133,44
39	2019	0,83	413	75	135,25
40	2020	0,85	415	77	138,85

The usually concentrations that are represented on the Table 2 as *ppm* values can be transformed into *mg/m³* by the application of the method given in [11]. So, the respective variation of *ppm* is:

$$\Delta C_{ppm} = \frac{24{,}4(l/mole)\cdot\Delta C[mg/m^3]}{M[g/mole]}$$

The variation of the concentrations of carbon dioxide $\Delta C[mg/m^3]$ in the atmosphere:

$$\Delta C[mg/m^3] = \frac{M[g/mole]\cdot\Delta C_{ppm}}{24{,}4}$$

The respective dependence of the variation of the temperature *ΔT* as the function of *ΔC* is represented on the "Fig. 8". The respective slope of the graphic $\Delta T = f(\Delta C)$ is:

$$(\gamma-1)\cdot\frac{T}{C} = 0{,}006\left(\frac{{}^0C}{\frac{mg}{m^3}}\right) \equiv \frac{6\left(\frac{{}^0C}{g/m^3}\right)}{44(g/mol)} = 0{,}136\left(\frac{{}^0C}{\frac{mol}{m^3}}\right) = 136\left(\frac{{}^0C}{mol/l}\right)$$

The atmospheric air has the concentration:

$$C = 0{,}04137(mol/l) = 41{,}37(mol/m^3) \equiv 29(g/mol).41{,}37(mol/m^3) =$$
$$= 1199{,}73(g/m^3) = 1{,}199(kg/m^3) = 1{,}199(g/l)$$

The value of adiabatic constant γ is calculated from the expression below:

$$(\gamma-1) = \frac{0.136.C}{T} = \frac{0{,}136.41{,}37}{288} \approx 0{,}02;$$
$$\gamma = 1{,}02$$

Such a way, the "16" could be written simply by proportional linear coefficient *a* as:

$\Delta T_e = a.\Delta C$; (e)-empirical

$$a = (\gamma-1)\cdot\frac{T}{C} = 0{,}02\cdot\frac{288(K)}{0{,}04137(mol/m^3)} = 139\left(\frac{{}^0C}{mol/l}\right)$$

$$\Delta T_e = 0{,}006\cdot\Delta C; \quad [\Delta C]=mg/m^3;$$

or: $\Delta T_e = 136\cdot\Delta C$; $[\Delta C]=mol/l$;

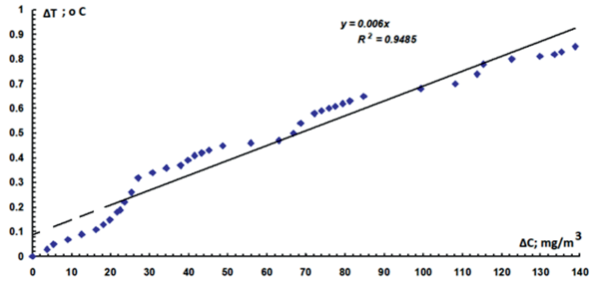

Fig. 8 The graphic of the dependence ΔT=f(ΔC)

The calculated values of ΔT_e by the empirical expression can be checked with the real variations of ΔT by the representation of the following graphic. On the "Fig. 9".

In order to have the important parameter like interval of time that can be included into the empirical expression, is necessary to represent the following dependence of the variation of concentration of carbon dioxide as the function of time and is represented on the "Fig. 10". The rate of increasing of CO_2 (speed of increasing of the concentration each year) is about *3,383((mg/m³)/year)*

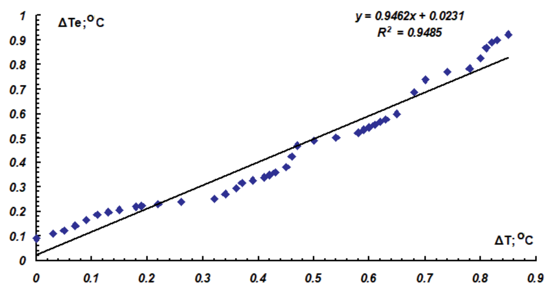

Fig. 9 The validity of empirical calculations of temperature variations

Such a way the empirical formula of the temperature variation can be written as:

$$\begin{cases} \Delta T_e(t) = 0{,}006 \cdot \Delta C(t) \\ \Delta C(t) = 3{,}3833 \cdot t; \\ [t] = years; \quad [\Delta C] = mg/m^3 \end{cases};$$

If each last years the concentration of carbon dioxide is increasing with the value of 3,383 *mg/m³,* then it would give the possibility to calculate the excess mass Δm_{CO2} during one year.

$$\Delta m_{CO_2} = \Delta C.V_{atm} = 3{,}383((mg/m^3)/year).4{,}27596.10^{18}(m^3) =$$
$$= 14{,}47.10^{18}(mg/year) = 14{,}47.10^{12}(kg/year) =$$
$$14{,}47.10^{9}(tons/year) = 14{,}47(Gtons/year)$$

The study [10] has such result about carbon dioxide: "Between 2009-18, however, the growth rate has been 2.3 *ppm per year*". Transposing *ppm* into mg/m^3, then:

$$\Delta C[mg/m^3] = \frac{M[g/mole] \cdot \Delta C_{ppm}}{24{,}4} = \frac{44.2{,}3}{24{,}4} = 4{,}14((mg/m^3)/year)$$

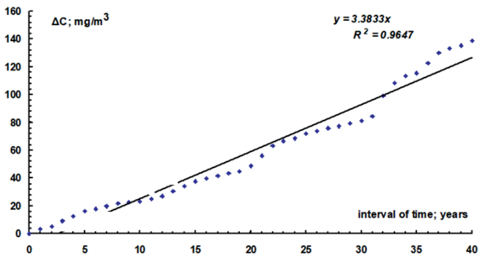

Fig. 10 The variation of the concentration of carbon dioxide as the function of time (starting reference year is 1980)

The result in this recent paper is 3,383 *(mg/m³)/year*. Then, the average value is 3,76 *(mg/m³)/year*. The respective admissible error of exactity is:

$$\varepsilon = \frac{|4{,}14 - 3{,}76|}{3{,}76} \cdot 100\% = \frac{38}{3{,}76} \approx 10\%$$

The comparison of the calculated value of the mass of carbon dioxide is of the same order within the limits of errors with the real one.

CONCLUSIONS

The suggested method of the recent study which is based on thermodynamic empirism gives us the possibility to obtain values that are calculated and that are of the same order with the real ones. The empirical expression allows us to predict the trend of the values of the future states of the atmosphere that are described by the variations of the pollutant concentrations. The validation of the suggested method is performed on the basis of known values such as the adiabatic constant of the atmospheric air. The importance of this empirical expression is based on the fact that if ΔC<0, i.e. the concentration of polluting gases decreases over time, then we could obtain a situation of the decreasing of the atmospheric temperature. Empirical intuition could give this result with the reality. The important problem of the World recently is to look for ways to solve the reduction of the emission of pollutants with such result that we could expect of the reduction of the atmospheric temperature and the attenuation of the global warming. This moment could be reached by the increasing of the forest areas with the aim of the acceleration of global photosynthesis.

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Distribution of Iron in Dust Near Streets: Case Study Jelgava City

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Abstract. **The world's urban population is projected to grow to 68% by 2050. According to statistics, 68% of the country's population already lives in Latvia in 2022. Much of the air pollution research in the city is focused on researching highways and streets of very intensive traffic. Small and medium-sized cities with their infrastructure remain unexplored. The population of cities of different sizes is growing every year, so it is important to understand the prevalence of pollution along the streets in small and medium-sized cities, as this pollution has a direct impact on the health of the city population. Snow and stored dust are good matrices to assess the extent of air pollution and metals in urban areas. It should also be stressed that the number of cars in cities is increasing, while the age of the car fleet remains increasing. The aim of the study is to find out how iron is distributed at different distances from the street section in Jelgava city research facilities. Snow samples were collected at 3 monitoring points with a distance of 1 m, 50 m, and 100 m to each side of the street. Snow samples were melted, acidified, filtered, and measured with ICP-OES spectrometer. For data analysis, descriptive statistics, the Kruskal-Wallis test, and the Steel-Dwass-Critchlow-Fligner procedure were used. In all monitoring points, iron pollution in air at 1 m is statistically significantly higher than at 50 m and 100 m (p-value 0.018; and 0.011), which directly indicates the impact of cars on air quality close to the streets. At the monitoring point located on Riga Street, the iron concentration at 1 m distance is 10.9 mg/l and at 100 m 0.33 mg/l. The data obtained can be used when designing streets and conducting urban planning.**

Keywords: Snow, iron, pollution, ICP-OES spectrometer, Kruskal-Wallis test.

I. INTRODUCTION

Iron is an essential component of (PM) particles and its presence in PM is associated with various impacts on human health and the environment. Studies have shown that iron oxide particles are the dominant component of PM in various anthropogenic environments. In research were investigated that iron oxide particles were present in most PM particle samples from the subway, suggesting iron distribution in urban environments [1]. PM particles containing iron were found to cause oxidative stress in human lung cells, highlighting the potential health effects of iron-rich PM particles [2].

The fact that PM particles, especially iron particles and their concentrations in the air, can serve as a source of air pollution for markers in the air, is significant. Research in Europe demonstrated that the percentage of iron particles in PM can indicate traffic-related pollution, highlighting iron's role in identifying sources of pollution [3]. Another research paper stressed that iron is a highly ubiquitous element in the environment and is the dominant transition metal in PM particles, its role in uranium air pollution has so far been underestimated [4].

So far, the biological effects of iron-containing PM particles have been studied in several research papers. In researchers linked iron concentrations in PM particles to respiratory compositions, indicating a link between iron levels and inflammatory effects on pulmonary epithelial cells [5]. In addition, group of scientists described how iron can affect inflammation caused by PM particles,

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suggesting that iron content in PM particles affects lung toxicity [6].

Iron plays a critical role in PM particles in the air, which affects human health and environmental quality. Understanding iron sources in the urban environment is essential to assess and mitigate the impact of particle pollution on public health and ecosystems.

The aim of the study is to find out how iron is distributed at different distances from the street section in Jelgava city research facilities.

II. MATERIALS AND METHODS

Jelgava is a city in the middle of Latvia, Zemgale Plain. The city is a transport corridor between various cities of Latvia and the national capital Riga. Jelgava has a total area of 60.3 km^2, a further description of the city can be found in [7].

Five days after snow fell, snow samples were collected at each point at a distance of 1 metre, 50 metres and 100 metres from the road perpendicular to both sides of the carriageway. Snow samples were collected at three areas of intense traffic flow in the city of Jelgava (see Figure 1). First point describes transit flow of cargo transport and residential traffic. Second location describe residential transport. Third location describe transit between Jelgava City and capital city Riga. A total of 108 snow samples were collected and analysed.

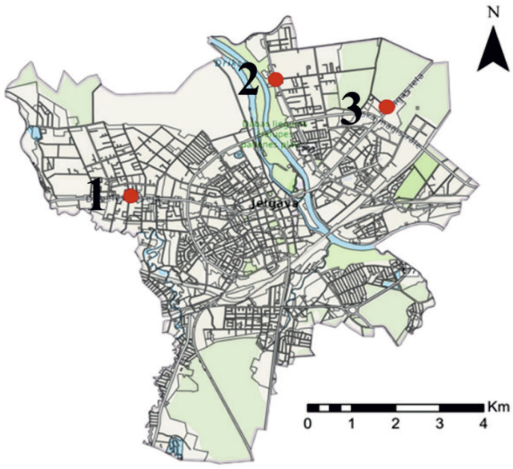

Fig. 1. The location of snow sampling areas in Jelgava City.

Snow samples were melted and analysed in two ways after collection. The first group of samples was filtered to remove PM particles and then acidified. On the other hand, the second group of samples was first acidified with all PM particles in solution and then filtered [8]. The filtered solution was analysed in an ICP-IOP analyser [9].

For data analysis, descriptive statistics, the Mann-Whitney test [10], the Kruskal-Wallis test [11], and the Steel-Dwass-Critchlow-Fligner procedure were used to identify differences between groups [12].

III. RESULTS AND DISCUSSIONS

The analysis of the results was divided into several steps, where samples with PM particles and samples without PM particles were compared in the first step. The next step assessed the effect of distance on the iron content of samples with PM particles and samples without PM particles. In conclusion, the impact of the particular transport corridor on the iron content of the solution was analysed.

Snow samples with PM particles showed much higher iron concentrations than those in the samples without PM particles. The mean iron concentration in samples without PM particles was 0.013 mg/l, while in samples with PM particles 2.26 mg/l. The descriptive statistics of the two groups of samples is presented in Table 1. A Mann-Whitney test was used to find out whether differences between two sample sets were statistically significant. This showed that there are significant differences *(p-value <0.0001)* in iron concentrations between samples with PM particles and samples without PM particles.

TABLE 1 THE IRON CONCENTRATIONS IN SNOW BY SAMPLE PREPARATION

Variable	With PM particles (mg/l)	Without PM particles (mg/l)
Minimum	0.171	0.006
Maximum	10.963	0.035
Mean	2.260	0.013
Std. deviation	3.517	0.011

In the next step were analysed a sample set with PM particles. According to a distance from the road, three groups of snow samples are formed, characterizing iron concentrations in snow samples at different distances -1m; 50m; 100m from the road. The maximum value for all samples is 10.963 mg l^{-1} and the minimum value is 0.171 mg l^{-1}(see Table 2).

TABLE 2 THE IRON CONCENTRATIONS IN SNOW SAMPLES WITH PM PARTICLES BY DISTANCE FROM ROAD

Statistics	mg l^{-1} | 1m	mg l^{-1} | 50m	mg l^{-1} | 100m
Minimum	1.211	0.183	0.171
Maximum	10.963	1.221	0.962
Range	9.752	1.038	0.792
1st Quartile	2.360	0.321	0.207
Median	5.984	0.332	0.236
3rd Quartile	9.258	0.465	0.311
Mean	5.940	0.482	0.356

The concentration of iron in snow is highly variable (see Fig.1.).

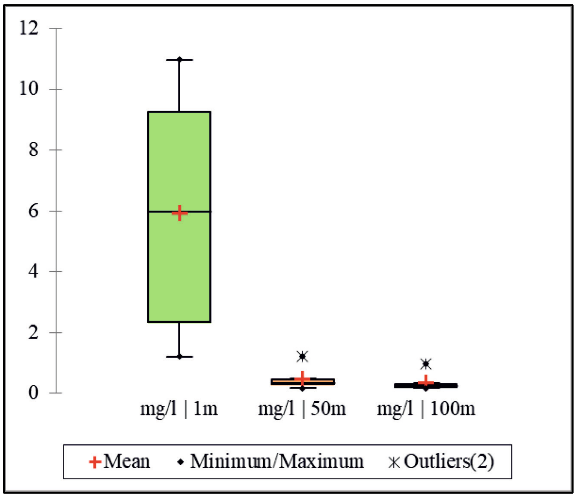

Fig. 2. The variation of iron concentrations by distance from road.

All values of descriptive statistics decrease as the distance from the street increases. The sharpest reduction is between 1 m distance and 50 m distance, while the reduction between 50 m distance and 100 m distance is but less pronounced.

Kruskal-Wallis test show significant differences between groups *(p-value<0.003)*. To understand the differences in between groups the Steel-Dwass-Critchlow-Fligner procedure were used to identify significance of differences between the groups of distances from street. The test results show significant differences between 1m and 50m groups *(p-value<0.018)* and 1m and 100m group *(p-value<0.011)*. There is no significant differences between group 50m and 100m (see Table 3).

TABLE 3 THE P-VALUES AND GROUPS OF IRON CONCENTRATIONS IN SNOW BY DISTANCE FROM ROAD

Distance	1m	50m	100m	Groups	
1m	1	**0.018**	**0.011**	A	
50m	**0.018**	1	0.501	A	
100m	**0.011**	0.501	1		B

The iron concentration in the snow, which characterises transport pollution, is variable not only by distance from the road but also by location in the urban system. Therefore, snow samples were analysed after localisation according to numbering (see Figure 1). All locations are with similar iron concentration variations (see Figure 3). All locations are shown to have extreme iron concentrations found in snow samples collected 1 m from the road (see Table 4).

The first location describes a transit flow that combines the light transport flow through the city of Jelgava and the cargo transport flow that uses this street because the Jelgava bypass flow connects. This location has the highest median value of 1.087 mg l^{-1} due to the presence of cargo transport transit.

The second location describes the average transport flow, which is mainly related to the daily resident transport flows.

The third location is linked to intensive daily traffic linking Jelgava to the capital Riga and the nearest settlements. At the sampling point, the road passes through the forest area, which is reflected in the lower median value of 0.325 mg l^{-1}, as in other locations.

TABLE 4 THE IRON CONCENTRATIONS IN SNOW SAMPLES WITH PM PARTICLES BY LOCATION IN JELGAVA CITY

Statistics	mg l^{-1} | 1	mg l^{-1} | 2	mg l^{-1} | 3
Minimum	0.202	0.171	0.183
Maximum	9.621	8.168	10.963
Range	9.419	7.997	10.780
1st Quartile	0.498	0.270	0.245
Median	1.087	0.414	0.325
3rd Quartile	1.218	1.536	2.933
Mean	2.260	1.883	2.636

Kruskal-Wallis test do not show significant differences between locations groups *(p-value 0.755)*.

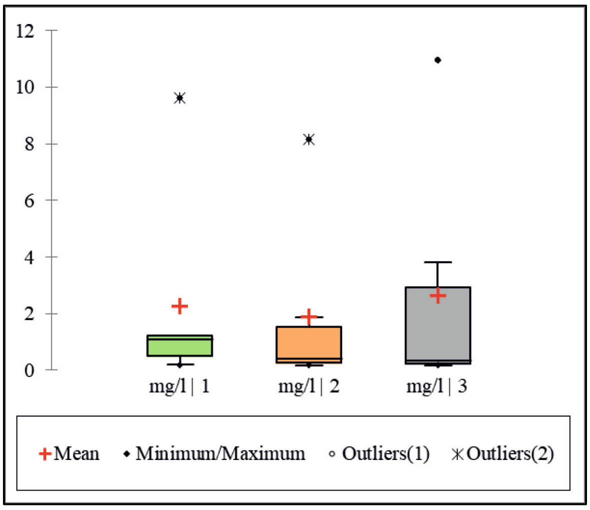

Fig. 3. The variation of iron concentrations by location in Jelgava.

In an research covering 2019 data of the entire city of Jelgava was divided into 4 clusters, with the second cluster describing monitoring points where the composition of chemical elements is typical of traffic-borne pollution, while the third cluster combines monitoring points where the content of chemical elements characteristic of waste and fossil fuel combustion is identified in addition to traffic pollution. [13].

The mean concentration of iron 11.692 mg kg^{-1} from the Suwałki builds dust [14]. In this research the results were quite similar with highest concentrations in snow samples collected 1m from road. Iron was associated with local industrial activities and motor vehicle movement [15].

Studies have shown that concentrations of heavy metals in soils near roads are declining as distance from roads increases. Iron concentrations in soils have been found to decrease away from the road. Negative correlation between iron concentrations in soils and distance from the road has been demonstrated [16]. These studies stifle the findings of this study that road transport is an important source of iron in PM particles that make up urban air pollution [17].

This study analysed the effects of distance and urban location on iron prevalence. However, future research should focus on spatial analysis of multifactors, which would allow more accurate identification of the diffusion of various heavy metals in urban environments.

IV. Conclusions

The transport related iron concentrations in snow samples the highest is at 1 m distance - 10.9 mg/l and the lowest is at 100 m - 0.33 mg/l.

The location in urban area do not play significant role of iron concentrations in snow samples, this show that all transport flows give significant iron particle emissions in atmosphere.

The results obtained can be used when designing streets and conducting urban planning.

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Advancing Sustainability: The Role of Green Economy in Environmental Conservation and Resource Management

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Abstract. **The global community faces unprecedented challenges in balancing economic development with environmental preservation and resource management. The concept of a green economy emerges as a promising solution, integrating sustainable practices into economic systems to foster environmentally friendly growth. This article examines the principles, benefits, and challenges of the green economy paradigm, exploring its potential to mitigate climate change, conserve natural resources, and promote socio-economic well-being. Through a comprehensive review of existing literature and case studies, this paper highlights the transformative power of green economy initiatives and outlines key strategies for its successful implementation in environment and resource management.**

Keywords: Green economy, Sustainability, Environmental conservation, Resource management, Climate change, Socio-economic development.

I. INTRODUCTION

The rapid industrialization and unchecked consumption patterns of the past centuries have triggered unprecedented environmental challenges, including climate change, habitat destruction, and pollution. In response to these crises, the concept of the green economy has gained traction as a viable pathway towards achieving sustainable development. Rooted in the principles of environmental stewardship, social equity, and economic viability, the green economy model aims to decouple economic growth from environmental degradation while promoting resource efficiency and resilience. This article delves into the fundamental tenets of the green economy paradigm and its pivotal role in addressing pressing environmental and resource management issues.

II. PRINCIPLES OF THE GREEN ECONOMY:

At the core of the green economy lie several key principles that guide its implementation and governance. These include:

Resource efficiency lies at the heart of the green economy, emphasizing the optimization of resource use throughout the production and consumption cycle. This involves minimizing waste generation, reducing resource extraction, and maximizing the productivity and longevity of natural resources. By adopting cleaner production methods, recycling strategies, and sustainable consumption patterns, societies can achieve more with less, minimizing environmental impact while enhancing economic efficiency [1].

Environmental conservation is a fundamental principle of the green economy, focusing on the protection, restoration, and sustainable management of ecosystems, biodiversity, and natural resources. This principle recognizes the intrinsic value of biodiversity and ecosystems, as well as their critical role in supporting human well-being and ecological resilience. Through measures such as habitat preservation, biodiversity conservation, and ecosystem restoration, the green economy seeks to safeguard the planet's natural capital for future generations.

Social inclusivity is essential for ensuring that the benefits and burdens of environmental conservation and sustainable development are equitably distributed across society. This principle emphasizes the need to address social inequalities, promote environmental justice, and empower marginalized communities in decision-making processes. By prioritizing inclusive policies, green economy initiatives can enhance access to clean air, water, and natural resources, as well as create green jobs and economic opportunities for all.

Economic resilience is a key pillar of the green economy, emphasizing the development of diversified, low-carbon economies that are robust to environmental shocks and global sustainability challenges. This principle recognizes the interconnectedness between economic prosperity and environmental sustainability, advocating for investments in green technologies, renewable energy,

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and sustainable infrastructure. By fostering innovation, entrepreneurship, and green finance, the green economy promotes long-term economic stability and prosperity while reducing dependence on finite resources and fossil fuels [2]. The green economy emphasizes the interconnectedness and holistic nature of environmental, social, and economic systems. This principle underscores the need for integrated approaches to policymaking, planning, and decision-making that consider the interdependencies between ecological health, human well-being, and economic prosperity. By adopting systemic thinking and cross-sectoral collaboration, the green economy seeks to address complex sustainability challenges in a coordinated and synergistic manner. Precaution and prevention are central to the green economy, advocating for proactive measures to avoid environmental degradation and minimize risks to human health and ecosystems. This principle emphasizes the adoption of precautionary approaches in environmental management, risk assessment, and technology deployment to prevent irreversible harm to the environment and future generations. By prioritizing prevention over remediation, the green economy seeks to mitigate environmental risks and uncertainties while promoting sustainable development pathways.

III. Benefits of the Green Economy:

The green economy offers a wide array of benefits across environmental, social, and economic dimensions, providing a pathway towards sustainable development and resilience. These benefits arise from the adoption of green technologies, sustainable practices, and innovative policies aimed at mitigating environmental degradation and promoting resource efficiency. Green economy initiatives play a crucial role in mitigating climate change by reducing greenhouse gas emissions and enhancing carbon sequestration. Investments in renewable energy, energy efficiency, and low-carbon technologies help decouple economic growth from fossil fuel consumption, thereby reducing the carbon intensity of energy production and consumption.

The green economy promotes sustainable land use practices, habitat restoration, and ecosystem protection, which are essential for safeguarding biodiversity and ecosystem services. By preserving natural habitats, promoting sustainable agriculture, and combating deforestation and habitat destruction, green economy initiatives contribute to the conservation of species diversity and ecological resilience. Resource efficiency lies at the core of the green economy, emphasizing the optimization of resource use and waste reduction across various sectors. By promoting circular economy models, eco-design principles, and sustainable consumption patterns, the green economy minimizes resource extraction, waste generation, and environmental pollution, leading to more efficient and sustainable resource management. The green economy has positive impacts on human health and well-being by reducing exposure to environmental pollutants, improving air and water quality, and enhancing access to green spaces and recreational amenities. Investments in clean energy, public transportation, and sustainable urban planning contribute to healthier and more livable communities, with benefits ranging from reduced respiratory diseases to enhanced mental health and quality of life [3]. Transitioning to a green economy generates employment opportunities and stimulates economic growth across various sectors. Investments in renewable energy, energy efficiency, sustainable agriculture, and green infrastructure create millions of jobs worldwide, fostering inclusive economic development and reducing dependency on fossil fuel-intensive industries. Moreover, green economy sectors often exhibit higher levels of innovation, productivity, and competitiveness, driving long-term economic resilience and prosperity.

The green economy enhances societies' resilience to environmental shocks and global sustainability challenges, such as climate change, resource scarcity, and natural disasters. By diversifying energy sources, building climate-resilient infrastructure, and adopting adaptive management practices, communities can better withstand and recover from environmental disruptions, reducing vulnerability and enhancing adaptive capacity [4]. Green economy investments offer significant cost savings and risk reduction benefits over the long term. Energy efficiency measures, for example, help businesses and households reduce energy consumption and lower utility bills, resulting in substantial economic savings. Similarly, investments in natural infrastructure, such as green roofs and wetland restoration, provide cost-effective solutions for flood mitigation, water purification, and erosion control, reducing the need for costly engineering interventions.

IV. Challenges and Considerations

Certainly, transitioning to a green economy comes with its set of challenges and considerations. While the benefits are substantial, addressing these challenges effectively is crucial for ensuring a successful transition. One of the primary challenges of transitioning to a green economy is the initial economic costs involved in implementing sustainable technologies, infrastructure, and practices. Investments in renewable energy, energy efficiency, and eco-friendly production processes may require significant upfront capital, posing a barrier for businesses, especially small and medium enterprises (SMEs) and developing countries. Overcoming this challenge

requires innovative financing mechanisms, such as green bonds, subsidies, tax incentives, and public-private partnerships, to incentivize green investments and facilitate the adoption of sustainable practices. Inadequate or inconsistent policy and regulatory frameworks can hinder the transition to a green economy by creating uncertainties for businesses, investors, and consumers [5]. Policy fragmentation, conflicting regulations, and lack of enforcement mechanisms may impede the uptake of green technologies and inhibit market transformation. To address this challenge, governments need to develop coherent and supportive policy frameworks that provide clear incentives for sustainability, streamline permitting processes, and establish ambitious targets for emissions reductions, renewable energy deployment, and resource efficiency.

The transition to a green economy requires the widespread adoption of innovative technologies and the development of sustainable infrastructure. However, technological barriers, such as the high costs of clean energy technologies, limited availability of sustainable materials, and technological lock-ins associated with incumbent fossil fuel-based infrastructure, can slow down progress towards sustainability. Overcoming these challenges requires investment in research and development (R&D), technology transfer, and capacity-building initiatives to accelerate the deployment of clean technologies and enable the transition to sustainable infrastructure systems. Ensuring that the benefits of the green economy are equitably distributed across society is essential for fostering social cohesion and addressing environmental justice concerns [6]. However, there is a risk that the transition to a green economy may exacerbate existing inequalities, particularly for marginalized communities and vulnerable populations. Green economy initiatives must prioritize social inclusivity by providing equitable access to green jobs, clean energy, and environmental amenities, as well as supporting the livelihoods of workers affected by economic restructuring. Additionally, participatory decision-making processes and community engagement strategies are essential for ensuring that diverse voices are heard and that local knowledge and perspectives are integrated into green economy initiatives [7]. Achieving a sustainable transition requires global cooperation and coordinated action among governments, businesses, civil society organizations, and international institutions. However, geopolitical tensions, trade disputes, and divergent interests among countries can impede progress towards collective goals, such as climate mitigation, biodiversity conservation, and sustainable development. Strengthening international cooperation mechanisms, such as the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD), is crucial for fostering multilateral dialogue, sharing best practices, and mobilizing resources to support the transition to a green economy on a global scale.

Transitioning to a green economy also requires a shift in societal attitudes, values, and consumption patterns towards more sustainable lifestyles and behaviours. However, changing entrenched habits and cultural norms can be challenging and may require targeted education, awareness-raising campaigns, and incentives to encourage sustainable choices. Empowering individuals and communities to adopt pro-environmental behaviours, such as reducing energy consumption, minimizing waste, and supporting local and organic products, is essential for driving systemic change and fostering a culture of sustainability

V. CASE STUDIES AND BEST PRACTICES:

Best practices from around the world offer valuable insights into successful initiatives and strategies for advancing the green economy. These examples demonstrate the feasibility and benefits of transitioning towards sustainable development pathways while addressing environmental challenges. Below are several case studies and best practices highlighting innovative approaches to green economy implementation:

- **Denmark's Wind Energy Success:** Denmark has emerged as a global leader in wind energy production, with wind power accounting for a significant portion of its electricity generation. The country's commitment to renewable energy dates back to the 1970s when it began investing in wind turbine technology and offshore wind farms. Through supportive policies, such as feed-in tariffs, tax incentives, and research funding, Denmark has fostered a thriving wind energy industry that has created thousands of jobs and reduced reliance on fossil fuels. Denmark's experience demonstrates the economic and environmental benefits of investing in renewable energy as a key driver of the green economy [8]. Denmark's success in wind energy production showcases the economic and environmental advantages of investing in renewable energy. Through forward-thinking policies and substantial investments, Denmark has established itself as a global leader in wind power, creating jobs and reducing reliance on fossil fuels.
- **Germany's Energiewende**: Germany's Energiewende, or energy transition, is a comprehensive strategy aimed at shifting the country's energy system towards renewables and reducing greenhouse gas emissions. Since its inception in the early 2000s, Germany has made significant progress in expanding renewable energy capacity, particularly in wind and solar power [9]. Through a combination of feed-in tariffs, renewable energy targets, and regulatory reforms, Germany has incentivized investment in clean energy technologies and decentralized energy production. Despite challenges such as intermittency and grid integration, the Energiewende has created jobs, reduced emissions, and positioned Germany as a global leader in renewable energy deployment. Germany's Energiewende exemplifies the transformative power of comprehensive strategies aimed at shifting energy systems towards renewables. Despite challenges, Germany's commitment to renewable energy targets and regulatory reforms has resulted in significant progress, positioning the country as a pioneer in renewable energy deployment.
- **Costa Rica's Conservation Policies:** Costa Rica is renowned for its progressive conservation policies and commitment to preserving its rich biodiversity and natural resources. The country has established a network of protected areas, including national parks, reserves, and biological corridors, covering over 25% of its territory. Costa Rica's emphasis on ecotourism, sustainable agriculture, and payments for ecosystem services has helped to generate revenue while conserving its natural heritage. By valuing and investing in ecosystem conservation, Costa Rica has not only safeguarded its biodiversity but also promoted sustainable development and economic growth [10]. Costa Rica's conservation policies highlight the importance of valuing and investing in ecosystem preservation. By prioritizing conservation efforts and sustainable practices, Costa Rica has not only protected its biodiversity but also stimulated economic growth through ecotourism and sustainable agriculture.
- **Circular Economy Initiatives in the Netherlands:** The Netherlands has embraced the concept of the circular economy as a means of promoting resource efficiency and reducing waste. Through initiatives such as the Circular Economy Roadmap and the National Waste Management Plan, the Dutch government has set ambitious targets for waste reduction, recycling, and the circular design of products and

materials. Collaborative platforms, such as the Circular Economy Coalition and the Amsterdam Circular Innovation Platform, bring together businesses, government agencies, and research institutions to drive innovation and knowledge exchange [11]. The Netherlands' efforts to transition to a circular economy demonstrate the potential for rethinking traditional linear production and consumption models to achieve environmental and economic sustainability. The Netherlands' circular economy initiatives underscore the potential for rethinking traditional production and consumption models to achieve environmental and economic sustainability. Through ambitious targets and collaborative platforms, the Netherlands is leading the way in promoting resource efficiency and waste reduction.

- **Green Building Standards in Singapore:** Singapore has prioritized sustainable urban development through initiatives such as the Green Mark Scheme, which sets standards for environmentally friendly building design and construction. Green buildings in Singapore incorporate features such as energy-efficient lighting, renewable energy systems, and water-saving technologies to minimize resource consumption and environmental impact. Through incentives such as tax breaks, grants, and fast-track approvals, the Singaporean government has incentivized developers to adopt green building practices. These efforts have not only reduced energy and water consumption but also enhanced the livability and resilience of Singapore's urban environment [12]. Singapore's green building standards demonstrate the importance of sustainable urban development in minimizing resource consumption and enhancing livability. By incentivizing green building practices, Singapore has reduced energy and water consumption while increasing urban resilience.
- **Community-Based Natural Resource Management in Namibia:** Namibia has implemented community-based natural resource management (CBNRM) programs to empower local communities to manage and benefit from their natural resources sustainably. Through initiatives such as conservancies and communal conservancies, communities have gained ownership and control over wildlife management, tourism enterprises, and other natural resource-based activities. CBNRM has helped to conserve biodiversity, generate income for rural communities, and promote social cohesion and empowerment. Namibia's experience demonstrates the importance of community involvement and decentralized governance in achieving conservation and development objectives [13]. Namibia's community-based natural resource management programs exemplify the significance of community involvement and decentralized governance in achieving conservation goals. By empowering local communities to manage natural resources sustainably, Namibia has fostered biodiversity conservation and socio-economic development.

These case studies illustrate the diverse approaches and strategies for advancing the green economy across different sectors and contexts. By learning from successful initiatives and scaling up best practices, countries and communities can accelerate the transition towards sustainability while reaping the economic, social, and environmental benefits of the green economy.

Conclusion

In conclusion, the green economy represents a pivotal pathway towards achieving sustainable development by harmonizing environmental conservation, social equity, and economic prosperity. Through the adoption of resource-efficient practices, environmental stewardship, and inclusive policies, the green economy offers tangible benefits across multiple dimensions, including climate mitigation, biodiversity conservation, resource security, and job creation. However, the transition to a green economy is not without challenges, including economic costs, policy fragmentation, technological barriers, social equity concerns, and the need for global cooperation.

Nevertheless, numerous case studies and best practices demonstrate the transformative potential of the green economy in driving positive environmental and socio-economic outcomes. Examples such as Denmark's wind energy sector, Germany's renewable energy transition (Energiewende), and Costa Rica's conservation policies highlight successful green economy initiatives that have yielded tangible benefits for both people and the planet. These case studies underscore the importance of visionary leadership, supportive policies, and multi-stakeholder collaboration in realizing the full potential of the green economy.

To address these challenges and accelerate progress towards a sustainable future, several recommendations can be implemented:

- Investment in Renewable Energy Sources (RES) -Governments and private investors should allocate funds towards the development and deployment of renewable energy technologies such as solar, wind, and hydroelectric power. Incentive programs and subsidies can be introduced to promote the adoption of renewable energy systems in both residential and industrial sectors.
- Enhancement of Energy Efficiency - Public awareness campaigns and educational programs can be launched to promote energy-efficient practices among consumers and businesses. Governments can introduce legislation mandating energy efficiency standards for buildings, appliances, and transportation systems.
- Promotion of Sustainable Agriculture and Forestry - Agricultural subsidies and incentives can be redirected towards sustainable farming practices that prioritize soil health, water conservation, and biodiversity preservation. Forest management policies should prioritize sustainable harvesting practices, reforestation efforts, and conservation of natural habitats.
- Promotion of Circular Economy - Governments can implement policies to incentivize recycling, reuse, and remanufacturing of products and materials. Businesses can adopt circular economy business models that prioritize product longevity, repairability, and recyclability.

- Investment in Green Technologies and Innovations - Research and development funding should be increased for green technologies that address environmental challenges such as climate change, pollution, and resource depletion. Public-private partnerships can be established to support the commercialization and scaling-up of innovative green technologies.
- Training and Capacity Building - Educational institutions and training centers can offer programs and courses on sustainability, green entrepreneurship, and environmental management. Capacity-building initiatives should target policymakers, businesses, and communities to enhance their understanding of green economy principles and practices.

By implementing these recommendations and leveraging the transformative potential of the green economy, societies can overcome barriers and accelerate progress towards a more equitable, resilient, and prosperous future for current and future generations. This necessitates collective action and collaboration among policymakers, businesses, civil society organizations, and individuals to drive positive environmental and socio-economic outcomes on a global scale.

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Regulating the Electric Vehicle Market within the Framework of the European Green Course

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Abstract. **Transportation is a strategic sector of the EU's economy and directly impacts the daily lives of all EU citizens. This industry is responsible for around 11 million jobs. It is vital for the integration of Europe, as interconnected and sustainable transport networks are necessary to complete and adequately function the European Single Market. Over the last few decades, passenger and freight transport volumes have grown, and they are expected to continue to do so, although at a slower pace. Most passenger and freight transport is through road transport, and this article focuses on regulating road transport and its compatibility with the objectives of the European Green Deal. The European Commission has put forth a set of propositions to align the EU's climate, energy, transport, and taxation policies to achieve a minimum reduction of 55% in net greenhouse gas emissions by 2030 compared to the levels recorded in 1990. One proposition is to reduce road transport pollution by increasing the percentage of electric vehicles operating in the road transport sector. This paper aims to introduce the concept of the electric road vehicle, analyse the objectives of the European Green Deal, and discuss Lithuanian policy actions regarding electric road vehicles and related infrastructure.**

Keywords: electric road vehicle, European Green Deal, infrastructure for electric vehicles.

I. Introduction

Transportation plays a vital role in the economy of the EU, and it significantly impacts the daily lives of all EU citizens. This industry is responsible for around 11 million jobs. It is vital for the integration of Europe, as interconnected and sustainable transport networks are necessary to complete and adequately function the European Single Market. While passenger and freight transport volumes have been steadily increasing in recent decades and will continue to grow, particularly in the road transport sector, there is a growing emphasis on aligning regulations with the goals of the European Green Deal.

The European Commission has put forth a set of propositions to align the EU's climate, energy, transport, and taxation policies to achieve a minimum reduction of 55% in net greenhouse gas emissions by 2030 compared to the levels recorded in 1990 [1].

One proposition is to reduce road transport pollution by increasing the percentage of electric vehicles operating in the road transport sector. This paper aims to introduce the concept of the electric road vehicle, analyse the objectives of the European Green Deal, and discuss Lithuanian policy actions regarding electric road vehicles and related infrastructure.

II. Materials and methods

In the study, the methods of analysis, comparison, and generalisation were applied. It analysed scientific and technical literature, statistical data, and technical data about electric vehicles, EU policy and law, Lithuanian policy and law, and Lithuanian municipalities' policy, law, and practice regulating the electric vehicle market within the Framework of the European Green Course. The comparison method was used to compare data from different periods and types of vehicles and determine the direction of the electric vehicle market regulation. By applying the generalisation method, the work summarises and highlights the policy gaps in Lithuanian policy and legal regulation regarding electric vehicles, indicating insufficient and unsuitable infrastructure and failure to ensure social justice. This method is also applied to present the conclusions of the study.

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III. RESULTS AND DISCUSSION

A. The role of the electric vehicle in the context of climate change, market trends and developments

Electric vehicles have been around since the late 19th century. “During the early 1900s, around 40% of cars were electric, 38% on steam and a mere 22% on gasoline” [2]. The scientific literature uses different names to refer to electric vehicles, including electric cars [3], electric vehicles [4], pure electric vehicles [5] or battery/battery electric vehicles [6]-[7].

An electric vehicle is a mode of transportation powered by an electric motor that receives its energy from a stored electrical source, typically a battery [8]. This vehicle runs exclusively on electric power and has a battery that should be periodically recharged with an external power source. As it is powered by electricity, it emits zero pollutants and operates silently. The vehicle's electric range varies between 80 and 400 kilometres, depending on the specific model [9]. Presently, hybrid-electric vehicles constitute a substantial segment of the automotive market. These vehicles integrate a conventional internal combustion engine fuelled by petrol or diesel with an electric motor that derives power from electricity stored within a battery [8].

Electric cars can be classified into five primary categories based on scientific and technical discourse:

- Non-rechargeable Hybrid Electric Vehicles (HEVs)
- Plug-in Hybrid Electric Vehicles (PHEVs)
- Range-extended Electric Vehicles (REEVs)
- Fuel Cell Electric Vehicles (FCEVs)
- Battery Electric Vehicles (BEVs) [10].

In non-rechargeable hybrid vehicles, the internal combustion engine charges the battery during braking or coasting, while the electric motor is an auxiliary function. This hybridisation increases fuel efficiency, thereby lowering greenhouse gas emissions. Depending on the model, the range is 0-10 km [11].

Rechargeable hybrid vehicles' batteries can be charged the same way as non-rechargeable hybrid vehicles but can also utilise an external power source during charging. The battery in rechargeable hybrid vehicles is larger, allowing short distances to be travelled using only electricity. The internal combustion and electric motors can operate together or separately [12].

In these vehicles, the internal combustion engine starts operating when the battery is depleted; energy is needed for rapid acceleration, intensive air conditioning, or heating. Depending on the model, the electric range of hybrid vehicles varies from 20 to 85 km. The internal combustion engine in heavy-duty rechargeable hybrid vehicles requires more frequent engagement; thus, their operation is more similar to that of non-rechargeable hybrid vehicles [13].

Extended-range electric vehicles are powered by an electric motor and a backup internal combustion engine that acts as a generator. This generator supplies electricity to the electric motor or recharges the battery. Since the vehicle is powered solely by electricity, the internal combustion engine is smaller, which reduces the overall weight of the car. Additionally, these vehicles can be charged using an external power source. The electric range can vary from 70 to 145 km, depending on the model. [9].

Electric vehicles powered by hydrogen fuel cells generate electricity from hydrogen, which provides a longer driving range and faster refuelling compared to traditional electric vehicles. The range of these vehicles varies from 160 to 500 km. However, it's worth noting that the technology is currently in the developmental stage [14].

Entirely electric vehicles rely on charging infrastructure, while hybrid vehicles do not require it as much. Three main ways to charge an electric vehicle are grid charging, battery swapping, and wireless charging. In Europe, most electric vehicle owners use grid charging, which involves connecting the vehicle to a charging point with a cable and plug. Charging stations are classified as slow, fast, or ultra-fast by power capacity. Slow charging is the most common and readily available, taking 4 to 14 hours to charge. Fast charging takes 1- 2 hours, while ultra-fast charging can charge a vehicle in 30 minutes [15].

Electric vehicles are often praised for their numerous advantages. Compared to fossil fuel-powered cars, they have a simpler operating principle and construction. The electric car engine is more efficient, as it transfers 90% of energy to the wheels, while a conventional engine only transfers 40%. Electric vehicles have fewer moving parts and don't require exhaust systems, filters, or oil. They also have a much simpler cooling system, which makes maintenance much simpler throughout their lifespan. Additionally, these cars operate quietly thanks to the electric motor and produce zero CO2 emissions during driving (if solely powered by electricity).

The fundamental difference between electric and fossil fuel-powered vehicles is how they transform potential (stored) energy into kinetic (motion) energy. In electric vehicles, energy is stored in chemical form in batteries and released during chemical reactions in the motor. Due to this, no fuels are burned in electric vehicles, resulting in zero emissions of CO2 and other pollutants [16].

The transportation industry is one of the EU's leading sources of greenhouse gas emissions. This requires immediate action to reduce emissions to align with the EU's objectives for climate neutrality. Starting in 2025, Regulation (EU) 2019/631 [17] mandates stricter EU-wide CO2 fleet targets. This includes a 15% reduction for cars and vans by 2025, a 50% reduction for vans, and a 55% reduction for cars by 2030, compared to 2021. Furthermore, this regulation sets a zero-CO2 emission objective for new cars and vans starting in 2035. Achieving these ambitious targets requires a significant increase in the adoption of electric vehicles.

Electric vehicles, such as battery electric vehicles and plug-in hybrid electric vehicles, have steadily increased their presence in the EU market. The number of new electric cars registered has surged from 600 in 2010 to approximately 1.74 million in 2021, accounting for 18% of all new car registrations. This trend continued in 2022 when electric vehicles represented almost 22% of newly registered passenger cars. Battery electric vehicles comprised 12.2% of total new car registrations, while plug-in hybrid electric vehicles accounted for 9.4% [18].

In 2022, approximately 56,500 electric vans were sold in the EU-27, comprising 5.5% of the market share and representing an increase of approximately 2.0 percentage points from 2020. The majority of electric vans sold were battery electric vehicles [18].

In 2022, there was a significant increase in the adoption of electric cars and vans in the EU. This was evidenced by the registration of electric vehicles, which accounted for 21.6% of new car registrations, totalling almost two million electric car registrations within a year. This marked an increase from 1.74 million in 2021. Additionally, the number of electric vans on European roads increased, comprising 5.5% of new registrations in 2022. Notably, the number of newly registered battery electric vehicles increased by 25% during the same period, while the count of plug-in hybrid cars remained stable. Moreover, battery electric vehicles made up the majority of electric van registrations in 2022 [9].

Although electric vehicles have grown substantially in recent years, they only make up 1.2% of the European car fleet. Expanding Europe's electric vehicle fleet is inevitable to meet emissions reduction goals and climate neutrality targets by 2050 [18].

B. The European Green Deal: main issues in the transport sector

The world is currently threatened by climate change and environmental degradation, and in response to this alarming situation, the EU has initiated a Green Deal [19]. Climate change is largely caused by human activity. The primary factor contributing to this negative trend is greenhouse gases, including carbon dioxide (CO2).

Greenhouse gases occur naturally, but human activities such as burning fossil fuels, agriculture, livestock farming and deforestation have significantly increased their levels. The main problem caused by additional greenhouse gasses is that they increase the greenhouse effect of the planet's atmosphere, increasing the Earth's air temperature. This is leading to significant climate change.

To combat transportation-related urban air pollution, reduce greenhouse gas emissions, and reduce dependency on fossil fuels, policymakers worldwide are advocating for the electrification of transportation [10]. Research indicates that a transition towards electric vehicles holds the promise for significant reductions on a global scale in climate change, air pollution, dependence on fossil fuels, and improved human health [20]. Many countries worldwide, including Britain, France, Norway, and India, plan to replace fossil fuel-powered vehicles with electric vehicles soon. Furthermore, China, Germany, Japan, the Netherlands, Spain, Denmark, Ireland, Portugal, South Korea, and Austria have announced national plans to phase out internal combustion vehicles [10].

The European Green Deal, published in 2019, is the largest initiative taken by the EU to achieve climate neutrality. EU institutions showed ambitions for greenhouse gas reduction. In the September 2020 proposal, the European Commission proposed reducing emissions by 55% by 2030 compared to 1990, whereas the European Parliament proposed a 60% reduction [21].

The European Green Deal is a comprehensive framework and strategic blueprint that outlines the EU's course of action towards achieving climate neutrality. It emphasises the crucial role of all EU actions and policies in reaching this overarching goal. It provides directives for legislative and non-legislative measures that will help facilitate its attainment. These initiatives cover various sectors, including industry, energy, finance, mobility, and transport.

Climate change and environmental degradation pose significant threats to Europe and the global community. In response to these challenges, the European Green Deal endeavours to metamorphose the European Union into a contemporary, resource-savvy, and competitive economy [1]. This initiative aims to achieve:

1. Zero greenhouse gas emissions by the year 2050.
2. Decoupling economic growth from resource consumption.
3. No marginalised or neglected individual or geographical area in pursuing environmental sustainability and economic advancement.

As per the updated CO2 standards, all newly registered cars and vans in the European region will transition to zero-emission vehicles by 2035. The emissions of new cars should be reduced by 55% and new van emissions by 50% by 2030. This strategic initiative is designed to firmly establish road transport on a trajectory towards zero emission by the year 2050 [22].

It is notable that the amount of pollutants emitted by the transportation sector is increasing, with fossil fuels remaining the primary source of energy [23]. Transportation is responsible for over one-fourth of Europe's total greenhouse gas emissions, with road transportation alone contributing more than half. Transportation also consumes one-third of the EU's final energy, most of which is derived from oil. As a result, the transportation sector contributes significantly to the EU's greenhouse gas emissions, worsening the effects of climate change.

Reducing the negative impact of transportation is a key objective of the European Green Deal. The primary way to achieve environmental sustainability in the transportation sector is through implementing more eco-friendly transportation technologies, fuels, and infrastructure, as well as the transition to the least polluting and most efficient modes of transport. It is widely believed that electrified transportation is low-emission and efficient. The EU aims to have over 30 million electric vehicles on the roads by 2030 - a significant increase compared to the 2 million electric vehicles currently navigating European streets and roads. [24].

The objectives of the European Green Deal for transportation are becoming more stringent and legally binding, as opposed to just being policies or strategies. These objectives are outlined in Regulation (EU) 2021/1119, which serves as a framework for achieving climate neutrality. [25]. To neutralise climate impacts in the transport sector:

1) Emissions must be reduced by 90% by 2050 [25];

2) Emissions of new passenger cars must be reduced by 55% and new light commercial vehicles by 50% by 2030 [26];

3) Zero average emissions of new passenger cars and new light commercial vehicles by 2035 [26];

4) Average CO2 emissions of trucks and other heavy-duty vehicles must be reduced by 15% by 2025 and 30% by 2030 [27].

To achieve the objectives set out in the European Green Deal, which prioritize sustainability and intelligence, member states need to improve several areas, such as implementing multimodal transportation, integrating automated and intelligent mobility solutions, reviewing tax policies, promoting the production and use of alternative fuels, and imposing stricter regulations on traditional transportation practices.

C. Situation in Lithuania regarding electric vehicles and policy measures

The transport sector is currently a significant contributor to greenhouse gas (GHG) emissions in Lithuania. In fact, it accounts for 29.88% of total GHG emissions in the country in 2021. [28]. While vehicle efficiency has improved during the period from 1990 to 2019, GHG emissions from the transport sector have been steadily increasing due to the rising number of vehicles and the intensification of freight transport activities [29]. In 2020, the situation has stabilised and started to improve, albeit very slowly. In 2020, GHG emissions decreased by 2.37% compared to 2019 and 2021 by an additional 0.23% compared to 2020.

In the transport sector, which includes road, rail, air, and inland waterway transport, road transport accounted for 96.16% of emissions in 2021. At the end of 2022, there were about 1.98 million registered road vehicles in Lithuania, of which about 1.65 million (83.28%) were passenger cars [28]. Lithuania has one of the oldest and most polluting passenger car fleets in the EU, with an average age of 15 years, and about 70% of passenger cars are diesel-powered [29].

The transport sector is also the largest energy consumer, accounting for 40.42% of the energy consumed in Lithuania in 2022 [30]. Most of the energy consumed by the road transport sector was produced from fossil oil or gas resources (91.39%). The share of renewable energy sources (RES) in road transport consumption in 2022 was only 8.6% [31]. The share of electricity used in the transport sector is still very low, accounting for only around 0.69% of total electricity consumption in 2022 [32]. 63.29% of the electricity consumed in the transport sector is consumed by road transport. This represents only 2.5% of the total energy consumption of road transport [31].

Electric car purchases are being promoted through various regulatory and financial measures. Vilnius allows electric vehicles to drive in a specially marked public transport lane to increase electro-mobility. It should be noted that the number of these lanes has recently been reduced. There are also various parking incentives in major Lithuanian cities. Funding for the purchase of electric cars is also available starting in 2020. Each person can get a compensation of €5,000 for a new pure electric vehicle and €2,500 for a second-hand one [33]. Individuals using the vehicle for economic activities can get a €4,000 compensation for a new M1 or N1 pure electric car [33]. Statistical data shows that from July 2022 to February 22, 2024, legal entities purchased 1406 LCVs and, in total, got €5,624,000 compensations. [34].

Lithuania is developing its electric vehicle charging infrastructure. Initially, electric vehicle connectivity was ensured in five major cities and national roads at 50 km intervals.

Currently, the electric vehicle's charging infrastructure is being expanded. In January 2024, the Public Electric Vehicle Charging Stations Registration System (CSRS) indicated 45 registered charging operators and 1312 public and semi-public electric vehicle charging stations in Lithuania [35]. Although the number of charging stations is relatively high, it should be noted that only 33 of them are ultra-fast charging [36].

In the CSRS, any registered user can find the nearest EV charging station at any time and learn its characteristics, availability, and charge price [37].

From 2 August 2021, stricter requirements for the public procurement of vehicles or services provided by vehicles were applied. Currently, contracting authorities and contracting entities must ensure that, when procuring vehicles or the services they provide, a defined proportion of the vehicles procured are environmentally friendly or that a specified proportion of the services offered are provided by environmentally friendly vehicles. Non-polluting vehicles of categories M1, N1, and M2 (up to 50 g/km CO2) must account for 60% of procurement transactions, and non-road vehicles of category M3 (powered by alternative fuels) must account for 80% [38].

As of 1 January 2022, 50% of the costs of connecting public and semi-public charging stations for electric vehicles to the electricity grid can be reimbursed [39]. From 8 June 2023, operators of pure M2, M3, N1, N2, and N3 electric vehicles do not have to pay road taxes for using highways [40].

Starting from January 1st, 2023, an economic unit can recover the VAT paid on a category M1 electric vehicle whose value, including VAT, does not exceed €50,000. This tax allowance does not apply to cars with internal combustion engines. [41].

While efforts to promote the use of electric cars are ongoing, they represent a small share of passenger vehicles in Lithuania. In 2023, out of the 123,943 passenger cars registered for the first time in Lithuania, only 4,147 were electric vehicles (3.35%). It should be noted that only 53.34% of the newly registered electric vehicles were new cars (2,212 units). Notably, the proportion of newly registered electric vehicles is slowly increasing compared to previous years. 0.26% of newly registered passenger cars were electric vehicles in 2019, 0.73% in 2020, 1.72% in 2021 and 2.14% in 2022 [42]. According to the data of REGITRA (entity registering vehicles in Lithuania), of 1 February 2024, a total of 20112 M1 and N1 class electric vehicles were registered in Lithuania, including 12185 BEVs and 7927 PHEVs. There were also 68942 hybrid M1 and N1 vehicles [43].

The policy document *Lithuania's vision for the future, "Lithuania 2050",* states that Lithuania in 2050 will have a "sustainable economy that is climate-neutral, resilient to adverse changes in climate change, is based on the restoration of natural ecosystems, balanced growth and moderation." [44]

Another policy document, the *National Agenda for Management of Climate Change*, shows the State's aims to reduce the emission of greenhouse gasses by at least 14 per cent compared with 2005 [45]. To achieve this, national policy documents foresee the following milestones:

- At least 20% of the light-duty vehicle fleet will be electric and clean vehicles, and all necessary charging and refuelling infrastructure will be established by 2030 [45] - [46]; the number of electric vehicles will be at least 118,000 [47];
- At least 10% of annual purchases of class M1 and 30% of annual purchases of class N1 will be electric vehicles by 2025; at least 50% of annual purchases of class M1 and 100% of annual purchases of class N1 will be electric vehicles by 2030 [45]; Budget for partial compensation of vehicle price for the period of 2022-2026 is 129 million Eur [48]
- Since 1 January 2030, vehicles of class N1 with internal combustion engines, except vehicles of class N1 powered by alternative fuels, shall not be registered [45];
- By 31 December 2030, 100% of M1, M2, M3, and N1 road vehicles and 16% of N2 and N3 road vehicles purchased through public procurement will be environmentally friendly [45];
- At least 60 000 charging stations for electric vehicles are established [45]; by 2030, 46 million Eur budget for partial compensation for the acquisition or installation of 54 000 private charging stations and 74 million Eur for the acquisition/installation of 6000 public and semi-public charging stations [48];
- From 2023, all petrol stations, bus and train stations, airports and seaports under construction or reconstruction must have at least one public charging station of fast or ultra-fast charging [45];
- 50% reduction of fossil fuels in road transport by 2035 (measures to increase energy efficiency, the use of renewable energy sources and alternative fuels) [45];
- 15% share of RES in the total final energy consumption of the transport sector by 2030 (measures for developing the charging network for electric vehicles and the refuelling infrastructure for alternative fuels) [49];
- By 2035, passenger transport and logistics services in cities will be provided only by environmentally friendly vehicles [45];
- Vehicle charging and refuelling infrastructure is consistently expanding in line with the increasing number of clean vehicles [45];
- No fossil fuels in road transport by 2045 [45];
- Prepared and adopted the plan for public and semi-public charging stations for electric vehicles on local roads by 2030 [45].

The analysis of Lithuanian policy and legal regulation regarding electric vehicles indicates insufficient and unsuitable infrastructure and inadequate policies and laws that fail to ensure social justice.

Speaking about insufficient and unsuitable infrastructure, it can be noted that the charging station network hinders the entry of cheap electric cars into the Lithuanian market. Research shows that more affordable electric vehicles, after fully charging the battery, travel 230 kilometres in summer and up to 200 kilometres in winter. Such mileage is insufficient for the movement of people in Lithuania. The round-trip distances between major cities are 280-500 kilometres. It is evident that electric cars with such a range need to be charged on the way. Currently, there are only a few ultra-fast charging stations in Lithuania where you can charge an electric car in half an hour, while in other places, it takes 6-9 hours to charge the car fully.

Relatively cheap, low-mileage electric cars are too small for a family ride and do not fit tall people. Such electric vehicles are suitable for driving only within the limits of one city. As a result, a person must also purchase a non-electric vehicle to drive between cities. In Lithuania, people with average or lower incomes buy one car, usually used, suitable for driving both in the city and between cities.

The Lithuanian electricity network and the amount of electricity that can be produced limit the development of the network of charging stations for electric cars. If the environmental protection goals were implemented only by expanding the fleet of electric vehicles and, accordingly, their charging network, the capacity of the current electric network would not be sufficient.

To achieve the goals of the Green Deal, the increase in the number of electric cars is justified to the extent that it is possible to produce electricity from renewable sources. Otherwise, the benefits of using electric vehicles may be lost due to the environmentally unfriendly method of producing electricity.

Furthermore, there are problems with the social justice aspect of electric vehicles. In Lithuania, the existing charging station network, in essence, is only suitable for owners of more luxurious cars that travel longer distances. The base price of such vehicles in the market starts from 40 thousand euros. In Lithuania, the disposable income of one household in 2022 amounted to an average of 1,504 EUR per month, and the disposable income per household member was 751 EUR per month [50]. A person with an average income will not buy such a car. A new electric vehicle is a luxury item that only people with higher incomes can afford.

Some charging stations for electric vehicles are free, especially those built with project funds. These are usually part of urban or state infrastructure. It is clear that all taxpayers, including those with lower incomes, pay for the electricity used to charge the electric cars of the wealthier people.

Finally, the analysis of the situation shows that all benefits (car movement lanes for electric cars, free parking, compensation for the purchase of a vehicle, free charging) are, in essence, support the rich in society at the expense of all taxpayers.

IV. Conclusions

Electric vehicles have been around since the late 19th century. An electric vehicle uses a motor powered by a stored electrical source, usually a battery. There are five main categories of electric cars: Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs), Non-rechargeable Hybrid Electric Vehicles (HEVs), Range-extended Electric Vehicles (REEVs), and Fuel Cell Electric Vehicles (FCEVs). The key difference between electric and fossil fuel-powered vehicles is how potential (stored) energy is converted into kinetic (motion) energy. In electric vehicles, energy is stored chemically in batteries and then released through chemical reactions in the motor.

The European Green Deal, released at the end of 2019, is the EU's most significant effort to achieve climate neutrality. The European Commission proposal of September 2020 (55% emission reduction in 2030 compared to 1990) and the European Parliament proposal that followed soon after (−60%) have changed ambitions on greenhouse gas reduction. The European Green Deal serves as a comprehensive framework and strategic blueprint delineating the course of action for the EU in its pursuit of climate neutrality. It emphasises the indispensable contribution of all EU actions and policies towards this overarching objective while providing directives for both legislative and non-legislative measures to facilitate the attainment of this goal.

Speaking about Lithuanian policy in the field of electric vehicles, the national agenda for the management of climate change aims to reduce the emission of greenhouse gasses by at least 14 per cent compared with 2005. To reach these aims, the national policy documents foresee a number of measures regarding electric vehicles. The analysis of Lithuanian policy and legal regulation regarding electric cars shows insufficient and unsuitable infrastructure. The policy and law do not ensure social justice. The charging stations network hinders the entry of cheap electric cars into the Lithuanian market. The Lithuanian electricity network and the amount of electricity that can be produced limit the development of the network of charging stations for electric cars.

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The information age in communications and its impact on consumer behavior in the tourism business

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Abstract: **In recent years, there has been an increased development of information technologies, which have a significant impact on the economic and social sphere worldwide and, in particular, on communications between consumers and companies. Dynamic changes in the global aspect of the economy and changes in consumer tastes and preferences are only part of the factors for the creation and integration of new modern technologies. It is the application of various technologies that is of key importance for communications with consumers in the tourism business.**

Attesting to the relationship between customer satisfaction and the success of a company's experience generation strategy is complex. Consumers may be very satisfied but completely unmotivated to make additional trips or recommend the company to others. It is precisely in this process and the resolution of various challenges that information technology is essential.

Keywords: information technology, digitalization, consumer behavior, marketing, tourism, information communication technologies, communications in tourism, communication framework

I. Introduction

The dynamic and continuous improvement of information and communication technologies determines the rapid development of new digital means that attract the attention of users and make them feel special. In parallel, modern consumers spend more and more of their time online, which is why the influence of digital marketing to build long-term relationships with consumers is also increasing, and hence a number of changes in the tourism sector.

A particularly great interest arises in the study of the impact of the overall digital transformation on this consumer behavior.

For a long time, individual companies relied on consumers to discover products themselves, or themselves, but this situation is changing. The seller's role is to ensure that the consumer finds the product, gets it where it is, and completes the entire purchase process - the sale, even if it's online.

It is the interrelationship between digital technologies and consumer behavior in tourism that comes to the fore, and the new business model of online commerce is optimized thanks to this interrelationship and directs users to subscribe to something relatively new, namely the "experience".

The purpose of the report is to present the impact of technology and communications on consumer behavior in the tourism business.

II. Materials and methods

The field of application of ICT - technologies is wide enough: these are also organizational culture, personnel management, strategic management, product quality management, marketing and communication policy, as well as the specific areas of communications specific to each individual company .

These technologies are aimed at providing an effective exchange of information between subjects and objects of management, improving interpersonal relations within individual structures and between structures involved in the process of providing tourist services and forming separate, specific, integrated ICT-

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channels, aimed at meeting the specific needs of tourists and companies providing tourist services.

The development of modern technology has provided new opportunities for the digital transformation of the tourism industry. An increasing number of tourism companies actively engage in livestreaming to promote tourism products and destinations [6] Tourism live-streaming not only breaks the boundaries of time and space [5] but also provides an immersive, entertaining, and authentic experience for tourism consumers through host interaction and live-streaming technology [8]. This gives them powerful capabilities to sell tourism products and recommend destinations [10] [4] The modern technologies of the 21st century are significantly changing people's lifestyles and are therefore a challenge for running a business. The free exchange and access to information lead to the development of a number of technologies such as social networks, the Internet of Things, electronic and virtual stores, artificial intelligence and a number of others that change the way people think, and hence change their behavior as consumers.

In turn, the modern consumer engages in the process of simultaneous production and consumption of the experience, which becomes the main type of good. This good called "human experience" is the most transitory and yet the most enduring product [2]. Today's digital reality is both good and bad, just like the "offline" world. By its very nature, it has many dark sides: the danger of exploiting users by violating their privacy and stealing personal data; taking advantage of children; spreading rumours, fabrications, defamation and other misinformation; manipulation of user behavior through social networks, etc.[1]. Research shows that there is a two-way process - extroverts tend to make more friends online, while introverts feel even more disconnected from the rest of the world [3].

Communication (communico - connect, connect, Latin) is a process of social interaction carried out through the mutual exchange of information, ideas, relations, through the use of symbols, signs, actions and images, as well as other verbal and non-verbal elements of speech and the writing.

Communication is an integral part of the other elements of the management process. Indeed, it is only through communications that management carries out its functions related to planning, organization, motivation and control.

The exchange of information carried out by the manager is essential to the planning process. Without accurate data and information, managers cannot formulate relevant plans and only through the process of communication do they bring them down the organizational hierarchy for implementation.

Managers must communicate to organize. The organization aims to combine certain activities that must be carried out to achieve the goals defined in the general plan.

Communication is always a two-way process, and although managers are usually seen as its initiators, with others listening and receiving information, managers spend most of their time receiving the product of communication, i.e. information.

It should be pointed out that the process of communications has different meanings in different spheres.

In other areas, to which all services, including tourist services, can reasonably be attributed, communications are not only part of the management process, but essentially constitute part of the product offered to consumers.

It is no coincidence that one of the first places in the analysis of users' opinions about a certain destination is their opinion about the quality of service when visiting a certain destination.

Therefore, the determination of the main trends that characterize the tourism activity in the modern stage of its development is important for the analysis of the changes in communications in the field of tourism.

Very often the consumer has already purchased the product or service and so the focus is on ensuring that both companies and consumers remain engaged and active. Most importantly, the company learns what the user likes, making them active and engaged in one way or another. In this model, the better products or services engage customers, the more the company will prosper.

The individual brands and the companies that create them are guided precisely by the new experiences that are the basis of the user's interaction with the experience.

Consumer behavior is changing, as are consumer experiences.

Today, the main preferences are concentrated on well-known products, and in the first place, such elements in the tourist destination as ensuring the security of tourists, understood in an extremely wide range, are starting to emerge.

Fig. 1 Sustainable tourism worldwide

Source: Vacation travel behavior in Europe/ https://www.statista.com/study/27521/holiday-travel-in-europe-statista-dossier/

Today, there are significantly fewer accidental trips, as consumers put in the first place not so much the unusualness of the respective destination, but the questions regarding the provided infrastructure allowing fast transportation, the absence of social, political or military conflicts not only in the specific destination, but also in the immediate vicinity of it, as well as the level of health care characteristic of the respective destination.

It is clear from the figure that consumers in the tourism sector pay more and more attention to sustainable tourism and strive to make exactly such trips. In the future, it is this behavior that will be key in building marketing strategies in the tourism business.

III. Results and discussion

In particular, several key trends and changes in consumer behavior deserve attention, which can be systematized as follows:

∗ First, striving for a modest and healthy way of life (clean living). It is expressed in a minimalist lifestyle, in which moderation, orderliness, integrity and harmony are key guidelines of behavior. Incorporating artificial intelligence into customer service. Artificial intelligence in digital communication with customers in retail finds its greatest application through the implementation of chatbots in service.

∗ Extensive use of influencer marketing. Influencer marketing uses online influencers to reach and influence potential consumers.

∗ Growth of the Internet of Things and the analysis of large databases.

Two main trends should be pointed out, which are characteristic not only of the tourism model that exists today, but will obviously predetermine its development in the coming years.

These main trends are the digitization and the use in tourism practice of large databases, as well as the need in the practice of modern tourism to increasingly actively attract social groups within a certain destination.

Both trends have a direct and immediate relation to communications within the tourist activity.

Thus, the process of digitalization and the use of large databases implies that before the realization of immediate communication, "communication in virtual space" is realized. It significantly defines the "framework" of actual communication, building cognitive and emotional expectations on the part of users.

The analysis of the peculiarities, both of the psychological characteristics of today's tourists and the trends characteristic of tourism itself, give reason to consider the following changes in the communication processes.

∗ In the first place, the expansion of communications, their complexity and comprehensiveness should be indicated.

∗ Considering the impact of different communication channels and conducting "parallel communication processes".

∗ Need to build a communication framework.

IV. Conclusion

On the basis of digitization and information channels, specific communication styles are formed, which give individuality to the communication process of a given tourist company and in most cases become a successful component of its marketing policy.

All this leads to a change in the offer of the tourist product. If in the last century, the tourist product was offered based on the principle: we offer what we can provide, then today, the tourist product must be offered according to the principle: we provide what the consumer is looking for, in full integration with nature and the interests of local communities.

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Seasonal Dynamic In Co₂ Absorption Capacities Of Natural Grasslands

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Abstract. **A world problem of increasing importance is the continuous increase of greenhouse gases and the accompanying global warming. Growing global industries, excessive use of fossil fuels, along with deforestation and agriculture, which are major greenhouse gas polluters, are cited as the main causes. Of the greenhouse gases with the largest share, but also the possibility of control is CO_2. This gas is vital for the growth and development of plants and, through them, is included in the continuous carbon cycle. On this basis, strategies for sustainable development in agriculture are built since this is one of the main sectors contributing to the increase in carbon emissions. The present study tracked the seasonal dynamic of CO_2 uptake by natural grasslands positioned at two altitudes by measuring photosynthesis and plant and soil respiration. A significant variation in CO_2 uptake capacity was observed depending on the climatic conditions.**

Keywords: Canopy photosynthesis, CO_2, greenhouse gas, pastures, soil respiration

I. INTRODUCTION

Greenhouse gases contribute to global warming when present in large quantities in the atmosphere. For the period 1906-2005, an increase in the average global temperature near the earth's surface by an average of 0.74 ± 0.18 °C was found (IPCC, 2007). The main greenhouse gases (GHGs) are water vapor (H_2O), which accounts for 36-70% of the greenhouse effect, carbon dioxide (CO_2) - 9 - 26%, methane (CH4) - 4-9%, and ozone (O_3) - 3 - 7% (Spahni Renato et al. 2005; Siegenthaler, Urs, et al. 2005).

The greenhouse gases whose concentration has increased since the beginning of the Industrial Revolution are carbon dioxide, methane, tropospheric ozone, freon, and nitrous oxide. Since 1750, the concentrations of carbon dioxide and methane have increased by 36% and 148%, respectively (Petit et al. 1999).

According to the World Meteorological Organization, the temperature in 2010 was - (0.53 °C) higher than the annual average, making it the warmest year since the early 19th century. The second warmest year was 2005 - (0.52 °C) and 1998 - (0.51 °C), higher than the average annual temperature, although the differences between them are not significant (Sutton, Rowan, et al. 2007; Ehhalt et al. 2001). Carbon dioxide is released into the atmosphere mainly through the burning of fossil fuels, agriculture, animal husbandry, decomposition of organic matter, volcanic activity, plant, and soil respiration. It is one of the main causes of the greenhouse effect and climate change. Although other gases also cause global warming, CO_2 is responsible for about three-quarters of global warming.

The Intergovernmental Panel on Climate Change has published a special report on global warming of 1.5 °C, which warns that if the current rate of greenhouse gas emissions is not reduced, major changes will occur by 2040, as the planet warms by 1.5 °C (Brigham-Grette et al. 2006).

The effects of global warming on the environment and man are numerous and varied. One hypothesis with a huge impact is that global warming will significantly weaken or even stop the Gulf Stream due to the release of too much freshwater from melting ice in the North Atlantic (Weart, R. Spencer 2008, 2014; IPCC, 2007).

The increased concentration of GHGs in the atmosphere affects plants' growth and physiological activities (Sharma et al., 2014; Domec et al., 2017; Tausz et al., 2017; Gamage et al., 2018). From the plant leaf physiology point of view, the rate of photosynthesis usually

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increases, while stomatal conductivity and transpiration rate decrease with increasing CO_2 concentration (Aspinwall et al., 2018; Paudel et al., 2018; Pastore et al., 2019). In terms of leaf morphology and anatomy, CO_2 increases the thickness, mass, and area of plant leaves (Ainsworth and Long, 2005; Leakey et al., 2009), reduces stomatal density (Woodward and Kelly, 1995), increases mesophilic tissue (Lin et al., 2001; Smith et al., 2012).

Soil respiration (SR) contributes to the most significant release of CO_2 into the atmosphere. It results from the metabolic activity of plant roots, soil microorganisms, and agricultural activity (Högberg & Read 2006). In turn, these events significantly impact SR through changes in the soil environment (e.g. soil water content and temperature) (de Araujo Santos et al., 2019; Huxman et al., 2004; Knapp et al., 2015; Nielsen and Ball, 2015). Therefore, many studies have been conducted to study the reaction of SR at different soil moisture contents. Apart from the different water regimes, other climatic elements (e.g. air temperature and solar radiation, etc.) also change the SR. Monitoring of SR is needed to clarify its impact on the climate and to make prescriptions for crop and tillage systems. The search for innovative and easy-to-implement methods for monitoring greenhouse gas ecosystem processes is crucial for the planet's sustainable development.

The research aims to adapt a methodology for monitoring the dynamics of CO2 fluxes in natural and artificial grasslands. The methodology establishes the influence of climate on the processes of photosynthesis and respiration of plants and soil in grass communities by tracking these processes during the different annual seasons and a certain time range. The results can help to develop and implement sustainable agricultural practices.

II. Materials and methods

Methodology

A camera was constructed to determine the activity of absorption or release of CO_2 from a unit area of the monitored objects for a limited period. The camera has the following dimensions: length - 100 cm, width - 25 cm, height - 25 cm, with internal volume - 0.0625 m^3 and area - 0.25 m^2, made of Plexiglas, is presented in Fig.1. The monitoring analysis for the detection of CO_2 includes a gas analysis system "PTM600" Multifunction Meter for determining the amount of CO_2, which can measure up to 6 types of gases simultaneously. It has a sensor for temperature and humidity. This analysis makes it possible to trace the dynamics of the absorption and release of CO_2.

The model presented here is based on the assumption that all other potential errors in the closed chamber, which are unrelated to the inherent changes in the concentration in the closed chamber space, are insignificant due to the careful planning of the experiment. This means that during the setup of the chamber, the air and soil temperature, the photosynthetically active radiation, and humidity are considered constant and approximately equal to the ambient conditions. When covering a vegetative surface of the soil with a closed chamber, the concentration of CO_2 changes over time in the chamber space, which is the effect of several separate processes with partially opposite directions Fig. 1. The free space is isolated from the surrounding atmosphere from the walls of the chamber. Depending on the time of the analysis - day or night, there is an increase or decrease in the concentration of CO_2. When measuring soil respiration, the soil surface is freshly cleared from the vegetation, and CO_2 is released from the soil (FSr) into the chamber. When measuring soil covered with plants, since they photosynthesize (Fph) during the day but respirate (Fr) during the night, in the chamber, the concentration of CO_2 could decrease or increase, which means that plants absorb or release CO_2.

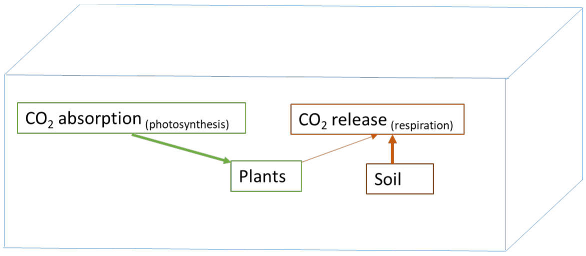


Fig. 1. Schematic description of CO_2 flows in the chamber, representing the net flow of CO_2. The scheme is a modification of one published by Kutzbach et al., 2007.

In the presented experimental setup, the change in the CO_2 content was traced at different times of the day, during different seasons, and on fields with different plant species compositions. To determine soil respiration (CO_2 release), the measurement was performed in field zones with freshly removed vegetation cover. That illustrates the CO_2 release during agricultural soil tilling. The measurement was performed in field zones with a comparable vegetation type to determine plants' photosynthesis or respiration (CO_2 absorption or release). All measurements were done in triplicates. The time range for the measurements was from 9:00 to 10:00 a.m. for photosynthetic or soil respiration and from 23:00 to 00:00 for respiration measurements (of plants and/or soil). Climatic data such as air temperature, humidity, and precipitation were collected for the same time ranges in which the measurements were made as the monthly average value was used for precipitation. Each measurement in the chamber was performed twice, immediately (initial) and 10 minutes after placing the camera. The limitation in the measurement duration is imposed by the fact that with a longer exposure, the humidity in the chamber increases significantly, which can affect the measurement's quality. The change in CO_2 concentration is determined relative to the external concentration, equal to the initial one, according to the formula Fnet = (Fph + Fsr + Fr)t0 - (Fph + Fsr + Fr)t10, where the "Fxs" are the different types CO_2 flows. The results are expressed per area of one square meter in one second CO_2 mg/m^2/s.

Object of investigation

The method was tested in two different areas, differing in altitude, to compare the CO2 absorption capacity of the vegetation in them. The measurements were carried out in May, July and October for three consecutive years. These months were chosen as representative of the different stages of vegetation development, namely active plant growth, summer retention and the onset of autumn changes.

Area 1 - Plovdiv

Location: On the land of Plovdiv, 1000 meters east of Plovdiv with exposure south-southeast and altitude:156 m. GPS: 42008`08``N 24048`28``E. The density of the soil cover is 100% composed of cereals and deciduous grasses.

Description: Artificial pasture from AU-Plovdiv, managed and used for grazing sheep from the Department of Animal Husbandry. Created for educational purposes.

Area 2 - Devin

Location: The plot is located in the western Rhodopes, 5 km northeast of the town of Devin, the boundaries of the municipality of Devin in the Smolyan region with south exposure, the tilt of 10 °, and an altitude: 1145 m. GPS: 42045`10``N 24027`07``E. The density of the soil cover is 85%, composed of cereals, deciduous grasses, legumes, sour grasses, and weeds. Bare soil is 15%. Description: The area is located about 600 m from the Kehayovi eco-farm. The pasture is used for grazing sheep.

Statistical analysis

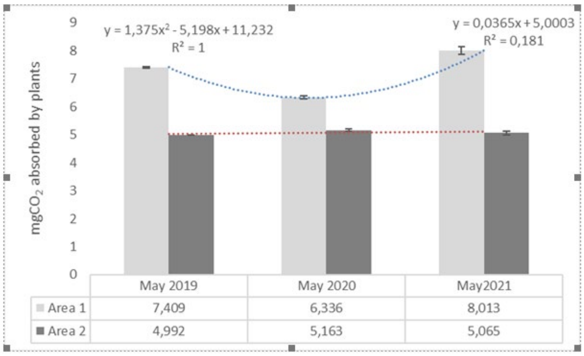
The data from the measurement with the gas analyzer are presented in ppm and then precalculated in mg. The data processing was performed with the statistical program SPSS 26.0. Data reported in the experiment was the mean of 4 replicates. Subsequently, Tukey's test was conducted to determine the significant differences among the values.

III. RESULTS AND DISCUSSION

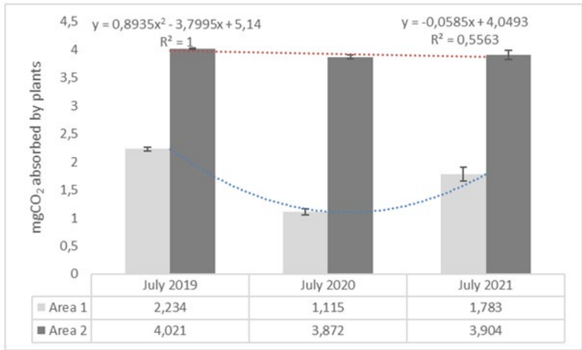
The results presented in Table 1 and Fig. 2 summarize the measurements of CO_2 flows in two pasture areas over three years. The activity of photosynthesis and respiration from the plant surface during the day, as well as respiration at night, were monitored. Similarly, soil respiration without vegetation was recorded during the day and at night, according to the description of the material and methods. As expected, the highest activity of photosynthesis and corresponding absorption of CO_2 was observed in May, when the vegetation cover is in active growth and the soil has sufficient water reserves (Fig. 2A). In the mountainous region (Area 2), CO_2 absorption during May shows a stable linear trend over the three-year period, which corresponds to the relatively stable daily temperatures at the time of measurement (Fig.3), as well as to the more substantial monthly precipitation characteristic of this area (Fig. 4).

In the years' basis comparison, the CO_2 absorption in area 1 shows a clear decline in all three months of measurement for 2020. These results correspond to the monthly precipitation data, which are the lowest for the Plovdiv region in 2020 (Fig. 4).

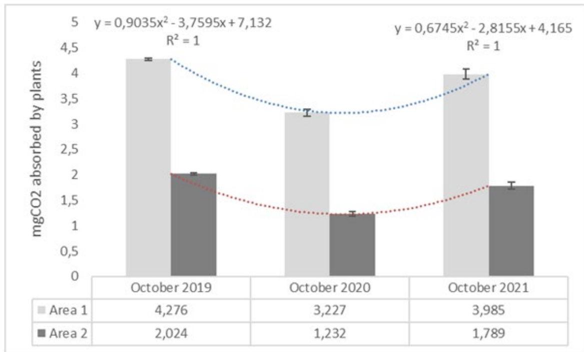
Usually, during the hot months, there is a significant decrease in the photosynthetic activity of vegetation, which is more pronounced in Area 1 (1,115 mgCO2 mg/m2/s) compared to the results obtained in Area 2 (3,872 mgCO2/m2/s). This can be explained by the altitude and the amount of precipitation, which are traditionally lower than in mountainous areas (Fig.3) and typically higher temperatures in Area 1 (Fig.2).



A)



B)

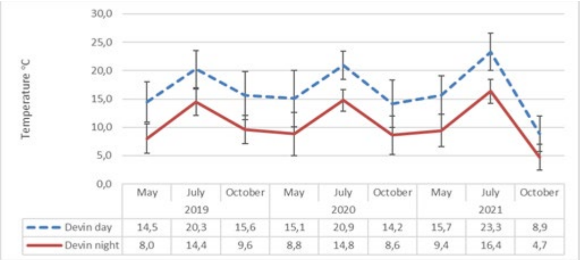


C)

Fig. 2. Comparative analysis of CO2 absorption in two grassland Areas during the growing season. The values represent the amount of CO2 in milligrams absorbed by vegetation through photosynthesis, expressed per area of one square meter in one second (mgCO2/m2/s). A) CO2 absorption in May, B) CO2 absorption in July, and C) CO2 absorption in October.

During the measurements in October, the opposite trend was observed – photosynthesis activity is lower in Area 2 than in Area 1. This may be due to the earlier dormancy of plants in mountainous areas due to adverse weather conditions.

A)



B)

Fig. 3. Temperature values recorded in both areas – A) Area 1 – Plovdiv, B) Area 2 - Devin. The day temperatures were measured at 9:00 a.m., and the night temperatures at 11:00 p.m., i.e. at the time when the gasometric analyzes were conducted.

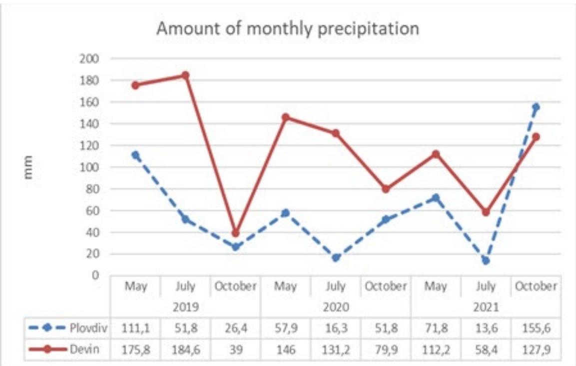


Fig. 4. Average monthly precipitation values in the two measurement areas - Area 1 - Plovdiv and Area 2 – Devin.

Regarding respiration as a process that releases CO_2 into the atmosphere, the results are very indicative (Table 1). Soil without vegetation is a serious factor contributing to increased carbon emissions. For this reason, freshly plowed fields are considered a serious source of CO_2. During the day, soil dwellers had increased respiration, as the strongest CO_2 release was reported in July in Area 1 (12,203 $mgCO_2/m^2/s$) (Table 1). The high temperatures in this month and the sunlight stimulate the activity of soil microorganisms, affecting the values of CO_2 released. The release of CO_2 from the soil at night is also to be considered. Depending on the metabolic activity of the soil microorganism populations and the environmental conditions, the values of released CO_2 vary. They are lowest in Area 2 (Devin) in the month of May (the lowest measured value of 0.185 $mgCO_2$ m^2/s is for the year 2021) because the soil in the mountainous areas is still very cold due to the past winter months, and the metabolic processes are not particularly active. With the increase in temperature in July, higher values of released CO_2 were recorded again in Area 2 (5,357 $mgCO_2/m^2/s$). As metabolic processes are affected by temperature, the observed results for soil respiration are consistent with it.

Table 1. Comparative analysis of CO_2 release flux in two grasslands during the growing season. The values represent the amount of CO_2 in milligrams released into the atmosphere through respiration, expressed per area of one square meter in one second ($mgCO_2/m^2/s$).

Measurement		Day		Night
Area	Date (month/year)	Released CO_2 by soil respiration (soil without vegetation)	Released CO_2 by plant respiration	Released CO_2 by soil respiration (soil without vegetation)
Area 1 Plovdiv	05/19	3,038b	4,984b	3,986c
	05/20	2,816c	5,867a	4,576ab
	05/21	3,265a	5,923a	4,899a
	07/19	11,086c	1,654a	2,003a
	07/20	12,203a	0,763c	0,939c
	07.21	12,101b	1,035b	1,652b
	10/19	2,145b	2,784b	3,128b
	10/20	2,288a	3,813a	3,461a
	10/21	1,967c	2,939b	2,689c
Area 2 Devin	05/19	4,311b	5,023b	0,513a
	05/20	4,459b	4,869bc	0,235b
	05/21	5,002a	5,921a	0,185c
	07/19	5,782a	6,345c	4,801b
	07/20	5,925a	6,981b	4,576c
	07/21	5,038b	7,012a	5,378a
	10/19	1,022b	0,219b	2,934b
	10/20	0,997b	0,176c	3,285a
	10/21	1,216a	0,323a	2,433c

Normally, plants breathe at night in addition to soil organisms. The intensity of this process depends on many factors - plant age, physiological condition, the presence of stress from injury, low or high temperatures, drought, season, etc. The activity of this process follows the physiological development of plants. In Area 1 in the month of May, the vegetation is growing, and the environmental conditions are favorable - the temperatures are not too high, and there are still water reserves in the soil. This determines the higher values of CO_2 released through respiration (5.923 $mgCO_2/m^2/s$). As the temperatures rose in July, there was a decrease in the respiratory activity of the vegetation in Area 1, as the vegetation died due to the very low rainfall values for this region (Fig.4). At the same time, in Area 2 (Devin) increased values of CO_2 released by plants were recorded for the month of July, in which there is active growth of vegetation supported by a sufficient amount of soil moisture. The lowest values for CO_2 released by plants through respiration were obtained for October in Area 2 (0,176 $mgCO_2/m^2/s$) because at this time of the year, in the mountainous regions the plants are at quiescency, and their metabolic processes are reduced to a minimum.

Pasture grasses assimilate and accumulate carbon in the form of organic matter used to grow aerial parts and the root system during their life cycle. As a result of the seasonal dying of different plant parts (aboveground and roots), organic matter passes into the soil and takes part in the soil carbon cycle. Some of this organic matter is used by soil dwellers as a food source and subsequently released as CO_2, referred to as soil respiration. Another part of the organic matter undergoes mineralization and enriches soil fertility. For this reason, grasslands can play a key role as sinks of CO_2 and the carbon cycle (Silveira et al., 2018). Proper pasture management can also promote carbon storage in the soil. Most techniques used to improve forage production promote carbon inputs to the soil and increase soil carbon sequestration. For instance, fertilization, irrigation, and grazing management can boost plant productivity while promoting soil carbon sequestration (Silveira et al., 2018, Whitehead, 2020).

IV. CONCLUSIONS

The methodology presented here is suitable for measuring pastures in all regions of the country. The obtained data are reliable and can be used for analysis, conclusions, and recommendations. On the other hand, they can be traced to the influence of climate change on photosynthesis and respiration, which are the main biological processes associated with the C cycle. The methodology can be used to build a system of sustainable pasture management, thus affecting the reduction of greenhouse gas emissions.

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Evaluation of oregano (Origanum vulgare L.) accessions by complex of functional traits

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Abstract. **During 2012-2020, 44 oregano (*Origanum vulgare* L. ssp. *vulgare*) accessions had been described at the *ex situ* collection of aromatic and medicinal plants (N 56º39´45.3´´; E 23º45´15.2), located at the Latvia University of Life Sciences and Technologies. The accessions were evaluated for morphological traits, growth and yield parameters, phenological properties, biochemical indices, plant resistance to diseases and pests, winter hardiness etc., using international Draft Descriptor List *Origanum vulgare* L. In our study, multi-criteria analysis was used to assign an overall value to each plant material as well accessions were grouped by complex of functional traits. In total, eleven accessions No. 2, 3, 12, 14, 17, 18, 24, 28, 29, 43 and 44, which had high evaluation of morphological and phenological properties, yield components, resistance to diseases and pests as well as winter hardiness, have the best growing potential in commercial plantations._Accessions No. 3, 9, 11, 14, 17, 23, 24, 26, 35 and 42, which were characterised by rare and unique morphological indices, high winter hardiness as well as resistance to diseases and pests, have the best potential as ornamentals. Accessions No. 23, 29 and 41 were selected as the best for food because of specific parameters, including yield`s quality (especially by content of C vitamin). Grouping or oregano accessions by complex of functional traits is important for selection the most valuable of them with specific features needed for cultivation, processing and trade.**

Keywords: ***oregano, accessions, variability, traits.***

I. INTRODUCTION

Oregano (*Origanum vulgare* L.) is multifunctional aromatic and medicinal plant that has been utilised in folk medicine for thousands of years in the Baltic countries [1]. Nowadays, fresh, dry or processed, oregano is widely used in culinary, medicine, veterinary medicine, pharmacy, aromatherapy, cosmetics, fragrance industry, floristics and decoration etc. [2]. By European Cooperative Programme for the Plant Genetic Resources, oregano is defined as one of priority species of aromatic and medicinal plants [3]. In Europe, including Latvia, wild populations of oregano are severely depleted because of the wide use of raw material. That is why cultivation of oregano is important for keeping a local genetic resource of oregano as well as for meeting the needs of herbs' production. Depending on marketing needs, productivity of oregano accessions can be evaluated by different criteria. For cultivation, food or ornamental horticulture, oregano accessions with specific valuable indices should be selected.

This study aimed to perform multi-criteria analysis to assign an overall value to oregano accessions from the *ex situ* collection of genetic resources as well as to group them by the complex of functional traits.

II. MATERIALS AND METODS

During long-term investigations (2012-2020), plant material of 44 oregano (*Origanum vulgare* L. ssp. *vulgare*) accessions from the *ex situ* collection of aromatic and medicinal plants (N 56º39´45.3´´; E 23º45´15.2´´), located at the Laboratory of Horticulture and Beekeeping, Institute of Soil and Plant Sciences, Faculty of Agriculture and food technology, Latvia University of Life Sciences and Technologies, was described. Initially, during 2001–2006, accessions were collected from local natural habitats in different regions of Latvia [4]. During the investigations in *ex situ* collection, the accessions were evaluated for morphological traits, growth and yield parameters, phenological properties, biochemical indices, plant resistance to diseases and pests, winter hardiness etc., using Draft Descriptor List *Origanum vulgare* L., prepared by the European Cooperative Programme for Plant Genetic Resources [5].

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In this study, multi-criteria analysis was used to assign an overall value to each plant material [6]. The formula was used:

$$SD = \sum_{i=1}^{N} \omega_i \left(I_i - x_{vid,\ i.}\right) / s_d \qquad (1)$$

Where:
SD – value of accession;
i – quantitative feature;
I_i – desired feature value of trait;
$x_{vid,\ i}$ – actual value of trait;
ω_i – feature contribution coefficient;
S_d – standard deviation;
N – count of traits.

Low value of accession indicates that the genotype is closer to the desired traits.

By the suitability for cultivation in commercial plantations, ornamental horticulture or food, plant material was evaluated according to the desired characteristics, important for achieving a certain goal. Accessions were grouped by complex of functional traits, using the received data of multi-criteria analysis.

For **cultivation in commercial plantations** (including for pharmaceutical purposes), the suitability of oregano accessions was evaluated according to 16 traits, N = 16. Traits were divided into 4 groups:

- morphology (ω_i 20%): erect habitus, plant height >50 cm, count of stems >100 stems per plant, count of internodes from the soil level till the inflorescence <5, length of inflorescence at least ½ from total plant height, width of inflorescence >10 cm, dense flowering;
- phenology (ω_i 20%): early (before 2nd decade of June) or late (later than 3rd decade of July – start of August) full flowering, duration of flowering longer than 40 days;
- yield and yield quality (ω_i 30%): fresh biomass >500 g per plant, dry biomass at least 30% fresh biomass), relatively higher content of essential oils and C vitamin;
- resistance to adverse conditions (ω_i 30%): high winter hardiness (0-4% of plants are damaged or dead), no visible symptoms caused by pests or diseases.

For **ornamental horticultural needs** (including cultivation in rock gardens, containers, kitchen garden), the suitability of oregano accessions was evaluated according to 13 traits, N = 13. Traits were divided into 4 groups:

- morphology (ω_i 25%): prostrate habitus, plant height <25 cm, count of internodes from the soil level till the inflorescence <5, dense foliage and dense flowering, unique color of petals (for example, white);
- phenology (ω_i 20%): different flowering period, duration of flowering longer than 40 days;
- yield and yield quality (ω_i 20%): relatively higher content of essential oils, relatively higher content of phenolic monoterpenes (indicates an expressive aroma);
- resistance to adverse conditions (ω_i 35%): high winter hardiness (0-4% of plants are damaged or dead), no visible symptoms caused by pests or diseases.

For **food** (including salad recipes), the suitability of oregano accessions was evaluated according to 9 traits. Traits were divided into 4 groups:

- morphology (ω_i 15%): count of stems >100 stems per plant, dense foliage, intensive green color of leaves;
- phenology (ω_i 10%): early start of vegetation;
- yield and yield quality (ω_i 40%): fresh biomass >500 g per plant, relatively higher content of C vitamin;
- resistance to adverse conditions (ω_i 35%): high winter hardiness (0-4% of plants are damaged or dead), no visible symptoms caused by pests or diseases.

III. RESALTS AND DISCUSSION

In total, eleven accessions No. 2, 3, 12, 14, 17, 18, 24, 28, 29, 43 and 44, with high evaluation of morphological and phenological properties, yield components, resistance to diseases and pests as well as winter hardiness, have the best growing potential in commercial plantations (Fig. 1). Accession No. 29 (SD = 1.32) can be defined as the most valuable. Also, for accessions No. 12, 24 and 7 the value of SD was not higher than 2, respectively 1.58, 1.84 and 1.99.

Accessions No. 3, 9, 11, 14, 17, 23, 24, 26, 35 and 42, which were characterised by rare and unique morphological indices, high winter hardiness as well as resistance to diseases and pests, have the best potential as ornamentals (Fig. 2), SD was from 3.00 till 4.00. For other accessions, SD was not higher than 5, excluding No. 1, 2, 16, 22 and 43 (SD was from 5.00 till 6.00).

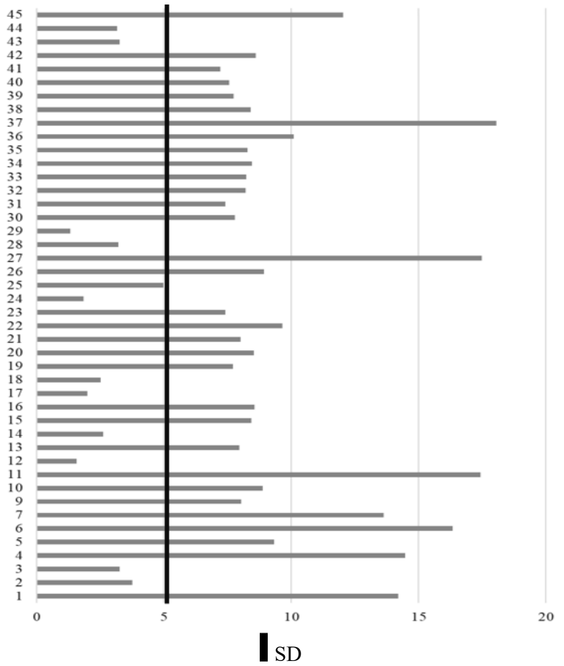

Fig. 1. Evaluation of oregano accessions by suitability for commertial cultivation.

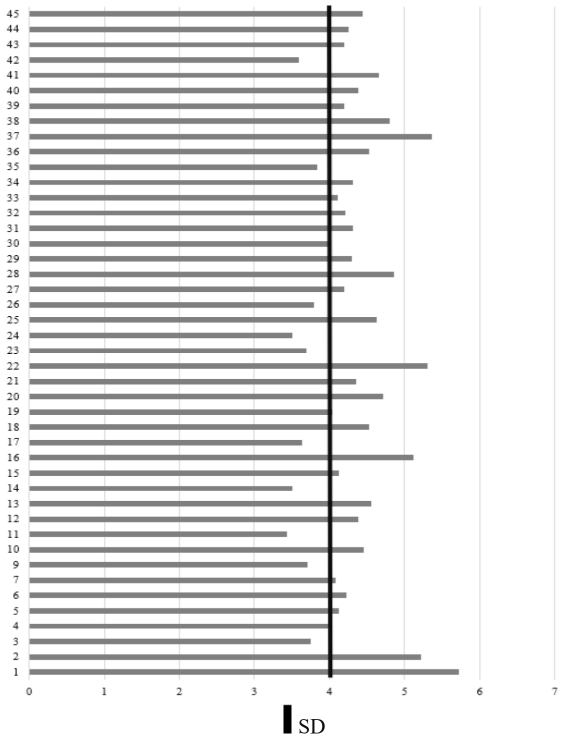

Fig. 2. Evaluation of oregano accessions by suitability for ornamental horticulture.

Accessions No. 23, 29 and 41 (SD was till 0.6, for No. 29 SD = 0.5) were selected as the best for food (Fig. 3), especially because of the content of C vitamin. By these indices, accessions No. 2, 5, 12, 42 ad SD respectively 0.7, 0.8. 0.8 and 0.7.

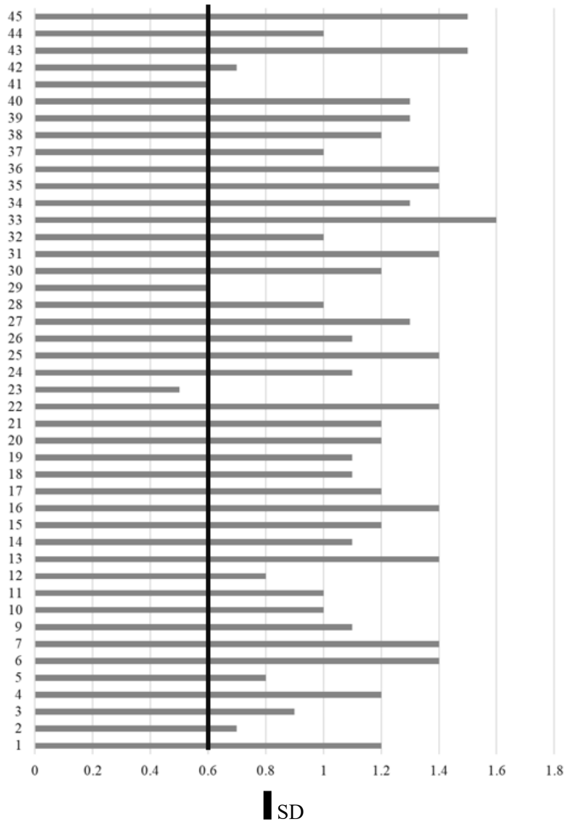

Fig. 3. Evaluation of oregano accessions by suitability for food.

In scientific literature, there is a lack of information about the use of multi-criteria analysis for evaluation the productivity of horticultural crops, including aromatic and medicinal plants. As well as only some research works present data about the differences between oregano accessions. Usually, only some quantitative and qualitative indices are compared [7] – [9]. Mostly, all described morphological or chemical indices are economically important indicators for selecting accessions suitable for cultivation [4], [7] – [10]. But for oregano, the indicators of productivity can be very specific, depending on marketing needs. By Kampuss, method of multi-criteria analysis can help to select accessions by a group of criteria, including the cases, that these criteria cannot be compared with each other [6]. Method of multi-criteria analysis is convenient; it can be used when for different measures separate scales should be used. Also, it is possible to group these features as well as to assign a significance coefficient to an individual characteristic or a group of characteristics.

IV. Conclusions

Multi-criteria analysis can be used for evaluation of plant material from *ex situ* collection. Grouping of oregano accessions by complex of functional traits is important for selection the most valuable of them with specific features needed for cultivation, processing and trade.

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*E*nvironmental *Problems of Ukraine During the War Period: Ways of them Overcoming*

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Abstract. **The article presents environmental problems of Ukraine. Attention is focused on the problems of the natural environment, which existed before (the Chernobyl disaster, disposal of radioactive waste, processing and cleaning of mixers, pollution of water resources, etc.) and greatly worsened due to military actions. In addition, a number of new environmental threats associated with war are listed. The territory of Ukraine is subjected to bombardment and destruction every day, one by one, once inhabited cities and villages disappear from the map, leaving behind either a burnt ruin, the products of combustion of which rise into the atmosphere and spread around the world, or a putrid supply, the products of which decay enter the soil and with underground water or vapors pose an irreparable threat to the entire environment and health. The article emphasizes ecological migrations caused by the war.**
In the first place in Ukraine is the safety of the population, protection against enemy attack for the preservation of life. Unfortunately, environmental problems have receded into the background, but they are not devalued, but remain promising on the way to victory. The Ministry of Environmental Protection and Natural Resources of Ukraine keeps statistics of environmental damage caused to Ukraine due to the war. Considering their depth and irreparability, these problems will have to be solved for more than a dozen years. And this, in turn, sets priority tasks that can already be solved today in the safer territories of our country. The publication highlights international connections and projects that contribute to the improvement of the ecological state and will be able to ensure the restoration of the environment in the post-war period. The article presents a survey of the population of Vinnytsia, Khmelnytskyi and Lviv regions regarding their actions to overcome the environmental crisis; implemented measures and prospective programs contributing to the improvement of the environment are presented. Attention is drawn to modern environmental education and volunteer nature protection activities of citizens of Ukraine.

Keywords: ecological problems, threat to the environment, overcoming the ecological crisis.

I. INTRODUCTION

Ukraine has long suffered from environmental problems, such as emissions of harmful gases into the atmosphere, pollution of water bodies by emissions from factories and plants, pollution of chernozems by fertilizers and pesticides, waste disposal. The development of metallurgy (mining and mining, chemical and metallurgical, machine-building, fuel and energy, construction, agro-industrial) annually affected the ecological situation in Ukraine. The explosion of the fourth nuclear reactor at the Chernobyl nuclear power plant became a major environmental crisis for Ukraine. It led to radiation contamination of more than 200,000 square kilometers. In Ukraine, there is still a 30-kilometer exclusion zone, an area deprived of free access, which has undergone intense contamination with long-lived radionuclides.

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With this in mind, Ukraine has always taken an active part in environmental activities and tried to support global environmental policy. It ratified and supported a number of conventions, in particular: the Convention on the Protection of Biological Diversity (Rio de Janeiro, 1992), the Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction (Paris, 1993), the Convention on Nuclear Safety (Vienna, 1994), Stockholm Convention on Persistent Organic Pollutants (Stockholm, 2001).

A large number of Ukrainian and European scientists studied the issue of overcoming the ecological crisis. H. Jonathan in the early 1990s characterized the global environmental crisis and insisted on the aggravation of the problems of the natural environment. In particular, he claimed that the emission of carbon dioxide causes great damage to the atmosphere, which in turn affects the destruction of the ozone layer [4]. The writings of C. Vlek, S. Clayton, P. Devine-Wright, P. Stern, L. Steg, L. Whitmarsh, A. Carrico, M. Bonnes emphasize the need to change the global thinking of mankind in order to overcome the ecological crisis. The authors claim that a humane ecological worldview affects the behavior of an individual in relation to the natural environment, stimulates it to environmental protection activities and life activities in harmony with nature [9], [2]. O. Mudrak emphasizes the importance of organizing and carrying out a number of environmental activities and involving the population in them for the real awareness of nature's problems and overcoming them [5].Focusing on the general environmental problems published by the Earth.ogr website in 2024, we determined that the most typical for Ukraine are: global warming, plastic pollution, the problem of food waste disposal, atmospheric pollution, a decrease in the amount of drinking water, a decrease in biodiversity, deforestation , soil degradation, etc. [1].Ye. Zasiadko, commenting on the ecological situation in Ukraine, claims that it will be impossible to restore some land plots or it will take hundreds of years; it is difficult to calculate the damage caused, especially in the occupied territories, however, assessing the general situation, it was established that Mykolaiv and Kharkiv regions are leading in the number of documented cases of negative impact on the environment in the territory controlled by Ukraine. “The global danger is connected to nuclear threats. Events at the Zaporizhzhia NPP, fires and the occupation of the Chornobyl Exclusion Zone, and missiles flying above the South Ukrainian NPP cause great concern. If any big incident happens at the Zaporizhzhia NPP, the resulting radiation pollution could affect not only Ukraine, but European countries, as well. It could be akin to a second Chornobyl disaster, and also affect the Black and, consequently, Mediterranean Seas” [3].

However, the full-scale invasion of russia on the territory of Ukraine on February 24, 2022 caused great damage to the natural environment. Because of military operations, it is not possible to fully assess the environmental situation, although the results are recorded every day. Dozens of cities and villages are wiped off the face of the earth, the territory of our country is repeatedly bombarded with cluster and phosphorus bombs, military actions affect the population of animals and plants, in particular, the explosion at the Kakhovka hydro-electric station and the massive flooding of several Ukrainian villages became a devastating disaster. With the unfolding of the war, it becomes unequivocally clear that the longer it lasts, the more ecological cover is deployed, and the more time it will take to eliminate it.

The purpose of the article: to generally characterize the current ecological situation in Ukraine and to predict ways to solve it.

The goals of the study are to model the ways to overcome the ecological crisis in Ukraine in the post-war period based on summing up the results of the theoretical generalization of the indicated issue.

II. MATERIALS AND METHODS

The aggravation of the environmental crisis in Ukraine affects the global environmental crisis in general and may lead to irreversible consequences. In the studies of O. Omelchuk and S. Sadogurska, the following environmental problems of Ukraine during the war were identified:

- *Impact on the landscape:* part of the forests of Ukraine (Donetsk, Luhansk, Zaporizhzhya, Kherson regions) are under the influence of the occupiers, their territory is littered with ammunition, which will pose a threat to the population for more than a dozen years. In addition, wood is used for the construction of fortifications, cooking and heating.
- *Loss of biodiversity.* Due to hostilities, migration routes of migratory birds are disrupted: Azov-Black Sea - with the highest concentration of migratory birds in Ukraine; Polissky latitudinal – along the Polissya forest belt and in the north of the Forest Steppe; and the Dnieper Meridian Migration Path, which runs along the Dnieper River and its tributary the Desna. Along these routes, migrating flocks of geese, ducks, swans, and cranes used to stop for rest and food, but now it has become impossible, many of them die when they get into the combat zone or do not have the opportunity to rest, which also affects them badly. In particular, in the forests, animals that fall on scattered explosive shells are destroyed, constant hostilities have a negative effect on the population of offspring, the breeding of baby animals.
- *Fires in ecosystems.* Due to explosions, detonations of oil stations and gas pipelines, territories are ignited, which leads to the release of harmful substances into the atmosphere, soil and water bodies. This leads to the pollution of a large number of territories, which negatively affects all living things.
- *Chemical pollution.* During the detonation of rockets and artillery shells, a number of chemical compounds are formed: carbon monoxide (CO), carbon dioxide (CO_2), water vapor (H_2O), brown gas (NO), nitrous oxide (N_2O), nitrogen dioxide (NO_2), formaldehyde (CH_2O), vapors of cyanic acid (HCN), nitrogen (N_2), as well as a large amount of

toxic organic matter, the surrounding soils, wood, turf, structures are oxidized. In the atmosphere, oxides of sulfur and nitrogen can cause acid rain, which changes the pH of the soil and causes plant burns, to which conifers are especially sensitive. Acid rain has a negative effect on the human body, other mammals and birds, affecting the condition of mucous tissues and respiratory organs.

- *Pollution of the seas.* The coastal zone of the Sea of Azov is covered with water mines that are encountered by marine life. In addition, during hostilities on the seas, ships sink, oil products are spilled, which negatively affect marine biocenoses, forming films on the surface of the water, which disrupts the exchange of energy, heat, moisture and gases between the sea and the atmosphere. In addition, they directly affect physico-chemical and hydrological conditions, cause the death of fish, seabirds and microorganisms. All oil components are toxic to marine organisms. Oil has another side property. Its hydrocarbons are able to dissolve a number of other pollutants, such as pesticides, heavy metals, which, together with oil, concentrate in the near-surface layer and poison it even more.
- *Soil pollution.* Explosions and detonations of agricultural machinery cause soil contamination with fuel and lubricants and other petroleum products. In soils contaminated with fuel and lubricants, water permeability decreases, oxygen is displaced, and biochemical and microbiological processes are disrupted. As a result, the water and air regimes and the circulation of nutrients deteriorate, the root nutrition of plants is disturbed, their growth and development are inhibited, which causes death.
- *Depopulation of cities and villages.* As a result of the military operations, more than a hundred Ukrainian cities and villages turned into wasteland. Their destroyed and bombed-out remains undergo oxidation, weathering, and rotting, and all this takes hundreds of kilometers. It is not soon to dispose of waste and clear the territory for the reconstruction of property, so it poses an ecological threat [6].

On the website of the Ministry of Environmental Protection and Natural Resources of Ukraine, 3,750 damages caused to the natural environment as a result of the war are recorded, of which: 622 cases of atmospheric pollution, 2,912 cases of soil pollution and 216 cases of water pollution, which in turn have many other consequences. As a result of military actions, 66,877 hectares of burned forests and other plantations were burned, which caused the release of about 54,685,316 tons of harmful substances into the atmosphere; the amount of burned oil, oil products and gas is 722,741 tons, which caused the release of 979,526 tons of harmful substances into the atmosphere; emissions of other pollutants into the air amounted to 98 tons. The area of littered land is 18,303,827 m², and the area of contaminated soil is 747,928 m². The mass of pollutants that got into water bodies is estimated at 1,693 tons, the mass of extraneous objects, materials, waste and/or other substances in water bodies is 36,205,704 kg, etc. [11].

In the course of the research, we used the following methods: analysis of scientific literature, analysis of statistical data of the Ministry of Environmental Protection and Natural Resources of Ukraine, analysis of the main environmental problems, population surveys.

349 respondents from Vinnytsia, Khmelnytskyi and Lviv regions took part in the survey. The purpose of the survey was to determine the readiness of Ukrainian citizens to change their way of life in favor of nature and to participate in overcoming the ecological crisis in the post-war period. The survey was conducted from December 2023 to February 2024. During the survey, respondents gave answers to 8 key questions.

Answering the question "Are you interested in environmental problems in Ukraine?", 196 citizens answered that they are very interested, 53 are interested from time to time, 73 people pay attention to those problems that are most often discussed in the mass media, 27 citizens are rarely interested in environmental problems . In the answers, the following phrases were most often heard: "even before the war, the issue of ecology worried me a lot, and now it is a hundred times more, if we do not stop military operations, our state will soon become unfit for life and will be a hotbed of global environmental problems"; "I have always been interested in healthy eating, and it is inextricably linked with ecology, today it is very difficult to grow ecologically healthy food, given the amount of harmful emissions into the natural environment"; "it seems to me that the issue of environmental security in Ukraine should be second only to the end of the war and the return of the territories".

To the question "How do you assess the current environmental situation in Ukraine?" 284 respondents answered that the situation is difficult, dangerous and needs a radical solution; 65 people indicated that the indicators of radiation, air and water quality still remain normal in the territory far from active hostilities, but the eastern part of Ukraine has worse indicators, and it is a matter of time when they will start to affect the whole of Europe and the world.

Difficulty answering the question "Can you name the main environmental problems of your region, city/village?" the respondents did not have any. In the Vinnytsia region, the citizens mentioned such problems as: waste disposal, decrease in the amount of fresh water, increased acid rain, increased soil degradation, deterioration of air quality. In the Khmelnytskyi region, the respondents singled out such problems as: the deterioration of water resources, the deterioration of the atmosphere due to a series of explosions of oil bases in the region, as well as the related ingress of various toxic chemicals into the natural environment, which affects human life. In the Lviv region, the respondents singled out such problems as: garbage disposal, problems with overpopulation of cities due to population migration from eastern regions to western regions, and correspondingly higher consumption of resources, problems with the deterioration of water resources. We conducted the survey in territories less affected by hostilities, but after two years of war, they are already feeling its ecological consequences.

Similarly, respondents listed environmental threats in war zones: land mining, destruction of biodiversity, transformation of cities and villages into ruined wastelands, which after bombing and massive explosions pose a threat to air, water, soil and all living things.

Next, we asked the respondents whether they are ready to change the style of their everyday life in order to minimize the use of resources and take care of their recovery. Answering this question, 145 respondents indicated that since the beginning of the war they had already changed their attitude towards the natural environment, began to treat it more carefully, realizing the threat posed by the war; 104 people indicated that they feel a great responsibility for the preservation and increase of natural resources, the restoration of the natural environment in the territories where hostilities are currently taking place, these respondents are trying to change their everyday behavior in order to actively participate in the ecological reconstruction of Ukraine in the future; 67 people are thinking about this issue, but have not yet taken active steps to preserve natural resources, and 33 respondents have not yet thought about this issue.

We also asked the respondents what environmental works they do to preserve and restore natural resources. The main answers are: sorting and humane disposal of garbage, evacuation of animals from the territory of hostilities and their resettlement in shelters, cleaning of springs and rivers, care of birds and animals in winter, economical use of water resources, clearing of destroyed buildings in areas where hostilities have passed, work on cleaning the soil after explosions of oil depots, prevention of forest fires, rejection of plastic.

Our next question was “What, in your opinion, is the first priority in solving environmental problems?”. We received the following answers to this question: “cessation of hostilities, development of a plan to stabilize the environmental situation, implementation of the world's leading practices of conservation and restoration of natural resources, training of ecologists capable of improving the environmental situation”.

The question “Are you ready to join the eco-restoration of Ukraine in the post-war period? How exactly?” respondents commented as follows: “this is a necessity for every citizen of our country, we are all responsible for the natural environment, its restoration and preservation for future generations”, “we will definitely join, and the first priority is to clean up destroyed cities, plant trees in forests, engage in restoration of soils and water bodies contaminated by lubricants and oil products”, “the environmental crisis in which our state is now will change the consciousness of citizens, we already feel the dangers that threaten us, so we should change our thinking style to an ecological one today”.

The results of the conducted survey proved that citizens of Ukraine are aware of the range of environmental dangers and threats facing them, they are ready for environmental and nature protection activities, many are already engaged in them, moreover, citizens of Ukraine are in the process of changing their attitude towards nature from a consumerist to a consumerist one, gentle and restorative.

III. Results of the Research

In order to overcome the environmental crisis in the war and post-war period, in our opinion, it is important to work in three main directions: this is an active environmental activity with the involvement of world experience in overcoming environmental dangers and disasters; this is the strengthening of the training of specialists in the environmental and nature protection sphere, the training of teachers who are able to raise a new ecologically literate and conscious generation; this is a large-scale educational activity among the population, involving citizens in a number of environmental actions, challenges that will affect their lifestyle and environmental awareness.

Eco-activism is progressing in Ukraine, today it has become popular to follow a healthy diet, travel on ecological modes of transport, and participate in environmental actions. It is important to continue this course, because it affects the ecological consciousness of the population.

It is important for Ukraine to work within the framework of “The European Green Deal” program, a set of political initiatives put forward by the European Commission with the general goal of making the European continent climate neutral by 2050. The main goals of the European Green Course are to transform Europe into a climate-neutral continent, improve the well-being of citizens, protect biological diversity, and green the economy. The main goals of The European Green Deal are to transform Europe into a climate-neutral continent, improve the well-being of citizens, protect biological diversity, and green the economy [10]. In the context of The European Green Deal, the Ukrainian economy is trying to adhere to a “green” policy, making maximum use of powerful cleaning filters at enterprises, reducing harmful emissions into the atmosphere, and manufacturing products that can be recycled after use.

Taking care of the ecological restoration of the country, it is important to enlist the support of foreign partners, use the world experience of environmental restoration, cooperate with global environmental organizations, such as: UNIDO (United Nations Industrial Development Organization, UNIDO), UNESCO (United Nations Educational, Scientific and Cultural Organization, UNESCO), OSCE (Organization for Security and Cooperation in Europe), EBRD (European Bank for Reconstruction and Development), GEF (Global Environmental Fund), EIB (European Investment Bank), EEA (European Environmental Agency). In addition, it is important to support and develop environmental organizations in Ukraine (National Environmental Center “MAMA-86”, “Ecology-Pravo-Lyudyna”, All-Ukrainian Environmental League, etc.).

Today, it is necessary to work on a plan to restore the natural environment and stabilize the ecological situation, clearly thinking through all the steps, taking into account the interrelationships in the natural environment. It is clear that it will not be possible to comprehensively grasp the entire threat, but it is possible to work selectively, for example, thinking of a plan for the restoration of forest plantations, water purification, waste disposal in occupied and bombed territories.

For the restoration and preservation of the natural environment, the education of the younger generation is of great importance, it is important to raise an eco-conscious nation capable of overcoming the ecological crisis, to treat nature with care.

IV. CONCLUSIONS

Ukraine has always suffered from environmental problems, but tried to solve them. Considering russia's military aggression against Ukraine, colossal damage has been caused to the environment. Pollution caused by explosions of phosphorus and cluster bombs, detonation of a number of factories, plants, oil bases, Kakhovska hydroelectric power station, pollution of soil, water bodies, atmosphere, etc. will have to be eliminated for more than a dozen years. Environmental danger is increasing every day. It is extremely important to stop hostilities for the preservation and restoration of nature.

The survey conducted during the research showed that the citizens of our country are aware of the deterioration of the ecological state and are ready to take active actions to overcome the ecological crisis. The Ministry of Environmental Protection and Natural Resources of Ukraine records the damage caused to nature and works on the development of promising ways to overcome the environmental crisis. The stabilization of the ecological situation in Ukraine will affect the stabilization of the ecological situation in the world.

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Sustainable Organizational Performance, its Trends and Developments

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Abstract. **The interest in sustainable organizational performance has increased strongly in the last decade. With the rising macroeconomic pressure and unforeseen circumstances such as global pandemic, an increased number of economies battle to ensure prosperity, performance, and target trans-formation.**

The aim of this study is to spot trends and developments on sustainable organizational performance observed in the academia for the last decade. More precisely, main sources of publications as well as biases within geographical, citation, authorship and thematic dimensions are to be identified. To achieve this aim, a qualitative study based on bibliometric analysis has been performed.

In total, 1286 relevant articles were retrieved for the last decade that examined sustainable organizational performance, however none of them has implemented a systematic literature review and bibliometric analysis and elaborate on progress within academic research. The bibliometric analysis within this study is based on a literature review of publications obtained from Scopus using an inclusive search strategy. In addition, the visualization of the data was carried out with the use of Bibliometrix and VOSviewer.

The article strives to contribute to the research on sustainable organizational performance, while performing keywords and co-occurrence analysis. It further defines top productive authors, structure of the research topic in the journals and countries. In addition to that, Lotka analysis has been performed to understand the interactions and structure of publications of the subject area.

The importance of the organizational framework, management and governance were identified as main keywords underlying once again that functional framework provides structure and hierarchy the entity may build on, while effective management ensures the utilization of resources within the established framework. Oversight, in turn, is organized by governance that guides both the framework and management practices.

The study comes with the conclusion and recommendations for both business and academia.

Keywords: ***sustainable organizational performance, bibliometric analysis, bibliometrix, development, trends***

I. INTRODUCTION

According to the World Uncertainty Index, the global uncertainty has increased since 2012 and reached its historical peak with the inception of SARS-CoV-2 in the beginning of 2020 [1]. Around the world the global uncertainty negatively reflected in global economic activities. With the impact of macroeconomic outcomes, stakeholders' pressure on the organization`s performance has increased.

As per Hossin [2], sustainable organizational performance (SOP) can support organization in finding its niche and providing difference in opposite to its competition if implemented properly. How to achieve sustainability and what is meant by that towards performance is an important topic for contemporary research. Sustainable performance is said to be keeping the healthy balance between financial, social, and environmental outcomes according to Stanciu [3]. By playing a long game and engaging stakeholders, strategic leadership aims to succeed in reaching competitiveness, sustainability, and performance benefits as has been stated by Klassen [4].

As a result, sustainable organizational performance management may become not only a challenge but a potential for organizational development.

Several authors contributed to the study of SOP and highlighted its role for management; however, no structural analysis of the topic and trend development has been made so far. Research trends can be determined through extended literature review [5]. In addition to that, to achieve the aim of this study, a qualitative study of an interpretive nature to be considered [6]. Analysing literature on sustainable organizational performance and its development for specific industry, bibliometric studies, specifically systematic literature review has been implemented, which is immanently used review methodology to

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alloy the existing literature overview in the specific field as Kraus has shown it [7].

The search period analysed was from 2012 to 2023-aligned with the increased global uncertainty. The data has been extracted from SCOPUS in the August of 2023, providing a comprehensive bibliometric analysis that offers a macroscopic view of the field's evolution amidst rising global uncertainties. The bibliometric analysis has been chosen to map out the predominant themes and knowledge gaps in the literature on SOP, while utilizing the systematic nature of bibliometric methods to identify the most pertinent areas of study and under-researched topics that may hold potential for future investigation. This analysis is based on structured method to quantitatively review the volume, breadth, and evolution of research on SOP. Bibliometric analysis enabled also to summarize the current state of knowledge and distil findings as proposed by Bolbot [8]. Macroscopic view on the evolution of SOP as well as global research trends were also identified. These were summarised from a bibliometric perspective using Scopus and VOSviewer.

The aim of the study is to conduct an in-depth bibliometric analysis of SOP and combine it with current perspective on biases, while prospecting and showing demands and fortuities. On top of that, important references for further academic research are provided.

In that sense, the article is divided into four sections: i) this introduction, ii) tools and methods, iii) results and discussion and v) discussions and final remarks.

II. TOOLS AND METHODOLOGY

A. Tools and data synthesis

The bibliometric analysis on sustainable organizational performance has been performed using Scopus core data. Scopus is a leading bibliographic database used prominently in academia since it offers access to larger data base in comparison to other others, providing more than 26000 active serial titles, more than 243000 books and 17.5 million unrestricted access items backdated to 1970 [9].

Only SCOPUS as data source for the bibliometric analysis was used due to consistency a single database can provide, ensuring comparability of the findings. Data from different databases may content variations in indexing practices and coverage.

The efficiency and user-friendly experience while using Scopus also plays a significant role during the research. Hence, search has been performed within article titles, abstracts and keywords while identifying relevant publications.

What has been crucial for this research is the possibility of filtering of provided information within the Scopus database. For the period of 2012-2023, 1289 relevant articles were retrieved on the sustainable organizational performance and this data has been analysed using bibliometric approach. Titles, keywords and abstracts have been reviewed to make sure that they are consistent with the specified search. On top of it, manual data cleaning has been performed on the identified results to ensure data stability and accuracy. Finally, further analysis has been performed on the extracted 1286 publication that correspondent fully to the search criteria. Author used a methodical and exacting techniques to proceed with data synthesis.

Filters have been set for the access type, research period, document type, publication stage and language.

B. Methodology

The Scopus platform was used to collect the initial data. In addition to that, the author used modern techniques and methods of bibliometric analysis and data visualization.

As recently confirmed by Syhyda [10], bibliometrics represent formalized research, successfully combining both qualitative and quantitative components.

It was supplemented by findings from Nielsen [11], that bibliometric analysis identifies emerging trends while building on various statistical methods to analyse large data set.

In frames of the study, keywords analysis has been performed. Keyword analysis provided the opportunity to build up cornerstones of relevance and determination of the scientific topic and relevant area. Subsequently, the network of relationships between keywords (co-occurrence) was then created.

A triple combination of the pre-defined words has been used within Scopus search ("sustainable" AND "organizational" AND "performance") for the assessment of the overall results in the first part of this article. Based on the proposed data outcome, the export of the data was done for further analysis in bibliometrix, and visualization was applied in the format of graphically mappings of material in VOSviewer. As a result, the most significant authors and journals in the area are determined, and the articles mentioned above are identified. Conducting the analysis of the co-occurrence of keywords and co-authorship on country level, as well as the topic trends, the topmost affiliates by university and by author's country are outlined. Cluster analysis has been performed to define data patterns. Moreover, overall outcomes have been presented and reported accordingly in this article.

As a limitation the chosen research period of 2012-2023 should be mentioned. This has been done to identify the inter-relation with the historical peak of World Uncertainty Index and increase number of publications in the defined period on sustainable organizational performance. It is to bear in mind that database is not reflecting real time publications hence time gap may occur. Since keyword analysis has been performed, sentences and their context could not be analysed fully. This dependency has been however, mitigated by using visualization to recreate trend and frame analysis.

In addition, affiliations and research areas have been reviewed in more detail to better understand the concept of sustainable organizational performance and identify research gaps to be further investigated.

The research has been concluded with the findings as well as practical and research implications.

III. Results and discussions on sustainable organizational performance

A. Systematic literature evaluation based on Scopus dataset

As part of the bibliometric analysis, citations and publication trends have been assessed since 2012 until nowadays as shown in Fig.1. Although the number of publications significantly increased while reaching its peak in 2022, the total number of yearly publications is varying between 200 and 246 for the last 3 years. It is to be mentioned that generic interest to the topic is notable only since 2018 while total number of yearly publications reached over 100.

General trends have been identified, showing less interest in the early research years, covering the period 2012-2017, followed by active publication period since 2018. This could be explained by the "governance through goals" and increased pressure coming from Sustainable development goals on companies as identified by Biermann [12]. The 2012-2023 period shows an 11-fold increase in the published publications on the topic.

Regarding citation trends, it, in general, proceeding similarly to the publication trends, showing exponential growth since 2012.

A clear correlation trend between published and cited publications is observed.

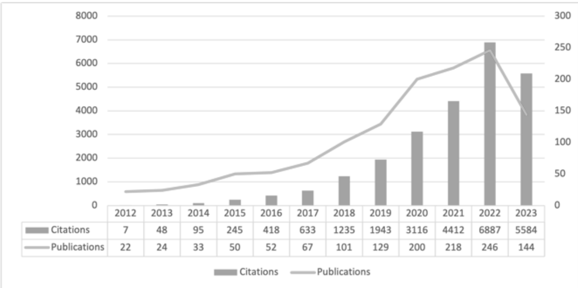

Fig. 1. Number of publications and citations on sustainable organizational performance (2012-2023)

Bibliometric results summarizing raw data output out of Scopus dataset for the research area are presented in Table I. Research fields in the Scopus dataset were used to determine the subject areas. The ranking results show that the research area is carried out in several scientific disciplines. Looking at the results, the top 5 fields have been identified: environmental sciences (17.73%), social sciences (16.87%), energy (13.99%), business, management, and accounting (11.74%) and engineering (10.25%). Since a publication may cover and refer to more than one field, there are more results (3289) than publications in total. An evaluation of disciplines and source groups revealed that the most popular research topic is sustainable development. Nevertheless, a strong fragmentation of subject areas should have been mentioned.

Regarding the evaluation of the top 10 sources, quite obviously Sustainability Switzerland journal is prevailing with significant coverage of 36.49%, publishing 354 papers in total.

In terms of affiliations, China is prevailing with 3 representing universities and 100 publications in total, following by India with 15 publications. However, there is no concentration of interest within one specific university noticed.

The evaluation of countries is confirming this trend and China - which is placing Top-1 - has been more active in the publications, representing 339 publications (10.63%) in total. Interestingly, the United Kingdom is second on the list with a total of 288 publications, representing 9.03% of the total. The United States follows in third place with 194 publications, representing 6.09% of the total. An analysis of the countries' publications shows a homogenous distribution, with an average of 100 publications represented per country.

TABLE 1. Top 10 subject areas, sources, affiliations, countries associated with sustainable organizational performance research.

Rank	Subject Area	Articles	% (of 3289)
1	Environmental Science	583	17.73
2	Social Sciences	555	16.87
3	Energy	460	13.99
4	Business, Management and Accounting	386	11.74
5	Engineering	337	10.25
6	Computer Science	303	9.21
7	Economics, Econometrics and Finance	138	4.20
8	Decision Sciences	110	3.34
9	Medicine	103	3.13
10	Earth and Planetary Sciences	58	1.76
Rank	**Source**	**Articles**	**% (of 1286)**
1	Sustainability Switzerland	354	36.49
2	Journal Of Cleaner Production	38	3.92
3	Iop Conference Series Earth and Environmental Science	27	2.78
4	International Journal Of Environmental Research And Public Health	26	2.68
5	E3s Web Of Conferences	20	2.06
6	Frontiers In Psychology	18	1.86
7	Business Strategy And The Environment	14	1.44
8	Sage Open	11	1.13
9	Frontiers In Environmental Science	9	0.93
10	Production Planning And Control	9	0.93
	Technological Forecasting And Social Change	9	0.93
Rank	**Affiliation (Country)**	**Articles**	**% (of 3188)**
1	School of Economics and Management (China)	41	1.29
2	School of Management (China)	37	1.16
3	Business School (China)	22	0.69
4	Department of Mechanical Engineering (India)	15	0.47

5	School of Business Administration (China)	12	0.38
6	School of Management and Economics (China)	9	0.28
	Department of Business Administration (Pakistan)	9	0.28
8	School of Business (China)	8	0.25
	Department of Management (Italy)	8	0.25
10	School of Management (Malaysia)	7	0.22
	Department of Management (Romania)	7	0.22
	Department of Accounting (Indonesia)	7	0.22
	Department of Business Administration (Taiwan)	7	0.22
	Department of Economics and Management (Italy)	7	0.22
	College of Economics and Management (China)	7	0.22
	Bucharest University of Economic Studies (Romania)	7	0.22
Rank	**Country**	**Arti-cles**	**% (of 3188)**
1	China	339	10.63
2	United Kingdom	288	9.03
3	United States	194	6.09
4	Italy	133	4.17
5	Indonesia	124	3.89
6	Spain	117	3.67
7	Australia	116	3.64
8	Malaysia	113	3.54
9	Portugal	94	2.95
10	Pakistan	93	2.92

B. *Fundamential notion, Research trends and Scientific Discussions on sustainable organizational performance*

Keyword analysis may be performed to outline the emerging trends and pivotal networks which supports visual exploration as suggested by Zhu [13] and Cheng [14].

Fig 2. represents the results of a keyword cluster analysis of the 75 most common keywords used in the publications by authors since 2012. In total, 6664 keywords were identified and analysed, 512 meeting the thresholds of 5 minimum number of co- occurrences, subsequently treated within keyword analysis from 2012 until 2023.

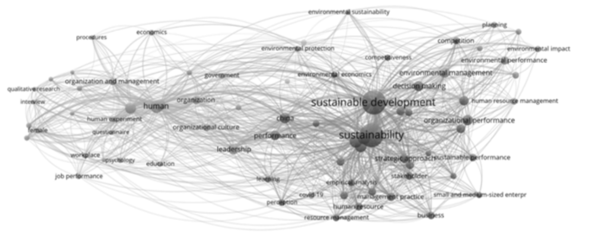

Fig. 2. 5 main research clusters (based on most frequently used keywords)

As presented in Fig 2., five clusters have been identified, showing relations of sustainable organizational performance and top related clusters around sustainable development (red), human resources (green), environmental management and performance (blue), covid 19 (purple) and governance (yellow).

Author has analysed further and established the overview of research trends with the main objective to establish the fundamental notion of SOP.

In general, the keywords with the highest occurrences of keywords have been analyzed, showing sustainable development (422), sustainability (415), innovation (124), performance assessment (117), organizational framework (105) as most arises. This finding provides the opportunity to investigate associations related to sustainable organizational performance further as well to understand notion and trends on scientific discussions around the topic.

Sustainable organizational performance alludes to the ability of an organisation to achieve its objectives and deliver values to stakeholders over longer run at the same time ensuring operational sustainability and lowering its environmental impact. As has been underlined by [2], "Sustainable organizational performance is the result of positive organizational support" [2] and is the reason to differentiate from competitors. Moreover, according to [15] organizational performance is a result from leadership at all levels. Put it another way, leadership is responsible for setting the strategic direction and empowerment to drive sustainable organizational performance as well to seize opportunities.

Key association identified groups around sustainable development. Some authors highlight the importance of going beyond traditional practices while targeting organizational development. In general, two trends have been identified: one emphasizing the human element impact, another technology or product driven approach impacting the corporation at most. Based on [16] key element of sustainable development is organizational citizenship (people-view) that is based on 3-factor approach: individual factors, leadership styles and organizational factors. Furthermore, the relationship between organizational citizenship and organizational performance to be treated as nuanced and significant, suggesting that behaviours extend beyond formal role requirements to impact on organization`s efficiency and effectiveness. Organizational citizenship drives a range of voluntary actions by employees that positively contribute to organizational goals, including beyond initiatives. These actions collectively enhance overall organizational performance. On the other hand, [17] are supporting product-view, stating that business analysis in addition to product design and testing increase sustainable innovation performance, thus impacting sustainable organizational performance. Author believes that this is the combination of both- people and product view that drives development and, in turn, organizational performance.

Further association identified is around organizational framework. Several studies illuminate the multifaceted approached to enhancing common organizational framework and organizational performance across different sectors. Especially the need for leveraging technology and adopting forward-thinking management practices to navigate the complexities of sustainability challenges have been explored within this cluster. [18] is discussing the adoption of big data analytics-powered artificial intelligence to develop circular economy capabilities based on resource-based view, founding that organizational flexibility and industry dynamism moderate the relationship between technologies and sustainable outcomes. This, obviously, offers additional insights into technological perspective enabling for sustainability. [19] are proposing a moderating model in which cultural dimensions represent significant differences between performance orientation and institutional collectivism. [20] thru interpretive structural modelling approach implies that "knowledge management practices and decentralization may proliferate the organizational growth and development".

Sustainability is recognized to be associated within next cluster. Sustainability involves assessing a company's performance while using a broad set of metrics to encompass economic, environmental, and social considerations as per [21]. According to [22], sustainability is a company`s ability to implement enduring strategies while generating social and economic values. [23] confirms the importance of the firm effect on sustainable organizational performance, regardless the firm size. On top of that, the research of [24] underlines "the need of a long-term plan for reaching the organizations aim" of sustainability.

The importance of innovation and cutting-edge perspective build next cluster around sustainable organizational performance. Research is increasingly focusing on technology and innovation that is exploring how to merge sustainability with innovation while offering a competitive edge [25] [26]. The traditional economic viewpoint suggest that innovation is to be pursued primarily for shareholder value creation while providing less attention to a social value. To include this second dimension, [27] newly developed sustainable innovation framework and implies not just making incremental improvements but fundamentally change corporate approach to prioritize sustainability and societal values alongside economic gains. Based on this framework, further research has been conducted and presented by [28], showing that "a greater emphasis on sustainable innovations has a positive impact on the organizational performance and competitive advantage of firms", highlighting the pivotal role of human capital and outlining critical paths for upcoming research.

Strong association between sustainable organizational performance and performance assessment has been identified as a last cluster. Several authors, among others, [29] enhance performance assessment and sustainable practices while proposing methods and models for improving performance thru strategic management and organizational practices. Thus, [29] is using principal component analysis and cluster analysis while identifying patterns in successful adoption of sustainable production programs, identifying six dimensions of environmental performance in total. Furthermore, to assess corporate performance, it has been amplified that traditional management methods are insufficient. [30] emphasizes the control system while incorporating critical success factors, addressing the importance of structured and continuous improvement process.

Table II shows the main keyword clusters generated by VOSviewer. In addition to that, it also shows number of items that build the cluster: cluster red representing 34 items, cluster green representing 28 items, cluster blue representing 10 items, cluster yellow representing 2 items and cluster purple representing 1 item accordingly.

TABLE 2. THE MOST IMPORTANT KEYWORD CLUSTERS OBTAINED WITH THE VOSVIEWER.

Cluster (items)	Keywords in a VOSviewer Network
Cluster Red (34)	business, business development, china, competition, competitiveness, conceptual framework, corporate social responsibility, decision making, empirical analysis, environmental economics, human resource, industrial performance, innovation, knowledge, knowledge management, learning, literature review, management practice, manufacturing, numerical model, organizational framework, organizational performance, perception, performance, performance assessment, questionnaire survey, resource management, small and medium-sized enterprise, stakeholder, strategic approach, supply chain management, sustainability, sustainable development, sustainable performance
Cluster Green (28)	adult, article, controlled study, delivery of health care, economics, education, employee, female, government, health care delivery, human, human experiment, humans, interview, job performance, leadership, male, organization, organization and management, organizational culture, organizational innovation, procedures, psychology, qualitative research, questionnaire, theoretical study, total quality management, workplace
Cluster Blue (10)	circular economy, environmental impact, environmental management, environmental performance, environmental protection, environmental sustainability, human resource management, planning, supply chains, sustainability performance
Cluster Yellow (2)	commerce, structural equation modelling
Cluster Purple (1)	covid-19

Based on trend topics and term frequency, the trend topic chart has been established as shown in Fig 3. showing the importance and development of keywords in addition to the field trends. The chart has an intuitive nature and is a list of the top five trends in relation to the main research topics each year. It is important to note that, in addition to the fragmentation of subject areas, there are research topics with a longer period of attraction for research. The focus on health care delivery (2014 – 2022), organization and management (2014-2022), united states (2014-2020) and government (2016-2022). In terms of frequency of occurrence of keywords, only sustainability and sustainable development were at the center of the documents. They reached a frequency of > 400 keywords. Covid-19 outbreaks and sustainable development goals are the most recent research topics listed. However, the frequency of terms is lower than 100 term occurrences.

The trend themes were summarized in Fig. 3.

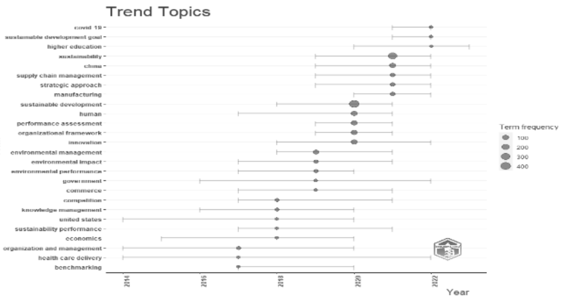

Fig. 3. Topic trends

Hence, it should be noted that in 2020 the main trend topic was sustainable development followed by human, organizational framework, and performance assessment with highest term frequency. Followed by sustainability, supply chain management, China and strategic approach as research trend topics in 2021. Interesting observation is that such topics as organizational innovation, delivery on health care, task performance and management are long-lasting, being researched for decades and with still prominent level of research interest.

In the last two years, since the global coronavirus pandemics, health care sector has been appearing again in the center of research as a respond to the unprecedent uncertainty and unpredictability of normal social life. The combination of this external environment together with the increasing interest regarding sustainable development goals, put the pressure on governance systems at the forehand.

The keywords were spread across different subject areas, and the observation of an unambiguous association with a specific research area was repeated.

C. Metric of the topmost cited documents

The metric of the most cited documents was carried out to identify the most influential and intensively cited documents.

The upmost and second studies examined sustainability at the organizational level, while the third-place ranked article focused on sustainability in an environmental context and the fourth placed article on people management. The top-5 list is concluded by research on eco-innovation.

According to Eccles, who discussed impact of corporate sustainability on organizational processes and performance, stated that the boards of directors of high sustainability companies are more likely to be formally responsible for sustainability, whereas top executive reimbursement incentives are more likely to be a function of sustainability metrics (1st place, 976 citations) [31].

Evans stated that changes to business models to be seen as a rudimentary path to perceive innovations for sustainability (2nd place, 582 citations) [32].

Geissdoerfer considers value-based view of sustainability performance on the so-called circular business models and necessity to integrate the concept on an organizational level (3rd place, 529 citations) [33].

El-Kassar & Singh develops and tests a holistic model on drivers of green innovation, considering it effects on overall organizational performance (4th place, 475 citations) [34].

The top-5 list on most cited articles is concluded by Cheng who investigates resource-bad view on eco-innovation (350 citations). [35]

D. Lotka Analysis on most productive authors

For a bibliometric analysis a Lotka` law has been conformed while investigating the frequency distribution as proposed by Lotka [36] and supported by Zhi [37]. Which does a grouping of the number of authors and the number of articles the authors produced. The results show the productivity of the authors in the research area. Table III is illustrating the rank, number of articles, the number of authors of the same group and global share. 92.13% of the author have only one article published in the research area. 6.09% have published 2 articles. The remaining 1.78% of the authors have published at least 3 times and up to the maximum of 10 articles.

TABLE 3. LOTKA ANALYSIS ON AUTHORS PRODUCTIVITY

Rank	N. Articles	N. Authors	Share
1	1	3735	92.13%
2	2	247	6.09%
3	3	51	1.26%
4	4	10	0.25%
5	5	5	0.12%
6	6	1	0.02%
7	7	3	0.07%
8	10	2	0.05%

Fig. 4. illustrates the productivity of the fifteen top authors in the last ten years in the research area. The larger the circles are the more articles the author has produced. The most productive author over time is Li J with 10 articles in total and a strong level of citations in 2021. The second author with an output of 10 articles in total in the research area is Zhang, H.

Here the limitation on technical possibilities of bibliometrix to be mentioned. Bibliometrix analyses authors by first and last name which could possibly lead to outcome merge on different authors with same name.

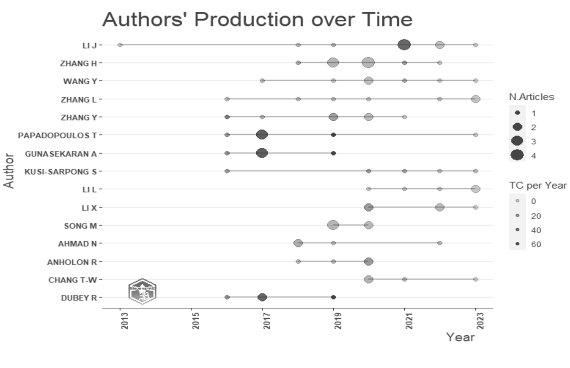

Fig. 4. Authors production over time.

E. Bibliometric analysis based on co-occurences

The evaluation of the countries with the most publications based on VOSviewer visualizations has been executed.

In general, 112 countries have been identified. Fig. 5. shows the thirty most eloquent countries in terms of research on sustainable organizational performance topic for the period 2012-2023. The top-10 most productive countries were China (185 articles), United Kingdom (171 articles), United States (116 articles), Malaysia (78 articles), Italy (74 articles), Spain (71 articles), Indonesia (66 articles), Australia (60 articles), Pakistan (58 articles) and Germany (52 articles). Below the cluster distribution is shown, representing 4 clusters in total. Red cluster includes European countries (like Netherlands, UK, and Germany), blue cluster includes Asian countries (like China and Malaysia), following by green cluster representing the US and south European countries (like Portugal and Spain), completing by yellow cluster representing Middle East countries.

Here the clear trend is not an observable and European countries are over-representing, however the distribution is quite homogeneous in all regions.

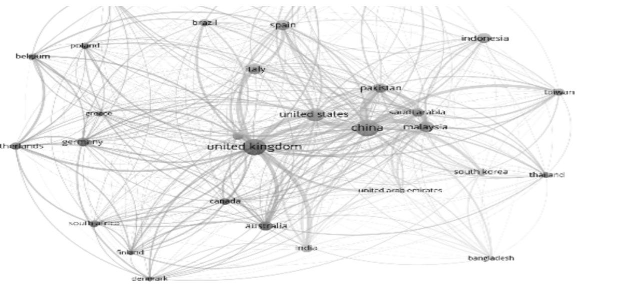

Fig. 5. The most eloquent countries

In addition to that and to spot the research trends on journals publishing articles on the research topic, further visualization has been performed. Fig. 6 presented the top thirty sources related to the research topic. The main productive journal identified has been Sustainability (Switzerland) publishing 352 articles on sustainable organizational performance so far and has been cited 5396 times in total. The second most popular publishing source was the Journal of cleaner production while publishing thirty-eight articles in total and showing 2777 times citations in total. The third most productive source has been identified being IOP Conference series: earth and environmental science with twenty-seven publications in total, showing 63 citations in general. However, in terms of total citations on the third-place Technological forecasting and social change to be mentioned with 1375 citations and nine publications in total.

The analysis conducted within this subchapter confirms the results analysed in the Scopus dataset.

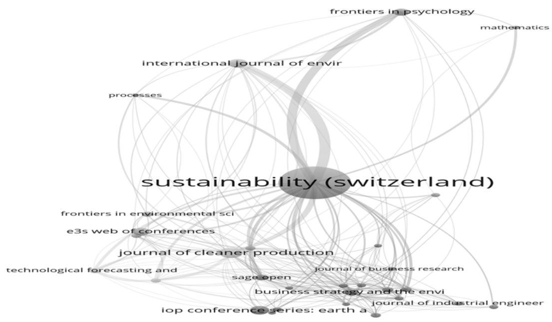

Fig. 6. The most eloquent sources

IV. FINAL REMARKS

This bibliometric study explored trends and development in the field of sustainable organizational performance. The article shows biases based on the countries, citations, authors, keywords as well as co-occurrences analysis.

An interest increase is observed in publications on sustainable organizational performance in general from theoretical perspective and as empirical research since 2012. Several authors confirmed the increase importance of sustainability and corporate responsibility reporting in their studies, validating additional value as part of social and economic benefits for the organization [38], [39].

As a matter of fact, several studies have exhibited that regulatory and customer pressures affect sustainable organizational responses, providing at the time challenges and opportunities for companies [40], [41]. Other authors are indicating on inner-company pressure to perform sustainable, notifying that sustainability and environmental awareness strengthen the process of employees' identification with the company, positively influencing its image [42]. Hence, the author refers to the need to apply multi-factor view to analyse sustainable organizational performance, its influence, and dependencies further. These studies, in turn, will stimulate companies to implement sustainable angle in their positioning and long-term strategy.

[43] brings SOP on the next level and illustrates the impact mapping as a research-based but practical approach for materiality assessment of prioritizing corporate sustainability impacts. Such causal pathway has been, however, criticised by other authors due to one-dimensional perspective of theory-based evaluation and, in turn, been currently developed further by [44] while also considering socio-demographic and behavioural drivers.

From the analysis conducted in this paper, several emerging trends and key concerns on SOP have been identified. For the current study, 1286 relevant articles were retrieved on sustainable organizational performance. Keyword analysis has been performed to outline the emerging trends and pivotal networks which support visual exploration. In total, 6664 keywords were identified and analysed in the field of sustainable organizational performance.

Regarding the evaluation of the top 10 sources, quite obviously Sustainability Switzerland journal is prevailing with significant coverage of 36.49%, publishing 354 papers in total on sustainable organizational performance.

In terms of affiliations, China is prevailing with 3 representing universities and 100 publications in total, following by India with 15 publications. However, there is no concentration of interest within one specific university noticed.

Notable observation was the evaluation on the authors, showing that 92.13% of the authors have only one article published on sustainable organizational performance so far, independently of the industry research has been performed on.

Further research could be performed considering all limitations mentioned, foremost the research period of the article being 2012-2023.

To put it in a nutshell, bibliometric analysis for sure, observes the past publications, however the general trends and interests of the researchers have been reflected and could be emphasize in the future research on sustainable organizational performance. Based on the study performed, it has been identified that there is none major subject areas and industry that prevail with research in the topic.

In future research, it will be beneficial to test SOP through a specific industry lens, by studying it in a real context. This will provide the possibility to assess and adapt enlarged performance perspective in companies that recognize and include sustainable goals in their strategy and its implication by management.

The contributions of this paper are multifaceted:

Firstly, a comprehensive synthesis of current knowledge on SOP has been conducted, offering a valuable reference point for practicians, researchers and policymakers.

Secondly, by revealing the discrepancies between the volume of research in SOP thru several angles like keyword, main authors and its productivity, publication countries and affiliations, the study highlights critical gaps, guiding future research to these less explored areas. In addition, it illuminates the ongoing academic quest and lays out a strategic blueprint for advancing further research.

Through multifaceted keyword analysis, emerging trends and key networks were identified that afford a visual and analytical understanding of the field's evolution. The analysis of 6,664 keywords in SOP has provided a scaffold for identifying research frontiers and thematic convergences.

Future studies, building upon the limitations and findings of this study, are poised to delve deeper into SOP's application in several industries by exploring real cases, potentially shaping the industry's evolution towards sustainability. The high level of single-publication authors digests a need for increased interdisciplinary collaboration which may lead to more robust and comprehensive research outcomes.

Declarations. The manuscript has not been previously published, submitted or uploaded to any archive or preprint server. Any tables or figures displayed in the manuscript are of authors own creation, and she holds the copyright for these materials. The author has no relevant financial or non-financial interests to disclose.

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Comparison of Natural Frequencies of a MacPherson Suspension Arm using Different Bushings

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Abstract. **The main function of the suspension system and its components is to absorb vibrations when the vehicle moves over bumps and to provide its stability in the different operating modes. Some of the vibration parameters are natural frequencies and mode shapes. This paper presents the results of the natural frequencies of an arm of the MacPherson front independent suspension using different bushings. For this purpose, three-dimensional geometric model of the arm was created and its frequency analysis was performed by Finite Element Analysis (FEA) using SolidWorks software. The obtained results of the natural frequencies of the arm with different bushings by FEA were presented and compared with those obtained experimentally.**

Keywords: experimental study, FEA, mode shape, natural frequency, polyurethane bushing, rubber bushing.

I. Introduction

The suspension system serves to transmit the forces acting on the wheel to the frame and ensure the smooth movement of the car. In the case of independent suspensions, the smoothness is improved by reducing unsprung mass, which also reduces the natural frequency of vertical vibrations.

It is well known that optimal ride comfort is achieved when the natural frequency is in the range of 1-1.5 Hz. The range of the natural frequency and vibration amplitude must be taken into account during the design process of the suspension and its components. Study [1] presents an investigation of the vibrational behavior of a car suspension in the frequency range from 50 to 200 Hz.

The suspension arm has been studied in various references [2]-[9] using Finite Element Analysis (FEA) software and experimentally. Studies [4], [6]-[8] provide results on the modal analysis of the suspension arm using FEA. In [2], [3], [9] the results of dynamic analysis of the suspension arm by FEA and experiment are presented. In most of the papers [3]-[5], [8], [9] in the study of the suspension arm, in the mounting locations of the bushings, their stiffness is not considered, and usually the constraints are set by using fixed supports. It is known that the elastic (stiffness) and damping characteristics of suspension components affect the ride comfort and must be selected appropriately. Therefore, it is correct to consider the stiffness characteristics of bushings when performing various analyses of the suspension and its components, which affects the natural frequencies of metal parts [10].

The purpose of this study is to determine and compare the natural frequencies of a front arm of a MacPherson type suspension using different bushings. The simulation results of the natural frequencies were confirmed by experiment, which is also part of the current study.

II. Materials and Methods

The MacPherson type is widely used in the front suspension of modern passenger cars and its advantages are simpler design and structure, small mass, low cost and good comfort.

The natural frequencies of the arm are most often determined by performing a physical experiment, analytically determined or by using FEA.

A control arm is one of the main suspension elements that connects the wheel hub to the vehicle frame. A connection between the arm and the frame is made by using various bushings, and between the wheel and the arm by using ball joints.

The object of the study is an arm of the MacPherson front independent suspension on the passenger car Skoda Octavia. Figure 1 shows 3D model of an arm and the place 1 and 2, where the bushings are mounted.

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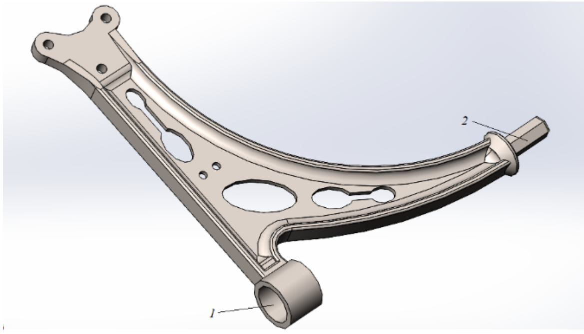


Fig. 1. The three-dimensional geometric model of an arm.

The correct setting of the supports is critical in determining the natural frequencies and mode shapes of the suspension and the arm, respectively.

Bushings were used as elastic supports of the arm and their stiffnesses were calculated by different methods and presented in another publication by the authors.

Recently, rubber bushings have been increasingly replaced by polyurethane bushings because the polyurethane material has many advantages, some of which are high strength, high elasticity, and the ability to suppress vibrations [11], [12]. The comparison of the natural frequencies of the arm was performed using two bushings of different materials. In the Case I, a rubber bushing was used as an elastic support at mounting location 1, and in the Case II, a polyurethane bushing was used. In both cases, the rubber bushing was mounted at position 2 of the arm.

Table 1 shows the bushing stiffness results needed to perform the arm frequency analysis using FEA.

TABLE 1 FEA STATIC STIFFNESS OF THE BUSHINGS.

Stiffness	**Values**		
	Rubber bushing 1	***Rubber bushing 2***	***Polyurethane bushing 1***
Axial stiffness (N/mm)	107	147.1	1407
Radial stiffness (N/mm)	3505	594	2923

Natural frequencies and mode shapes were determined by frequency analysis in SolidWorks Simulation. The arm is made of cast steel, according to EN10293 and its mechanical properties are presented in [13], [14].

Figure 2 shows the fixation of the arm by elastic supports at the mounting locations of the rubber bushing surfaces.

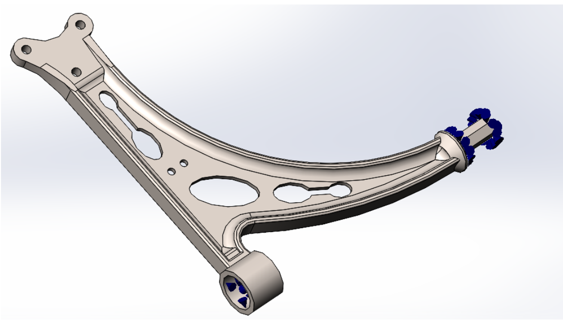


Fig. 2. Elastic supports.

A three-dimensional curvilinear mesh was generated (fig. 3). It includes 206 546 nodes and 129 397 elements.

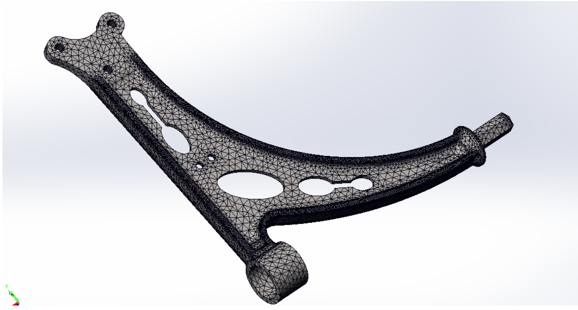


Fig. 3. FEA mesh.

The natural frequencies of the arm were also determined by a physical test. It was carried out by measuring and recording the accelerations along the three axes x, y and z. The experimental study was carried out using a developed system for determining the natural frequencies presented in [13],[14]. Each test was performed ten times for accuracy and reliability.

Fig. 4 shows the object and the measuring equipment for the experiment, which is consisted of the following components: 1 - arm, 2 - accelerometer ADXL335, 3 - multifunction I/O Device NI USB-6343, 4 - power supply and 5 - PC. Fig. 4a shows the experiments using rubber bushings 1 and 2, and Fig. 4b shows the experiments using polyurethane bushing 1 and rubber bushing 2.

a) Case I

b) Case II

Fig. 4. Experimental determination of natural frequencies.

The accelerometer was attached to the suspension arm. The mass of the accelerometer is very small and this has a negligible effect on the measurement. The FFT method in MATLAB software was used.

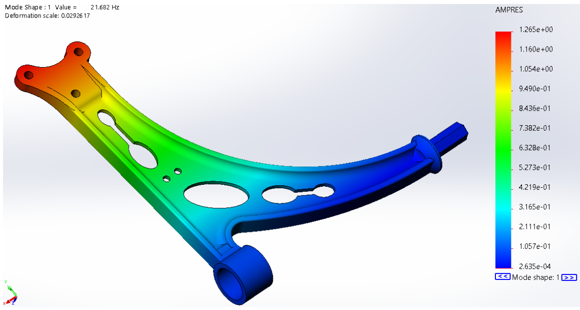
III. RESULTS AND DISCUSSION

Table 2 shows the results of the six natural frequencies of the arm obtained by FEA for both cases.

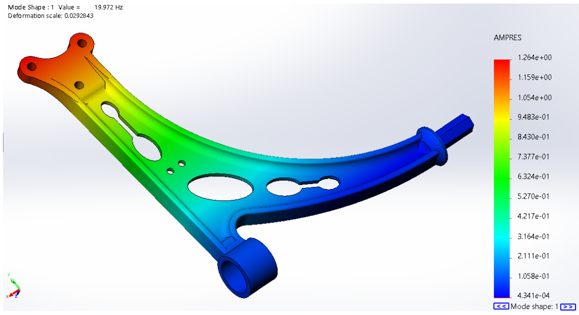
TABLE 2 THE NATURAL FREQUENCY FROM FEA.

Mode number	Natural Frequency, Hz	
	Case I	***Case II***
1	21.68	19.97
2	78.16	76.77
3	128.34	122.89
4	134.38	127.32
5	232.71	217.5
6	250.31	231.19

The first mode shape in the Case I and Case II are shown in Fig. 5a and Fig. 5b. Fig. 6a and Fig. 6b present the second mode shape in both cases.

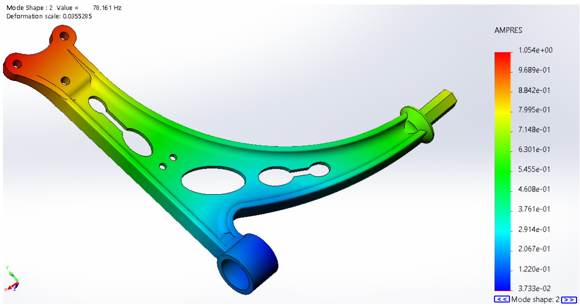


a) Case I

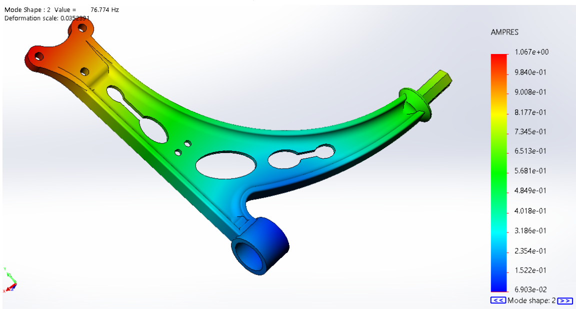


b) Case II

Fig. 5. The first mode shape.



a) Case I

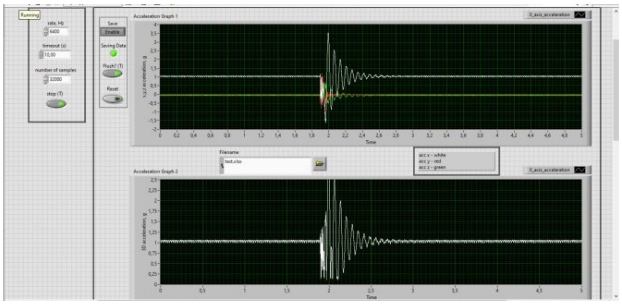


b) Case II

Fig. 6. The second mode shape.

Fig. 7 illustrates the obtained experimental results for acceleration in raw format along the three axes - x, y, and z. The electrical signal received from the accelerometer was processed without software filtering.

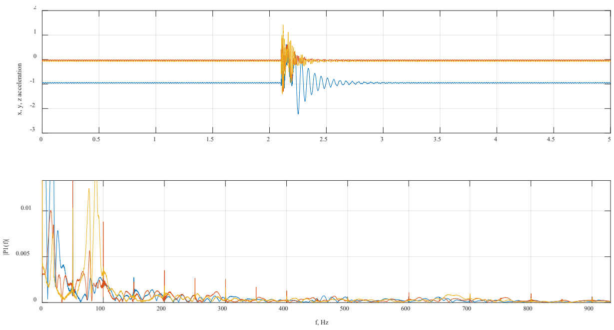
a) Case I



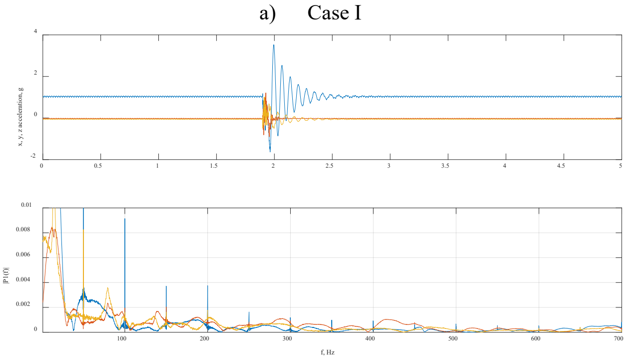
b) Case II

Fig. 7. Experimental acceleration results.

FFT analysis of the experimental data was performed and the results for the natural frequencies for each axis are shown in Fig. 8.



a) Case I



b) Case II

Fig. 8. FFT analysis.

Table 3 presents the experimental results obtained for the both cases.

TABLE 3 THE NATURAL FREQUENCY FROM EXPERIMENTS.

Mode number	**Natural frequency, Hz**	
	Case I	***Case II***
1	22.4	21.6
2	92.8	79.2
3	134.8	108
4	149	116
5	233.6	208
6	247.6	226

The natural frequency results obtained by FEA are comparable to those obtained experimentally.

It can be seen that the relative errors between simulation and experimental results does not exceed 15.78%.

IV. CONCLUSIONS

On the basis of the results of the study, the following conclusions can be drawn:

The overall results (based on both cases) regarding the natural frequencies of the arm obtained by FEA show that the lowest value is 19.97 Hz (Table 2, Mode number 1, Case II) while the lowest value obtained by the experiment is 21.6 Hz (Table 3, Mode number 1, Case II). The next value of natural frequencies is significantly higher than the frequency of excitation forces generated by road surface irregularities [2].

The results of natural frequencies of the arm with rubber and polyurethane bushings obtained by FEA (Case I and Case II) are close and the most significant difference is about 8%.

Corresponding values of the natural frequencies obtained by FEA are close to experimentally registered once, e.g. Table 2 Case I versus Table 3 Case I.

The results obtained for the natural frequencies from the numerical study by FEA and the experimental study show that the first six natural frequencies when the original rubber bushing is used are higher in value compared to the variant where the polyurethane bushing is used. This is due to the different characteristics of the two materials.

From the obtained experimental results of natural frequencies when using different bushings, it can be seen that the significant difference is in the fourth natural frequency - 28.4%, and in the results of numerical simulation with FEA, in the first - 7.89%. The significant difference in the experimental study may also be due to the fact that the rubber bushing, unlike the polyurethane one, is not new, which to some extent may be related to the change in the material properties.

The obtained results of natural frequencies can be used as a basis for solving various problems of suspension system and its components.

ACKNOWLEDGMENTS

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Strength and Frequency Analysis of the Lower Arm of a Double Wishbone Suspension of a Passenger Car

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Abstract. **One of the main elements of the suspension system is the lower control arm, which serves to transmit horizontal forces from the wheels to the chassis, while also defining the nature of the wheel movements relative to the chassis and the road surface. The implementation of guiding, elastic, and damping devices requires a comprehensive modelling of the vehicle's motion during the design stage. This paper presents results from static strength analysis and frequency analysis of the lower control arm of an independent front double-wishbone suspension of a passenger car. For this purpose, a three-dimensional geometric model of the lower control arm was created, using the Honda Civic as a prototype for the passenger car. The loads under various operating conditions necessary for conducting static analysis were determined. The Finite Element Analysis (FEA) was employed using the Simulation module of the SolidWorks software to solve the problem. Stresses, displacements, natural frequencies, and modes of the control arm were determined. The results were compared with experimentally obtained data for the natural frequencies.**

Keywords: experimental study, FEA, natural frequency and mode shape, rubber bushing, strength analysis.

I. Introduction

Suspension systems play a crucial role in reducing dynamic loads on vehicle bodies and wheels by mitigating shocks and vibrations. They often adjust the position of the vehicle chassis.

One of the primary challenges in car suspensions involves the distribution of stresses during vehicle movement, along with managing the magnitude of vibrations.

It is widely recognized that optimal driving comfort is attained when the natural frequency falls within the range of 1-1.5 Hz. In real-world vehicle applications, natural frequencies fluctuate between 0 to 20 Hz due to road imperfections [1].

Studies [2]-[4] provide results regarding various analysis of the suspension system using modern software tools.

The control arm of the suspension has been the subject of investigation in several studies [1], [5]-[14]. Specifically, research [7], [9], [14] has focused on static strength and frequency calculations of the suspension arm using FEA with different software platforms. During the suspension design phase, emphasis is placed on the geometry, mass, and individual components, prompting numerous studies [6], [7], [10], [11] dedicated to the structural and topology optimization of the arm. Additionally, various dynamic analyses of suspension components, including the lower arm, have been conducted through numerical and experimental studies as outlined in [1], [4], [5], [8], [13].

The aim of this study is to present a static strength analysis and frequency analysis of the lower control arm in an independent front double-wishbone suspension system of a passenger car. To achieve this objective, a three-dimensional geometric model of the lower control arm was developed using SolidWorks, with the Honda Civic serving as a prototype. FEA was employed to conduct simulations, and the natural frequencies obtained were experimentally validated as part of the study.

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II. MATERIALS AND METHODS

A. Determination of the forces

For light vehicles with front suspension, MacPherson struts, double wishbone, and multi-link suspensions are most commonly used. The main advantage of the double-arm suspension is that by selecting the lengths and spatial positions of the arms, minimal change in the angle of their side inclination and convergence can be achieved during wheel lift and drop. The load-bearing capacity of the double-arm suspension is high, and it can be applied to all types of vehicles.

Fig. 1 represents the kinematic scheme of the double wishbone suspension, with the Honda Civic passenger car used as a prototype.

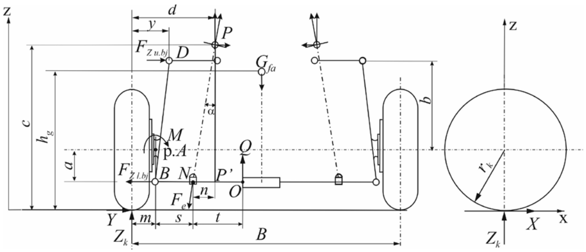


Fig. 1. Scheme of a double wishbone suspension.

To determine the initial conditions for simulating the suspension, the forces acting during characteristic load cases of vehicle movement were predefined. These include acceleration with maximum intensity, lateral loading, and dynamic loading when overcoming on road obstacles.

The static load on a front wheel is determined by the formula

$$Z_k = \frac{m_{fa}}{2}.g \quad ,N \quad , \tag{1}$$

where m_{fa} is the mass of the front axle of the vehicle, [kg]; g is acceleration due to gravity, g = 9,81 m/s^2.

The maximum driving force on the wheel (acceleration with maximum intensity) is determined according to the relationship [15]

$$X_{\max} = \varphi.\xi_a.Z_k \quad , N \tag{2}$$

where φ is the grip coefficient on dry asphalt road; ξ_a is the weight distribution coefficient for the specified axle during acceleration is assumed, and for the front axle: ξ_a= 0,8÷0,9.

The maximum braking force on the wheel is calculated according to the relationship [15]

$$X_{c\max} = \varphi.\xi_b.Z_k \quad , \tag{3}$$

where ξ_b is the weight distribution coefficient for the specified axle during braking, for the front axle: ξ_b=1,1÷1,2.

The maximum lateral force for the inner and outer wheels is determined according to the relationships [15]

$$Y_{\max in.wheel} = \varphi.Z_k\left(1-\varphi\frac{2.h_g}{B}\right), \tag{4}$$

$$Y_{\max out.wheel} = \varphi.Z_k\left(1+\varphi\frac{2.h_g}{B}\right), \tag{5}$$

where h_g is the height of the vehicle's center of gravity; B is the track width of the axle.

The maximum value of the lateral force Y is the greater of the two.

The dynamic load on the wheel when overcoming individual obstacles is determined according to the relationship [15]

$$Z_{max} = k_d \,.\, Z_k \,, \tag{6}$$

where k_d is the dynamic coefficient for vehicles primarily moving on flat, hard-surfaced roads k_d =1,5-2,1.

The forces in the supports and joints caused by the normal, lateral (transverse), longitudinal reactions, and dynamic loading are determined, with reduction to point A in force and moment (fig.1). The forces acting on the shock absorber are not considered because the scheme is analyzed statically.

The main dimensions of the suspension, necessary for the calculations, are presented in Table 1.

The proper adjustment of supports is crucial for determining the stress displacement, natural frequencies, and mode shapes of both the suspension and the arm. The static stiffness of rubber bushings can be determined through mathematical equations, FEA, or experimental methods.

TABLE 1 GEOMETRIC PARAMETERS OF THE SUSPENSION.

Parameter	Designation	Value
Mass of the front axle	m_{fa}	885.5 kg
Radius of the wheel	r_k	0.27 m
Front axle track width	B	1.475 m
Height of the center of gravity	h_g	0.524 m
Coefficient of grip normal/during braking	φ	0.8/0.6
Parameters based on the fig. 1.	m	0.040 m
	s	0.120 m
	t	0.270 m
	a	0.115 m
	b	0.380 m
	y	0.150 m
	d	0.3 m
	c	0.7 m
	n	0.075 m
	α	7°50’

B. Methodology of study

The focus of this study is the lower arm of the double wishbone front independent suspension installed on the Honda Civic passenger car. Fig. 2 illustrates a 3D model of the lower arm. The geometric representation of the lower arm primarily includes two arms - longitudinal and transverse, bolted joints, three rubber bushings, and a component for attachment to the frame. Each geometric detail of the arm is individually modeled and subsequently assembled to form the complete unit.

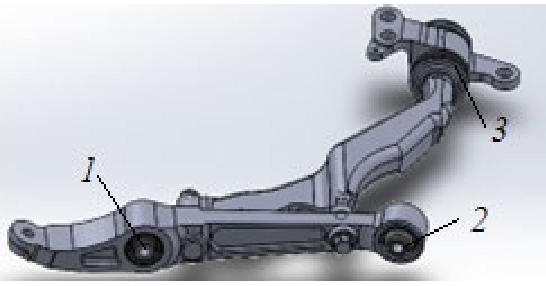


Fig. 2. Three-dimensional geometric model of a lower arm: 1, 2 and 3 – rubber bushings.

The strength calculation of the lower arm was conducted under static loading in three typical scenarios: maximum braking force (Case I), maximum lateral force (Case II), and maximum force encountered when the car overcomes single obstacles (Case III). Table 2 provides the values of the forces necessary for the strength calculations. These forces were oriented and designated relative to a coordinate system situated within the hole where the ball joint is installed. The strength analysis was performed utilizing the geometric model of the lower arm, excluding the rubber bushings and ball joint.

TABLE 2 FORCES OF THE LOWER ARM.

Option	**Forces, N**		
	***X*-axis**	***Y*-axis**	***Z*-axis**
I	351	4343	3764
II	6601	4343	-
III	702	8687	-

Rubber bushings were employed as elastic supports for the lower arm. The proper definition of their fixing was determined based on the stiffness results of the rubber bushings obtained from a separate study by the same authors.

The lower arm is assembled from five distinct components, which two arms are made of cast carbon steel and the bolted joints – alloy steel, according to EN 1.0406. Their mechanical properties were shown in Table 3.

TABLE 3 MECHANICAL PROPERTIES OF THE LOWER ARM DETAILS.

Properties	**Cast carbon steel**	**Alloy steel**
Elastic modulus, MPa	200000	210000
Poisson's ratio	0.32	0.28
Mass density, kg/m^3	7800	7700

Fig. 3 shows arm fixation established by elastic supports on the mounting locations on the surface of the rubber bushings.

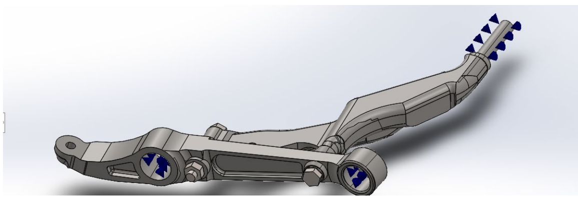


Fig. 3. Elastic supports.

Fig. 4 shows the load on the lower arm during braking (Case I). The other loads are implemented in a similar way.

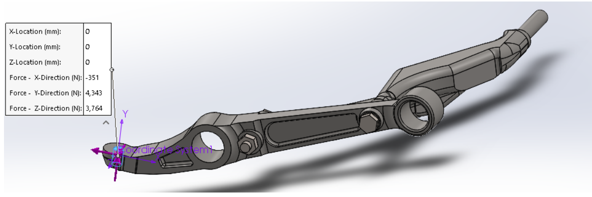


Fig. 4. Loads of the lower arm – Case I.

A three-dimensional curvilinear mesh was generated (fig. 5). It includes 86578 nodes and 53845elements.

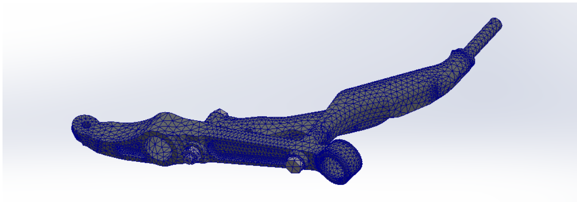


Fig. 5. FEA mesh.

The frequency analysis was performed by fixation as in the strength analysis.

The natural frequencies of the lower arm were also obtained by conducting a physical test. The experimental study was carried out by using a developed system for determining the natural frequencies presented in [16,17].

Fig. 6 shows the object, and the measuring equipment for the experiment.

Fig. 6. Experimental determination of natural frequencies.

The accelerometer was attached to the arm. The mass of the accelerometer is 1,27 g while the mass of the arm is approximately 7200 g. The total mass of the accelerometers on the suspension arm has negligible effects on the measurement. The FFT method in the Matlab software was used.

III. RESULTS AND DISCUSSION

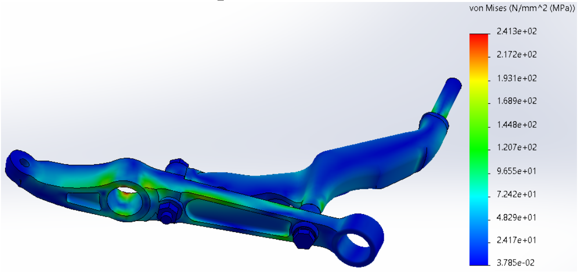
Table 4 presents the results of the stiffness obtained via FEA, which are necessary for conducting the lower arm analyses.

TABLE 4 FEA STATIC STIFFNESS OF THE RUBBER BUSHINGS.

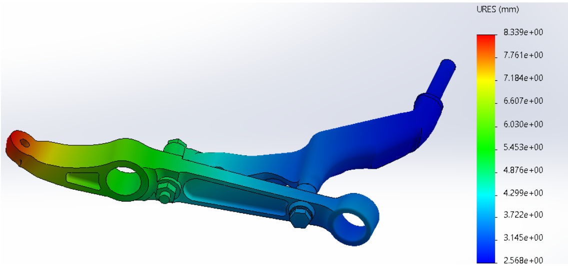
Stiffness	**Values**		
	Rubber bushing 1	***Rubber bushing 2***	***Rubber bushing 3***
Axial stiffness (N/mm)	460.5	234.1	376.9
Radial stiffness (N/mm)	5014	1743.4	3959

A. Static strength analysis results

The following figures show some of the obtained results of the numerical study, which include equivalent stress and absolute displacement.

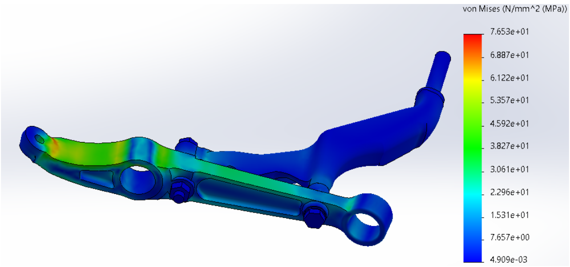


a) equivalent stress

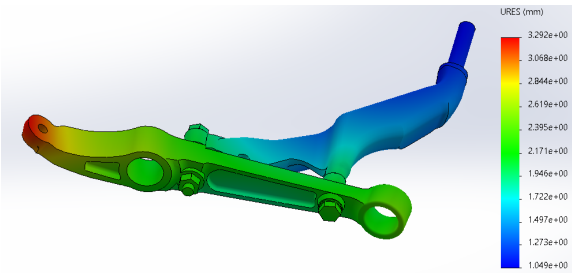


b) absolute displacement

Fig. 7. Result for load Case I

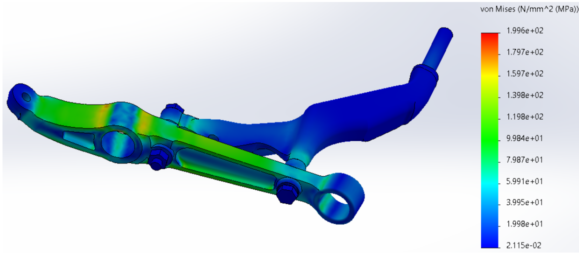


a) equivalent stress

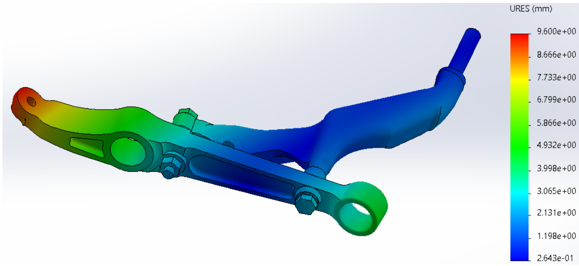


b) absolute displacement

Fig. 8. Result for load Case II



a) equivalent stress



b) absolute displacement

Fig. 9. Result for load Case III

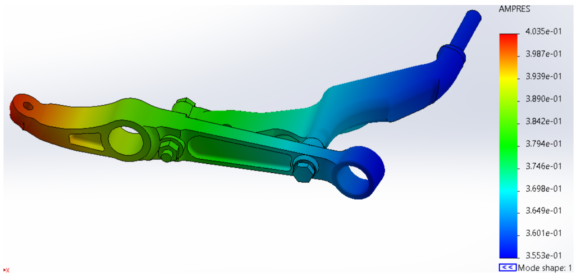
Among the three considered variants of static strength analysis, the highest values of the obtained stresses are observed in load Case I, with a maximum value of around 241 MPa.

B. Frequency analysis results

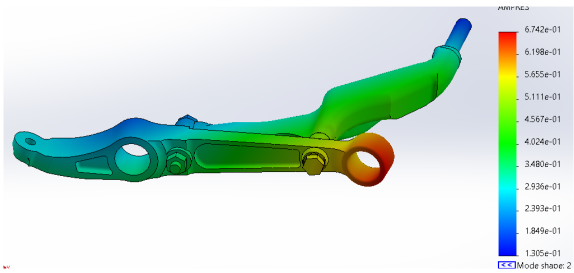
Table 5 presents the obtained results of the six natural frequencies from FEA of the lower arm. The first, second and third mode shapes were shown on Fig. 10 a, b and c, respectively.

TABLE 5 NATURAL FREQUENCY FROM FEA.

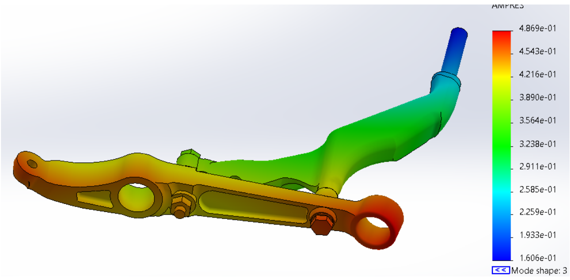
Mode number	Natural Frequency, Hz
1	61.8
2	129.9
3	134.1
4	160.5
5	162.6
6	267.4



a) first mode shape



b) second mode shape



c) third mode shape

Fig. 10. Mode shapes.

C. Experimental results of Frequency Analysis

Fig. 11 presents the obtained experimental results for acceleration in raw format along the three axes - x, y, and z. The electrical signal received from the accelerometer was processed without software filtering.

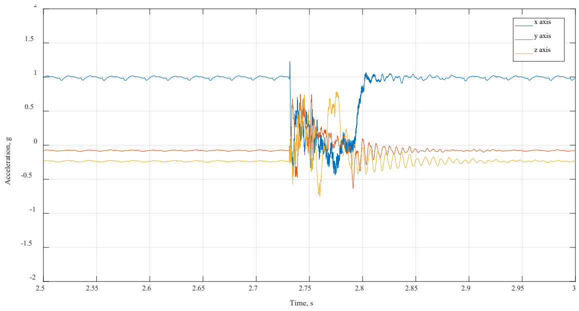


Fig. 11. Experimental acceleration results.

FFT analysis of the experimental data was performed and at fig. 12 were presented results for the natural frequencies.

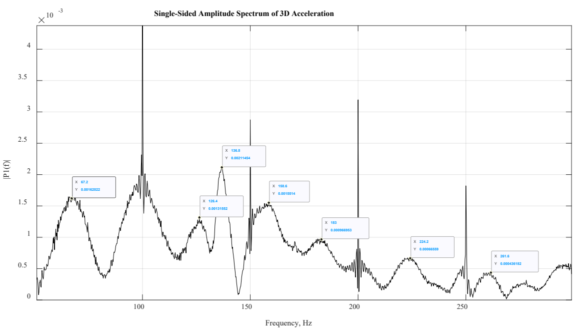


Fig. 12. FFT analysis.

Table 6 presents the results regarding the natural frequencies obtained by FEA and results obtained experimentally.

TABLE 6 NATURAL FREQUENCY.

Mode number	FEA Natural frequency, Hz	Experimental Natural frequency, Hz
1	61.8	67.2
2	129.9	126.4
3	134.1	136.8
4	160.5	158.6
5	162.6	183
6	267.4	224.2

The results obtained of natural frequencies by FEA are comparable to those obtained experimentally.

IV. CONCLUSIONS

Based on the performed study the following conclusions are made:

Using the geometric model of the support and the determined force values in various loading scenarios, a FEA was conducted within the SolidWorks Simulation environment. Significant for the strength analysis are the load Case I (maximum braking force) and load Case III (maximum force encountered when the car overcomes single obstacles). The largest stresses are obtained in the range 200 ÷ 240 MPa in the area of attachment of shock absorber, and the largest displacements in the range 8.3 ÷ 9.6 mm around of the hole for the ball joint.

To validate the FEA model developed for the lower arm of the front double wishbone suspension, an experimental frequency analysis was conducted, yielding results close to those obtained through FEA. The obtained results indicate that the lowest natural frequency of the lower arm is approximately 70 Hz, significantly higher than the frequency range of road surface irregularities (0 to 20 Hz). This supposes that when the vehicle is in motion, there will be minimal vibrations in the arm, preserving passenger comfort.

In a related study by the authors, the characteristics of rubber bushings of suspension were obtained. The use of this data and the elastic support fixation allows more realistic results to be obtained in the analyzes performed, which more accurately reflect the actual behavior of the lower arm of suspension.

The developed lower arm model, along with the study methodology and results, can be used for various types of analysis, for example topology optimization and fatigue assessment.

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Stiffness Analysis of the Rubber Bushings of MacPherson and Double Wishbone Suspensions

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Abstract. **The rubber bushings are important components of automotive suspensions. These bushings play an important role in reducing noise and vibrations, enhancing ride comfort, and ensuring smooth vehicle motion. Therefore, investigating their elastic is of significant interest. This article presents the results of a force/torque analysis conducted on rubber bushings used in MacPherson and double wishbone front independent suspensions. To achieve this, three-dimensional geometric models of the rubber bushings were created using the SolidWorks software, employing two types of passenger cars as prototypes. The results were determined through Finite Element Analysis (FEA), and the radial force for all bushings was experimentally measured. The obtained results were then compared for validation.**

Keywords: FEA and experimental, rubber bushing, stiffness, suspension.

I. INTRODUCTION

Rubber bushings are commonly utilized as elastic supports in vehicle suspensions. The characteristics of these bushings are of paramount importance for conducting qualitative, frequency, and dynamic analyses, as well as for solving optimization tasks in suspension design and related components. Designing new bushings also requires understanding their deformation characteristics.

A significant portion of publications are focused on the design and optimization of rubber bushings [1]- [5]. Various analytical [3], [6], [7], [8] and genetic algorithms [1] are primarily used for design, aimed at determining optimal geometric parameters, with particular attention to sought-after characteristics of radial, axial, and torsional stiffness.

Various software products for Finite Element Analysis (FEA) are utilized in the design and determination of stiffness, with simulations analyzing stress and deformation changes [1]-[5], [8]-[11]. Publications employing FEA also explore the hyperelastic behavior of rubber (elastomers) [7, 12], utilizing well-known constitutive hyperelastic models such as Mooney-Rivlin [1],[5], [9]-[11], Marlow [9], Ogden [2, 10], and Neo Hooke and Yeoh in [11]. Comparison between constitutive hyperelastic models in FEA and experimental tests for rubber with varying hardness is presented in [10], while theories and execution of non-linear finite element analysis of elastomers and mechanical characterization testing of composite materials are discussed in [7], [12]-[14].

Experimental determination of bushing stiffness is also conducted, with methodology developed and dynamic stiffness and damping of suspension bushings defined in [15], and results for static stiffness presented in [8], [9],[11], [13].

FEA enables the construction, enhancement, and optimization of bushings before production; however, the analysis may not always be economically feasible due to requirements for increased computational resources, licenses for specialized software, and processing time.

Hence, determining the static stiffness of bushings from different suspensions remains a relevant task. Determination of stiffness is necessary for the accurate definition of fixation in various analyses [8, 16].

The purpose of this study is to determine the stiffness (through force/torque analysis) of rubber bushings used in MacPherson and double wishbone front independent suspensions. To achieve this, three-dimensional geometric models of the rubber bushings were created using SolidWorks software. Nonlinear FEA of the bushings was conducted, and the radial force for all bushings was experimentally measured.

II. DETERMINING OF THE STIFFNESS

The static stiffnesses of rubber bushings can be determined through mathematical equations when the

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material hardness is known, through FEA, and experimentally.

The most critical deformations include radial, axial, and torsional. Fig. 1 illustrates the deformations of a simple bushing, comprising inner and outer cylindrical steel sleeves and a rubber cylinder.

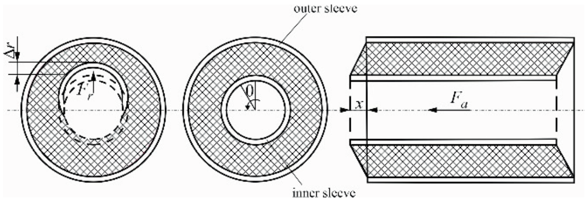


Fig. 1. Radial, torsional and axial displacements in bushing [1].

The stiffness of bushings can be obtained using analytical methods. Radial stiffness, specifically, can be determined by a specific formula [1], [7], [8]

$$K_r = \frac{7,5.\pi.L.G}{\ln\left(D/d\right)} k_l, \tag{1}$$

where k_l is the form factor and it is defined by the graphical dependence from [7], [8]; G is the shear modulus, *MPa*, it is defined by Shore hardness Hs, $G = 0,117e^{0,034Hs}$ or through the graphical representation $G = f(Hs)$ [7], [8], [10]; *L*, *D (R)*, *d (r)* are length, outer and inner diameter (radius) as shown in fig.1.

The axial stiffness can be determined by dependencies [7], [8]

$$K_a = \frac{2.\pi.L.G}{\ln\left(D/d\right)}. \tag{2}$$

General equation for torsional stiffness was developed by Adkins and Gent [6] and it can be determined

$$K_\theta = \frac{\pi.L.G.10^{-3} r^2 R^2}{R^2 - r^2}. \tag{3}$$

Determining the stiffness characteristics of the rubber bushings is also possible by constructing a mechano-mathematical model using the FEA. The hyperelastic constitutive models were first developed by Mooney (1940) and Rivlin (1948), and then from Valanis and Landel (1967), Treloar (Neo Hooke -1975), Ogden (1972; 1984), Gent (1992) and other authors.

The hyperelastic constitutive models describe the behavior of nearly incompressible materials and they are expressed in terms of function of the strain tensor invariants [1], [7], [9].

$$W = W(\bar{I}_1, \bar{I}_2, \bar{I}_3), \tag{4}$$

where $(\bar{I}_1, \bar{I}_2, \bar{I}_3)$ are the invariants of the Green strain tensor.

The Mooney-Rivlin models are very popular and the form of the strain-energy potential for a five parameters model is determined by the dependence [9],[12]

$$\begin{gathered} W = c_{10}\left(\bar{I}_1 - 3\right) + c_{01}\left(\bar{I}_2 - 3\right) + c_{20}\left(\bar{I}_1 - 3\right)^2 + \\ + c_{11}\left(\bar{I}_1 - 3\right)\left(\bar{I}_2 - 3\right) + c_{02}\left(\bar{I}_2 - 3\right)^2 + \frac{1}{D_1}\left(J-1\right)^2 \end{gathered}, \tag{5}$$

where c_{10}, c_{01}, c_{20}, c_{11}, c_{02} are constants dependent on the type of material, determined based on experiments; J is volumetric deformation.

The three invariants are given in terms of principle extension ratios (nominal strains) λ_i, (i=1,2,3) [7];

Under uniaxial stress, the nominal strains are [7]

$$\lambda_1 = \frac{L}{L_0} \text{ и } \lambda_2 = \lambda_3 = \frac{1}{\sqrt{\lambda}}, \tag{6}$$

where L is the length after deformation; L_0 is initial length.

Under uniaxial stress, the nominal stress is determined by the relationship [7]

$$\sigma_1 = \frac{F}{A}, \ \sigma_2 = \sigma_3 = 0, \tag{7}$$

where F is the applied force; A is the initial cross-sectional area.

The stiffness of the bushings is also determined through conducting experimental tests on stands developed for this purpose.

III. Materials and Methods

The study focuses on various rubber bushings found in the prevalent front independent suspensions of passenger cars. Fig. 2 illustrates the MacPherson suspension along with the stiffnesses of the rubber bushings mounted in the arm. Fig. 3 depicts the double wishbone suspension and the stiffnesses of the rubber bushings installed in the lower arm.

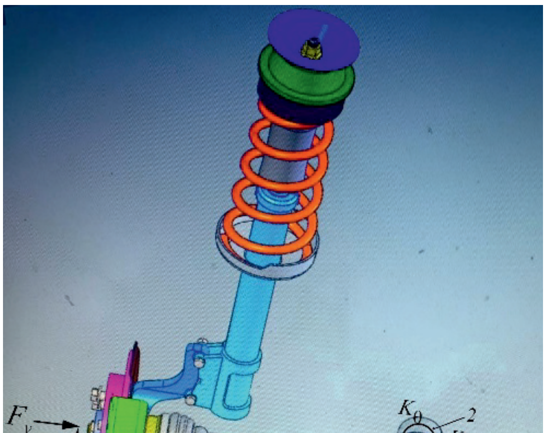


Fig. 2. MacPherson suspension and radial, axial and torsional stiffnesses in rubber bushings of an arm [16].

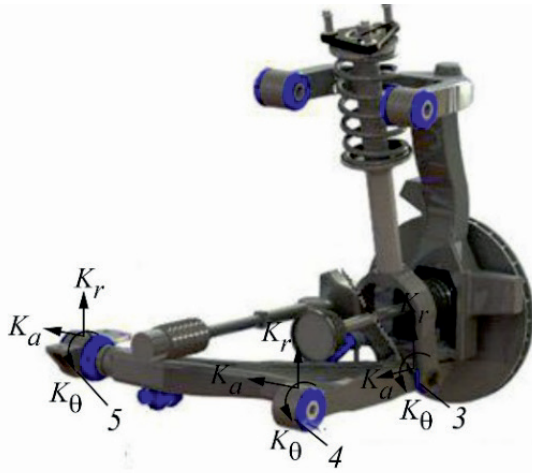
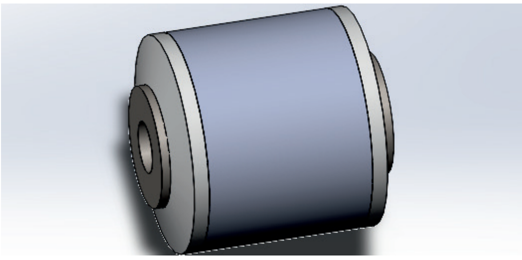


Fig. 3. Double wishbone suspension and radial, axial and torsional stiffnesses in rubber bushings of a lower arm.

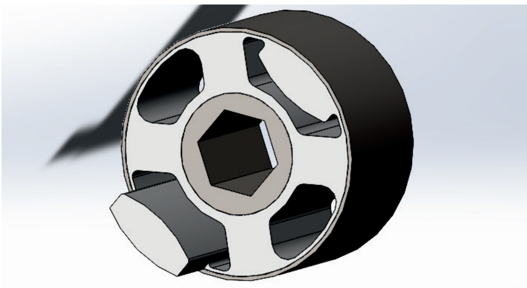
The rubber bushings models were developed using SolidWorks software.

Fig. 4 depict the three-dimensional geometric (3D) models of rubber bushings 1 and 2, respectively. A Skoda passenger car served as a prototype for their modeling.

Fig. 5 depict the 3D models of rubber bushings 3, 4, and 5, respectively. A Honda Civic passenger car was utilized as a prototype for modeling the bushings of a lower arm from a double wishbone suspension.

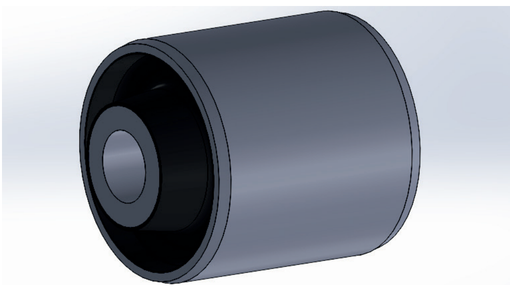


a) rubber bushing 1

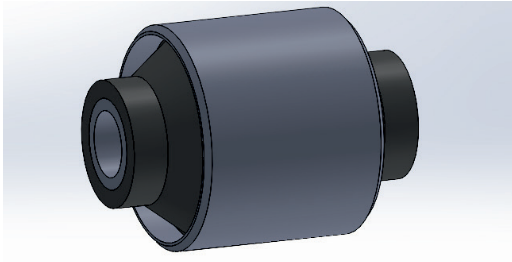


b) rubber bushing 2

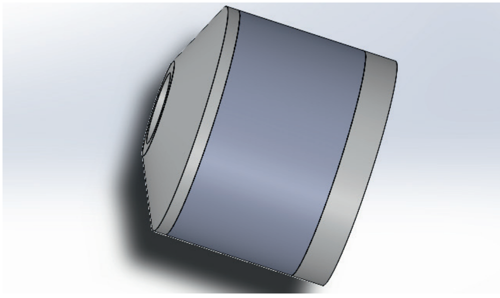
Fig. 4. Three-dimensional geometric models of the bushings.



a) rubber bushing 3



b) rubber bushing 4



c) rubber bushing 5

Fig. 5. Three-dimensional geometric models of the bushings.

The stiffness of the rubber bushings was determined through non-linear SolidWorks Simulation analysis. The elastic properties of the rubber bushings were estimated using the Mooney-Rivlin material model with five constants. Experimental stress-strain curves obtained from uniaxial tension tests for various hardness levels [10] were utilized as input for the automatic calculation of the five material constants performed by SolidWorks. A Poisson's ratio close to 0.5 was selected for rubber [7], and the density was assumed to be 1130 kg/m^3 [7]. The metallic components of the rubber bushings are fabricated of steel-normalized 4340, according to EN 10250. A three-dimensional curvilinear finite element mesh was employed for modeling the rubber bushings.

To determine the material constants of the bushings, their Shore hardness was initially assessed. The hardness of the bushings was measured using a Shore A Durometer tester. Fig. 6 illustrates the Hardness tester Shore A Durometer along with the rubber bushings. Table 1 displays the results of the rubber hardness for all the bushings.

Fig. 6. Tester Shore A Durometer and the bushings.

TABLE 1 HARDNESS OF THE BUSHINGS

Bushings	**Hardness, HA**
1	70
2	70
3	64
4	70
5	64

Compression tests of rubber bushings were conducted using an electric universal testing machine „WDW-20A“ (see Fig. 7). All bushings underwent three mechanical tests. To conduct the experiments, additional components were designed. The experiments were carried out at speed of 5 mm/min until a maximum force load (force) of the rubber bushings was reached.

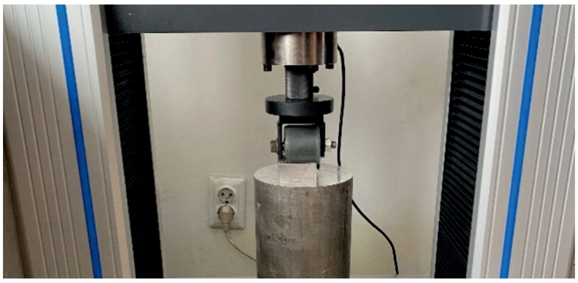
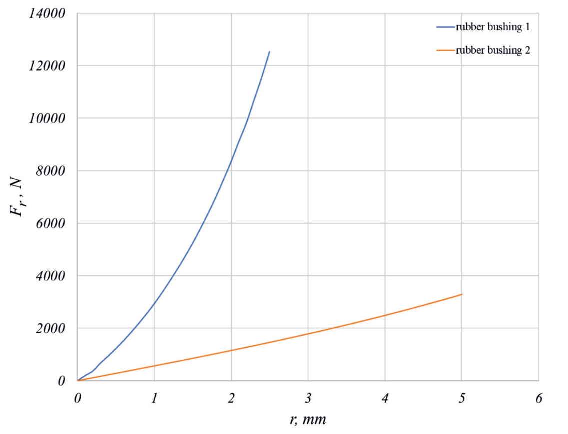


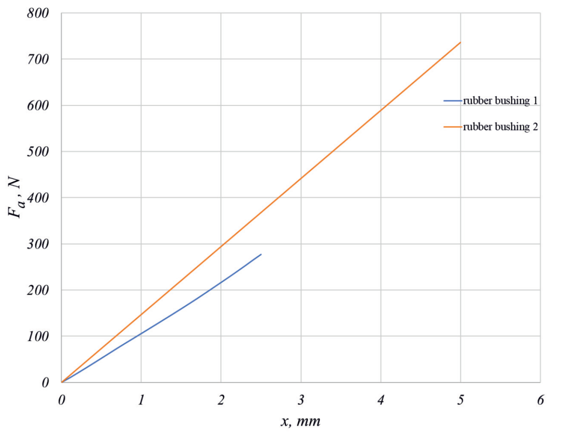
Fig. 7. Experimental test.

IV. Results and Discussion

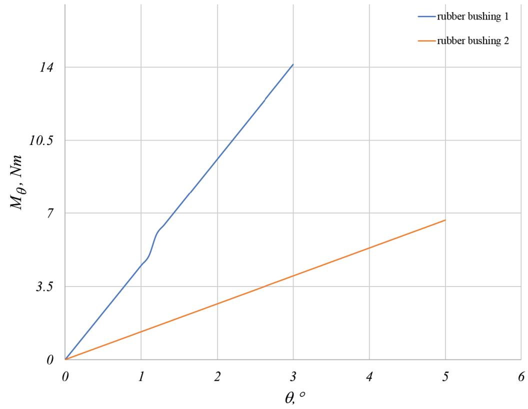
Fig. 8 illustrates the results obtained through FEA depicting the variation of load/torque with displacement/rotation for rubber bushings 1 and 2 in a MacPherson suspension. Fig. 9 displays the load/torque variation with displacement/rotation for rubber bushings 3, 4, and 5 in a double wishbone suspension.



a) radial loads

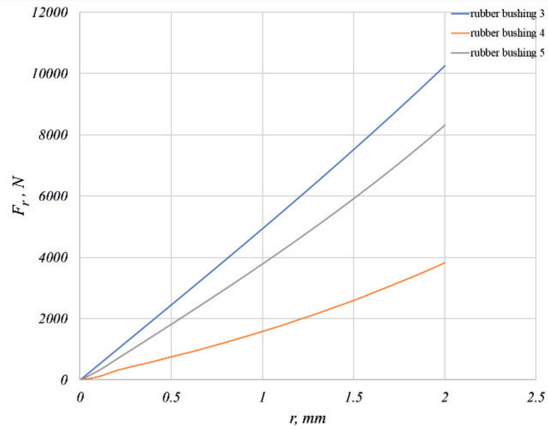


b) axial loads

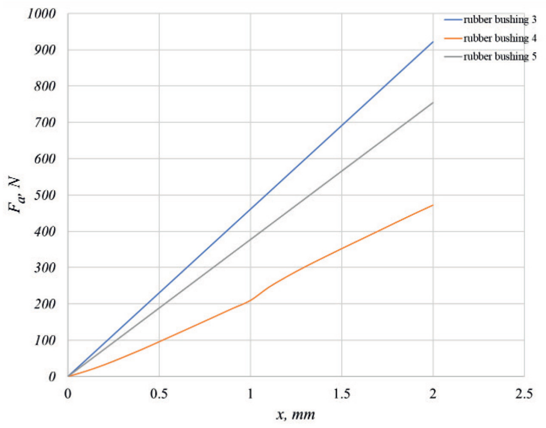


c) torsional moments

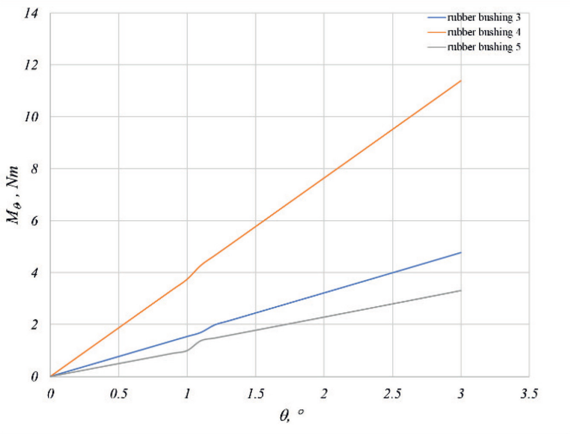
Fig. 8. FEA results for rubber bushings of MacPherson suspension.



a) radial loads



b) axial loads



c) torsional moments

Fig. 9. FEA results for rubber bushings of double wishbone suspension.

Fig. 10 presents the results obtained through FEA and experimentally for the variation of load with displacement of rubber bushings in one type of suspension. Similarly, Fig. 11 illustrates the results for the other type of suspension.

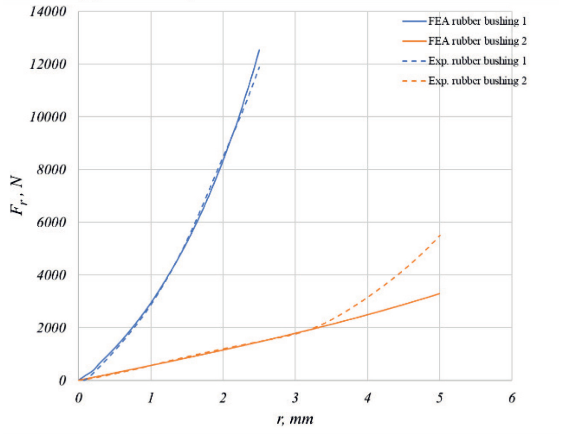


Fig. 10. Results for radial loads for rubber bushings of MacPherson suspension.

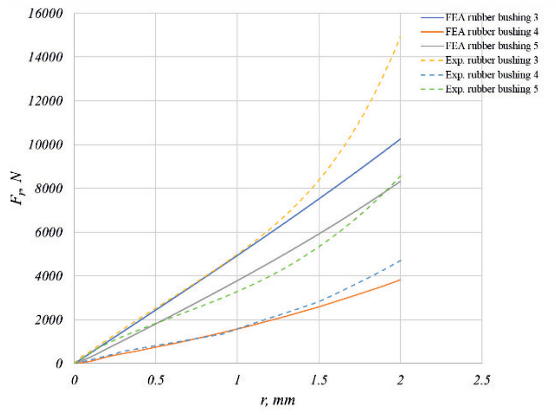


Fig. 11. Results for radial loads for rubber bushings of double wishbone suspension.

Table 2 presents the results for the radial stiffness of the bushings obtained by FEA, by experimentally and by formula.

TABLE 2 RADIAL STIFFNESS OF RUBBER BUSHINGS

Bushings	Radial Stiffness, (N/mm)			Deviation FEA and Exp,%
	FEA	Exp.	Formula	
1	3505	3694	5288	≈6%
2	567	596	1713	≈5%
3	5014	5532	4253	≈10.4 %
4	1743	1926	1619	≈10.4%
5	3959	3544	1303	≈10.5%

The results for radial stiffness determined by FEA are close to the results obtained experimentally, and analytically calculated ones differ significantly.

V. CONCLUSIONS

The study allows to make the follow conclusions:

The radial stiffness results obtained from FEA closely align with experimental results, with a maximum deviation of 10.5%.

When conducting experimental investigations to determine axial stiffness and torsional stiffness, deviations from both FEA and experimental results are expected to be of similar magnitude as those observed for radial stiffness.

For determining the stiffness of bushings with complex geometries, the FEA method is preferred.

The stiffnesses results obtained for the rubber bushings can be applied in various analyses, such as strength and frequency analysis of components and suspension assemblies.

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Mechanical Behavior and Stiffness of a Polyurethane Bushing of a Passenger Car Suspension

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Abstract. **Suspension bushings play an important role in reducing vibrations, minimizing noise, absorbing road irregularities, and controlling joint movements. Polyurethane bushings, in particular, contribute to improved vehicle handling, exhibiting lower moments of inertia and greater strength under increased loads. However, this enhancement in performance may come at the expense of reduced ride comfort. This paper presents the results of a study on the mechanical characteristics of polyurethane material and the stiffness of bushings made from the same material, specifically in the context of the MacPherson front independent suspension. To achieve this, mechanical tension tests were conducted on polyurethane specimens, obtaining stress-strain curves. Additionally, a three-dimensional geometric model of the polyurethane bushing was created using the SolidWorks software. The paper presents the results of bushing stiffness obtained through nonlinear Finite Element Analysis (FEA). Experimental determination of radial stiffness was also performed, and the results were compared for validation.**

Keywords: experimental, FEA, polyurethane bushing, stiffness, suspension.

I. Introduction

The bushings play a critical role in the suspension system, serving to diminish the magnitude of vibrations and noise while also influencing the handling characteristics of the vehicle.

The rubber bushings of car suspensions are the subject of many studies by using FEA with modern software products [1]-[3], by further developing known analytical dependencies [2], [4], [5] and by experimental studies [1], [5], [6].

Various researchers [1], [5], [7]-[11] have addressed issues concerning the mechanical properties, analysis, and validation of various FEA models of elastomers. Their investigations delve into understanding the behavior of elastomers when subjected to diverse influencing factors.

Polyurethane bushings possess the strength and resilience of wood and plastic, combined with the flexibility and elasticity of rubber. Their durability makes them particularly suitable for automotive use. As suspension bushings are continuously subjected to stress and stretching, the hardness of polyurethane provides drivers with enhanced road feel and increased vehicle control [12].

The primary advantage of polyurethane over rubber as a bushing material lies in its durability. Polyurethane's strength and toughness enable it to outlast rubber by five to ten times [12], making it a preferred choice for longer life cycles.

In a study by [13], polyurethane bushings for suspension arms were designed using rapid prototyping and simulated with SolidWorks. Other research [14], [15] focused on fatigue and stress analysis of anti-roll bars using FEA with various polyurethane rubbers. Additionally, [16] presented four types of mechanical tests (tear, tension, compression, abrasive wear) on polyurethane materials with different hardness levels (80 and 90 ShA) used in car suspension systems, elucidating the impact of hardness on key mechanical properties.

The study aims to determine the mechanical characteristics and stiffness of polyurethane bushings. To achieve this objective, mechanical tension tests were conducted on polyurethane specimens to obtain stress-strain curves. Subsequently, a three-dimensional geometric model of the polyurethane bushing was generated using SolidWorks software. The determination of bushing stiffness was carried out through nonlinear FEA, and the obtained results were compared with experimental data.

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II. Materials and Methods

The study focuses on analyzing a polyurethane bushing used in the suspension arm of a passenger car. These bushings serve as elastic supports for the arm, requiring the determination of stiffness to ensure accurate fixation. Fig. 1 depicts a 3D model of the polyurethane bushing without the outer sleeve.

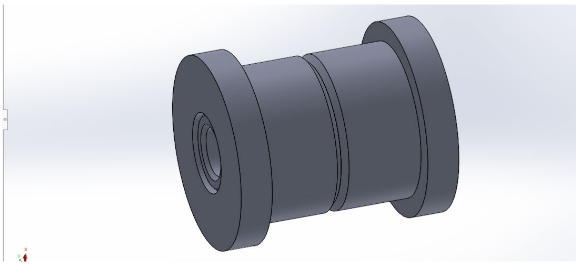


Fig. 1. 3D model of polyurethane bushing.

The stiffness of the polyurethane bushing was assessed through non-linear SolidWorks Simulation analysis. Elastic properties of the polyurethane were approximated using the Mooney-Rivlin material model. Material constants were derived from experimental results of stress-strain curves obtained from uniaxial tension tests on specimens. A Poisson's ratio close to 0.5 was chosen [1], and the density was calculated as 1110 kg/m^3.

The hardness of the specimen and the polyurethane bushing were determined by using a tester Shore A Durometer. This device is commonly utilized for measuring the hardness of various materials, including general rubber, synthetic rubber, soft rubber, poly-resin, wax, and others, across a range of hardness levels, from low to high. The characteristics of the tester Shore A Durometer are pressure force 0.55 N – 8.06 N, range 0 – 100 Shore A and accuracy ±2. Fig. 2 show Hardness tester Shore A Durometer, polyurethane bushing and specimen.

Fig. 2. Tester Shore A Durometer, specimen and bushing.

Inner sleeve of the bushing is made of aluminum alloy 2024, according to DIN 3.1355 while outer sleeve is made of steel-normalized 4340, according to EN 10250. Mechanical properties of metal parts of the polyurethane bushing are shown in Table 1.

Table 1 Mechanical properties.

Properties	Aluminum	Steel
Elastic modulus, MPa	73000	205000
Poisson's ratio	0.33	0.32
Mass density, kg/m^3	2800	7850

A three-dimensional tetrahedral curvilinear mesh was generated (Fig. 3). It includes 108 619 nodes and 589 840 elements.

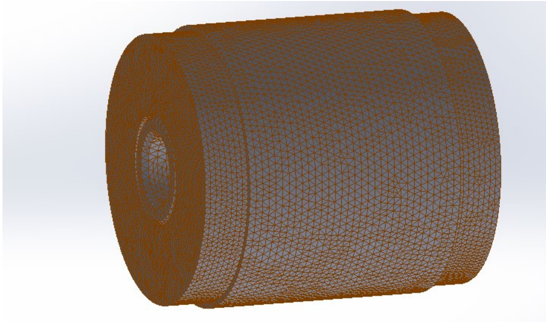


Fig. 3. FEA mesh.

The main goal of the experimental tests were to determine the curves "stress-strain" and "force-displacement". Tests was performed at Electric universal testing machine „WDW-20A". Fig. 4 shows the machine was used. The maximum load of the machine is 20 kN. Both parts of the machine were used for conducting the experiments. The stress-strain curve of the specimen was generated using the dedicated section of the machine designed for tensile testing (1). Similarly, the force-displacement curve of the polyurethane bushing was acquired using the compression testing section (2). Additional components have been developed specifically for conducting the polyurethane bushing compression test. Data from the experimental studies were recorded and exported to an Excel file. Each test was conducted thrice for accuracy and reliability.

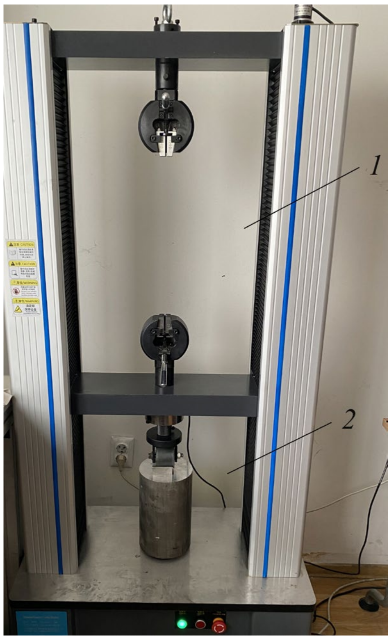


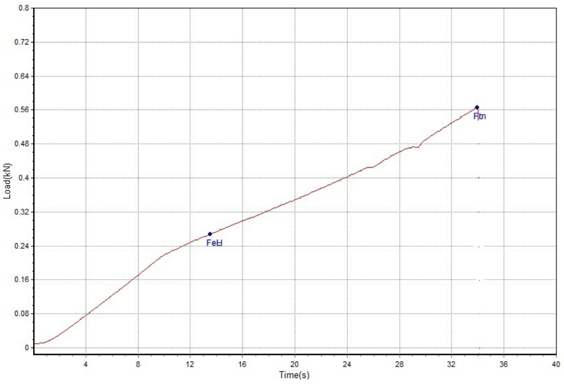
Fig. 4. Experimental test machine.

III. Results and Discussion

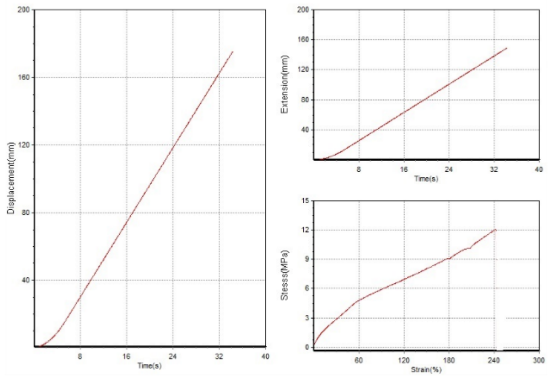
The measured hardness of the polyurethane bushing and the specimen is 80 Shore A.

Pre-tensioning of the specimen was done to eliminate the Mullin's effect.

Fig. 5 presents the result of the software screen for one of the tensile tests performed for the specimen.



a) Load – time curve

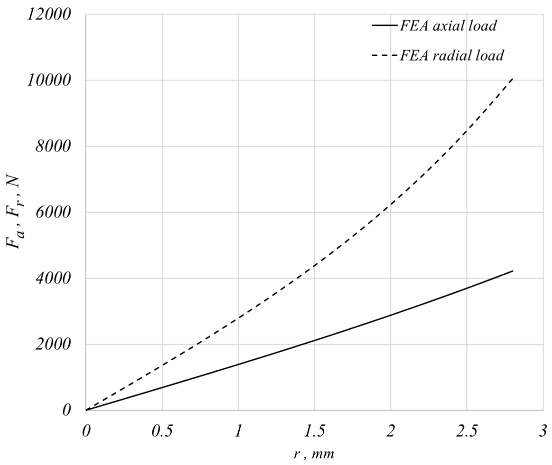


b) displacement, extension and stress representation

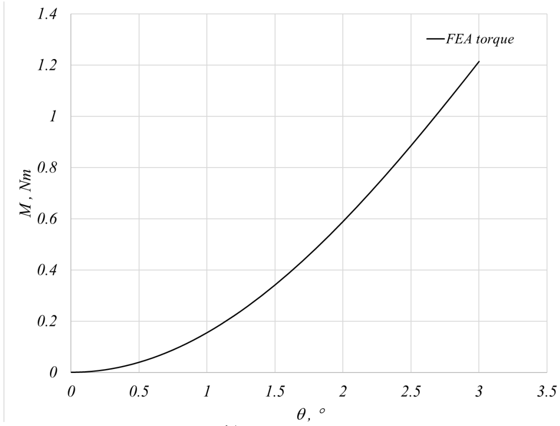
Fig. 5. Experimental results of tensile test.

The experimental stress-strain curve, as depicted in Fig. 5b, served as the basis for determining the necessary parameters for FEA simulation. The five constants of the hyperelastic Mooney-Rivlin model were determined by curve fitting and a non-linear analysis was performed.

Fig. 6a illustrates the results obtained through FEA depicting the variation of loads as a function of the displacement of the polyurethane bushing. Additionally, Fig. 6b presents the FEA results showing the torque variation as a function of rotation.



a) axial and radial loads



b) torque

Fig. 6. FEA results of polyurethane bushing.

The axial and radial and torsional stiffnesses can be determined from the result presented in Fig. 6.

Fig. 7 presents one of the experimental compression test performed on the bushing.

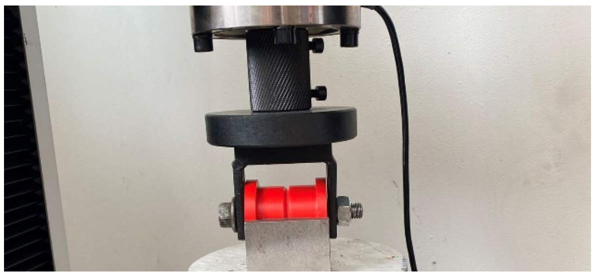


Fig. 7. Experimental compression test of polyurethane bushing.

Fig. 8 shows the variation of radial load versus displacement of the polyurethane bushing obtained from the compression test and FEA.

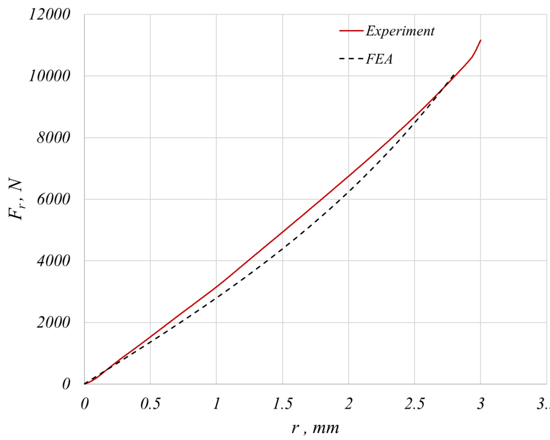


Fig. 8. Result of test and FEA of polyurethane bushing.

Table 2 presents the results for the static radial stiffness of the polyurethane bushing obtained by FEA and results obtained experimentally.

TABLE 2 RADIAL STIFFNESS

Radial Stiffness of Polyurethane Bushing, (N/mm)		**Deviation, %**
FEA	***Experimental***	
2922.6	3327.53	13.85

The results for radial stiffness obtained by FEA are close to the results obtained experimentally, with a maximum deviation of 14%.

IV. Conclusions

The study allows to make the follow conclusions:

The mechanical behavior of polyurethane was determined through experimental investigation of tensile strength. The stress-strain curve necessary for numerical analysis of the bushing was determined. The material hardness for the specimen and the bushing was 80 on the Shore A scale and was measured with a Shore A Durometer tester.

The results for the radial stiffness of the polyurethane bushing obtained through FEA closely match the experimentally obtained results, with a maximum deviation of 14%.

Following the conducted experimental investigation of the radial stiffness of the polyurethane bushing, it is recommended to use FEA for determining stiffness. The determined stiffness of the polyurethane bushing can be utilized for conducting various suspension analyses and related component studies. Additionally, they can serve for conducting comparative analyses between suspension setups using rubber and polyurethane bushings.

Acknowledgments

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Investigation of the Impact of Compressed Natural Gas on Heat Release Rate in Dual-Fuel Operation of a D3900 Diesel Engine at Mid Loads

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Abstract. **This article delves into the influence of Compressed Natural Gas (CNG) on the heat release rate of a D3900 diesel engine operating under a dual-fuel cycle, specifically at mid loads (45%). The study explores the effects of varying proportions of CNG in the total fuel supplied to the engine. Experimental investigations reveal a consistent reduction in heat release rate during dual-fuel operation, proportionate to the quantity of CNG introduced into the combustion process. Notably, the research identifies that the maximum heat release rate occurs at higher crankshaft angles. The article also contains information regarding the in-cylinder pressure and temperature when the engine operates in dual-file mode. These findings contribute valuable insights into the combustion characteristics of dual-fuel systems, shedding light on the interplay between CNG proportions and heat release dynamics in the D3900 diesel engine at mid loads.**

Keywords: heat release rate, diesel engine, dual-fuel diesel cycle, CNG.

I. INTRODUCTION

Diesel engines are extensively used in the transportation, agricultural, and industrial sectors worldwide due to their superior energy efficiency, reliability, adaptability and cost-effectiveness than gasoline equivalents [1]. Along with the positives, diesel engines also pose complex problems related to the ecology and their dependence on fossil fuels.

The reduction of petroleum reserves on a global scale necessitates exploration of strategies to decrease fuel consumption or adopt alternative fuels in modern engines. The escalating environmental requirements for contemporary vehicles [2], [3] and engines constitute a crucial precondition for the utilization of alternative fuels or additives to existing ones, aiming to emit fewer harmful emissions during internal combustion engine operation [4].

Compressed Natural Gas (CNG) is one of the most common and easily available gaseous fuels applicable to compression ignition engines for implementing a dual-fuel duty cycle. Natural gas is a hydrocarbon gas formed through the anaerobic decomposition of organic materials. The primary source for its extraction is gas fields, where the predominant component is methane [5]. Natural gas generally consists of a mixture of hydrocarbons with methane (CH_4) as the main constituent. Ethane, propane, butane, nitrogen, and carbon dioxide gases contribute to the remaining composition while traces of water vapor and hydrogen sulphide may be present in some natural gases. The properties of natural gas are vary depending on the location, processing and refining facilities. Usually, the maximum and minimum compositions are specified to enable comparisons to be made – Table 1 [6].

TABLE 1 MAXIMUM AND MINUMUM

Conpound	Typical	Maximum	Minimum
Methane -CH_4	87.3%	92.8%	79%
Ethane – C_2H_6	7.1%	10.3%	3.8%
Propane – C_3H_8	1.8%	3.3%	0.4%
Butane – C_4H_{10}	0.7%	1.2%	0.1%
Nitrogen – N_2	2.2%	8.7%	0.5%
Carbon dioxide-CO_2	0.9%	2.5%	0.2%

The burning process in a compression ignition internal combustion engine of the fuel-air mixture can be conventionally divided into four periods [7], [8]: the ignition delay period, the premixed combustion phase (rapid combustion), the mixing-controlled combustion phase (main combustion period), and the late combustion phase (burning-out period).

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The ignition delay period (induction period), also known as the first period, begins with the start of diesel fuel injection and ends with the autoignition of a portion of the cycle fuel quantity as the pressure curve separates from the compression polytrope (Fig. 1 – Stage I) [9]. During the first period, physical-chemical preparation of the forming fuel mixture takes place, and the first autoignition focal points are created. The portion of the cycle fuel quantity entering the combustion chamber during the first period is approximately 40-50% of total diesel fuel amount and depends on period duration and the integral fuel delivery law. The larger the amount of fuel entering during the first period, the higher the rate of pressure rise in the cylinder after the start of autoignition is. The duration of the first period depends on the cetane number of the fuel, the injection advance angle, and the air-fuel ratio. The angle at which the crankshaft turns during the ignition delay period depends on its duration and the engine speed [6].

The rapid burning period (second period) begins when the pressure curve separates from the compression polytrope and ends when the maximum pressure in the cylinder (Pz_{max}) is reached (Fig. 1 Stage II). During this period, there is a high rate of heat release and a rapid increase in temperature and pressure. By the end of the second period, about 30 - 40% of the total heat input from the fuel is released. The maximum heat release rate – $(dX/d\varphi)_{max}$ is obtained around the top dead center (TDC), just before the pressure maximum. The duration of the second period mainly depends on the rate at which the flame front propagates, i.e., the degree of turbulence of the fuel mixture. The injection advance angle also influences the duration of the second period [7]. The rapid burning period can be in principle divided into two phases: the explosive (uncontrolled) burning phase and the controlled burning phase – corresponding to zones IIa and IIb in Fig. 1 [9]. In the explosive (uncontrolled) burning phase, the fuel injected during the ignition delay period and mixed in a combustible ratio with air in the combustion chamber burns aggressively over a few degrees of crankshaft rotation [9]. It also realizes a very high rate of heat release. Its limits are defined by the separation of the pressure curve from the compression polytrope (point P_c) until reaching the maximum heat release rate point $P_{Z'}$ (Fig. 1 – Phase IIa) [9]. The controlled burning phase begins at point $P_{Z'}$ and ends when the pressure in the cylinder reaches its maximum value. The values and location of Pz_{max} relative to TDC to a large extent determine the efficiency of the fuel process [9].

The main (mixing-controlled) burning period (third period) begins at the maximum pressure in the cylinder and ends when the gas temperature reaches its maximum value (T_{max}) - Fig. 1 – Stage III. The rate of heat release during the third period decreases as the concentration of oxygen in the combustion chamber decreases, and the concentration of exhaust gases increases. During this period, there may be a second (local) maximum in the rate of heat release [8]. The pressure also begins to decrease due to the increase in the volume of the clearance space. The duration of the third period depends on the engine speed and the air-fuel ratio [7].

The late combustion phase (fourth period) begins at the moment of reaching T_{max}, and its end can be determined by the law of heat release – $X = f(\varphi)$ (Fig. 1 – Stage IV). The fuel process is completed when the coefficient of heat release, X, is approximately 0.98 – 0.99. If the analysis of the fuel process is based on the law of active heat release – $Xa = f(\varphi)$, its end is considered the moment when the coefficient of active heat release reaches its maximum value – $Xa_{max} \approx 0.7 - 0.8$. In the case of poor organization of the fuel process, complete combustion of the cycle fuel quantity cannot be ensured, which can be determined by the absence of a maximum in the dependence $Xa = f(\varphi)$ – until the moment the exhaust valve opens [6].

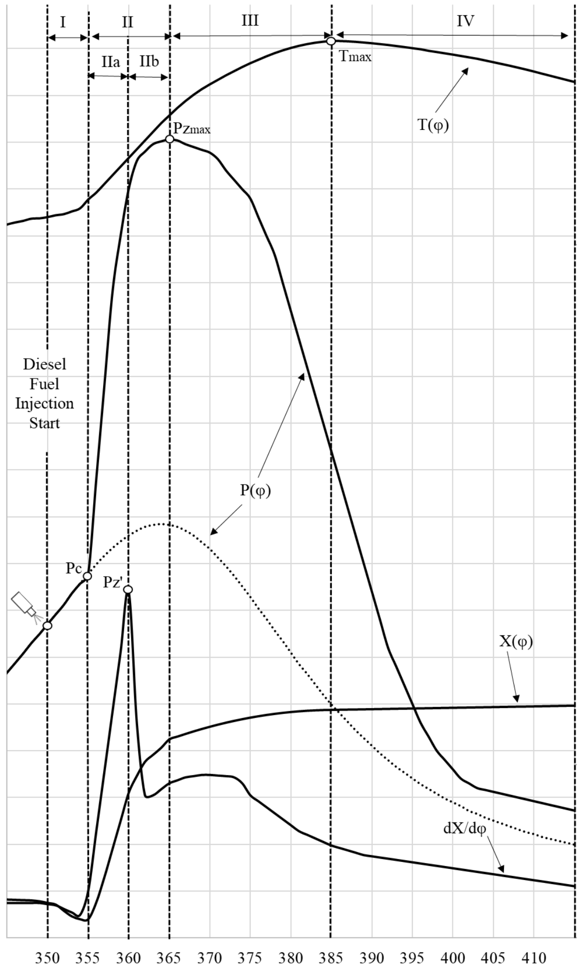

Fig. 1. Combustion parameters of compression ignition engines.

II. Materials and Methods

The investigation of CNG impact on heat release rate (HRR) is based on experimental results obtained by the application of the test setup described on Fig. 1. For the purpose of the study a four cylinder, water cooled, direct injection diesel engine *Perkins D3900* is used. The engine has the following parameters: bore– D = 98.4 mm; stroke – S = 127 mm; compression ration – ε = 16; nominal brake power – N_e = 57.4 kW at engine speed – n = 2500 min^{-1}. The test bench is equipped with the systems listed below which allows detailed monitoring of the performance parameter of the engine operates on CNG-diesel cycle:

- Direct current dynamometer– 11, used to define engine brake power and corresponding load conditions;
- The system used for measuring engine intake air flow includes throttle device (orifice) – 2 and differential water pressure gauge - 1;
- The measurement system of the diesel fuel provided to the engine is consist of fuel tank, two solenoid valves – 14, two photoelectric sensors – 15, weight measuring device (scale) – 16 and control unit 13;
- The CNG injection system is consist of CNG tank – 21; pressure reducer – 22; electronic device – 7 which controls the duration of open condition of the gas valve – 6 while the timing of CNG injection is defined by tandem work of sensor 20 and the pin mounted on the crankshaft pulley;
- Measurement system determining the amount of gas fuel injected in the intake manifold consist of manometer – 3, gas flow meter (G4 type) – 5, thermocouple (K type) – 4 connected to the measurement device 9;
- Engine speed measurement device – 12 receiving signal from induction sensor – 17 which works in combination with tooth gear with 60 teeth;
- In cylinder pressure is measured by AVL system consist of – piezoelectric sensor – 8 mounted in the cylinder head, two speed sensors: one for determining the engine speed – 19 and one for defining the top dead center of the measured cylinder, visualizing and storage system 10.

The amount of CNG injected in the engine is defined as percentage of the total amount of fuel consumption by means of coefficient *K*.

$$K = \left(\frac{B_{CNG}}{B_h}\right).100,\% \qquad (1)$$

where B_{CNG} is he hourly CNG consumption, kg/h; B_h – the total hourly fuel consumption, kg/h.

The total hourly fuel consumption can be calculated by the following equation:

$$B_h = B_{CNG} + B_D \qquad (2)$$

where B_D is the hourly diesel fuel consumption.

The methodology for the experimental study consists in based on comparison of the engine heat release rate as a function of the mass fraction of the gaseous fuel - regulating characteristics with variable gaseous fuel content. The regulating characteristics are obtained at constant engine load (constant mean effective pressure). More details on the on the methodology and obtaining of the relevant characteristics can be found in [10].

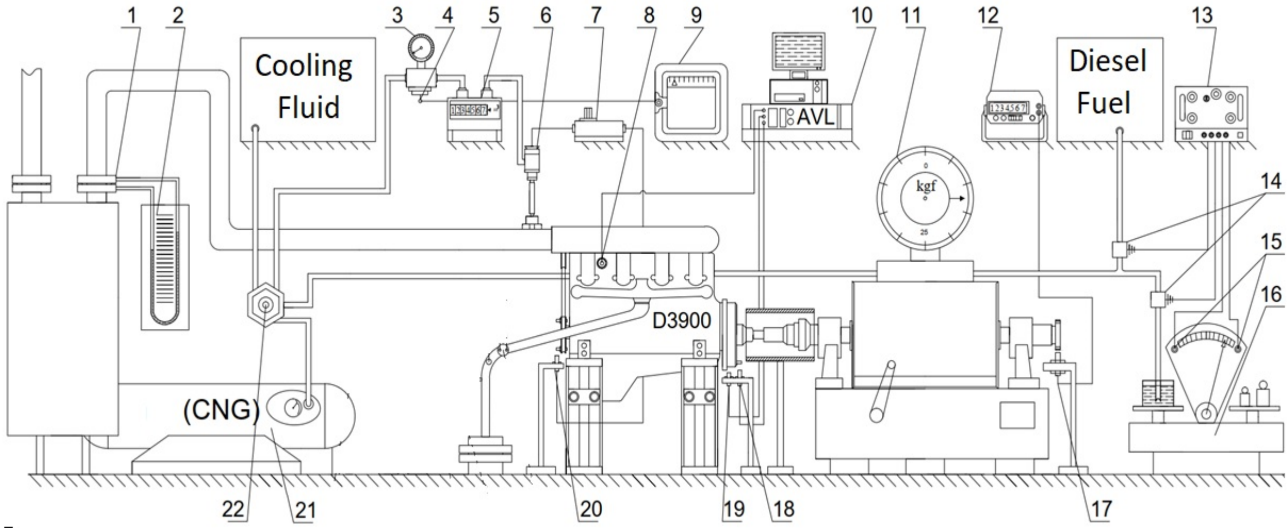

Fig. 2. Test setup for dual-duel mode of *D3900* engine .

III. RESULTS AND DISCUSSION

The results of the heat release (Fig. 4), heat release rate (Fig. 5) and in cylinder temperature (Fig 3) are derived by numerical processing of the indicator diagrams (Fig. 3) by usage of dedicated computer program described in [11]. It is notice that the usage of CNG as a gas fuel for dual-fuel duty cycle of *D3900* engine at mid loads lead to decrees of the heat release and heat release rate. It is also observed that the total heat release decrease in dual-fuel mode which is an indication of less effective combustion process. The effect is proportional to the amount of gas fuel provided to the engine. The reason for the change with an increase in the amount of natural gas supplied to the engine is the lower value of maximum pressure in the cylinder and an increased duration of ignition delay. Consequently, there is a displacement (in the direction after top dead center) of the angle at which the maximum pressure in the cylinder is reached. In addition to the reasons mentioned so far, it should be noted that the results were obtained at 45% load, which makes oxidation of part of the air-fuel mixture difficult. This is due to the relatively cold walls of the combustion chamber. Also the small quantity of diesel fuel supplied, the autoignition of which does not generate enough heat for the oxidation of the entire quantity of the gas-air mixture in the cylinder leads to decrease of the heat release rate proportional to the volume of gas fuel (increase of gas fuel portion leads to decrease the diesel quantity).

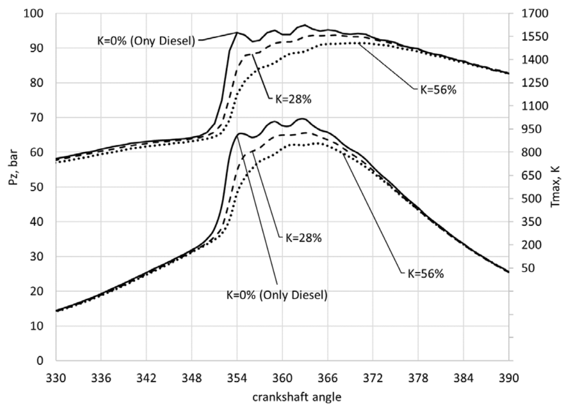

Fig. 3. Cylinder pressure and temperature of *D3900* at 45% load and 1400 min^{-1}.

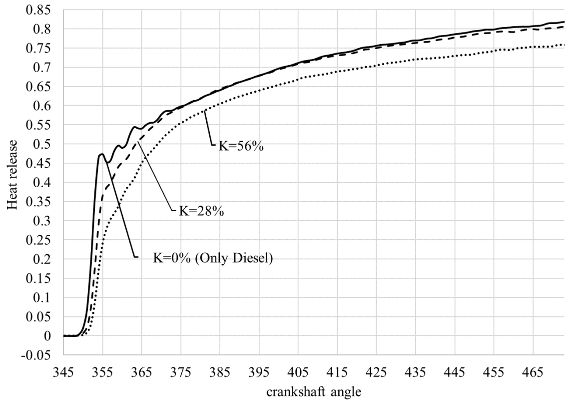

Fig. 4. Heat release of *D3900* at 45% load and 1400 min^{-1}.

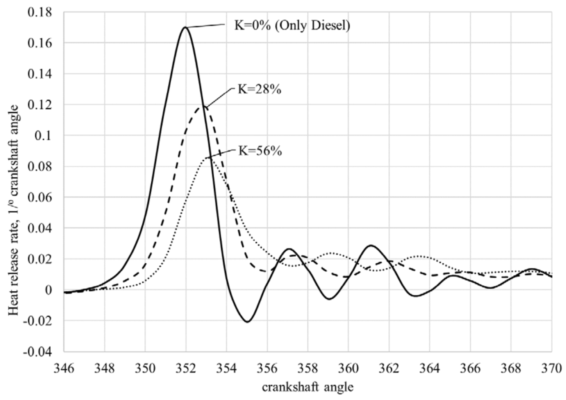

Fig. 5. Heat release rate of *D3900* at 45% load and 1400 min^{-1}.

IV. CONCLUSIONS

Based on the performed experimental study of the CNG effect on the heat release rate of *D3900* diesel engine operating on dual-fuel mode at mid loads (45%load at 1400 min^{-1}) the following conclusions can derived:

- In cylinder pressure decrease proportional to the amount of gas fuel provided to the engine;
- Peak of cylinder pressure is observed at higher crankshaft angle when the engine operates on dual-fuel mode;
- In cylinder temperature decrease when the engine operates in dual-duel mode;
- The heat release and the rate of heat release decrease with increase of the amount of CNG provided to the engine;
- The maximum of the heat release rate is achieved at higher crankshaft angle.

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Some Aspects of the Water Crisis in Bulgaria

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Abstract. **The failure of providing reliable water supply with standard water quality to the households is seen as a specific aspect of the water crisis. In this study, the drinking water supply of the households in Northeastern region of Bulgaria (Varna, Shumen, Dobrich, and Targovishte districts) for the period 2010-2021 was studied and analysed. During the studied period, the relative share of population affected by lack of drinking water supply for over 180 days per year varies between 0.0% in 2011 to 0.7% in 2020 of the total percentage of affected population on national scale. For Varna and Dobrich districts, the share of the affected population from prolonged interruptions in the water supply does not exceed 1%. The most severely affected is the Targovishte district's population, where between 8.8% in 2010 and 24.3% in 2020 experience water supply regime with long, regular interruptions of water supply. In the municipality of Omurtag, approximately 80% of the population does not receive continuous water supply. Households in some of the villages in this municipality receive regulated water supply once every 480 hours. Based on the analysis, settlements with a regime of water supply and poor drinking water quality were identified, as well as the time intervals of supply interruption for the period studied. The main reasons for the manifestations of this specific aspect of the water crisis in Northeastern region of Bulgaria were identified. The shortage of water and the inability to provide households with the necessary water quantities with the required quality confronts Bulgaria with an ever-growing problem, the solution of which requires a complex institutional response, including from the water supply and sewerage sector.**

Keywords: households, water crisis, water supply

I. Introduction

The water crisis has many aspects- environmental, economic, health-related aspect. At the same time the water crisis is rooted simulations to the unequal distribution of freshwater resources and climate change on one hand and to the constantly increasing water needs and water consumption of modern societies of the other hand. Increasing water scarcity is one of the major global challenges today. As the water demand from industry, agriculture, households and the ecosystems rise above available supply in many regions, the maintenance and further development of water infrastructure and governance over water resources become major issues to achieve water security at all levels, as it is shown in [1], [2]. The United Nations recognise the sustainable provision of population with clean water and sanitation as one of the 17 global goals for sustainable development, listed in the UNEP Agenda 2030.

Today, 780 million people still lack sustainable access to safe drinking water and another 2.5 billion lack basic sanitation. [3]. We see the failure of providing reliable water supply with standard water quality to the households as a specific aspect of the water crisis too. Even if the fair access to water can't be a matter of daily survival in Bulgaria, and 99.1-99.5% of the population benefits, being connected to public water supply system there still is a significant room for improvement.

The identification of changes related to water management involves not only the demand but also the supply of this resource. Water scarcity is an emerging threat, facing challenges requiring institutional reforms in the water sector. Considering the specifics of the regional distribution of water resources, the question "Who and when can use water equally and efficiently?" will contribute to the loss of local balance and the creation of a competitive environment, with severe consequences for many regions in the country [4]. The water crisis confronts the population with three main problems related to the quantity and quality of water resources, access and increase in freshwater consumption and water losses.

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The conservation and restoration of natural resources are the necessary steps in minimizing the effects of the global water crisis [5], [6], [7]. The use of innovative remote sensing methods, as in [8] and [9] could contribute to the registration of accidents, leaks and losses on the water supply network. At present, their use is limited to pilot projects.

II. MATERIALS AND METHODS

To develop a comprehensive and clear analysis of the provision of water services, with a focus on public water supply, statistics from the National Statistical Institute of Bulgaria were used. The statistical data used in the analytic work data are based on annual statistics in the Water Supply and Sewerage sector and are derived from a comprehensive monitoring of the country's water supply for the period studied. In addition, publicly available data from official reports from water companies, municipal administrations, etc. was used. The data are based on annual statistics in the Water Supply and Sewerage Sector and are derived from a comprehensive monitoring of the country's water supply for the period studied.

The relative share of a population with a water supply regime is calculated as a share of the connected population with public water supply. The indicator covers the population with a water supply regime due to drought (water scarcity) [10]. The study adopted 2 categories with a water supply regime, in which the water regime is seasonal in nature and covers a period of up to 180 days a year and year-round over 180 days a year.

The survey was carried out using data on water supply in statistical regions. The analysis covers the statistical regions NUTS-2, according to the classification of territorial units for statistics, and for the statistical Northeastern region and at NUTS-3 level, which corresponds to an administrative territorial unit - district.

Of interest is the Northeastern region of Bulgaria, which includes Varna, Shumen, Dobrich and Targovishte Districts.

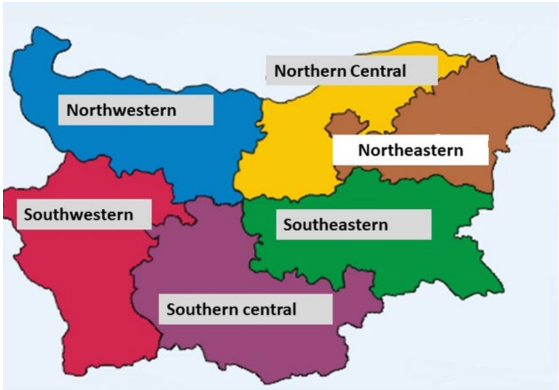

Fig.1. NUTS-2, Bulgaria

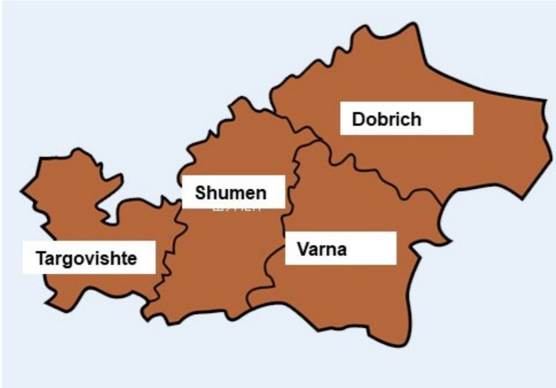

Fig. 2 NUTS-2, Northeastern region, Bulgaria

The reported data for analyses related to population density for Varna district is at 123 inhabitants per sq. km, while the national average population density is 63 inhabitants per sq.km. That makes Varna district the second most populous in the country. The other districts in the Northeastern region are significantly less populated: Shumen District - 51 inhab/km^2, Targovishte District - 41 inhab/ km^2 and Dobrich District - 31 innab/ km^2 (based on national statistics of 31.12.2022). Dobrich district contains 215 settlements – town and villages, Targovishte district - 194, Shumen - 151, and Varna – 159 settlements.

III. RESULTS AND DISCUSSION

Irregularity of water supply is a long-lasting persisting problem in many districts in Bulgaria.

In the Northeastern region shows a specific feature regarding households' water consumption. Targovishte District persistently shows the lowest level of water used by households from public water supply on average per person in the country. Long-term levels of reduced drinking water use: from 58 liters per person per day, registered in 2010. to 72 liters per person per day in 2022, vs. the national average of 97 l/h/day in 2010. and 103 l/h/day for 2022, as it is presented in Table I.

For the studied period from 2010-2021. in Bulgaria, the population affected by lack of water supply due to drought ranged from 0.6% (45, 206 inhabitants) in 2014. to 6% (418,546 persons) in 2019. [10]. The percentage share for 2021. It accounts for 2.5%, equivalent to 171, 944 persons. Population with seasonal water supply regime formed between 0.5% (36,120 inhabitants) in 2014. to 5.8% (404,594. inhabitants) in 2019. of the total percentage of affected population for the country. By 2020. accounted for 3.3% (228 823 inhabitants) and in 2021. 2.4% (165, 065 inhabitants) of the total for the country share of population affected by a water supply regime. The influence of a population with a water supply regime of more than 180 days a year, which occupies between 0.0% in 2011, is negligible. to 0.7% (48,538 inhabitants) in 2020. [10] (Fig. 3).

TABLE I. AVERAGE HOUSEHOLDS' WATER CONSUMPTION, 2010-2022, L/PERSON/DAY

Year	Districts				Region	Bulgaria
	Varna	*Dobrich*	*Targovishte*	*Shumen*	*Northeastern*	
2010	97	73	58	74	**82**	**97**
2011	94	78	64	78	**84**	**100**
2012	95	80	64	81	**86**	**102**
2013	93	68	65	86	**84**	**99**
2014	90	75	67	79	**82**	**96**
2015	92	78	67	81	**84**	**99**
2016	94	78	69	80	**85**	**100**
2017	95	78	68	80	**86**	**99**
2018	94	78	69	78	**85**	**99**
2019	97	80	66	78	**87**	**99**
2020	101	84	68	76	**89**	**102**
2021	99	83	64	79	**88**	**102**
2022	105	90	72	83	**95**	**103**

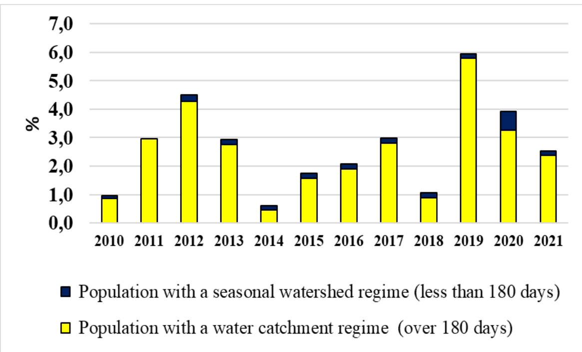

Fig.3. Relative share of population on water supply regime, Bulgaria, 2010-2021, [%.]

According to official statistics on the number of the population in the country for the studied period, the uneven trend with a decrease in the percentage of population affected by the water supply regime is accompanied by a decrease in the urbanization of the country.

As the main cause of a population with a water supply regime of seasonal type is determined by the type of feeding and the balance of river systems. Thus, the uneven distribution of water resources in the country determines the uneven distribution of a population with a water supply regime.

Household water use is only 5-6% of the total water used. The highest use values were 271.01 million m3 recorded in 2012 and the lowest were 250.48 million m^3 in 2019. The quantities of water used vary within a narrow range for the whole studied period. Since 2014 until 2019 there is a decline in water consumption in the household sector. These results reflect a stable water use in the segment over the past decade. The general trend is towards a slight decrease in the water use from households.[11]

When considering regions in the country by territorial distribution, the results are identical. The Northwest region accounted for 0.2% in 2018. to 23.9% in 2019. of the total percentage share. For the North Central region, data vary between 0.7% in 2014. to 5.8% in 2012. For the Northeastern region ranged from 1.1% in 2011. to 5.6% in 2020. The Southeastern region accounted for between 0.0% in 2015 and 2016. and 4.5% in 2020. For the South-East region, % ranged between 0.0% in 2014. to 5.5% in 2020. For the South Central region, the relative percentage share is between 0.1% in 2014. to 1.5% in 2020. [12] (Fig.4). Of interest is the Northeastern region, which includes Varna District, Shumen District, Dobrich District and Targovishte District, shown in Fig. 5

During the studied period, the percentage share of Varna and Dobrich districts was insignificant, not exceeding 1%. Shumen District accounted for 0.0% in 2010 and 2011. to 12.5% in 2020. (21 473 inhabitants) of the total % for the region. The most significant percentage of population with a water supply regime is in the district of Targovishte, where in 2010 according to data they were 8.8% (11 249 inhabitants), and in 2020. reaches 24.3% (or 26 272 inhabitants).

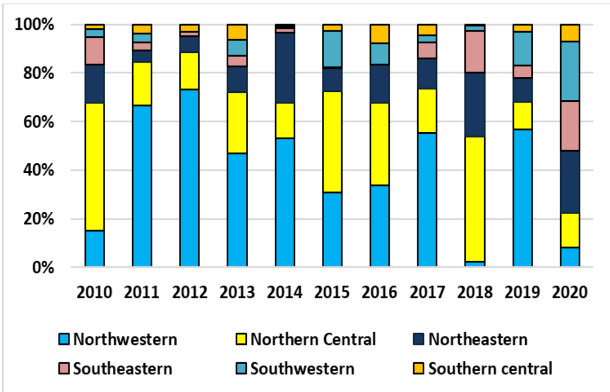

Fig. 4. Relative share of population on water supply regime by NUTS-2, Bulgaria, 2010-2020, [%.]

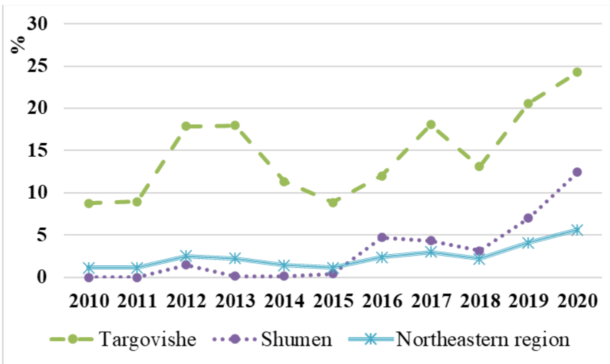

Fig. 5. Relative share of population on water supply regime, Northeastern region, Bulgaria, 2010-2020, [%]

Targovishte District's water supply system serves 5 municipalities (Targovishte, Omurtag, Opaka, Antonovo and Popovo) and includes 134 urban water supply zones. A total of 746km external water mains and 1375 km of internal water mains were built to supply the settlements in the district. The condition of the water supply network is severely deteriorated. The total water losses, Northeastern region, for the studied period, vary from 59 to 61% of the total water supplied.

Targovishte region is poor in water resources - more than 95% of the more than 300 water sources have a flow rate of less than 5 l/sec. and are dependent on rainfall, with some of them drying up in years with poorer rainfall which limits the normal water supply. In the region rainfall is below the average annual rainfall amounts for the country, with a summer maximum in June and a winter minimum in February. The snow cover lasts for about 44 days. The rivers are low-water, with small catchment areas. River flow is erratic. All rivers have a snow-rain regime. Karst springs in the area have a small flow rate and their importance is related only to the water supply of some smaller settlements. Almost all catchments and drains are shallow subsoil and their flow rates are rapidly influenced by atmospheric conditions [13].

The most severe is the water supply regime for the municipality of Omurtag, where about 80% of the population does not receive continuous water supply [14]. The municipality of Omurtag has a total population of 20674 and is supplied with water from 29 water supply zones, 12 of which distribute water below 10 m^3 per day, 16 zones distribute water from 10 to 100 m^3 per day, and only one is a large water supply zone "Kipilovo ".

The town of Omurtag and villages of Veselche, Zmeino and Pticevo are supplied with water from a captured spring BG2G00000K2033 Kipilovo", located in the village of Kipilovo, Kotel municipality, Sliven district, part of the Kotel Karst Basin [10]. The main quantitative features of the underground water body are presented in Table II.

TABLE II. DISTRIBUTION OF WATER QUANTITIES UNDERGROUND OF WB BG2G00000K2033, 2014 - 2022, [L/S].

Year	***Free water quantities***	***Permitted water quantities***	***Available water resources***
2014	718.12	39.88	758
2015	714.36	57.64	772
2016	730.94	57.64	792
2017	693.11	95.47	792
2018	743.35	95.63	842.4
2019	660.32	95.66	759.4
2020	662	96.98	762.4
2021	656.07	94.91	754.4
2022	660.07	94.91	758.4

Water losses along the route from the water source to the town and in the internal network are significant which is why the city is on regime water supply. The internal water supply network of the town of Omurtag is 25 km long. The plumbing diversions are constructed of galvanized pipes, which are subjected to rapid corrosion. All this leads to daily accidents, large losses, and impaired water supply of the population.

According to the Targovishte Water Supply and Sewerage Company, the reasons for the water crisis in the area are due to water shortages in the water source, interrupted power supply to the "Kanino" PS and a compromised water supply and internal water supply network [11].

The water crisis affects the town of Omurtag with a year-round water supply regime, as well as many settlements in the municipality. Some of the villages are supplied with water from other water sources but nevertheless the population suffers from water supply irregularity. Households in some villages in this municipality receive regulated water supply once every 480 hours, for others there is no water supply due to water scarcity in the water source. The affected population of lack of water varies between 30-430 people, depending on the settlement. During the winter months (December and January) the population of town of Omurtag has access to drinking water for only 2 hours every 72 hours. During the summer months (August) the water supply is limited to 3-4 hours in every 20 hours [15]. The situation worsens in an accident on the water supply network, after its removal the water travels 11 hours on the extremely long route. This also changes the water supply planned by the water supply to the settlements. Priority is given to educational and social institutions. The hospital in the city has the tanks with the help of which the hospital serves patients. The water crisis affected 4,002 people in the town.

There is an alternative solution to use water from the Yastrebino dam. The conducted preliminary analyzes regarding water quality show that there are no deviations from drinking water standards. The location of the Yastrebino dam shows a promising section for a new water catchment for the needs of the local water supply company, but it would also significantly reduce drinking water losses along the route. Currently, regional studies are being carried out - pre-investment studies for the entire region.

IV. CONCLUSIONS

We define the inability of providing reliable water supply to the population with clean drinking water in many regions in Bulgaria as a specific dimension of the water crisis in the country. From the data presented, it is clear that in the Targovishte district, and more specifically in the municipality of Omurtag and other small settlements, the seasonal and year-round subjugation of the population to the water supply regime is a significant, persistent problem.

The deepening of the problem in the Northeastern region has continued in recent decades, with the relative share of the population affected by systemic interruptions in water supply continuing to increase from 1.1% in 2011 to the 5.6% in the end of the study period (2021). The manifestation of the crisis in the Targovishte district is extreme, where the affected population has grown more than twice (from 11,249 inhabitants in 2010 to 26,272 inhabitants in 2020). This cannot be explained only by the prolonged seasonal droughts, reflecting on the capacity of the water sources from which the supply of drinking water is provided. The total water losses throughout the country are huge, as their main component is the real water losses. The Targovishte water supply system in particular are in a deplorable state and needs immediate rehabilitation and/or replacement and real losses drastic reduction.

In addition, the low flow rate of the spring Kipilovo, the difficult-to-access terrain to the water source contribute to the serious water insecurity of the town of Omurtag. One possibility to eliminate the interruptions of water supply and to limit the effects of drought is to expand the range of water sources used for water supply and further development of water supply and sewerage infrastructure. For more than 10 years, the potential of the Yastrebino dam has remained unused, which demonstrates a lack of adequate timely actions on the part of water supply and sewerage companies, in order to ensuring water supply safety and security.

To eliminate the manifestations of the water crisis, coordinated actions by the state and the water supply and sanitation sector and change of water resources' management at all levels and are needed.

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Challenges to the Development of the Marine Litter Monitoring System in Bulgaria

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Abstract. **This report presents the results of a study of the development of the marine litter monitoring system in Bulgaria in the period 2016-2022. The system has been structured and operates as part of the implementation of the requirements of the Marine Strategy Framework Directive 2008/56/EC and in particular Descriptor 10 "Marine litter". Until 2022, the monitoring surveys of the distribution, abundance and accumulation of marine litter were carried out in accordance with specific criteria for macro- and micro-litter. In parallel, the potential sources of marine litter and the pressure of its introduction into the marine environment, beaches, water column and seabed have been analyzed. A comprehensive comparative analysis has been conducted in regards to the applied monitoring procedures, as well as the results of numerous monitoring surveys conducted in the frames of Bulgarian national marine litter monitoring system, during the studied period. As a result the main challenges for the development and the upcoming increase in the scope of the system were identified end presented in this paper. Opportunities to improve the functioning of the system, directed to eliminating weaknesses in relation to used observation protocols, monitoring sites, frequency of monitoring, ensuring representativeness and comparability of monitoring data and information are listed.**

Keywords Marine litter, monitoring system, Marine Strategy.

I. INTRODUCTION

At global and regional scale marine litter is environmental, economic, health, aesthetic and cultural problem [1]. The overloading of the marine environment with marine litter – floating debris as well as contained in the water column and accumulated on the sea bottom, and its increasing accumulation on the coasts has been recognized as one of the main environmental problems worldwide. [2],[3]. The huge variety of anthropogenic waste enters the marine environment from human activities on land and at sea. According to United Nations Environment Programme (UNEP), marine litter is any persistent, manufactured or processed solid material discarded, disposed of/ or abandoned in the marine and coastal environment [4]. This definition once more gives a glance at the interconnection and interdependence between socio-economic development and the disturbance of ecological balance on a global scale. Marine litter affects negatively coastal and marine ecosystems, wellbeing of societies, especially the coastal population, e.g. fisheries, tourism and recreation, sea-oriented economy, industry, shipping, etc. Impacts to marine life vary from physical or chemical harm to marine biota, to wider effects on biodiversity and ecosystem functioning [5].

Among the diversity of material, plastics are the largest, most harmful and persistent part of marine litter. (ML) Their product characteristics - light, durable, economical for mass production and single use, due to improper disposal have turned them into a pervasive environmental pollutant in the long term [6]. In addition, majority of plastics are insoluble and non-degradable in the marine environment. Low relative weight of products made from synthetic polymers contributes to their spread over extremely long distances, through aeolian and hydrological transport. According to the UNEP, approximately 7 billion of the 9.2 billion tonnes of plastic produced between 1950 - 2017 became waste in landfills or dumped [7]. Particularly, the amount of plastic litter in the world's oceans has been constantly rapidly growing (Borrelle et al., 2020; Jambeck et al., 2015; Ryberg et al., 2019), accounting for at least 85 % of total marine litter [7]. Pieces of plastic have been found in the digestive system of many aquatic organisms, including marine turtle species, seabirds and marine mammals. [7]. Particles smaller than 5 mm (microlitter) are included in food chains [8]. Ingested by marine organisms, they have a direct negative impact on ecosystems and indirectly on the humans consuming sea food.

Marine litter is a complex and transboundary problem although it is included in international, regional and national plans, the problem requires implementation of

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active measures to reduce quantities and limit the distribution in the marine environment. Despite of institutional efforts and involvement of citizen science there still is a lack of public understanding and behavior on negative effects of marine litter.

Monitoring and assessment of marine litter in the coastal and marine environment, requires a high-resolution classification system for litter items, which enables them to be recorded in a clear, and harmonized way [9], [10], [11].

In this context the national ML monitoring system has been established in Bulgaria in 2015. Now still further development and coordination at regional level in order to ensure collection of the required ML data in proper manner is needed.

Current research aims to identify the gaps and organization, structure and functioning of the system for ML in Bulgarian part of the Black Sea.

II. Materials and methods

The subject of the present study is the ML monitoring system in Bulgaria with its structure, provision and functioning. A comprehensive detailed analysis has been performed to evaluate the level of conformity of Bulgarian ML monitoring system's state of art to the required EU level regarding scope, organization, and performance of the system.

Marine Strategy Framework Directive (MSFD) [9] is one of the pillars of the integrated EU Maritime Policy and tackles the achievement of good environmental status (GES) of marine environment via 11 quality desctriptors. EU member states are obligated to monitor and access the achievement of GES under all descriptors including Descriptor 10 (D10) "Marine litter".

Monitoring protocols have been developed in order to obtain comparable data regarding composition, abundance and accumulation of marine litter. Implementing the MSFD as a part of European Union Bulgaria has developed national monitoring program on D10.

The research has been specifically focused on the subsystem marine macro litter monitoring. Official data, including statistical data and information, e.g. annual reports, survey protocols and other relevant documentation, had been used for the purposes of this investigation [12].

III. Results and discussion

In order to provide consistency, compatibility and comparability of monitoring data a classification system has been developed by OSPAR Commission [13]. It has been adopted by Bulgarian Ministry of Environment and Waters prior first ML monitoring survey in Bulgaria, 2015, because of its applicability to ML in coastline, surface layer of the water column, seabed and biota.

That detailed identification, recording and reporting is organized in specific categories. In this way it is provided a link between monitoring data and the ML potential sources. By MSFD technical groups were developed protocols for monitoring of marine litter with photo catalogue and list of categories to increase the comparability of data and assessments between Member States. In order to understand better the impact of marine litter to the marine environment were given methodological recommendations and advice on how to sample, analyze, and record marine litter to support designing and implementing monitoring programmes [14], [15], [16]. Monitoring programmes under MSFD D10C1, indicator 1 had been established and implemented by the Ministry of Environment and Water [17]. Thus, the national monitoring system partially meets the requirement regarding commonly structured monitoring structured systems in EU.

To specify the monitoring sites or monitoring polygons a set of unified criteria has been applied in the frames of the subsystem Beach marine litter monitoring. Aassessed beach systems included in the programme have minimal anthropogenic activities - no concession or municipal regular cleaning and maintenance, because of the impact on the accumulation and distribution of macrolitter on the coast. Monitoring campaigns had been conducted along the Bulgarian Black Sea coast in regard to above mentioned criteria – in order to escape of maintenance influence.

Surveys include following beaches: Durankulak North - 1, Krapets – North, Channel 2 - Varna (coastline along a canal connecting the Black sea with Varna lake), Shkorpilovtsi- North, Byala – Kara dere, Children camp Obzor, Irakli, Black Sea saltpans – Burgas, Alepu, beach at the mouth of the Veleka river and Lozenets - Coral (Table I).

Two of the monitoring sites - Channel 2 - Varna and Black Sea saltpans JRC- Burgas, are within the scope of the two largest cities on the Bulgarian Black Sea coast with ports of public importance and the rest are close to small villages, far away from industrial areas but overpopulated by tourists during the summer season.

Bulgarian monitoring system on Descriptor 10 (D10), criteria D10C1 has to provide information on the quality (individual categories and subcategories) and quantity of macrolitter along the Bulgarian coast (number and weight of individual categories, total weight and number of all collected debris from a specific section). Assessment is based on the main eight categories in accordance to main recommendations of the European Guidelines for Monitoring Marine Litter under MSFD [14].

The monitoring methodology in use for monitoring according to criterion D10C1 along the Bulgarian coast follows the recommendations indicated in the Monitoring Guidance under Descriptor 10. The same recommends that survey and data collecting is from at least two 100 m sections (100 m length and 100 m width) of the selected at least 1000 m beach or coastline for lightly or moderately polluted beaches. [14], [18].

Method applied for conducted monitoring on marine debris is in situ manual collecting in a site with length of 100 m along the coast line and the back of the beach (dunes, cliff, vegetation line, artefacts). Samples collected are classified according to the Guidance of MSFD Technical Subgroup on Marine Litter [14] and with Revised Decision 2017/848/EU repealed 2010/477/EU established specific criteria (including criteria elements), methodological standards, specifications and standardized methods for monitoring and evaluation, and determination of threshold values. [10].

TABLE I SAMPLING UNITS ON MARINE MACROLITTER PROGRAMME, 2016 – 2022

	Sampling units on marine macrolitter programme, 2016 – 2022		
	Sampling unit	***Category***	***Pressure***
1	Durankulak North - 1	Unguarded beach	Transboundary transfer of waste
2	Krapets - North	Coastline	Transboundary transfer of waste
3	Canal 1 - Varna	Unguarded beach	Pressure from large populated area, with >100000 p.e (Varna town)
4	Shkorpilovtsi North	Nature-friendly tourism beach; Unguarded	Pressure from less populated area, with < 2000 p.e (Shorpilovtsi village); seasonal recreational sites; recreational activities during summer; influence of the river "Fundukliyska" and transfer of waste from currents
5	Byala - Karadere beach	Unguarded beach	Reference site; inflow of small rivers - the river "Cherna" and the river "Byala"; transfer of waste from currents
6	Children camp Obzor	Nature-friendly tourism beach; Unguarded	Pressure from large settlements > 10000 p.e. (town of Obzor); influence of the river "Dvoinitsa"; seasonal resort sites; agricultural lands and forests
7	Irakli	Unguarded beach	Offshore reference place; mainly forests and arable land; transfer of waste from currents
8	Black sea Salt Pans JSC	Unguarded beach	Pressure from settlement with > 100000 p.e. (Burgas town) and Sarafovo neighborhood; in close proximity to "Black Sea Solnitsi" AD Salt plant; balneotherapy spot
9	Alepu	Unguarded beach	Pressure from large settlements > 10000 p.e. (town of Sozopol); seasonal resort sites ("Dyuni" resort and other smaller ones); close to "Alepu" swamp and transfer of waste from currents
10	Veleka river	Unguarded beach	Pressure from small settlements < 2000 p.e. (village of Sinemorets); seasonal resort sites; influence of the "Veleka" river and transfer of waste from currents
11	Lozenets - Coral	Unguarded beach	Pressure from small settlements < 2000 p.e. (village of Lozenets); seasonal resort sites and camping; transfer of waste from currents

The results for the period 2016-2022 were summarized in tabular format, on marine macrolitter on beaches (D10C1) as well as comparability by researches per year and seasons, category, total amount in kg and number of items collected. [12].

In order to understand the effectiveness of the conducted monitoring during the observed period 2016 - 2022 it has been done a comprehensive and comparative analysis on applied monitoring procedures and results of the surveys along the Bulgarian black sea coast. During the studied period number of beaches observed has fluctuated from 8 to 10, Veleka river was changed with Lozenets – Coral beach in 2021.

National monitoring system on beach macrolliter, although it was developed according to the requirements of the MSFD, does not address the specifics of the selected areas - their lithodynamic and hydrodynamic characteristics, which are decisive for the distribution and retention of macrolitter in the coastal unit. Information on any entangled fauna encountered during the survey (details of the organism, nature of entanglement, live or dead).

Regarding survey frequency and timing, it should be carried out 4 surveys per year for each survey unit. The proposed periods are winter in January, spring in April, summer in July and autumn in October [16]. These periods are more or less evenly distributed throughout the year. However, regional or even local conditions might prevent the performance of surveys in the periods proposed. Weather conditions (e.g. snow) in particular could prevent surveys in winter or spring. In addition, a high volume of tourists and extremely hot weather might hinder surveys in July. Surveys should not be undertaken during periods when there is a risk of affecting endangered or protected species, such as sea turtles and birds (i.e. nesting period). While using harmonized monitoring periods among the countries is highly recommended, it is up to the national coordinators of beach litter surveys to choose the survey periods best suited for their regions.

Sampling frequency was not achieved in any of the years. Winter period (January) has been observed/ monitored once in winter period (2016), only 8 sampling units. As pilot monitoring on D10C1, indicator 1 surveys are conducted mostly in spring, summer and autumn (Table III).

The comparative analysis shows direct proportionality when comparing the number of units and the total weight of the marine debris. 2017 is an exception due to a high number of marine litter G79 in the area at the mouth of the Veleka River. In this case, 33 car tires were found. (fig.1, Table II)

The result of data analysis from the implementation of the monitoring system during the observed period identifies that the coordinates of the 1000 m and 100 m sections coincide in the period 2016-2022, except for the replacement of one beach system with another (Veleka river with Lozents - Coral) but the scope of the territories of the selected beaches for the presence of macro litter was not measured or reported.

The width of the sampling unit (perpendicular to the shoreline) is defined as the distance between water's edge and beach back (dune base, rock, vegetation line or human artifacts) and measured at half the length. The width of the beach should be measured at the mean water level in regions with small tidal amplitudes as Black Sea.

Meta data from sampling units do not include the width of the selected transects. For a correct analysis and comparability of the results, it is necessary to take into account the changes in the beach systems as a result of the different hydro-meteorological conditions according to the seasonal dynamics of the coastline (water's edge) affecting the width of the beach, respectively of evaluated area size [16]. With an inscribed width of each section of 100 m, there will be consistency and coparabiliy in the assessment.

In regard to other 2 indicators Floating marine litter (D10C1 indicator 2) and Seafloor macro litter (D10C1 indicator 3) the data on the conducted monitoring are extremely limited. The studies were carried out in the period 2016-2017: on D10C1, indicator 2, a pilot monitoring campaign was carried out within 8 days. Classification on amount, type, size and spatial distribution of litter floating on the sea surface >2.5 cm has been done in the coastal and shelf areas of the Bulgarian waters of the Black Sea.

Marine macrolitter on the sea bottom - the research was carried out in the shelf area in 2017. The results for the distribution and quantity were calculated as items/km^2.

The national macro waste monitoring system is characterized by incompleteness of research and data sets on floating and seabed sediments. No program, research or results available for Mesolitter and Pellets [16].

Data and information from the conducted studies is fragmented and not available in a single open portal, platform or data center for future and analysis. On messoplastics and pellets (also called plastic nurdles) programme has not been developed.

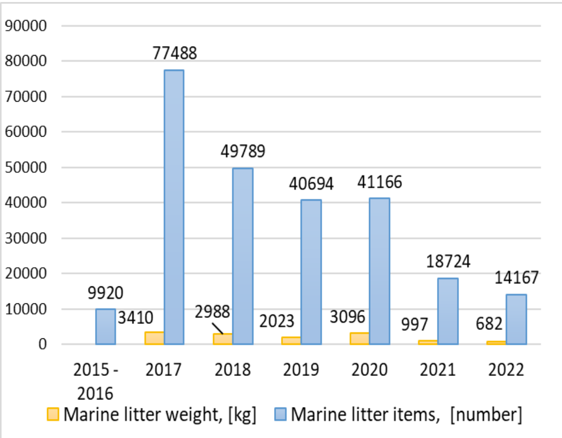

Fig. 1 Total number of items and total wight, [kg/year], 2015-2022

TABLE II MARINE MACROLITTER MONITORING SURVEYS

Year	Marine macrolitter monitoring surveys, 2015-2022			
	Number of surveys	*Number of beaches*	*Total weight, kg*	*Number of items*
2015 - 2016	4	8		9920
2017	3	10	3410.204	77488
2018	4	10	2987.644	49789
2019	4	10	2023.293	40694
2020	4	9	3095.88	41166
2021	4	10	996.539	18724
2022	4	10	682.479	14167

TABLE III MONITORING SURVEYS D10C1, MACROLITTER ON BEACHES, 2016-2022

Season	Winter	Spring	Summer	Autumn
Reference JRC 2023	***January***	***April***	***July***	***October***
2015				September October December
2016		March		
2017			August September	October November
2018		May	July	September October
2019		June	July August	September October
2020		May	July	September October
2021		April June		September November
2022		May, June		September, November

IV. CONCLUSIONS

Monitoring results and data collected from surveys conducted during the period 2016-2022 has been analysed, in particular for criteria D10C1 – beach macrolitter. Comprehensive comparative analysis has been done in regards to the applied monitoring procedures. As a result, it has been identified gaps and weaknesses in the monitoring system, applied protocols, monitoring sites, frequency of observations, representativeness and comparability of monitoring data used for the assessment of the environmental status in accordance to MSFD [12].

Despite conducting regular long-term monitoring in the period 2016-2022, there has no regularity by seasons, during the winter season monitoring has not been provided. That is very important factor because of hydrometeorological conditions typical for the coastal area - strong winds and swell, which are affecting the transport of macrolitter from the sea to the land.

Analysis of collected information in the period 2016-2022 raised the question how is guaranteed the validity, representativeness and the comparability of the results and the quality of the data collected by national marine litter monitoring system. Due to the lack of information on the size of coastline areas observed, also because chosen subcontractors and participants were mostly volunteers, data obtained need to be confirmed - has the monitoring meets the minimum requirements for methodology and representativeness of the results. It is an option to verify the reliability of the results with other methods (e.g. ROV, UAV).

Forms/protocols for fieldwork should be revised so it is provided the actual field area and obtained reliable and comparable data on the composition, abundance and accumulation of ML.

An additional challenge for the marine litter monitoring system is the lack of an adequate legal definition, which leads to a gap in the state's responsibility as an institution in law enforcement and commitment in providing financial resources.

The opportunity for future development and improvement the system consists in an update of the program in accordance with the recommended guiding documents at the European and international level, as well as meeting the minimum scientific requirements for presentation and comparability of the results. In that way the suspicion of working with unreliable data would be avoided and convergence ensured, as well as the subsequent correct interpretation of the data and assessment of the GES of the marine environment under descriptor D10.

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The Application Perspectives of Lake Clay Infused with Natural Active Agents - Essential Oils in Cosmetology and Dermatology

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Abstract. **The aim of the research is to experimentally test and scientifically substantiate the mixture of lake clay and a natural active agent – essential oil, in perspective of its application in cosmetology and dermatology. Sensory properties of lake clay and mixtures of lake clay with essential oils were tested. The presence and quantity of *Staphylococcus aureus, Pseudomonas aeruginosa, Candida albicans, Escherichia coli*, and aerobic mesophilic microorganisms in lake clay and lake clay with essential oils mixtures were determined. Thyme (*Thymus vulgaris*), apple mint (*Mentha suaveolans*), and caraway (*Carum carvi*) essential oils, which not only improve the cosmetic value of the product but also act as antimicrobial agents and preservatives, showed the best results. They meet the requirements of Latvian Cabinet Regulation No. 354 "Procedure for Meeting the Significant Requirements for Cosmetics" and European Standard EN ISO 17516: 2014, Cosmetics - Microbiology - Microbiological limits.**

Keywords: lake clay, essential oil, microbiological quality

I. INTRODUCTION

Currently, a healthy lifestyle is gaining popularity and consumers demand for natural products - including cosmetics, is soaring. The use of clay minerals, especially in biomedical applications, is known from ancient times and they are regaining attention in recent years [1]. Clay has effectively proven itself in both cosmetology and dermatology. Clays have cleansing, moisturizing, soothing, regenerative, anti-inflammatory, sedative, anti-septic, and detoxifying effects, they rejuvenate, tone, and nourish the skin [2] - [5]. Clays can eliminate excess grease and toxins from the skin, and hence are said to be effective for dermatological diseases such as furunculosis and management of ulcers [6]. They are used to treat various cutaneous conditions such as seborrheic dermatitis, psoriasis, chronic eczema, and acne [7]. An overview of the use of clay in skin and hair care cosmetics has been published, presenting a general introduction regarding these minerals and its wide-ranging application potential in the biomedical field, which could be useful for formulating novel solid shampoo formulas [8]. Most of the clays in Latvia are brown, they can be applied as pigment in sunscreens or tonal creams. At the same time, the addition of the clay fraction increases the sun protection factor (SPF) of the product, thereby decreasing the necessary amount of synthetic UV filters to obtain a certain SPF value [9]. Latvia is one of the European countries that have the richest clay deposits per resident [10]. Latvia is rich in waters; its territory contains 2256 lakes with the water surface area over 1 ha and the total area about 1001 km2, which is 1.5% of the territory of Latvia [11]. Latvian lakes are rich in clay deposits, which is a valuable, but little studied natural resource. Lake clay effect can be different from lithospheric clay considering that lake clay has formed in different environment and is covered by sapropel layer which medical effectivity has been proven. Considering lake clay chemical parameters, granulometric content, specific surface area and adsorption capacity, lake clay is suitable for cosmetic and dermatological application [12], [13]. However, the presence of some microorganisms in the clay presents the risk of infection, spoilage of the product during storage. Therefore, in this study, control of microbiological contamination of clay and clay essential oils was carried out.

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Up to 73.3% of individuals have been affected by *Acne vulgaris* by the age of 20, furthermore, up to 12% of women and 3% of men have active acne in the age group of 25-58 years [14], [15]. Acne is associated with decreased quality of life and can sometimes lead to depression and even suicidal thoughts; additionally, inflammatory lesions tend to resolve with scarring. Therefore, prompt and effective treatment is of outermost importance [16], [17]. Clay promotes the absorption of active substances in the deeper layers of the epidermis [18]. The positive effect of the use of certain essential oils on the skin and their successful use in cosmetology and dermatology have been proven, which means that adding essential oils to clay could improve the effectiveness of the clay and the Clay - essential oil mixture could be an effective treatment aid in cosmetology and dermatology.

Study aim - to experimentally test and scientifically substantiate the perspectives of a mixture of local lake clay and essential oils for safe use in cosmetology and dermatology.

II. MATERIALS AND METHODS

Z/S "Rūķīšu tēja" is a Latvian company that cultivates medicinal plants and produces essential oils. The experiments utilized 8 essential oils from Z/S "Rūķīšu tēja": thyme (*Thymus vulgaris*), caraway (*Carum carvi*), apple mint (*Mentha suaveolens*), sage (*Salvia officinalis*), lavender (*Lavandula angustifolia*), wormwood (*Artemisia absinthium*), German chamomile (*Matricaria recutita*), peppermint (*Mentha piperita*), and lake clay obtained from Lake Zeiļu at a depth of 5-6 meters.

Microbiological analysis and sensory properties – aroma, color, and consistency were determined on the 5th day and after 4 months of mixing clay and essential oils.

Sample preparation: The experiments utilized a 0.3% mixture of essential oil and clay. To prepare it, 100 grams of clay were weighed in a sterile container, 0.3 grams of oil were added, and mixed with a mixer for 5 minutes. In Regulation No. 354 of July 2, 2013, of the Cabinet of Ministers, the microbiological cleanliness criteria for cosmetics are specified, including the quantity of aerobic mesophilic microorganisms (mesophilic bacteria, yeast, and mold), *Staphylococcus aureus, Pseudomonas aeruginosa, Candida albicans, Escherichia coli*. Therefore, samples of lake clay and clay with essential oil mixtures were tested for the presence and quantity of *C. albicans, P. aeruginosa, S. aureus,* aerobic mesophilic microorganisms.

Sample preparation for the microbiological testing: 10 g of sample + 90 mL of 2% Tryptone water + LP80, mix the sample in a stomacher for 30 seconds, let it rest for 10 minutes, prepare dilutions of 1:100, 1:1000, 1:10 000, which are then plated on 3 parallel Petri dishes.

Determination of mesophilic aerobic microorganisms:

1 mL from each dilution is spread on Tryptone soya broth (TSB) agar in a volume of 12–15 mL, at a temperature of 45°C. After pouring the agar, the sample is gently mixed in the container.
Incubation at 32.5°C ± 2.5°C for 72 hours ± 6 hours.

Determination of *Staphylococcus aureus*:
1 mL from each dilution is spread on Petri dishes with Baird Parker agar, leveled with a spatula.
Incubation at 32.5°C ± 2.5°C for 48 hours.

Determination of *Pseudomonas aeruginosa*:
1 mL of the sample is spread on Nutrient agar.
Incubation at 32.5°C ± 2.5°C for 24 hours.

Determination of *Candida albicans*:
1 mL of the sample is spread on Sabouraud dextrose chloramphenicol agar.
Incubation at 32.5°C ± 2.5°C for 48 hours.

Determination of *Escherichia coli*:
1 mL of the sample is spread on MacConkey agar.
Incubation at 32.5°C ± 2.5°C for 24 hours.
After incubation, colonies are counted on Petri dishes. The number of microorganisms per 1 mL of the sample is calculated using the formula:

$$X = a \times b / c \tag{1}$$

where a - number of colonies grown on Petri dishes; b - dilution factor; c - number of Petri dishes plated; X - number of colony-forming units per 1 mL of the sample (CFU/1mL).

III. RESULTS AND DISCUSSION

A. Sensory properties of lake clay and mixtures of lake clay with essential oils

The sensory properties of clay and clay with essential oils are summarized in Table 1. The smell of clay samples is characteristic of clay, with a consistency that is plastic, soft, and smooth, and a color that is greenish gray. When oils were added to the clay, the color of the mixture remained unchanged, except for the clay-chamomile mixture, where the chamomile oil has a bluish hue, resulting in a bluish gray color of the mixture. The criteria for aroma of the mixtures were categorized as - unnoticeable, vague, strong, very strong. For all samples, the smell remained unchanged and pleasant even after 4 months of storage (see Table 1).

B. Microbiological properties of lake clay and mixtures of lake clay with essential oils

None of the samples were found to contain *Staphylococcus aureus, Pseudomonas aeruginosa, Candida albicans*, or *Escherichia coli*. The quantity of mesophilic aerobic microorganisms (bacteria, yeasts, and molds) in the lake clay is ≤ 1×10^3 CFU per 1 mL. Therefore, based on the conducted microbiological analysis, the lake clay meets the requirements of Latvian Cabinet Regulation No. 354 “Procedure for Meeting the Significant Requirements for Cosmetics” and European Standard EN ISO 17516: 2014, Cosmetics - Microbiology - Microbiological limits.

Thyme (*T. vulgaris*) essential oil, which not only improved the cosmetic value of the product but also acted as antimicrobial agent and preservative, showed the best results.

In the clay without additives, the quantity of mesophilic aerobic microorganisms was 7.1 x 10^2 CFU/1mL, but in the clay and thyme oil mixture on the 5th day, the number of microorganisms decreased to 7.4 x 10 CFU/1mL. After 4 months, the number of microorganisms in the clay sample increased to 9.0 x 10^2 CFU/1mL, while in the clay-thyme oil mixture, it increased to 1.1 x 10^2 CFU/1mL (see Table 2). Thus, the thyme oil possesses antimicrobial properties.

T. vulgaris essential oil prevents premature hair loss and dandruff [19] - [21]. Due to its antiseptic properties, thyme essential oil prevents wound infections. The oil improves acne and scar healing; it can be used to treat eczema, dermatitis. Thymol, the most prevalent terpene in thyme oil, has antimicrobial properties [22]. One study found that thyme oil was effective in treating bacterial infections, especially caused by *Staphylococcus spp.* and treatment-resistant strains like methicillin-resistant *S. aureus*. Thyme essential oil has also shown to be effective against bacterial strains *Enterococcus* and *Escherichia* [23]. Thyme oil has strong antibacterial activity against *Propionibacterium acnes* [24]. Along with action against bacteria, thyme essential oil also has anti-fungal properties which might be effective against *Candida albicans,* a type of yeast commonly found in and on the body [25].

Clay masks have been historically used as auxiliary treatment measures for acne [26]. Acne is a chronic inflammatory condition that involves the formation of non-inflammatory lesions known as comedones. Comedones are formed due to the hyperkeratosis of the follicular unit that causes retention of sebum produced by the sebaceous gland [27]. Overgrowth of the commensal Gram - positive bacteria *Propionbacterium acnes* and rupture of the follicular wall promotes inflammation that clinically manifests as inflammatory lesions such as papules and pustules [28]. Local tissue and systemic oxidative stress have also been demonstrated in acne patients [16]. Acne prone skin has impaired epidermal barrier function that is associated with increased TEWL, furthermore, common medication used to treat acne, including benzoyl peroxide and retinoids, can cause skin irritation and even damage the skin barrier [29] – [31]. Administration of appropriate skin care is crucial to improve the epidermal barrier [32]. In long–term tests lake clay applications showed a statistically significant impact on skin elasticity and hydration with no significant changes in skin pH. Even though statistically insignificant, TEWL had a tendency to decrease [33]. Clay has been reported to remove excessive sebum and hyperkeratosis from the acne-prone skin, thus impeding the formation of comedones [26]. Zhang et al. [34] study demonstrated the clay mask's efficacy in managing acne and oily skin, improving hydration and texture. Therefore, the combination of clay and thyme oil could be an effective aid in acne treatment.

The mesophilic aerobic microorganism count also decreased in the clay mixture with apple mint and caraway essential oil (see Table 2). Apple mint (*Mentha suaveolens*) essential oil possesses cell regenerative, antioxidant, antiseptic, and insecticidal properties. The oil's anti-aging activity has been demonstrated [35] – [36]. Therefore, this oil and clay mixture could also be an effective aid in acne treatment.

In clay mixtures with oils such as chamomile, lavender, peppermint, and thyme, the count of mesophilic aerobic microorganisms increased on the 5th day already and exceeded the requirements of Latvian Cabinet Regulation No. 354 after 4 months (see Table 2)

TABLE 1 SENSORY PROPERTIES OF LAKE CLAY AND MIXTURES OF LAKE CLAY WITH ESSENTIAL OILS

Parameter	Smell		Consistency		Color	
Time	**1***	**2***	**1**	**2**	**1**	**2**
Clay	Unnoticeable	Unnoticeable	Applies easily on the skin	Applies not so well on the skin	Greenish gray	
Clay + *T. vulgaris*	Strong	Strong, pleasant	Slightly softer, applies easier on the skin			
Clay + *C. carvi*	Very strong	Vague, pleasant				
Clay + *M. suaveolen*	Vague					
Clay + *S. officinalis*	Strong					
Clay + *L. angustifolia*						
Clay + *A. absinthium*						
Clay + *M. piperita*						
Clay + *M. recutita*					Bluish gray	

1* - 5th day after mixing
2* - 4 months after mixing

TABLE 2. MICROBIOLOGICAL PROPERTIES OF LAKE CLAY AND MIXTURES OF LAKE CLAY WITH ESSENTIAL OILS

Types of microorganisms	*Stafilococcus aureus*		*Pseudomona aeruginosa*		*Candida albicans*		*Escherichia coli*		Total Aerobic Mesophilic Microorganisms (AMC)	
Measurement unit	**CFU/1 mL**									
Time	1*	2*	1	2	1	2	1	2	1	2
Clay	Not detected; < 10								7.1 x 10^2	9.0 x 10^2
Clay + *T. vulgaris*	Not detected; < 10								7.4 x 10	1.1 x 10^2
Clay + *C. carvi*	Not detected; < 10								6.9 x 10	6.1 x 10^2
Clay + *M. suaveolen*	Not detected; < 10								1.1 x 10^2	8.0 x 10^2
Clay + *S. officinalis*	Not detected; < 10								1.2 x 10^2	1.0 x 10^4

Clay + *L. angustifolia*	Not detected; < 10	3.1 x 10^3	4.7 x 10^3
Clay + *A. absinthium*	Not detected; < 10	3.4 x 10^3	6.7 x 10^5
Clay + *M. recutita*	Not detected; < 10	3.5 x 10^3	1.1 x 10^4
Clay + *M. piperita*	Not detected; < 10	2.3 x 10^5	2.8 x 10^5

1* - 5th day after mixing
2* - 4 months after mixing

Cellulite is a condition that affects 85-95% of post-pubertal females and manifests as skin dimpling in specific body areas such as pelvis, thighs, and abdomen. The skin in these areas can sometimes resemble an orange peel. There is a gender predilection and men usually do not develop cellulite. Diet rich in carbohydrates, sedentary lifestyle, pregnancy and increased body mass index usually facilitate development of the condition. Cellulite forms due to protrusions of subcutaneous fat tissue between fibrous septae. Subcutaneous tissue in women prone to cellulite differs from men and women without cellulite in a structural level. Women with cellulite have a higher number of thinner perpendicularly oriented hypodermal septae, whereas in men there is a higher number of fibrous septae organized in a criss-cross pattern [37]. At the moment there is no single method for the treatment of cellulite that is completely effective. Therefore, a combination of topical therapies and procedures such as massages, laser therapy, ultrasound, and radiofrequency are frequently administered due to the possible synergistic effect of several methods. The goal of these procedures is not only to decrease the amount of subcutaneous fat tissue, but also to tighten the skin and enhance the fibrous septae in the subcutaneous layer and in the reticular dermis [38]. To our knowledge topical clay applications have not been widely studied as an auxiliary for the treatment of cellulitis. However, clay has shown promotion of collagen synthesis in vivo and even improves wound healing [39], [40].

CONCLUSIONS

The mixtures of lake clay with essential oils of thyme (*T. vulgaris*), apple mint (*M. suaveolans*), and caraway (*C. carvi*) showed the best compatibility, enhancing the cosmetic value of the product and acting as antimicrobial agents and preservatives.

According to the performed microbiological analysis, lake clay and clay-thyme *(T.vulgaris)*, clay- apple mint (*M. suaveolans*) and clay-caraway (*C. carvi*) essential oil mixtures meet the requirements of Latvian Cabinet Regulation No. 354 "Procedure for Meeting the Significant Requirements for Cosmetics" and European Standard EN ISO 17516: 2014, Cosmetics - Microbiology - Microbiological limits.

According to the performed microbiological analysis and literature data, the lake clay – thyme *(T.vulgaris)* essential oil mixture has a high potential as an acne vulgaris treatment aid.

Chamomile, lavender, peppermint, wormwood essential oil mixtures with lake clay exceed the requirements of Latvian Cabinet Regulation No. 354 and European Standard EN ISO 17516: 2014, Cosmetics - Microbiology - Microbiological limits, therefore these oils are not suitable for combination with clay.

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Sovereign Sustainable Bond Market – Positioning and Effects

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***Abstract.* The sustainable bond market emerges in 2007-2008 but significantly impacts capital markets after 2015. It can be argued that one of the reasons for its development is due to the issuances from supranational financial institutions, governments, and other public sector organizations. This article focuses on sovereign bonds issued for sustainable development, covering four main themes: green bonds, social bonds, sustainability bonds, and sustainability-linked bonds. Using methods of descriptive statistics, analysis of variance and correlation-regression analysis, the article examines the position of sovereign bonds in the sustainable bond market and the achieved outcomes in the environmental and social spheres in issuing countries. The application of the methodology reveals an increasing share of sovereign bonds in the sustainable debt segment, along with a statistically significant relationship between thematic sovereign bond issues and the overall volume of thematic debt. Positive changes in the indices measuring the sustainable development of the countries suggest a policy of increasing the relative share of government securities with a thematic focus in the overall government debt market.**

Keywords: sustainable bond market; sovereign issues for sustainable development; green bonds; sustainability-linked bonds.

I. Introduction

The topic of sustainable development with the complex of environmental, social, and economic problems is increasingly entering every sphere of public life. This happens at the same time with digitalization, which expands the opportunities to achieve a greater level of stability by introducing ‘smarter’ processes [1]. In turn, financing the transition to sustainability is an integral part of policy agendas at national, regional and global levels over the past few years [2]. One of the mechanisms used in this context are debt securities. For their launch, a major role is played by international development banks, such as the European Investment Bank, which issued ‘climate responsible bonds’ (CABs) in 2007, and the World Bank with the green bonds issued in 2008 to meet the specific investment demand of Scandinavian pension funds [3]. The subsequent numerous initiatives and agreements lead to an exponential increase in the volumes of green bonds issued and the application of their model for the creation of other thematic financial instruments, such as social bonds, sustainability bonds, etc. Factors contributing to this development include the adoption of the Green Bond Principles in 2014, the late 2015 Paris Climate Agreement, and the UN Summit of September 2015, among others. The formation of the sustainable bond market is also related to the natural expansion of the issuer base to the private sector, local authorities, etc., to the extension of the geographical scope and to the diversification of the currency denomination of the newly issued bonds. Thus, by the end of the third quarter of 2023, the cumulative volume of the so-called GSS+ debt – comprising green bonds, social bonds, sustainability bonds, sustainability-linked bonds (SLBs) and transition bonds, has reached 4,2 trillion USD, and new issuance is now stabilizing at 5% of total debt issuance [4]. Sovereign thematic bonds have a relatively late appearance on the market – towards the end of 2016 with the green issue of Poland, but subsequently their share has seen a significant growth [5], which is an indicator of increasing commitment of the public sector to financing environmental and social problems.

Recently, in business and scientific circles, there has been a growing research interest in the sustainable debt market and the role and place of green and other thematic supranational, sovereign, and sub-sovereign securities. Studies on sovereign debt for sustainability are scarcer and more recent due to shorter dynamic data series. However, highlighting the emergence of sovereign green issues in the European Union and the subsequent rapid growth of the segment, some authors investigate the impact of sovereign green bonds in member countries on mitigating country risk and developing local green debt markets [6] - [7]. In IMF working papers, with the emphasis on the recent start of the market, the presence of so-called sovereign *greenium* is sought – i.e., the positive green premium or lower yield compared to similar

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conventional bonds [8]. In World Bank reports, with the presumption of the role of states through regulatory frameworks and bond issues for the realization of green goals and channelling the financing of sustainable activities, a strong correlation is demonstrated between GDP per capita, on the one hand, and the share of green and social bonds in total public debt, on the other [9].

From the review of publications on the topic, it is found that the research is primarily directed towards green bonds, leaving the impact of sovereign GSS+ bonds as a whole on certain aggregate indicators insufficiently studied and quantified.

The current work focuses on the study of the correlation between the volume of sovereign GSS+ bonds and the volume of the total sustainable debt market. It also aims to initiate analyses regarding the presence of a statistically significant dependence between sovereign issues and changes in macro indicators and indices related to the sustainable development of countries.

II. Materials and Methods

The study uses data from the annual and interim reports of the Climate Bonds Initiative [10] on the state of the sustainable debt market, and especially the systematized information by year from the 2022 report [11]. Separate analyses also incorporate data from the World Bank on GDP by country [12], as well as data from the UN's SDS Network for the SDG indices [13]. The calculations are performed using the capabilities of the statistical toolbox in MS Excel™.

Data for new issue thematic bonds (GSS+ bonds) are presented by year from 2016 (the start of the sovereign segment) to 2022, due to the lack of data for the entire year 2023 at the time of the study. Sovereign bonds are separated from all themes and their relative share is calculated. Only central government issues are included, excluding sub-sovereign issues, as well as issues by other public-private sector institutions and state-owned enterprises. The working algorithm is as follows:

1) The dynamics of the thematic debt market and the dynamics of sovereign issues, both in general and by individual themes, are investigated.

2) Regression and correlation analysis are applied to establish the existence of a dependence between the dynamics of sovereign issues and the dynamics of the entire sustainable debt market.

3) In order to establish the presence of a statistically significant influence of thematic sovereign bonds on the sustainable development of countries, a macroeconomic indicator measuring comprehensive improvement in environmental, social, and economic development is chosen. As such, the preferred indicator is the Sustainable Development Goals (SDG) index. Since the effect of financing through bonds occurs after a certain time lag, only thematic sovereign issues until the end of 2021 are taken into account, and their relative volume compared to the country's GDP for 2021 is calculated. The correlation between this indicator and the change in the country's SDG index for 2022 compared to 2015 is studied, first applying the analysis of variance (ANOVA) to establish a statistically significant influence, and then making more precise conclusions through the correlation-regression method. Specifically, for the application of the ANOVA, four groups of countries are formed – randomly selected countries without GSS+ bond issues, countries with such issues up to 1% of GDP, countries with sovereign issues of thematic bonds from 1 to 3% of GDP, and countries with issues over 3% of GDP.

III. Results and Discussion

Firstly, the dynamic analysis of the sustainability debt market as a whole and in particular the sovereign segment shows ascending trends with a certain decrease in the volume of total issues and retention of growth in the sovereigns in 2022, as a result of geopolitical catalysts (Fig. 1 (a)). At the same time, for the period, an increase in the number of issuer countries (a total of 43 by the end of 2022) and diversification of individual thematic instruments is established (Fig. 1 (b)). In 2019, the issuance of social bonds and sustainability bonds begins (with the allocation of funds for both environmental and social purposes), and in 2022, Chile and Uruguay initiate the sovereign SLBs bonds, where coupon payments are tied to the achievement of pre-set sustainability goals. At the end of the period, the cumulative volume of issued sovereign bonds reaches 324,2 billion USD from a total of 43 countries, 25 of which have more than one issue. Therefore, regardless of the later appearance of sovereign thematic debt, its stable growth is evident and, in parallel with this – a substantial increase in the volumes of the entire sustainable debt market. From here, the hypothesis can be set for the presence of a catalytic effect of the sovereign GSS+ bonds on the GSS+ debt market as a whole.

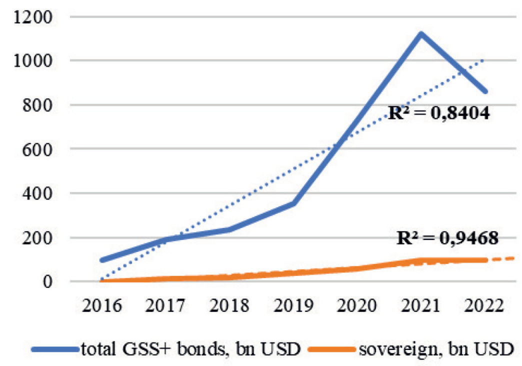

Fig. 1. (a) Dynamics of issues of GSS+ bonds in general and sovereign GSS+ bonds for the period 2016 – 2022

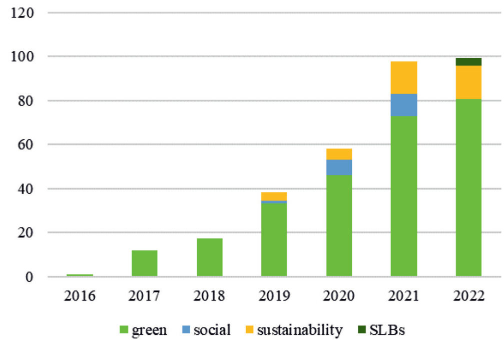

Fig. 1. (b) Dynamics of sovereign GSS + issues by individual themes for the period 2016 – 2022 in billion USD

Secondly, to establish the influence of sovereign issues on the entire thematic debt market, a regression and correlation analysis is applied, the results of which are presented in Table 1.

TABLE 1 RESULTS FROM REGRESSION-CORRELATION ANALYSIS FOR THE INFLUENCE OF THE TOTAL VOLUME OF ISSUED GSS+ SOVEREIGN BONDS ON THE ENTIRE GSS+ BOND MARKET

SUMMARY OUTPUT						
Regression Statistics						
Multiple R	0,9678					
R Square	0,9367					
Adj. R Square	0,9240					
Standard Error	107,8176					
Observations	7					
ANOVA						
	df	*SS*	*MS*	*F*	*Signif. F*	
Regression	1,0000	859535,20	859535,20	73,9409	0,0004	
Residual	5,0000	58123,13	11624,63			
Total	6,0000	917658,34				
	Coefficients	*Stand. Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	76,3662	64,9954	1,1749	0,2929	-90,7098	243,4422
X Variable 1	9,4240	1,0960	8,5989	0,0004	6,6068	12,2413

The coefficient for X Variable 1 (the volume of sovereign GSS+ bond issues) is 9,42. This means that for every unit increase in the volume of sovereign GSS+ bond issues, the total volume of GSS+ bond issues increases by 9,42 units, assuming all other factors remain constant. The P-value for X Variable 1 is almost zero, indicating a significant relationship between the volume of sovereign GSS+ bond issues and the total volume of GSS+ bond issues. The R-squared value is 0,9367, or about 93,67% of the variation in the total volume of GSS+ bond issues can be explained by the volume of sovereign GSS+ bond issues. The F statistic is 73,94 and the Significance F is very small (0,00035086), i.e., the model is statistically significant. Therefore, there is sufficient evidence that the volume of sovereign GSS+ bond issues has a significant impact on the total volume of issued GSS+ bonds.

The last and most important study is based on specific country data (Table 2). The general overview shows that there is a considerable differentiation in the absolute size and relative share of sovereign thematic debt. For example, by the end of 2021, the cumulative size of issues is under 100 million USD in Lithuania, Nigeria, and Ghana, and over 30 billion USD in France, Germany, the United Kingdom, the USA, and Chile. The lowest relative share to GDP is in Nigeria and Ghana (respectively about 0,02% and 0,05% of GDP for 2021), and the highest in Chile (10,5%) and Benin (almost 4%).

TABLE 2 SOVEREIGN GSS+ BONDS ISSUERS TILL 2021 (ANDORRA AND SEYCHELLES EXCLUDED DUE TO MISSING SDG INDEX DATA)

Country	**cumulative volume of sovereign bond issuances up to 2021 in bn USD**	***GDP 2021 in bn USD***	**share of sov. GSS+ bonds issued until 2021 relative to GDP 2021**	**SDG index 2015**	**SDG index 2022**	**change of SDG index**
Chile	**33,4**	316,58	10,55%	76,05	78,22	2,85%
Benin	**0,7**	17,69	3,96%	47,78	55,12	15,36%
Belgium	**17,1**	600,75	2,85%	77,94	79,46	1,95%
Hong Kong	**9,8**	369,2	2,65%	68,92	72,01	4,48%
Hungary	**4,8**	182,09	2,64%	78	79,39	1,78%
Slovenia	**1,4**	61,83	2,26%	79,12	81,01	2,39%
Luxemburg	**1,8**	85,58	2,10%	76,13	77,65	2,00%
France	**58,8**	2960	1,99%	79,84	82,05	2,77%
Guatemala	**1,7**	86,05	1,98%	58,01	59,38	2,36%
Peru	**4,4**	223,72	1,97%	69,33	71,66	3,36%
Serbia	**1,2**	63,1	1,90%	73,61	77,34	5,07%
Latvia	**0,7**	39,44	1,77%	78,47	80,68	2,82%
Netherland	**17,3**	1030	1,68%	78,48	79,42	1,20%
Thailand	**7,7**	505,57	1,52%	72,39	74,74	3,25%
Ireland	**7,8**	513,39	1,52%	79,28	80,15	1,10%
Fiji	**0,05**	4,296	1,16%	69,41	72,88	5,00%
Italy	**24,4**	2160	1,13%	76,88	78,79	2,48%
United Kingdom	**33,7**	3140	1,07%	80,43	81,65	1,52%
Germany	**42,7**	4280	1,00%	81,92	83,36	1,76%
Spain	**9,3**	1450	0,64%	77,88	80,43	3,27%
Poland	**4,3**	681,35	0,63%	79,02	81,8	3,52%
Mexico	**7,1**	1310	0,54%	66,85	69,71	4,28%
Indonesia	**6,1**	1190	0,51%	64,7	70,16	8,44%
Ecuador	**0,4**	106,17	0,38%	69,93	70,43	0,72%
Uzbekistan	**0,2**	69,6	0,29%	66,31	71,15	7,30%
Malaysia	**0,8**	373,83	0,21%	67,78	69,85	3,05%
Egypt	**0,8**	424,67	0,19%	66,39	69,62	4,87%
Colombia	**0,5**	318,51	0,16%	68,79	70,05	1,83%
Lithuania	**0,1**	66,8	0,15%	74,91	76,81	2,54%
USA	**33,7**	23320	0,14%	73,99	75,91	2,59%
South Korea	**2,6**	1820	0,14%	76,95	78,06	1,44%
Ghana	**0,042**	77,59	0,05%	60,06	61,08	1,70%
Nigeria	**0,1**	440,84	0,02%	52,46	54,27	3,45%

The application of the ANOVA for the influence of the scales of the thematic government debt on the changes in the SDG Index leads to the results presented in Table 3. From them, it can be seen that the F-statistic is 5,60 with F-crit. equal to 2,87, and the p-value is 0,003, from which it follows that the hypothesis of equality of SDG index between the groups is rejected. Therefore, there are statistically significant differences between the groups of countries according to the share of GSS+ bonds to GDP.

TABLE 3 RESULTS FROM THE ANOVA FOR THE INFLUENCE OF THE SHARE OF ISSUED GSS+ BONDS UP TO 2021 BY COUNTRIES ON THE CHANGE IN THE SDG INDEX FOR THE PERIOD 2015-2022

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
no sovereign GSS+	6	0,1214	0,0202	0,0002		
GSS+ debt up to 1% of GDP	14	0,4900	0,0350	0,0005		
GSS+ debt from 1% to 3% of GDP	17	0,4527	0,0266	0,0002		
GSS+ debt over 3% of GDP	2	0,1822	0,0911	0,0078		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0,0084	3	0,0028	5,6005	0,0030	2,8742
Within Groups	0,0176	35	0,0005			
Total	0,0260	38				

The ANOVA is based on the grouping of countries by intervals of thematic debt to GDP. Through regression-correlation analysis, the strength and closeness of the dependence between the relative share of GSS+ bonds and changes in the sustainable development index by individual countries can be specified. The results of the applied one-factor regression and correlation are presented in Table 4 and Fig. 3.

TABLE 4 RESULTS FROM REGRESSION-CORRELATION ANALYSIS FOR THE INFLUENCE OF THE SHARE OF ISSUED GSS+ BONDS UP TO 2021 BY COUNTRIES ON THE CHANGE IN THE SDG INDEX FOR THE PERIOD 2015-2022

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0,1756							
R Square	0,0308							
Adj. R Square	0,0047							
Stand. Error	0,0261							
Observations	39							
ANOVA								
	df	*SS*	*MS*	*F*	*Signif. F*			
Regression	1	0,0008	0,0008	1,1777	0,2848			
Residual	37	0,0252	0,0007					
Total	38	0,0260						
	Coefficients	*Stand. Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 68%*	*Upper 68%*
Intercept	0,0288	0,0051	5,6246	0,0000	0,0184	0,0391	0,0236	0,0339
X Variable 1	0,2507	0,2310	1,0852	0,2848	-0,2173	0,7186	0,0178	0,4835

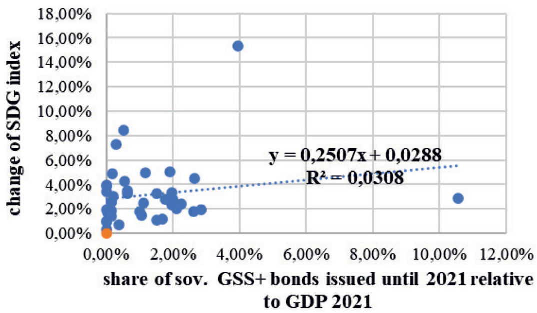

Fig. 3. Distribution of the countries included in the model according to the relative share of issued sovereign GSS+ bonds and change in the SDG index for 2022 compared to 2015

The value of the correlation coefficient R is 0,18, which indicates a weak positive correlation. The coefficient of determination (R Square) is 0,0308, i.e., 3% of the variation in the sustainable development index can be explained by the issues of sovereign GSS+ bonds. The adjusted coefficient of determination (Adjusted R Square) is 0,0047, which means that after adjusting for the number of independent variables, the influence of sovereign bonds (GSS+ bonds) on the sustainable development index is only 0,5%. Other factors, beyond sovereign issues, likely have a stronger influence on the index. An important circumstance in studying the factor influence of sovereign GSS+ bonds is their longer maturity, the need for time to absorb the financing, and for the effects to manifest, including through changes in the sustainability indices.

The complex linking of the results of the applied analyses gives reason to draw a conclusion about the catalytic role of government debt for sustainable development as an incentive for increasing the scale and relative share of the issued GSS+ bonds in each individual country, and hence the realization of the goals for sustainable development. Given the still insignificant share of thematic compared to conventional government debt, there are substantial reserves for increasing the relative share of GSS+ bonds at the expense of reducing government securities for general financing without increasing the total debt burden.

IV. CONCLUSIONS

The conducted studies have shown that financing the transition to sustainability and comprehensive integration of economic development with ecological balance and social prosperity is becoming a priority in the debt policy of more and more countries. Following the debut of the Republic of Poland, over 40 other countries have issued bonds, the proceeds of which are specifically intended for environmental, social, or mixed projects, contributing to the achievement of sustainable development goals. The application of the methodology also proved the significant influence of sovereign thematic bonds on the development of the GSS+ debt market and the presence of a weak but positive influence on the sustainable development index. Research on the topic remains open in connection with the increase in the share of government debt for sustainability, due to the reflection of the effects of its absorption further in time and the necessity to encompass the influence of other factors, such as: GSS+ bonds of local authorities, GSS+ bonds of other issuers – banks and non-financial companies, the actual allocation and use of proceeds, control exercised, normative changes and regulations, etc.

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Antifungal activity of medicinal herbs aqueous extracts: common wormwood (Artemisia absinthium L.), greater burdock (Arctium lappa L.), common thyme (Thymus vulgaris L.) and pot marigold (Calendula officinalis L.) on yeast Saccharomyces cerevisiae

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Abstract. **One of the modern approaches to identifying alternative broad-spectrum against microorganisms that cause human diseases raises an urgent need to search for bioactive compounds with antifungal activity from medicinal plants. One of the main problems of antibiotic therapy for diseases is the development of resistance to opportunistic diseases of relatively low virulence, which are caused by yeast. In this regard, the search for natural medicinal herbs is relevant. The present study was undertaken to evaluate the effectiveness of the antifungal activity of different medicinal plant aqueous extracts: greater burdock (*Arctium lappa* L.), common wormwood (*Artemisia absinthium* L.), common thyme (*Thymus vulgaris* L.), and pot marigold (*Calendula officinalis* L.) on the growth of yeast: *Saccharomyces cerevisiae*. Aqueous extracts were prepared from leaves, stems, inflorescences, and roots of ready-made medicinal mix, and their antifungal activity against yeast was tested using the Kirby-Bauer standard disk diffusion method. Disks were soaked in aqueous extracts of medicinal plants and were placed on an agar medium previously inoculated with yeast *Saccharomyces cerevisiae* as a test object. The prepared agar plates were cultured in the dark at 30°C for 3-5 days. The results obtained showed that the aqueous extracts of medicinal plants demonstrated different antifungal activity concerning test culture, the level of which variable by the plant species. The aquatic extract of medicinal plants: common wormwood (*Artemisia absinthium* L.), and pot marigold (*Calendula officinalis* L.) had the most noticeable antifungal activity. The results obtained during the preliminary suggest that the studied aqueous extracts of medicinal plants of natural origin can be used as antifungal agents with a specific mechanism of action.**

Keywords: antifungal activity, disk diffusion method, medicinal plants, Saccharomyces cerevisiae, SEM, yeast.

I. Introduction

Higher plants are highly biodiverse which can provide a huge range of various active compounds with different biological activities. These chemical compounds produced by plants can serve as attractants for pollinators and as chemical defenses against insects, herbivores, and microorganisms. Medicinal plants are rich in a variety of complex and structurally diverse chemical compounds that

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have antimicrobial and antifungal activities [1]. Of an estimated 250000 higher plants in the world, only 5-15% have been studied for therapeutic potential [2]. Extracts isolated from medicinal plants exhibit various biological activities such as antifungal, antibacterial, antioxidative, anti-inflammatory, antiviral, and insecticidal activities which may inhibit the growth of bacteria, fungi, viruses, and protozoa as well as may have a significant clinical value in the treatment of resistant strains of microbes [3]. These antimicrobial and antifungal compounds produced by plants are active against plant and human pathogenic microorganisms. Recently, there has been a growing interest in investigations of new potential antimicrobial and antifungal agents that focus on plant and microbial extracts, essential oils, pure secondary metabolites, and newly synthesized molecules [4], [5].

The World Health Organization (WHO) has revealed that approximately 80% of the developing world's population continues to benefit from using traditional medicines obtained from medicinal plants [6]. The WHO has also recorded the names of more than 20000 species of medicinal plants and has described medicinal plants as one of the potentially cheaper and safer alternative sources of new drugs [1]. Antimicrobials of medicinal plant extracts are natural, safer than synthetic alternatives, available in local communities, cheaper to purchase and they can offer profound therapeutic benefits and more affordable treatment. Thus medicinal plants can be regarded as the richest bio-resource of drugs of modern medicine, folk medicine, and chemical entities for synthetic drugs. Natural antifungals can act alone or in combination with antibiotics to enhance antifungal activity against a wide range of microorganisms.

Saccharomyces cerevisiae is one of the most intensively studied versatile eukaryotic model organisms in molecular and cellular biology. *Saccharomyces cerevisiae* is a single-celled fungus that reproduces by budding from an existing cell representing the main components of a typical eukaryotic cell. Its cell wall is a dynamic structure, relatively rigid, which protects cells, and osmotic support and determines the shape of cells. Cells of *Saccharomyces cerevisiae* are round or egg-shaped and have a diameter of approximately 5–10 micrometers [7].

Under certain conditions, for example, under reduced immunity, *Saccharomyces cerevisiae* can cause various infectious diseases in a person. There are also known cases of infections of the oral cavity and pharynx caused by *Saccharomyces cerevisiae* [8]. There are known cases where the fungus *Saccharomyces cerevisiae* was discovered in people whose professional activities were associated with regular stays in various bakeries and caused lung disease. It is believed that the source of infection in this case was inhalation of dry yeast powder [9]. In rare cases, *Saccharomyces cerevisiae* causes invasive infections infecting the main bloodstream or other body fluids that should normally be sterile, or internal organs, such as the lungs, liver, and spleen. Such an infection can become systemic, that is, affect several organs. Invasive mycoses caused by *Saccharomyces cerevisiae* are very dangerous – the mortality rate is more than 30% even with treatment [10].

The present study was undertaken to evaluate the effectiveness of the antifungal activity of different medicinal plant extracts: greater burdock (*Arctium Lappa* L.), common wormwood (*Artemisia absinthium* L.), common thyme (*Thymus vulgaris* L.), and pot marigold (*Calendula officinalis* L.) on the growth of yeast.

II. MATERIALS AND METHODS

Plant material and preparation of aqueous extracts

The dried samples from the pharmacy of greater burdock (*Arctium Lappa* L.), common wormwood (*Artemisia absinthium*), common thyme (*Thymus vulgaris*), and pot marigold (*Calendula officinalis*) were used. To prepare freshly prepared aqueous extracts of plants, 5 g of dried plant materials of each plant were pulverized (~5 μm) by using CryoMill (Retsch GmbH, Germany). The crushed raw materials of each sample were poured into flasks and 100 mL of distilled water was added. The mixtures were sterilized for 5 minutes at 100°C (HSP Laboklav Steriltechnik AG, Germany) and then cooled to room temperature for 30 minutes.

Fungal test-culture, preparation of culture-media and scanning electron microscopy (SEM) of yeast

A test yeast culture of *Saccharomyces cerevisiae* was used for the experimental study. This is a type of unicellular microscopic (5-10 microns in diameter) fungi (yeast) from the class of *Saccharomycetes*, widely used in scientific research. Nutrient agar powder Mueller–Hinton agar (Thermo Fisher Scientific, US) 9.5 g was suspended in 250 mL of cold, distilled water, the mixture was stirred and boiled to dissolve the agar powder.

The nutrient media was sterilized by autoclaving at 121°C (15psi) for 15 minutes. After autoclaving the agar was cooled and poured into sterile Petri plates (90 mm diameter). Mueller-Hinton agar is primarily used for antimicrobial susceptibility testing (AST) and it has become the standard medium for the Bauer-Kirby method as more suitable for yeast culture comparing with others [11] – [13].

For scanning electron microscopy (SEM), isolated colonies of *Saccharomyces cerevisiae* from Petri plates were slowly air-dried (1 h) at room temperature (20 °C ±2°C) and transferred to observation chamber of SEM TM 1000 (Hitachi Tabletop Microscope, Japan), the colonies were located on the temperature-controlled SEM cooling-stage (Deben, UK) according to simplified procedure [14].

The yeast colonies surface structure was observed at x10k magnification without digital zooming, DPI=130.05, accelerating voltage 15kV, working distance=9620 μm, emission current=76000nA and under high vacuum conditions. The uncoloured (SEM) of *Saccharomyces cerevisiae* colonies during experiment represented in Fig.1.

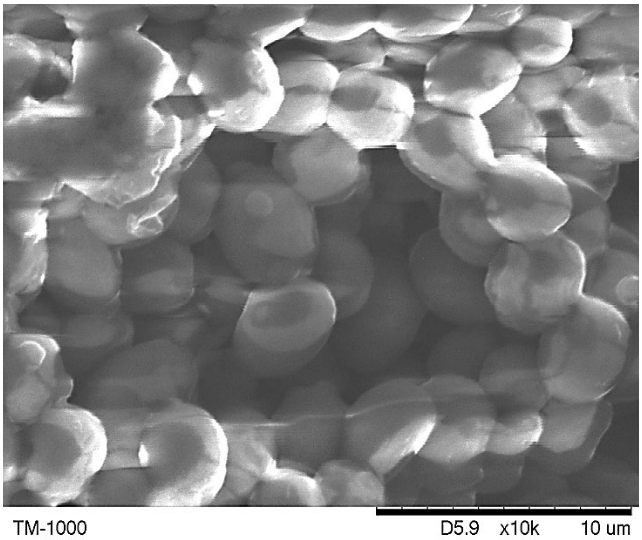

Fig.1. Image of *Saccharomyces cerevisiae* cells gained by SEM.

Disk diffusion test and antifungal activity assay

Antifungal activities of the plant extracts of four selected plants were tested on nutrient agar Mueller–Hinton agar (Thermo Fisher Scientific, US) by disk diffusion method [15] with some modifications. 1 g of *Saccharomyces cerevisiae* was inoculated into 9 mL of Brain Heart Infusion Broth (BioMaxima, Poland). Test tubes were placed in a thermostat for 24 hours at a temperature of +25°C. Using a sterile dry cotton (150mm) swabs (Aptaca SPA, Italy) the culture was applied to the surface filled with nutrient agar medium Mueller–Hinton agar (Thermo Fisher Scientific, US) by surface method and cultivated at 25°C within 48 hours in Refrigerated Thermostat Incubator FTC 90E (Velp Scientifica, Italy) [16].

Inoculated plates were allowed to dry for ten minutes at room temperature in a secure box. Filter–paper discs having a diameter of 5 mm were prepared, sterilized, and impregnated with extracts. Paper disks were placed on the previously inoculated agar plates with yeast using sterile forceps. Four filter–paper disks were placed on each plate and were placed at the distance from each other and the edge, to prevent overlapping of inhibition zones.

The plates were incubated within 48 hours at 25°C on nutrient agar. After 48 hours of incubation, the inhibition zone of *Saccharomyces cerevisiae* around the disks immersed in plant extracts was determined. For measuring distances of zones of yeast growth inhibition, the software: Acquisition & analysis Ver. 8.20 (Vision Works, US) was used. Results were documented by measuring and calculating the zone of inhibition in millimeters (mm), including the diameter of the disk. The experiment was repeated three times for each extract and the mean diameter was taken.

Statistical analysis

All the data are reported as mean ± standard deviation (SD) and ± error mean (SE). Each value of 4 different plant extracts was the mean (n=48) of 3 replicates and performed with Microsoft Excel Ver. 14.0.7214.5000.

III. RESULTS AND DISCUSSION

Saccharomyces cerevisiae is an opportunistic pathogen of relatively low virulence [17] and under certain conditions, for example, when immunity is reduced, it can cause infectious diseases in humans. Obtaining nutrients from natural food sources is the best option, which is necessary for the construction and continuous renewal of cells and tissues, the supply of energy necessary to replenish the body's energy however, in case of illness, widely available dietary supplements are commonly used which offer the potential to improve health.

The analysis of the antifungal parameter values shows that the aqueous extracts of medicinal plants, namely common thyme (*Thymus vulgaris* L.), pot marigold (*Calendula officinalis* L.), and common wormwood (*Artemisia absinthium* L.) had the most noticeable antifungal potency against the test organism *Saccharomyces cerevisiae*. The growth inhibition zones were 8.71±0.156 mm for common thyme (*Thymus vulgaris* L.), 10.23 ±0.176 mm for pot marigold (*Calendula officinalis* L.), and 10.45 ± 0.235 mm for common wormwood (*Artemisia absinthium* L.) respectively. The results of the research are represented in Fig. 2. The antifungal effects of aqueous extracts of these tested plants can be attributed to the presence of bioactive compounds that can act alone or in synergy, as demonstrated by other studies [18], [19].

In addition to this, the tannins contained in these medicinal plants have noticeable toxic activity against bacteria and fungi, which may have pharmacological importance. Furthermore, the studied plants contain saponins, which are a special class of glycosides with soapy properties and are considered active antifungal agents [20]. In turn, the flavonoid artemisinin contained in wormwood, considered one of the most powerful, can also kill pathogens of fungal diseases [21].

It is known that the contents of active ingredients in plant materials fluctuate constantly with the genetic heterogeneity of a plant species, differences in soil condition, variations in a seasonal cycle, climatic influences, age of the plant, and alterations in weather, sun, and shade fluctuations [22]. The variability of their efficiency would be not only connected to various secondary metabolites content (alkaloids, flavonoids, anthocyanins, lignans, terpenoids, amines, polyphenols, quinones, peptides, coumarins) that plants produce but also to the toxic power of these biomolecules to microorganisms [23].

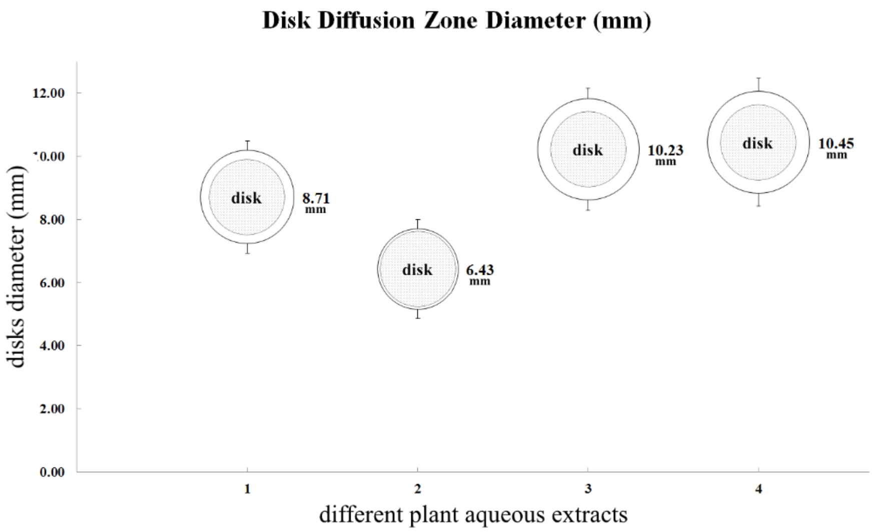

Fig.2. Zones of suppression of yeast activity by various medicinal plant aqueous extracts: 1- common thyme (*Thymus vulgaris* L.) 2- greater burdock (*Arctium Lappa* L.), 3- pot marigold (*Calendula officinalis* L.) 4- common wormwood (*Artemisia absinthium* L.).

The obtained results show that the tested plant aqueous extract of greater burdock (*Arctium Lappa* L.) possesses some very low levels of antifungal activity 6.43 ±0.208 mm. It is well known that plant extracts with good antifungal activity usually have high levels of total polyphenols and titratable acidity, as well as low pH values [24].

However, burdock roots contain insignificant content of phenolic acids and flavonoids, particularly quercetin and luteolin, which are antioxidants promoting health through cytotoxic, anti-inflammatory, and antioxidant effects [25].

At the same time, the results of previous investigations revealed that the hydroethanolic extracts concentrating a greater proportion of active principles are more active than their equivalent aqueous extracts [26].

Aqueous extracts contain a great content of macromolecules (polysaccharides, proteins, and glycoproteins) and also a few species of polar lipids of small size, whose structures are simple [27].

This high content of polysaccharides, glycoproteins, and proteins may explain why aqueous extracts are always less active. Many authors explained that most plants synthesize various secondary metabolites that are useful for their normal biology and to fight pathogenic microorganisms (viruses, bacteria, fungi, and various parasites) attacks which in hydroethanolic extracts concentrate a greater proportion of active principles than their aqueous equivalents [27] – [29]. It has been pointed out that there is a relationship between the antifungal activity in various extracts and their bioactive compounds, for example, fatty acids play an important role in fungal resistance. All bioactive compounds present in plant extracts act synergistically on fungi either by inactivating enzyme production, inhibiting, or reducing the ergosterol content in filamentous fungi, which enhances the overall antifungal activity [30].

Commonly using medical antifungal agents has varied toxicity, efficacy, and cost differences, as well as low biological digestibility, and its repeated usage leads to the emergence of resistant strains that cannot be treated with normal antifungal drugs [31] which represents a serious barrier for using them in the therapy. In addition, biologically active compounds of common wormwood (*Artemisia absinthium* L.) can neutralize individual determinants of antibiotic resistance and thereby restore the sensitivity of resistant strains to the appropriate drugs [32].

Taking into account the growing demand for new remedies to overcome various infections caused by antibiotic-resistant microorganisms, the practice of using plant-derived bioactive products as secondary metabolites has been widely studied in various scientific communities all over the world for more than many centuries, and the considerable practical achievement in this regard could be the creation of the new effective agents with fungicidal and antimicrobial properties from medicinal plants which could be outperforming the best traditional methods of infectious disease treatment.

IV. CONCLUSIONS

On the whole, our current study revealed that the aqueous extracts of traditional medicinal plants: common thyme (*Thymus vulgaris* L.), pot marigold (*Calendula officinalis* L.), and common wormwood (*Artemisia absinthium* L.) that produce various types of secondary metabolites have noticeable antifungal effect, but aqueous extract of greater burdock (*Arctium lappa* L.) showed insignificant antifungal effect against yeast. For this reason, these tested medical plant species with antifungal properties can be used as a remedy with a specific mechanism of action and are recommended to treat yeast infections as an auxiliary tool.

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Multifunctional Orchard Model For Synergistic Production

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Abstract. **The world's growing population requires increased crop yields for their feeding. In food consumption, fruit is relied upon as one of the sources of vitamins. This necessitates an increase in perennial fruit plantations. Another important product is the consumption of animal foods and products. On the other hand, a growing population is in dire need of electrical energy to meet its needs. This also requires an increase in the production of this type of energy. Worldwide, in order to protect the environment and reduce the consumption of raw materials, it is necessary to produce electricity from RES.**

This article discusses a model of complex production of plant production from an orchard, animal production and energy from a photovoltaic plant in a unit of arable area.

In practice, these are three separate productions to meet the needs of the population, which, however, have the same area and are located in the same place. Using the specifics of the individual productions, an attempt was made for the joint use of the areas, in which case it is possible to eliminate part of the various technological operations or serve as a basis for the other type of production. Such can be the irrigation of the plantation, the presence of shade from photovoltaics, fertilization of the plum plantation by the animals, fresh food for the animals, etc. The interrelations and the main points in the symbiotic production are given. The model can also be used in other types of joint "green" proceedings, after clarifying their specifics.

Keywords: symbiosis, res, model, plant production, fruit plantation

I. Introduction

Links between individual ecosystems are the subject of an increasing number of studies [1] as understanding them is essential for designing societal practices and management strategies to promote sustainability of ecosystem products and services provided [2-6].

Non-productive agroecosystems provide many non-market services such as improving soil structure, fertility, water quantity and quality, biological pest control, pollinators and combating climate change through carbon sequestration and greenhouse gas (GHG) mitigation. [7-9]. Links between agroecosystem services are strongly influenced by agricultural practices [9-12].

Relationships predetermine positive (synergies) and negative (trade-offs) interactions between different ecosystems. From them the main management activities are differentiated [13].

Orchards are interesting to study because of the impact of their perennial nature on biogeochemical cycles, their productive potential and the importance of their management practices [14,15].

This article discusses a model for synergistic production several types of production from one production area, which aims to improve the condition of employees and serve as an idea for deeper study. The model will serve to study the relationships between its main elements in obtaining plant production from plum plantation, animal production in the form of dairy products and meat, biomass and electricity production from a photovoltaic plant.

II. Materials and Methods

Synergistic orchard production is understood as an approach in which different types of produce are produced. They are grown together by positively interacting with each other. This method of farming aims to improve crop yields and protect the ecosystem.

The multifunctional model refers to an intelligent system for growing and selling production from plum plantations and its adjacent production of products from different industries. Suitable for this purpose is the area of the city Troyan.

The municipality is located in the southern and south-eastern part of Lovech region. With an area of 888,839 km^2, it occupies the 2nd place among the 8 municipalities of the district, which accounts for 21,53% of the district's

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territory. The relief of the municipality is high and medium and low mountainous, and its territory falls entirely within the Central Stara Planina and the Middle Fore-Balkan. The climate is temperate continental with a pronounced mountain influence, with four seasons, no fog and strong winds. Rainfall is above the national average. The snow cover lasts about 50 days a year.

The area is famous for its plum plantations of prunes and the famous "Troyan plum brandy".

III. RESULTS AND DISCUSSION

The model includes the following key points:

1. Cultivation of plant production from plums
2. Growing animal production.
3. Obtaining green electricity.
4. Obtaining biomass.
5. Obtaining organic products from the plant and animal farm.

Suitable terrain for the realization of the model is the land of the village of Debnevo with an array of 800 ha. Typical for it is the relatively mild climate. The good soil and climatic conditions the region have given a good livelihood to the population for years. The model (Figure 1) is part of the so-called circular bioeconomy giving high added value to products.

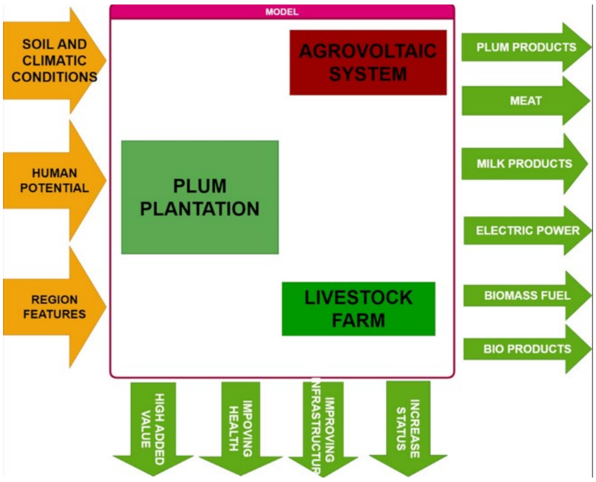

Fig. 1. General appearance of the model structure

The organization of the model implies the establishment of one plant and one animal farm, factories for the processing of organic products from the plant and animal farm, as well as an energy holding (Fig. 2).

At the heart of the model is the plant farm for growing plums. In the area over the centuries have grown plantations of gray plum in high yield. Currently, low-stemmed prunes plantations are relied upon. The plantations are low-stemmed with a small crown. This allows the free space above the crown and between the rows to be used for another type of production.

The change in the soil-climatic conditions of the farm environment is taken care of by a network of sensors that show the vital parameters in the cultivation of plum plantations. With the help of a developed algorithm and artificial intelligence that takes into account all factors of the environment, a dynamic technological map for growing the crop is made, and all operations for the cultivation of the plantations are performed, depending on the change in environmental conditions. The ultimate goal of these measures is to obtain the maximum yield from the plum plantation. With the fulfilment of the technological conditions, a yield of 30 t/ha or 24 000 t is planned.

In the cultivation of plum plantations, pruning operation is vital for obtaining high yields. In this regard, it releases a biomass product (about 1000 kg / ha or for the 800 t array), which can be processed into pellets or chips from the energy holding.

Since the plant farm is located in the field, it is necessary to provide an energy source for the monitoring and implementation of the tasks of the technological map. A suitable energy source is a photovoltaic system made up of agrovoltaics [16]. The characteristic of them is that they are located above the plum plantations and are vertical. Thus, the penetration of direct sunlight, which is vital for plant growth, will not be interfered with. The surplus of the electricity produced is envisaged to be sold by the energy holding.

The livestock farm is also located in the plum plantation. It will be located in the interrow space of the plum plantation. Pair-hoofed mammals can be raised. To avoid scattering the herd, it is planned to breed in special pens, which will move in the interrow. In turn, the crib gives safety to the herd from raids of wild animals (this is semi-mountainous terrain).

Symbiotic cultivation of plant and animal production has its advantages. Production areas are in one place and monitored simultaneously. No further processing of the inter-row space is needed, because the animals graze the grass and take care of its maintenance within certain limits. This reduces the cost of servicing the plantation. Another advantage is obtaining natural manure from animals. It feeds crops to increase yields. Again, the cost of growing plant products is reduced. Apart from this, the irrigation system of the plantations also feeds the lawn for animal feed. In this way, fresh feed for animals is obtained all year round. The cost of obtaining food for animals is eliminated.

In order for this system to work well, it is necessary to monitor the condition of the plantation and lawns in the inter-rows. The right watering mode also requires some power consumption. All the energy for servicing the plant and animal farm is obtained from the agrovoltaic system above the plantations. This energy cost is also eliminated. Part of the feces from the animals can serve to make pellets or for liquid fertilizers from the energy holding. They are collected by special devices at the end of the pen.

Processing factories have the obligation to process all production. In these factories, organic products of a plant or animal nature are obtained. They are again in the land of the model. The energy to operate these factories is supplied by the energy holding, at fixed prices suitable for both parties. This energy can be thermal or electric.

In the plant processing factory, the raw material was obtained from the tenants. Plums are targeted, dried and dried plums are obtained as a final product from one assembly line. The model provides a packing line for dried fruits. A shock freeze line is also planned. The other end product is the preparation of oil from the plum's pit. This is the third assembly line in the factory for processing. It is suitable for making medicines and the cosmetic industry.

The waste from the plum processing factory will be handed over to the energy holding to make biofertilizer or biomass for energy.

The animal production processing factory processes the products of the animal farm. Production lines for processing milk, yellow cheese, cheese and local products are envisaged. The products are organic because the animals are grown in a natural environment without the use of synthesized feed mixtures. A packing line for finished products is again envisaged in the factory.

The waste is again handed over to the energy holding.

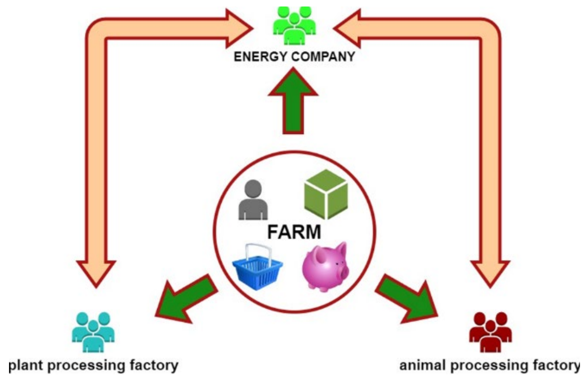

Fig. 2. Interaction between the main elements of the model

The energy holding aims to control and redistribute the energy obtained from the agrovoltaic systems, from the biofertilizer from the animal farm, from the excess hay from produced from the inter-row space of the plum plantation and from the waste from the various industries such as pruning branches, plum pits, etc. Once the needs of individual consumers in the model are satisfied, surplus energy will be sold on the free energy market or used to meet the energy need of households involved in the processes.

As a result of the produced organic products and the consumption of such, it is assumed that the health of the population will improve. Due to the increased trade turnover, it is assumed that this will lead to improved infrastructure to allow production to reach the markets. The profit made will improve the situation of all stakeholders and involved in the process. A well-functioning structure will be built, in which everyone will have an interest in developing it and improving the well-being of those involved.

This will lead to increased interest in involving new tenants or process actors, resulting in population growth in the region. New structures such as a school, a medical centre and other adjacent units will be built.

As elements of the circular economy, they will all lead to the high added value of manufactured products.

The model relies exclusively on human potential, on the soil-climatic conditions of the environment and on the peculiarities of the region. It is located in the centre of Bulgaria and can be a key centre for the preservation and development of the livelihood of the population.

IV. Conclusions

A model of symbiotic cultivation of plant and animal production, as well as the receipt of electricity and energy from biomass, has been developed. The developed model will allow to increase the living status of its participants through sustainable development. Lifestyle and infrastructure will be improved. The developed model can serve as an example of symbiotic sustainable development of society.

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Green Human Resource Management as a Component of Sustainable Organizational Development in Environmental and Natural Economics

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***Abstract*. A growing number of public personalities, politicians, non-profit organizations, and members of civil society are demonstrating their social duty and dedication by adopting a green philosophy that focuses on three key areas: the environment, human well-being, and the green economy.**

The terms "green management", "green public procurement", "green marketing", "green human resource management" and "green PR" are becoming more and more popular to improve the environmental condition. Because of their mutual dependence, applying one idea promotes the growth and advancement of another.

This study attempts to present a research model, on the one hand, emphasizing the thesis that environmental management should be viewed as a moral concern rather than an adaptable procedure and that it can influence as a source of competitive advantage by providing strategic and economic advantages [1]. The idea that the application of green practices in human resource management extends beyond the implementation of environmental protection initiatives and includes the formulation of policies and practices that support sustainable development and people management is another popular hypothesis in the field. Taking into consideration the interaction between institutions and human resources, the concepts of meaning, value, and integrative communication are strengthened in this context to create ideal conditions for the implementation of "green ideas" with a sustainable outcome. The conceptual linking of these management fields is presented in a 'management waterfall for re-innovation' model for positive, integrative 'green' organizational behavior.

The aim of the study is to make a comparative analysis of the challenges facing the green management of human resources, summarizing and presenting some interesting ideas in this scientific field. Through comparative analysis, key characteristics are summarized and conclusions are drawn for the improvement of these processes.

A series of empirical and theoretical analyses, a deductive technique, and a descriptive-correlative approach are all combined in the structure of scientific research. The research directs the rethinking of hierarchical structures in "networked" models based on cooperation between two functional areas of the organization and gives arguments supporting the idea.

Keywords: *green HRM, green PR, management; waterfall for re-innovations.*

I. INTRODUCTION

The powerful influence on the environment is a consistent trend that is highlighted by the growth of industry, particularly the chemical, energy, construction, and food industries. An increase in the number of organizations, a rise in the global population, and afterward a rise in the consumption of goods and services as well as the use of automobiles negatively affects the quality of the air, which rapidly deteriorates the general health of those living in certain settlements. The European Union actively pursues improving the overall well-being of its citizens through some directives, strategic plans, and legal agreements. A major contribution to the improvement of the ecosystem is the European Green Deal, whose main goal is to achieve climate neutrality by 2050 through several main initiatives: the Package "Ready for Target 55"; European Climate Law; EU Strategy for Adaptation to Climate Change; EU Biodiversity Strategy 2030; Farm to Fork Strategy; European Industrial

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Strategy; Circular Economy Action Plan etc. A growing number of municipalities in Bulgaria are beginning to update their eco-normative framework by implementing programs aimed at enhancing the environment, air quality, energy efficiency, and the use of renewable energy sources and biofuels. These initiatives are based on the public policies presented in Europe.

The research has shown that the evolution of the idea of human resource management (HRM) is crucial to the growth of companies that may affect worker performance in a good way by implementing focused, efficient, and open people management practices. In this regard, fostering an understanding of the function of green HRM in the framework of an organization's sustainable development is also a part of any organization's security system.

However, given the current public discussion surrounding climate change, sustainability is starting to take center stage when it comes to organizational requirements. Green HRM (GRM) is a modern derivative of HRM and combines human resource management with environmental management. HRM is applied by organizations to implement corporate green strategies by providing opportunities and motivating employees to participate in environmental activities, and there is currently a real boom in interest in practices in this area. At the same time, the technique of "green PR" is perceived as a catalyst for raising public awareness and involving people in sustainable development and ecological balance restoration. For public relations practitioners, this means going outside of their comfort zone and modifying their approach to include these environmental projects. to properly handle environmental public relations. „Green public relations describes the act of highlighting and communicating your client, brand, or company's sustainability efforts, environmental friendliness, and ESG initiatives. Some detractors believe that Green PR is just a fad—but that view is easily debunked. Today, major organizations such as the UN continue to push for green economies. Businesses like Uber, a global transportation powerhouse, have goals to emit zero CO2 emissions by the year 2040. This isn't just a fad—we're in the middle of foundational changes"[2].

II. MATERIALS AND METHODS

A series of empirical and theoretical analyses, a deductive technique, and a descriptive-correlative approach are all combined in the structure of scientific research. The research directs the rethinking of hierarchical structures in "networked" models based on cooperation between two functional areas of the organization and gives arguments supporting the idea.

III. RESULTS AND DISCUSSION

The extent to which employee perceptions of an organization's green HRM policies influence employee behavior and social and psychological processes in the workplace has not been sufficiently or thoroughly empirically investigated [3]. Green HRM is a relatively new term that has been conceived to explain how employee behavior in the workplace is affected by it. GRM is restricted to a single impact that mediates the psychological green climate's indirect influence on workers' mindful behavior at work [4]. Individual green values do not affect the impacts of GRM or psychological green climate on behavior; however, they do moderate the effects of psychological green climate on employees' off-role green conduct [5]. These findings suggest that green HRM influences employees' role and non-role behaviors in the workplace, but this manifests itself in different individual social and psychological processes. This focus is undoubtedly related to the motivation of employees in organizations [6].

Over the last decade, there has been a growing realization of the need to integrate human resource management (HRM) and environmental management.

There is a significant relationship between Perceived Organizational Green Readiness and the institutionalization of Green HRM [7].

GHRM practices provide a framework for incorporating sustainability concepts into various HR operations, including recruiting, selection, training, performance management, and compensation. These practices go beyond simply adhering to environmental legislation and instead aim to foster an organizational culture of environmental responsibility and sustainability[8].

Researchers Saeed, Afsar, Hafeez, Khan, Tahir, and Afridi (2019) point to two key psychological parameters as major influencing factors in green HRM:

- ✓ Environmental knowledge: Awareness of the need to protect the environment and increase the likelihood of environmentally friendly behavior.
- ✓ Environmental psychological climate: This climate indicates that the organization encourages ecologically responsible activities and attitudes. This encourages environmentally conscious conduct among employees who adapt their workplace behavior to the adopted company culture.

Over the last few years, there has been a tendency to blur the line between different types of crisis situations [9].

In connection with the global energy crisis of the last 2-3 years, the topic of energy resources and sources on a global scale is extremely relevant and is discussed at numerous high-level meetings between the heads of state of countries from all continents [10]. This crisis did not pass by Europe and it can even be argued that the countries of Europe are one of the most affected by the energy and accompanying financial and resource crisis [11].

In recent years, scientific research and publications in Bulgaria have increasingly touched on components of these ideas, especially in the part of corporate social responsibility and the role of motivation in the human resources management process.

Complementing empirical results in the direction of the development of the concept of green HRM and its correlation with integrative communication, we find in the data from the latest editions of the multidisciplinary, global survey of trust of Edelman Data & Intelligence, the Edelman Trust Barometer and the special reports of the Edelman Trust Barometer (Edelman Trust Barometer 2021, 2022 and 2023). One of the examined elements demonstrates that employees are guided by their values when choosing and remaining with a business, much as consumers are when purchasing and keeping with the employer brand. Along with the requirements for occupational well-being, the role of the employer's commitment to act for the good of both employees and society is added. The focus is on a "contract" between employee and employer that encourages businesses to play a more ambitious role in society while fundamentally rethinking workers' motives [12].

Consumers, like employees, are becoming more concerned with environmental issues, and they are willing to pay extra for sustainable products. Consumers now expect organizations and companies to be good for individuals and society [13]. Businesses that engage in green and sustainable marketing benefit the environment while also positioning themselves for long-term success. To remain competitive, firms must discover ways to limit their environmental effect and implement sustainable policies, which are not just the ethical thing to do, but also beneficial to business.

It follows that the "green idea", as we call it for short, is on the agenda of all stakeholders - employees, customers, local communities, and global environmental organizations. Trends show that people are becoming more aware of the environmental impact of human activity, and the concept of sustainability is gaining popularity. Customers are increasingly looking for eco-friendly goods and services as they become more conscious of how their shopping habits affect the environment. Green marketing, which entails advertising goods and services with little to no impact on the environment, has emerged as a result of this. Companies are beginning to understand the value of sustainability and their potential role in supporting it. Since businesses increasingly realize the value of sustainability in their operations, green marketing has emerged as a dominant trend in today's business world. Meeting present-day demands without sacrificing the capacity for future generations to do the same is the idea behind sustainability. In this proposal, we will discuss how sustainability has become a reality in marketing, and the benefits that companies can derive from embracing green marketing practices [14].

The "green idea" permanently begins to take its place in all management, communication, and production mechanisms in a significant part of organizations. To ensure long-term growth, we think that a symbiotic interaction between stakeholders as well as an ecological relationship with society is required, which increasingly necessitates the provision of green products and services, green management practices, and green human resource management. Enforcing such a trend will guide society toward a more sustainable, long-lasting, and ecological environment. Undoubtedly, the obstacles to fully implementing this theory necessitate the establishment of a behavioral culture based on habits, guesses, current knowledge, and their application.

Understanding the challenges and benefits of implementing the "green idea" that has become a long-term objective necessitates integrative communication, consensus support, and true repetition of activity in the form of a well-thought-out decision. Implementing "green thinking and action" is more than simply a goal; it is a process that alters a society's way of thinking and living. This is not only a priority of the Green Pact, of the ruling majority, it is not a matter of actions of external institutions, nor is it a one-time or repeated gesture of corporate social responsibility. This is a process of separating the personal, organizational, and public in the lives of citizens, who are expected to become increasingly active participants in environmental protection activities. The activity must be exhibited through improving one's overall image in society and modifying everyday and professional actions. All of this is only possible if strategic public relations tools and tactics are employed in an intelligent manner within the boundaries of a green communication paradigm, and interested parties are included in the European public space in this direction. This notion should encompass the entities, their means, and duties for sustaining a continuous public debate on the subject. Because "Strategic management in PR is concerned with the end as well as the means. The purpose is to improve the subject-object relationship from its starting state. The means demonstrate how the desired condition will be achieved. Public relations strategy is linked to a systemic approach, a creative and conceptual view of communication policy based on facts, analysis, and the organization's overall goals and policies. The incorporation of a plan makes it easier to make tactical decisions about how to implement PR efforts for the organization's audiences. It illuminates the path and decreases the likelihood of deviating from the goal at a time when individuals who recognize it are preoccupied with their everyday responsibilities. At the same time, the PR strategy unites many and different activities, and is not a single intervention." [15]

In the context of the research object, the direction that is identified in PR is the so-called green PR, also known as ecological (the beginning of the 1990s is considered to be the beginning), whose main goal is to support the development of civil society as an expression of the population's right to a good environment. From an organizational standpoint, green PR is an activity that seeks to foster a positive and mutually beneficial relationship between the organization and its target audience. Often, the subjects of green PR are different and reveal collaborative partnerships in the field of existing types of public relations, including green PR, which is the basis of corporate social responsibility in society. It is logical to conclude that green public relations has a vocation to promote ideas, inform, engage the public in public debate on environmental issues, explore solutions to environmental issues, and participate in their activities using instruments suitable to the circumstances and activities. The goal of this green PR exhibition is to clarify the technical potential of social science and technology PR in the process of adopting and spreading "green ideas". PR theory and practice have several aspects and communication-management approaches that are useful tools for public communication about areas such as the environment, economy, and societal aspects. To continue to contemplate the prospect of a green lifestyle, green PR is an essential component of the company.

Green PR is on the rise to address increased public scrutiny, media attention, environmental concerns and government intervention. Green PR is about environmental sustainability, in other words, maintaining the factors and practices that contribute to the quality of the environment on a long-term basis [16].

To fully realize the objectives of the European Green Pact, which envisages complex measures aimed at managing the negative external environmental factors generated by human activity and improving social problems, social change is necessary, as it is unavoidable and has always been part of progress towards a more sustainable future. In recent years, accelerated transformation and increased awareness have resulted in social, environmental, and economic gains. Information, communication, and connections are essential components of a thriving democracy. In this case, it is not about a single communication act or the transmission of specific information, but about a full communication strategy. Efforts should therefore focus on providing facilities and tools – forums for debate and channels of public communication – that will give as many people as possible access to the diverse aspects of the 'green idea'. PR best lays the groundwork for dialogue between institutions and their audiences. “AI tools undoubtedly can greatly enhance PR efficiency and performance, they should be used in conjunction with human expertise and judgment. The utility of automation in processing Big data is undeniable, as it saves time, effort and man-hours. PR professionals play a vital role in understanding the context, interpreting data insights, and crafting appropriate communication strategies [17]. The European Union (EU) is the undisputed leader, at the international level, in promoting the principles of sustainable development through complex measures that have allowed the creation of a coherent legal and institutional framework [18].

IV. DISCUSSION

Companies actively participate in avoiding and resolving societal issues, such as those connected to the environment. One of the most effective approaches is to establish "green" practices, which involves establishing an environmentally friendly and human-friendly workplace, as well as sharing and implementing eco-friendly methods in professional and everyday settings.

Conceptual elements of the above definitions of GRM include the ability-motivation-opportunity model, degree of employee perceptions of green policies, influence on employee behavior and social and psychological processes in the workplace, mediation of psychological green climate, role orientation and non-role behavior of employees at work, environmental knowledge as an apparent requirement to increase environmental behavior in the implementation of a model that includes.

To achieve the goal in a conceptual form of presents the authors' conceptual view of the importance of the relationship "green HRM" with sustainable organizational development, in the context of practices such as, for example, green management is achievable with the application of the idea of green human resource management and related it functions of selection, training, performance management, participation and reward in relation to the environmental objectives of the organization. I.e. factors that generate daily activity and prompt a rethinking of one's priorities. For all of the reasons stated above, the principles of perception, retention, and processing of information, regardless of whether it is related to information, training, persuasion, or pleasure, are being transformed, resulting in an improvement of communications in organizations from the perspective of the "green idea". Concepts on the importance of public communication in organizational and social change are demonstrating their validity. Today, they represent a projection of effective organizational design based on internal and external elements. The presented approach has heuristic potential and applies to current social developments; it is a tool for effective adaptation, transformation, rapid growth, sustainability, and trust.

A holistic approach to the "green idea" in the organization is a concept that recognizes the interconnectedness of all aspects of the life and activity of the organization. This approach acknowledges that all of these factors are interrelated and have an impact on employees, customers, counterparties, and the organization's well-being.

The "Management waterfall for re-innovations" model, which we present below visually and sequentially from top to bottom, is in the process of interacting with the elements of the management system and information about them. Its vision, understanding, and operation require a mixture of all, as well as communication between them, to blend into one knowledge pool that molds the organization's internal relationships and reputation contextually in a "green idea". It is distinguished by methodology, process, structure, principles, functions, techniques, and management, just like each "step". As a result, the system visualizes the functional structure and organizational links to integrate them into a system for communication, management decision generation and implementation, and information understanding and support. Progress in organizational understanding is viewed as a downward-flowing activity since each element to be finished borrows and builds on the outcomes of the preceding one, as the methodology of returning from a previous phase to a higher and higher level must mirror the established goals.

"Management waterfall for re-innovations" [19]

1. Strategic communication management

2. Leadership, emotional intelligence, and "Change-story" model

3. Motivation, organizational culture, and "storytelling" model

4. Sustainable brand and sustainable development

The waterfall model follows the unifying concept of strategic communication management. It should be understood, on the one hand, as a PR plan or communication strategy that is consistent and adheres to the principles of coordination and integration - internal to external relationships. When using these concepts, it is also crucial to consider the unique characteristics of the enterprise's or institution's organizational structure. The implementation of the strategy necessitates the creation of a strategic plan, budget, and procedures (campaigns or activities), which can be classified as medium and short-term plans. An essential component is the conceptual framework of internal communications is described through three main units that unite the detailed vision of internal communication management in clear collaboration with HR. The strategic communication model, developed in combination with the HRM model and based on the vision that employees are not passive recipients of performance information, but active participants who take their communication initiatives, exhibit projective behavior toward "green initiatives," attempting to make sense of situations and influence the formation and maintenance of the employer brand in a "green light."

"Regarding branding and brand - as an idea, brand is related to the sustainable accumulation of associations and impressions, which in turn can be a major prerequisite for achieving integration. Of course, strategies in this area at corporate level evolve, they vary considerably, but ultimately the responsibility for building a conceptual framework that brings together and integrates all communications can be given to branding. [20] "

The concept of collaboration between HRM – and PR, on the one hand, brings out solutions for support, communication, joint organizational design, and knowledge sharing, and, on the other hand, solutions for cooperation. Here it is necessary to open a parenthesis for the fact that "the role of human resource management plays a central role in organizational development and organizational changes. It is a bridge between management and staff in communicating towards a positive organizational assessment and acceptance of management changes" [21].

"It is very important to emphasize stakeholder analysis and identification in order to steer communication in the right directions based on a clear idea of what the information needs, the excitement, the opinions are" [22].

Once a common vision and mission are established, the plan can fully fulfill the function of strategic internal public relations in assisting in the definition and implementation of corporate and business strategies, shaping both strategic and downstream levels of operational and management decisions to work from the start, combined in communication programs aimed specifically at transforming green ideas from a green office to a green reputation.

The combination of HRM and strategic internal communications in their bridging role provides employees with critical information about their daily work, the organization, their environment, and themselves in a productive relationship. The strategy of understanding, support, and feedback must be used to create a green environment that encourages the expression of thoughts, views, and feelings, as well as the sharing of dreams and objectives, and the celebration of achievements. Communication is the foundation that allows individuals and groups to understand their organization, what it is, what it stands for, and how to work effectively for it.

V. CONCLUSIONS

With a growing awareness of sustainable development and the green revolution, the vast majority of people place a high value on real commitment to sustainable development, including manageability in terms of air pollution, noise pollution, water pollution, and any other feature that removes natural assets from climate change in the normal eco-framework. Without pretensions to comprehensiveness, the article discusses theoretical-applied proposals, at the heart of which is HRM, in progress to help organizations manage environmental impact. In this context, it means that the firm adjusts its strategy to include environmental efforts that are relevant, applicable, and shared by its human resources, even if they are outside of its comfort zone. To fully realize the ecological potential, it is required to develop and progressively introduce the ingredients, processes, and organizational culture. The green idea, like other organizational improvements, has been embedded into the organizational core.

In summary, it can be noted that the implementation of components of green human resources management leads to the imposition of sustainable practices in the development of the organization. Moreover, the expansion of the applied description in the scientific study of management techniques significantly increases the motivation of employees and leads to high results.

In conclusion, if we use the term micromanagement of processes, we believe that it can build ecological thinking and action, innovation as part of the culture. „Culture, unlike the unifying effect of lobalisation, differentiates different communities“ [23].

The 'green idea' co-op sits at the intersection of business, creativity, and a broader sense of social responsibility, giving it a distinct and vital place in today's ever-changing social landscape. It requires a long-term commitment, but it is also satisfying in and of itself. Although this demands a significant amount of effort, it is worthwhile because the objective is noble, and green HRM in communicative cooperation has the potential not only to enhance the bottom line of the business but also to make a genuine impact in the world.

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The Impact of Human Capital on Strategic Plannig and implementation of CRM for Enhancing Customer Realitionship in Enveroument and Resources

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Abstract. **In today's dynamic business landscape, effective strategic planning and the implementation of Customer Relationship Management (CRM) strategies are crucial for organizations, particularly those operating in the field of environment and resources. This article explores the significant influence of human capital on the strategic planning process and the successful deployment of CRM systems aimed at improving customer relationships within this sector. Drawing upon interdisciplinary research from management, environmental studies, and information technology, this study investigates the intricate relationship between human capital, strategic planning, and CRM implementation. Through a comprehensive review of relevant literature and case studies, the article highlights key considerations for leveraging human capital to optimize strategic planning and CRM implementation, ultimately fostering sustainable customer relationships in environment and resources.**

Keywords: Human capital, Strategic planning, Customer Relationship Management (CRM), Environment and resources, Sustainability

I. Introduction

This critical role of human capital is explored in shaping the strategic planning and successful implementation of Customer Relationship Management (CRM) initiatives within the context of environment and resources. As organizations increasingly recognize the importance of customer relationships in achieving sustainable growth and competitiveness, the integration of CRM strategies becomes paramount. However, the effectiveness of CRM implementation is contingent upon the organization's human capital, encompassing the knowledge, skills, and commitment of its workforce. The problem is that the growth of human capital often leads to an increase in industrialization and urbanization, which can have serious negative consequences for the environment, such as air, water and soil pollution, increased greenhouse gas emissions and loss of ecosystems.

Furthermore, the high consumption of resources by individuals with high levels of human capital can lead to excessive depletion of natural resources, such as fuels, water, and minerals.

Additionally, inequality in access to education and opportunities to develop human capital can contribute to social problems, which, in turn, can have a negative impact on the environment. For example, inequality can lead to an unfair distribution of environmental burdens, such as pollution and ecosystem destruction, which most often affect poorer communities.

Moreover, unchecked expansion of human capital may result in the excessive exploitation of natural resources without adequate consideration for preserving biodiversity and ensuring the sustainability of ecosystems.

Also, heightened industrialization and consumption, frequently linked to advanced human capital development, can exacerbate greenhouse gas emissions and hasten climate change.

These concerns underscore the necessity for sustainable management of human capital development, considering both the environmental and social dimensions of growth.

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The objective of this article is to investigate how human capital influences the strategic planning and execution of CRM in the unique landscape of environment and resources. The environment and resources sectors face intricate challenges, including regulatory complexities, stakeholder engagement intricacies, and the imperative to balance ecological conservation with resource utilization. CRM systems provide a means to navigate these challenges by facilitating efficient communication, data management, and stakeholder collaboration.

II. MATERIALS AND METHODS

This section outlines the methodologies, procedures, and tools employed during the course of this study.

Study design: The study design encompasses various essential components. Observational studies incorporate cross-sectional studies, cohort studies, and case-control studies. Experimental studies entail manipulating variables to discern cause-and-effect relationships. Qualitative studies concentrate on grasping social phenomena from participants' viewpoints, often utilizing methods like interviews, focus groups, or ethnographic observation. Mixed-methods studies amalgamate qualitative and quantitative approaches to furnish a comprehensive understanding of the research subject.

Sampling strategy: The method used for participant or case selection encompasses surveys, interviews, observations, experiments, archival data, or secondary data analysis.

Data collection methods: Data gathering involves surveys, interviews, observations, or the examination of existing datasets.

Data analysis: Analytical methods encompass qualitative techniques such as thematic analysis and content analysis.

Validity and reliability: Ensuring the trustworthiness, applicability, dependability, and confirmability of the study was accomplished through an extensive literature review.

III. RESULTS AND DISCUSSION

Significance of CRM Effective CRM implementation enables organizations in these sectors to not only meet regulatory requirements but also build and sustain positive relationships with customers, communities, and regulatory bodies. The success of CRM initiatives, however, relies heavily on the competence and adaptability of an organization's human capital [1].

The Significance of Human Capital in CRM:

Human capital serves as the linchpin in the successful adoption and execution of CRM initiatives. In the context of environment and resources, the diverse skill set of employees plays a pivotal role in navigating the complexities associated with sustainable practices and stakeholder engagement. The ability of employees to comprehend and align their efforts with organizational CRM goals is essential for the effective implementation of CRM systems [2].

Human Capital and Strategic Planning:

Strategic planning is the foundation upon which successful CRM initiatives are built. Human capital contributes to strategic planning by providing insights into customer behaviors, market trends, and environmental dynamics. Organizations that invest in developing the analytical and strategic thinking capabilities of their workforce are better equipped to formulate CRM strategies that are attuned to the unique challenges of the environment and resources sector [3].

Human Capital Dynamics in Environment and Resources:

This section delineates the unique challenges and opportunities associated with human capital in organizations operating within the environment and resources sector. It examines how the knowledge, skills, and attitudes of employees influence the adoption of CRM systems and their alignment with overarching organizational goals, including environmental sustainability and stakeholder engagement. In the environment and resources sector, human capital dynamics are particularly complex due to the multifaceted nature of the industry. Employees in this sector need to possess a diverse skill set, combining industry-specific knowledge with an understanding of environmental regulations, sustainable practices, and stakeholder expectations. The human capital framework must consider the recruitment, training, and retention of individuals capable of navigating the delicate balance between economic viability and ecological responsibility [4].

Moreover, the concept of 'green skills' becomes pivotal, encompassing competencies related to environmental stewardship, renewable resource management, and the ability to integrate sustainability principles into daily operations. Organizations that invest in cultivating these green skills within their workforce are better positioned to align CRM strategies with environmental goals, fostering a more resilient and responsible approach to customer relationship management [5].

Aligning Organizational Goals Strategic planning involves aligning organizational goals with CRM objectives. Human capital with a deep understanding of the sector's intricacies is crucial for identifying synergies and formulating strategies that contribute to both regulatory compliance and enhanced customer relationships. Gap Analysis Conducting a comprehensive gap analysis of the existing human capital is essential for identifying skill deficiencies and planning targeted recruitment or training programs. This section discusses how organizations can bridge these gaps to ensure that the CRM strategy aligns seamlessly with the organization's overarching goals [6].

Implementation Challenges and Human Capital:

The implementation of CRM systems in the environment and resources sector is often met with challenges such as regulatory compliance, stakeholder engagement, and the integration of sustainability goals. Human capital becomes instrumental in overcoming these challenges through effective communication, collaboration, and adaptability. Training programs that enhance employees' understanding of CRM tools and methodologies are vital for ensuring seamless implementation. Implementation challenges in CRM initiatives within the environment and resources sector often stem from the sector's unique characteristics, such as stringent environmental regulations, diverse stakeholder interests, and the need for transparent communication. Human capital solutions involve the development of cross-functional teams with expertise in environmental science, regulatory affairs, and effective communication [7].

Training programs should not only focus on the technical aspects of CRM systems but also on instilling a deep understanding of the environmental and social impact of organizational activities. Employee engagement becomes a critical component, emphasizing the importance of fostering a culture where employees feel empowered to contribute ideas and feedback regarding CRM implementation. This ensures that CRM strategies are not only compliant with regulations but also reflective of the organization's commitment to environmental responsibility [8].

Resistance to Change Resistance to change is a common challenge during CRM implementation. This section explores how skilled and motivated human capital can mitigate resistance through effective communication, fostering a sense of ownership, and highlighting the benefits of CRM adoption [7-8].

Customization for Sector-Specific Requirements The environment and resources sectors often have unique CRM requirements. Human capital with domain-specific knowledge is instrumental in customizing CRM systems to meet these sector-specific needs, ensuring that the technology aligns seamlessly with the organization's workflow [9]

Employee Engagement and CRM Success:

The commitment and motivation of employees significantly impact the success of CRM initiatives. Organizations that foster a culture of customer-centricity and sustainability within their workforce are better positioned to create lasting relationships with customers. Employee engagement programs, recognition, and continuous skill development contribute to a positive and customer-focused organizational culture [10].

Case Studies:

This section provides real-world case studies illustrating the correlation between human capital, strategic planning, and successful CRM implementation in environment and resources organizations. These cases highlight best practices, challenges faced, and the outcomes achieved, offering insights for practitioners and researchers alike.

In this section, case studies could include examples of organizations in the environment and resources sector that have successfully integrated CRM strategies, highlighting the role of human capital. For instance:

Case Study 1: Sustainable Supply Chain Management

An organization with a focus on sustainable resource extraction implemented a CRM system that traced the entire supply chain, from raw material extraction to end-user. Human capital played a crucial role in training employees on data input accuracy, ensuring that environmental impact data was accurately captured. Additionally, cross-functional teams consisting of environmental scientists and CRM experts collaborated to create a system that not only enhanced customer relationships but also showcased the organization's commitment to sustainability [11].

Case Study 2: Stakeholder Engagement in Renewable Energy

An energy company transitioning to renewable sources faced challenges in stakeholder engagement. Human capital initiatives included training employees in community relations and sustainable development. The CRM system was then adapted to include modules for transparent communication, allowing the organization to build and maintain positive relationships with local communities, regulatory bodies, and investors [12].

These case studies highlight the direct correlation between strategic planning, human capital investment, and successful CRM implementation in the environment and resources sector. They serve as practical examples for other organizations seeking to integrate CRM in a way that aligns with their environmental and social responsibilities [5].

Leveraging Technological Capabilities

This section explores how organizations can capitalize on the technological capabilities of CRM systems to enhance the efficiency of environmental and resources management. Human capital's role in integrating these technologies seamlessly into existing workflows is crucial for realizing the full potential of CRM systems [13].

User Adoption Strategies Successful CRM implementation relies heavily on user adoption. Human capital plays a key role in fostering a positive attitude towards CRM systems among employees. This section discusses strategies for overcoming resistance and ensuring enthusiastic user adoption, emphasizing the need for effective training programs and ongoing support [14].

Data Security and Ethical Considerations

Ensuring Data Security

The environment and resources sectors often handle sensitive information, requiring robust data security measures. Human capital, particularly individuals with expertise in data privacy and security, plays a vital role in designing and implementing secure CRM systems. This section delves into the strategies organizations can employ to safeguard customer and environmental data.

Ethical Considerations in CRM Maintaining ethical standards in customer relationships is paramount. Human capital with a strong ethical foundation ensures that CRM practices align with societal expectations and environmental stewardship. This section discusses the ethical considerations organizations must incorporate into their CRM strategies and how human capital can contribute to ethical decision-making [15].

Continuous Improvement and Adaptation

Feedback Mechanisms Continuous improvement is essential for the long-term success of CRM systems. Human capital, particularly those engaged in customer-facing roles, can provide valuable insights through feedback mechanisms. This section explores the importance of creating channels for continuous feedback and how organizations can leverage this information for system refinement.

Adaptive Capacity The environment and resources sectors are subject to constant change, be it regulatory updates, technological advancements, or shifts in public perception. Human capital with adaptability is crucial for ensuring that CRM systems remain effective and aligned with the evolving landscape. This section discusses strategies for cultivating an adaptive culture within the organization [16].

Future Trends and Implications

Technological Advancements As technology continues to advance, this section explores emerging trends such as artificial intelligence, machine learning, and predictive analytics in CRM systems. Human capital's role in understanding, integrating, and harnessing these technologies is crucial for staying ahead in the environment and resources sectors.

Implications for Industry Practices The implications of the study on industry practices are discussed, offering insights into how organizations in the environment and resources sectors can adapt their CRM strategies and human capital development programs to remain competitive, sustainable, and customer-centric [17].

CONCLUSION:

This study sheds light on the pivotal role of human capital in shaping the strategic planning and successful implementation of Customer Relationship Management (CRM) initiatives within the environment and resources sector. Through an interdisciplinary approach encompassing management, environmental studies, and information technology, we have explored the intricate relationship between human capital, strategic planning, and CRM implementation.

Our findings underscore the significance of human capital in driving effective CRM strategies tailored to the unique challenges of the environment and resources sector. Human capital serves as the linchpin for successful CRM adoption, contributing to strategic planning, stakeholder engagement, and sustainable practices.

The case studies presented illustrate how organizations can leverage human capital to align CRM initiatives with environmental stewardship, regulatory compliance, and stakeholder expectations. From sustainable supply chain management to stakeholder engagement in renewable energy, these examples highlight the transformative impact of strategic human capital investment on CRM success.

Moving forward, we recommend several strategies to address the challenges identified and capitalize on the opportunities presented:

Investment in Green Skills: Organizations should prioritize the development of 'green skills' among their workforce, focusing on competencies related to environmental stewardship, renewable resource management, and sustainability integration.

Enhanced Training Programs: Comprehensive training programs should be implemented to equip employees with the necessary technical skills and environmental awareness required for effective CRM implementation.

Cross-functional Collaboration: Establishing cross-functional teams comprising environmental scientists, CRM experts, and regulatory affairs specialists can facilitate seamless integration of CRM systems with environmental goals.

Ethical Considerations: Ethical standards should be embedded into CRM strategies, ensuring that customer relationships align with societal expectations and environmental responsibility.

Continuous Improvement: Organizations should embrace a culture of continuous improvement, fostering adaptive capacity and leveraging feedback mechanisms to refine CRM strategies in response to evolving industry trends and stakeholder needs.

By adopting these recommendations, organizations in the environment and resources sector can enhance their CRM practices, strengthen customer relationships, and contribute to sustainable development goals. Through strategic human capital management, organizations can navigate the complexities of the environment and resources sector while fostering innovation, resilience, and responsible stewardship of natural resources.

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Environmentally Acceptable Synthesis Of Magnesium Bearing Fertilizers. III Solid State Synthesis

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Abstract. **Nutrition is a key factor in human life and the development of civilization. The production of sufficient food requires the use of: efficient agricultural techniques, suitable soils and the use of nitrogen (N) fertilizers. However, the use of synthetic nitrogen fertilisers is associated with significant problems, caused by the fact that they are not sufficiently retained in soils to be taken up by plants and a significant proportion of the applied fixed nitrogen is lost. This is a serious economic problem for the farmers and a serious environmental problem for the society. In this work, the known methods for reducing the loss of bound nitrogen when fertilizer formulations are applied to the soil are discussed, and a promising preparation is presented, which is a complex of urea with magnesium sulfate, named magnesium sulfate hexaureate hemi hydrate, [Mg $((H_2N)_2CO)_6$] $SO_4{}^1/_2$ H_2O, which can find application both alone and in the formulation of the complex fertilizer formulations, as well as a convenient method for its preparation. The use of [Mg $((H_2N)_2CO)_6$] $SO_4{}^1/_2$ H_2O, instead of conventional nitrogen fertilisers, besides the reduction of losses of fixed nitrogen, is that it supplies the soil with the trace elements Mg and S. The low hygroscopicity and the good stability of the preparation are also essential. The known ureate complexes of magnesium sulphate and their preparation are discussed. The proposed new method of solid-phase synthesis, has certain advantages. The use of solid synthesis state methods has a number of advantages: solvent-free synthesis, low-temperature operation, high yields, and the absence of by-products make these methods the most environmentally acceptable.**

Keywords: fertilisers, nitrogen losses, magnesium sulphate, urea

I. Introduction

Food is a key factor in the development of civilization. Despite efforts to reduce food deficits, there are still hundreds of millions of people who are starving. An additional negative factor is the growing population of the earth, which has now reached 8 billion people. Despite the progress made, on average, between 1908 and 2008, the number of people living on 1 hectare of cultivable land increased by 200% [1]. Such an increase in agricultural productivity is impossible without the use of nitrogen (N) fertilizers. The use of synthetic N fertilizers, however, is associated with significant problems conditioned by the fact that they are not retained in soils sufficiently to be absorbed by plants and a significant portion of the applied fixed N is lost. In the first place to the atmosphere mainly as ammonia, but also as nitrogen and nitrogen oxides (N_2O). Losses of bound nitrogen are estimated to be up to 40% of the amount applied. Zhenli& Kumar [2] give the following order of losses in the form of ammonia depending on the applied fertilizer in percentage:

NH_4CO_3: 23.2; $(NH_4)_2SO_4$: 21.7; $CO(NH_2)_2$: 21.3; NH_4NO_3: 17.6

Additionally, losses are also caused by the processes of leaching and erosion. Losses can reach up to 70%, but it is accepted that more than half of the applied fixed nitrogen is lost during fertilization [3]. This is a serious economic problem for farmers and a serious environmental problem for society. The continuous use of synthetic (N) fertilizers, causes degradation of both soil and water ecosystems [4].

Therefore, the development of new strategies to reduce the losses of bound nitrogen during fertilizer application appears to be a priority task [5].

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One of the most commonly used nitrogen fertilizers, is urea. Approximately 60% of the bound nitrogen used for fertilization is applied as urea [6].

Various methods have been applied to reduce the losses of bound nitrogen when urea is used for fertilization:

- coverage of the urea fragments with a polymer shell;
- addition of the urease enzyme inhibitor NBPT (N-n-butyltriamide thiophosphate) or NPPT (reduce the rate of hydrolysis of urea in the soil and losses of bound nitrogen, but are ineffective in the presence of phosphorus fertilizer);
- addition of a porous component with a highly developed surface which immobilizes the active substance;
- other supplements: phosphogypsum (PG), diammonium phosphate, $ZnSO_4$, NH_4Cl or KCl

These approaches have different limitations. For example, the use of polymer-covered urea does not lead to an increase in nitrogen availability to plants in the soil, or to an increase in accumulated dry biomass compared to urea [7], [8], or phosphogypsum, depending on the apatite used in its preparation, which usually contains a large number of heavy metals that contaminate the soil.

One new highly efficient method to reduce the losses of bound nitrogen in fertilization is the use of urea complexes instead of pure urea. Typically, calcium or magnesium is used as a complex-forming reagent [9].

The use of magnesium solutions is definitely to be preferred because magnesium is an important bioelement and has a significant role in energy transfer in organisms and their absorption by plants. Figure 1, shows the reduction in losses of bound nitrogen as NH_3 when **$[Mg((H_2N)_2CO)_6]\ SO_4.\ ^1/_2\ H_2O$** is applied to a soil-fertilizer mixture relative to a urea control. The observed reduction is more than a doubling, which is an excellent result, higher than published results for urea complexes of calcium.

Currently there are more than 300 known enzyme systems in which magnesium ions are a cofactor, and which regulate various biochemical reactions in organisms participating in virtually all types of metabolism [10].

Magnesium is bound to ATP (adenosine triphosphate) and activates it, being the basis of energy transfer and the construction of ribonucleic acids [11].

Magnesium is involved in the structure of chlorophyll. In green plants, the magnesium ion is at the center of the porphyrin ring of chlorophyll [12] – the pigment that converts sunlight into absorbable energy by living organisms. Its presence in sufficient amounts in the environment is a necessary condition for efficient photosynthesis and growth.

Magnesium is an intracellular cation [13]. About 1% of the magnesium contained in multicellular organisms is located outside the cells. In plants, magnesium is mainly concentrated in chloroplasts.

On the other hand, many soils and crops are deficient in magnesium and require its application as fertilizer.

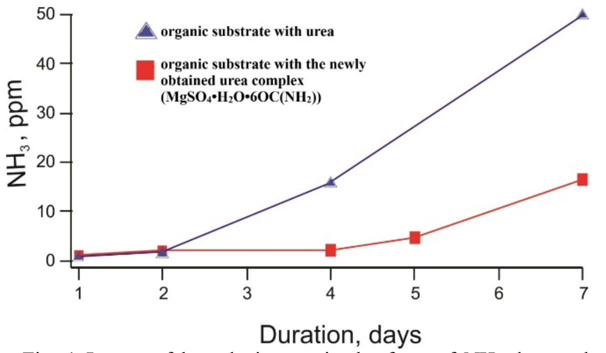

Fig. 1 Losses of bound nitrogen in the form of NH_3 due to the application of **$[Mg((H_2N)_2CO)_6]\ SO_4.^1/_2H_2O$** and **$(H_2N)_2CO$** in a soil-fertilizer mixture [33].

II. MATERIAL AND METHODS

It was used: $MgSO_4\ .7H_2O$ - Fluka, Pour analyse and urea –Fluka, puriss.

Obtaining $[Mg\ ((H_2N)_2CO)_6]\ SO_4.\ ^1/_2\ H_2O$

2.46 g (10^{-2}mol) $MgSO_4\ .7H_2O$ and 3.6 g (6.10^{-2}mol) $(H_2N)_2CO$ are placed in an agate mortar and are grinded for two or three minutes. The resulting semi-liquid paste is transferred to a beaker and placed in a thermostat at 60º C. The sample is placed in the oven and left to stand for 48 hours to complete the reaction and for drying. The resulting of **$[Mg\ ((H_2N)_2CO)_6]\ SO_4.\ ^1/_2\ H_2O$**is characterized by XRD and IR spectroscopy.

Obtaining $[Mg(H_2O)((H_2N)_2CO)_4(SO_4)]$

2.46 g (10^{-2}mol) $MgSO_4\ .7H_2O$ and 2.4 g (4.10^{-2}mol) $(H_2N)_2CO$ are placed in an agate mortar and are grinded for two or three minutes. The resulting semi-liquid paste is transferred to a beaker and placed in a thermostat at 60º C. The sample is placed in the oven and left to stand for 48 hours to complete the reaction and for drying. The resulting of**$[Mg(H_2O)((H_2N)_2CO)_4(SO_4)]$** is characterized by XRD and IR spectroscopy.

Obtaining $Mg(H_2N)_2CO)(\ H_2O)x\ SO_4$ (X=2;3)

2.46 g (10^{-2}mol) $MgSO_4\ .7H_2O$ and 600 mg (10^{-2}mol) $(H_2N)_2CO$ are placed in an agate mortar and are grinded for two or three minutes. The resulting semi-liquid paste is transferred to a beaker and placed in a thermostat at 60º C. The sample is placed in the oven and left to stand for 48 hours to complete the reaction and for drying. The resultingof **$Mg(H_2N)_2CO)(H_2O)_2SO_4$**and **$Mg(H_2N)_2CO)(H_2O)_3SO_4$** are characterized by XRD and IR spectroscopy.

IR spectroscopy

Infrared spectra were measured using Tensor 37 (Bruker) FT-IR spectrometer with 4 cm−1 spectral resolution after averaging 128 scans on standard KBr pallets in the spectral region 500-4000 cm at room temperature.

Powder X-ray diffraction (PXRD)

Powder XRD patterns of the studied samples were recorded on Empyrean Powder X-ray diffractometer (Malvern Panalytical, Netherlands) in the 5°- 90° 2θ range, scanning time 15min, using Cu radiation (λ =

1.5406 Å) and PIXcel3D detector. Phase identification was carried out using the HighScore Plus program [35] and/or through X-ray powder diffraction patterns simulated on the basis of the single-crystal studies for each of the studied complex salts using the PowderCell program [36]. The semi-quantitative phase analysis was also conducted in the same environments.

III. RESULTS AND DISCUSION

The important role of the bioelement magnesium determines efforts to study its coordination chemistry. The preferred coordination number of magnesium is six. This applies both to solutions where the magnesium ion is coordinated by six solvent molecules in the first coordination sphere [14] and to the vast majority of known crystalline phases of magnesium ligands [15]. The solvation of the magnesium cation has been modeled repeatedly using methods ranging from molecular mechanics to rudimentary quantum calculations [16]. The preferred coordination number of 6 is easily explainable by considering that the magnesium cation coordinates through the unoccupied sp3d2 hybrid orbitals that point to the octahedron vertices. Figure 2 shows their location in the lattice as well as the typical magnesium envelope in its complexes.

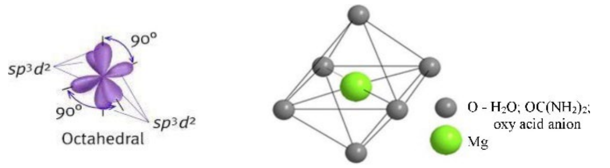

Fig. 2 Spatial distribution of the sp3d2 orbitals of the magnesium cation and a typical octahedron coordination of magnesium.

The object of study in this work is the urea complexes of magnesium, so in the further discussion we will focus on them. The urea molecule has a simple and compact planar structure [17]. The heavy atoms are arranged in a single plane and are in the sp^2 hybrid state. The structure of urea is schematically represented in Figure 3. The oxygen atom has two free electron pairs suitable for the formation of donor-acceptor bonds. They are located on nonbonding sp^2 hybrid orbitals, located in the same plane and form an angle $\Theta \approx 120^o$ with the double bond of the urea molecule.

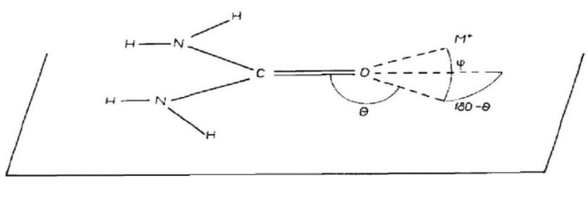

Fig. 3 Structure of urea.

Indeed, the urea forms a complex with the magnesium cation using the non-bonding electrons of the oxygen atom. Lebioda [18] has summarized the structural data known at that time for complexes of urea with metal ions, and his data confirm this consideration. The orientation of the urea molecules with reference to the metal ion is in the direction of the oxygen electron pairs while in water it is in the direction of the dipole moment.

Complexes of urea with various magnesium salts are known. The crystal structures have been determined: nitrate [19], [20], chlorate [21], tetrafluoroborate [19], sulfate [22], [23], [32], chloride [19], bromide [24], [25], iodide [26], perrenate [27], formate [28] and dihydrogen phosphate [29].

Table 1 shows the known urea complexes of magnesium sulfate.

Complex numbers 1 and 3 are highly hygroscopic [31] and are not relevant for agrochemical use.

From the presented complexes, magnesium sulfate hexa urea hemi hydrate: **$MgSO_4.6U.\ ^1/_2\ H_2O$** (2) has the highest potential for agrochemical use due to its high urea/magnesium sulfate ratio, low hygroscopicity and high stability. The structure of **$MgSO_4.6U.\ ^1/_2\ H_2O$** is determined by monocrystalline X-ray structure analysis [23].

A number of magnesium salts also find their application in agrochemistry as a source of magnesium. These are the minerals: magnesite ($MgCO_3$) and dolomite ($CaCO_3.MgCO_3$), as well as magnesium nitrate. As a source of magnesium and sulphur, magnesium sulphate crystal hydrates are used. Most of these are minerals and are presented in Table 2.

The syntheses of urea complexes of magnesium salts can be reduced to two methodologies.

The first one is: Crystallization from solution under slow solvent evaporation. Typically, water is used as the solvent although the use of methanol as a solvent has been described [30].

$$\mathbf{Mg^{2+}\ SO_4^{2-}+6(H_2N)_2CO \rightarrow [Mg\ ((H_2N)_2CO)_6]^{2+}SO_4^{2-} \rightarrow [Mg\ ((H_2N)_2CO)_6]SO_4.{}^1/_2H_2O\ (1)}$$

The method is suitable for obtaining pure phases as well as single crystal patterns suitable for single crystal X-ray structure experiment.

Another method is the mechanochemical synthesis [33].

$$\mathbf{Mg\ SO_4\ .H_2O+\ 6(H_2N)_2CO \rightarrow [Mg\ ((H_2N)_2CO)_6]\ SO_4.\ {}^1/_2H_2O\ (2)}$$

The method has many benefits. Easy and fast. No need for solvents, lots of energy and no waste products. It can be said that it is an "eco-friendly" process.

The main disadvantage is that it can only produce the complex with the highest stability. For $MgSO_4$ and $(H_2N)_2CO$, this is $MgSO_4.6U.\ ^1/_2\ H2O$.

Here we describe a new method for the preparation of urea complexes of magnesium sulfate - solid-phase synthesis. The reaction is proceeded by grinding the crystal hydrate of magnesium sulfate (epsomite, $MgSO_4.7H_2O$) in the presence of urea in an agate mortar for several minutes, during which the reaction mixture is wetted by the water evolved during the interaction, forming a semi-liquid paste (Fig. 4).

TABLE 1 COMPLEXES OF MAGNESIUM SULFATE WITH UREA

№	*Complex*	*Notes*	*Source*
1	$MgSO_4.6U.\ 2H_2O$	Obtained from Yee in methanol	[30]
2	$MgSO_4.6U.\ ^1/_2\ H_2O$	Slow evaporation, water	[23]
3	$MgSO_4.5U.\ 2H_2O$	Obtained from Yee in methanol	[30]
4	$MgSO_4.4U.\ H_2O$	Slow evaporation, water	[22]
5	$MgSO_4.U.\ 3H_2O$	Slow evaporation, water, 70°C	[32]
6	$MgSO_4.U.\ 2H_2O$	Slow evaporation, water	[32]

TABLE 2 MAGNESIUM SULFATE HYDRATE MINERALS FOUND ON EARTH AND MARS *

Hydrate	*Mineral*	*Formula*
undecahydrate	Meridianiite*	$MgSO_4.11H_2O$
heptahydrate	Epsomite	$MgSO_4.7H_2O$
hexahydrate	Hexahydrite	$MgSO_4.6H_2O$
pentahydrate	Pentahydrite	$MgSO_4.5H_2O$
tetrahydrate	Starkeyite	$MgSO_4.4H_2O$
dihydrate	Sanderite	$MgSO_4.2H_2O$
monohydrate	Kieserite	$MgSO_4.H_2O$

Fig. 4 Type of the sample reaction before and after milling during solid phase synthesis of **$[Mg(H_2O)((H_2N)_2CO)_4(SO_4)]$**.

After that the sample is placed in a thermostat at 60°C to complete the interaction and to remove excess water.

$Mg\ SO_4\ .7H_2O + x(H_2N)_2CO \rightarrow [Mg\ ((H_2N)_2CO)_x\ H_2O_{6-x}]\ SO_4 + y\ H_2O$(3)

X = 1, 4, 6

The products are characterized by infrared spectroscopy and powder X-ray phase analysis.

The recorded infrared spectra are presented in Figure 5. In the assignment of the absorption bands, the classical work of Nakamoto [34] was used, as well as published experimental and model data (Ab Initio Calculation) for similar complexes of magnesium salts with urea-iodide [26] and perrenate [27].

Powder diffractograms of **$[Mg(H_2O)((H_2N)_2CO)_4(SO_4)]$** и **$[Mg\ ((H_2N)_2CO)_6]\ SO_4.\ ^1/_2\ H_2O$** are presented in Figures 6 and 7. Phase identification was carried out using the HighScore Plus program.

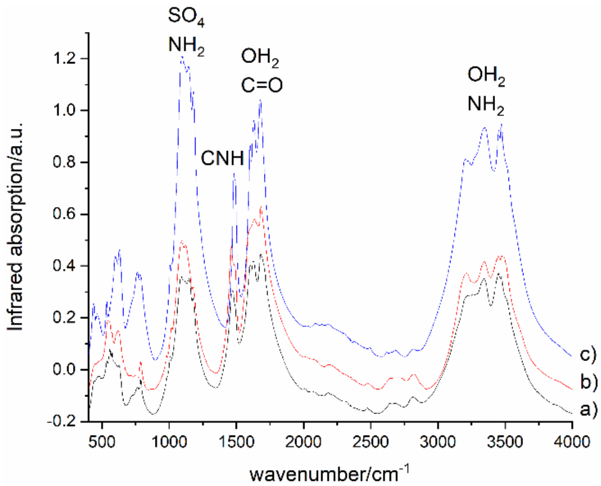

Fig. 5 IR spectra of reaction products:

a) **$[Mg(H_2O)((H_2N)_2CO)_4(SO_4)]$**;

b) **$[Mg\ ((H_2N)_2CO)_6]\ SO_4.\ ^1/_2\ H_2O$**;

c) **$Mg(H_2N)_2CO)(\ H_2O)x\ SO_4$, (X=2;3)**.

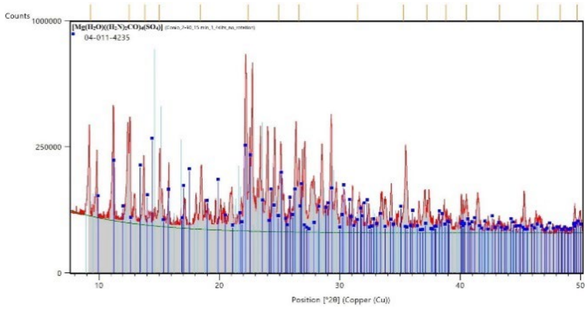

Fig. 6 Powder diffractograms of **[$Mg(H_2O)((H_2N)_2CO)_4(SO_4)$]**, referred to (High Score 4.8) magnesium sulfate urea hydrate with reference code: 04-011-4235.

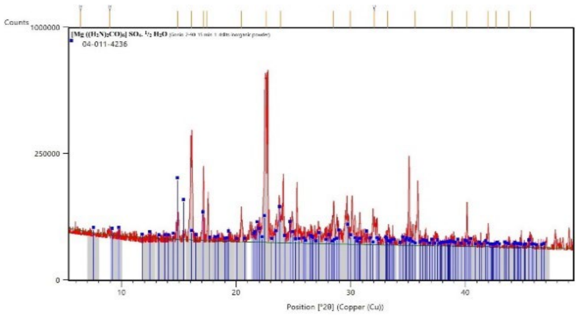

Fig. 7 Powder diffractograms of **[$Mg((H_2N)_2CO)_6$] SO_4. $^1/_2$ H_2O**, referred to (High Score 4.8) magnesium sulfate urea hydrate with reference code: 04-011-4236.

Data for the phases of **$Mg(H_2N)_2CO)(H_2O)x$ SO_4, (X=2;3)**are absent in the databases and therefore the generation of calculated diffraction patterns was performed for identification as well as relating the peaks of the experimental diffractogram to them. The result is presented in Figure 8.

The main product is **[$Mg(H_2N)_2CO)(H_2O)_3$] SO_4** as is to be expected at a temperature of 60° C. By variation of the temperature, the pure phases **[$Mg(H_2N)_2CO)(H_2O)_3$] SO_4**and **[$Mg(H_2N)_2CO)(H_2O)_2$] SO_4**can be obtained [32].

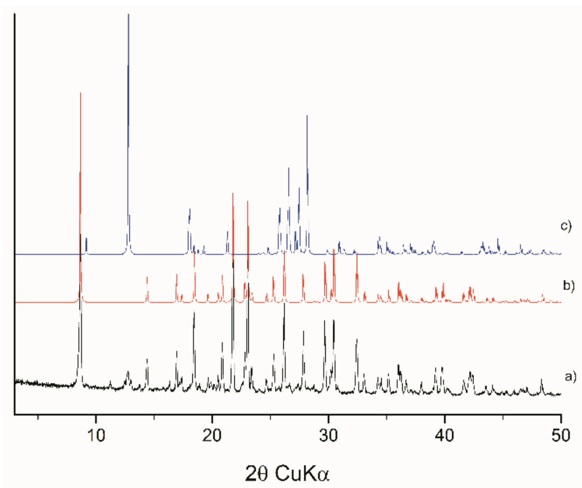

Fig. 8 **PXRD**diffractograms of **$Mg(H_2N)_2CO)(H_2O)x$ SO_4 (X=2;3)**:

a) experiment;

b) calculated **[$Mg(H_2N)_2CO)(H_2O)_3$] SO_4**;

c) calculated **[$Mg(H_2N)_2CO)(H_2O)_2$] SO_4**.

IV. CONCLUSIONS

The main problem in the application of bound nitrogen to soil is the losses associated with the formation of the volatile products and their evaporation into the atmosphere. Methods and developments to reduce these losses are described. A new highly effective method of reducing these losses is the use of urea complexes instead of pure urea. Urea complexes of magnesium sulphate used as fertiliser, in addition to nitrogen, introduce Mg and S into the soil – two bioelements commonly used in the composition of complex fertiliser applications. For this purpose, we are suggesting the use of magnesium sulphate hexaureate hemi hydrate – **$MgSO_4$.6U. $^1/_2$ H_2O**, which has a high urea/inorganic salt ratio in addition to good physicochemical properties. The developed solid-phase synthesis method, has the following advantages: no use of solvents, no side products, low energy consumption. It can be boldly stated that this is an "eco-friendly" process.

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Rationale for the combined cultivator design for cultivating soil littered with plant remains of rough-stemmed crops

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Abstract. **After harvesting corn, an important question is to cultivate the soil and prepare the field for sowing another crop, because after harvesting there are root and leaf residues that need to be destroyed in time and quality, earning them in the soil. Based on the analysis of the state of the field after harvesting corn, an assessment of quantitative and qualitative indicators of surface contamination and distribution of plant residues in rows and between rows was given. This allowed us to draw conclusions about the effective method of tillage contaminated with crop residues of coarse-stemmed crops. Taking into account the biological, physico-mechanical and morphological features of corn residues (fibrousness, elasticity, stiffness), it was concluded that for grinding post-harvest corn residues it is necessary to use active working bodies with L-shaped knives that will cultivate the soil to a depth of 6-8 cm. grind stems and root parts, ensure a sufficient degree of grinding, good wrapping and mixing with the soil. However, the high energy costs of milling the soil make us look for solutions for the strip use of cutters, while ensuring continuous tillage to a given depth. According to the conclusions of these studies, a combined cultivator is proposed, which provides passive cultivation of the row spacing with folding of plant residues that are on the surface in the row zone, milling this area with cutters 20-25 cm wide. This combination will allow to qualitatively prepare the field with grinding of all plant residues with minimization of energy costs and traction performance of the tractor. The proposed design of the cultivator-shredder is protected by a patent of Ukraine.**

Keywords: field littering, leaf and root residues, maize, pre-sowing tillage, combined unit, cultivator-shredder.

I. INTRODUCTION

As a row crop, corn is a good and most common precursor for spring cereals, and when harvested for green fodder and silage - for winter cereals. At the experimental stations, after corn, good harvests of barley, millet, peas, fodder and other crops were obtained. Corn for silage is the main predecessor of winter crops, and in the extreme south of the country, winter crops are also sown after corn for grain and sunflower. Also, many studies do not exclude the possibility of long-term cultivation of corn in one place with the introduction of fertilizers.

However, in-row predecessors are harvested shortly before the optimal time for sowing winter crops, so there is little time left for soil cultivation. In particular, harvesting corn for silage in the phase of milky-wax grain ripeness, when the largest dry matter yield per hectare is formed, and its stems and leaves still contain enough moisture for ensiling the mass, coincides in most regions of Ukraine with the optimal sowing dates of winter wheat. At the same time, the sowing of wheat is often delayed by the harvesting of corn and the subsequent preparation of the soil. In this regard, they switch to earlier harvesting of corn for silage, when the plants contain even more than 80 % of moisture (at the same time, the collection of fodder units in the silage mass is reduced by 42.7...43.3 % of the milk-wax maturity collected at the end).

In order to reduce this negative factor, there is a need to free the field from the previous crop as soon as possible and

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to prepare the soil in a short period of time. However, the situation is complicated by the fact that after harvesting corn, root and leaf stalk residues remain on the field, which must be destroyed in a timely and qualitative manner, having worked them into the soil. This is an important condition for high-quality soil cultivation and preparation of the field for planting another crop.

In agriculture, high-quality cultivation of fields littered with coarse plant residues after harvesting still remains a problem. And there are a lot of such fields in Ukraine, because:

1) crops of rough-stemmed crops, in particular sunflower, increased significantly;

2) recently, corn is grown mainly for grain without shredding the stalks during harvesting;

3) during harvesting of grain crops, tall stubble (more than 20 cm) remains on the field;

4) there were a lot of neglected and abandoned fields, weedy or untimely processed, which are simply impossible to process without shredding the stems [5], [6].

An important role in soil cultivation after harvesting coarse-stemmed crops is played by the quality of shredding and plowing of root and crop residues, which contributes to their rapid decomposition and the entry of organic and mineral substances into the soil. Of course, the problem of clogging the field with coarse crop residues has been known for a long time, but traditional ways of solving and some new ones do not fully provide and give the desired result.

Scientific studies are devoted to soil cultivation problems [7]-[11]. They proposed a mechanized technology, the essence of which consists in multi-track discing in different directions with heavy disc tools. Long-term data of scientific research institutions and production experience indicate that in the Ukrainian steppe zone, after the row-row predecessors, as a rule, shallow soil cultivation of 8-10 cm is more effective. For such cultivation, disk harrows are most often used. In the future, the field is cultivated with simultaneous harrowing for soil development and weed destruction [12], [13]. In the forest-steppe zone of Ukraine, after corn for silage, when there are at least 20 days left before sowing, with sufficient soil moisture practice husking with disc tools to a depth of 5-6 cm followed by plowing to a depth of 20-22 cm with simultaneous rolling. Immediately after that, the soil is cultivated with disk cultivators, ring-spur rollers, and cultivators with harrows [14].

The disadvantage of traditional disk tools when performing soil cultivation is the low efficiency of shredding plant residues in one pass and, as a result, a low degree of mixing them with the soil, which is important in the further use of the field. The remains of plant stems have the ability to resist deformation, so they are not grind to some extent, but crumpled, part of them passes between the disks.

At the current stage of development of agricultural production, the problem of maximum loading of energy-rich high-speed wheeled tractors comes to the fore. It is recommended to use active working bodies to implement unused engine power through the tractor's power take-off shaft. In this way, continuous milling tillage of the soil comes to the fore, which is considered more effective from the point of view of shredding the crop residues and mixing them with the soil [12], [16]. Thus, scientists of the National Research Center "Institute of Mechanization and Electrification of Agriculture" (Ukraine) suggest pre-shredding the surface leaf-stem mass with the drums of a forager [17].

It should be noted that when using such means, the accompanying rotation of the active working body is accompanied by the emergence of a pushing force, the direction of which coincides with the direction of movement of the tractor. Taking into account that active rotary means of mechanization perform a technological process with large energy costs, it is worth while conducting theoretical studies to determine the parameters that ensure the minimum energy consumption of soil cultivation.

Taking into account the indicated shortcomings, for effective use in pre-sowing soil cultivation, combined aggregates were developed. Scientists have proven that the scope of use of combined aggregates in agriculture is determined by both the natural and climatic conditions and the physical and mechanical properties of the cultivated soils. The farming system, agrotechnical requirements for soil and crop processing, and energy equipment are very important components for achieving the desired result.

Scientists claim that in order to obtain the desired result from the use of combined aggregates, the following basic requirements must be observed [6]:

1) the technological process performed by the combined unit must be more energy-efficient than the total energy consumption when it is performed by single-operation machines;

2) the productivity of combined machines should not be lower than a set of replaceable single-operation machines;

3) good adaptation to work in adverse weather and soil conditions;

4) assistance in increasing the yield of crops, preservation of soil fertility, provision of a reliable working system-new technologies, etc.

Original solutions in combining active and passive working bodies are offered, in particular, by Schulte, Bomford, Kuhn, Lemken and others, producing shredders of plant residues in a wide range of standard sizes. In these technical means, two types of shredding bodies are used - with a vertical and horizontal axis of rotation of the rotor, on which the knives are installed.

In addition to the traditional method, the search for more rational ways of solving the tasks of freeing the field from plant residues is underway. Among the developments, the combined machine of the Southern Department of UNDIMESG, which includes active and passive working bodies, is well-known. The main working body is a milling drum with a two-tiered arrangement of knives. The milling drum consists of a shaft on which disks are mounted, to which L-shaped knives are attached. Milling working bodies grind the post-harvest residues and soil to a depth of 1-2 cm - the first layer and 6-7 cm - the second. Then the flat-cutting paws move, which grind the layer in the third tier to a depth of 12-14 cm. The needle harrow, which moves behind, additionally loosens the soil, levels the surface and compacts the upper layer [16], [18].

The most common options for soil preparation technologies after harvesting rough-stemmed crops are presented in Table 1.

TABLE 1 THE MOST COMMON TECHNOLOGIES FOR PROCESSING THE FIELD SURFACE AFTER HARVESTING ROUGH-STEMMED CROPS IN UKRAINE

Sufficient moisture (classic technology)	**Insufficient hydration (South of Ukraine)**	**Low clogging with crop residues**	**High clogging with coarse harvest residues**	**Processing with combined units**
1.Disc tillage in two tracks skim plow with disc working bodies	1.Disking. Disc harrows with disc working bodies	1.Cultivation ^^^^^ ^^^^^^ Cultivator of continuous cultivation with arrow legss	1. Milling Milling cultivator with active working bodies	1. Combined cultivation ^^^^^ or ^^^^^ ^^^^^^ Combination machine
2. Plowing or shallow cultivation				
3. Pre-sowing treatment I. To a depth of 8...10 cm. II. To the depth of seed wrapping				
4. Sowing				

There is no single, rational, recommended mechanized technology for shredding leaf-stem and root mass before soil cultivation in Ukraine. Therefore, there is an acute production problem that needs a scientific and applied solution.

In solving this problem, we see a classic scheme, namely:

- study of the object of processing;
- analysis of existing machines that are used for similar types of work;
- development of a special design of the shredder.

Purpose and scope of work

The purpose of this publication is to select the optimal cost-effective unit for tilling the field after harvesting rough-stemmed crops in one pass.

The primary task for the realization of this goal is to conduct scientific research on the study of the object of cultivation - a field littered with leaf, stem and root residues as elements that need to be grind and plowed. The list of issues under study includes: systematization of residues by size; mutual arrangement on the area and in depth; determination of size characteristics.

The obtained results will be the basis for further engineering decisions regarding the development of machine designs, the selection of a technological scheme, and the determination of technological parameters, which will allow us to offer our vision of the construction of a plant residue shredder.

II. MATERIALS AND METHODS

The study of the issue of field clogging after harvesting corn and the direct development of the design of the cultivator-shredder of plant residues was carried out as part of the scientific work of the educational and scientific laboratory "DAK GPS" of the Higher Education Institution "Podilskyi State University" [19]-[23].

The first stage of the study is to determine the quantitative and qualitative characteristics of the field after harvesting the corn. Field research was conducted on the experimental fields of the University after harvesting corn for silage.

Analysis of the quantitative characteristics of the field after harvesting corn was carried out by direct counting and measurement of the remaining plant remains.

The field was divided into plots 2 m long and two rows wide (1.4 m). The scheme of dividing the field into diagonal sections was used (Fig. 1).

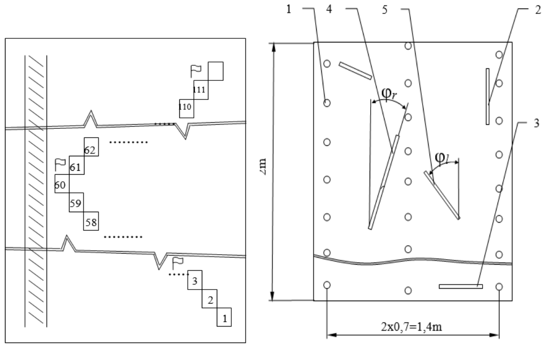

Fig. 1. Division of the field into measurement sites and placement of plant remains on the site: 62 - research sites; - a section of the field where corn was not cut; - sites on which research of rhizomes and above-ground parts was carried out; 1. basal lobes, 2 – longitudinal stems, 3 – transverse stems, 4 – stems deflected to the right, 5 stems deflected to the left, φ – deflection angl

On the site, the number of stems placed along the rows, across, at an angle to the left and right is counted; length of longitudinal (as well as deviated up to 40°) and transverse (50-80°) stems; diameter of plant residues on the site.

The planning of experiments and processing of the obtained results was carried out according to the existing methods of field and engineering experiments [10], [17].

The variability of the measurements of the object under investigation is determined by variation series and variation curves.

In order to construct a variation series or curve, the selected parameter is measured (at least 100 measurements) and the obtained measurements are divided into classes. For this it is necessary:

1. Find the smallest and largest measurement X_{max}, X_{min} ;

2. Find the number of intervals (classes) K:

a) you can use the formula

$$K = 3.2 \cdot \lg n , \quad (1)$$

where n is the number of measurements.

b) Divide into intervals, setting the step Δ

$$K = \frac{X_{\max} - X_{\min}}{\Delta} \tag{2}$$

3. The lower limit of the 1st class

$$X_1^{low} \le X_{\min} \tag{3}$$

upper limit of the 1st class

$$X_1^{up} = X_1 + \Delta \tag{4}$$

Other classes are calculated in the same way.

4. Count the frequency m - the number of measurements in each class. It is evaluated in absolute numbers, as well as percentages.

5. Determine the middle of the intervals

$$X_{ic} = \frac{X_i^{н} + X_i^{в}}{2} \tag{5}$$

Based on the data of the variation series, variation curves are constructed, which are a graph, on the abscissa axis of which the measured values that correspond to the average value of the class boundary are plotted, and on the ordinate axis - the frequency (m or p, %) of measurements within each class.

Variational series and curves can be compared by the arithmetic mean value of M_c and the root mean square deviation σ (dispersion of measurements).

$$M_c = \frac{\sum m_i * x_{ic}}{\sum m_s}, \tag{6}$$

$$\sigma = \sqrt{\frac{\sum (M_c - X_{ci})^2 * m_i}{\sum m_i}}, \tag{7}$$

Size changes in most cases are subject to the law of normal distribution. It is known from the probability theory that with a normal distribution of dimensional characteristics, 99.7% of the amount of material is laid within the limits.

Processing experimental data according to this method, we obtain a number of variation curves, which are used to calculate the above parameters.

III. Results and Discussion

A. Analysis of the state of the field surface after harvesting coarse-stemmed crops

The obtained data are processed by grouping by quantitative indicators and the corresponding calculations, based on which variation series and variation curves are constructed as shown in Figure 2. In order to construct a variation series or curve, the selected parameter is measured (at least 100 measurements) and the obtained measurements are distributed by classes. Based on the data of variation series, variation curves are constructed, which are a graph, on the abscissa axis of which the measured values corresponding to the average value of the class boundary are plotted, and on the ordinate axis - the frequency (m or p, %) of measurements within each class.

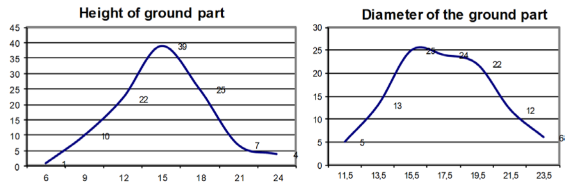

Fig. 2. Sample variation curves

Variational series and curves can be compared by the arithmetic mean value of M_c and the root mean square deviation (dispersion of measurements). As the results showed, size changes in most cases are subject to the law of normal distribution.

Having these data, it is possible to carry out a detailed analysis, the purpose of which is to form the main characteristics of the machine for solving the tasks. The following conclusions can be drawn based on the results of measurements carried out in separate areas for the study of basal remains:

- dispersion, or the root mean square deviation of all measurements is quite significant, that is, a fluctuation of the parameters (within $M_c \pm 3 * \sigma$) is not excluded;
- the arithmetic average deviation of the height of the rhizome and the range of heights indicate that for processing the root system, taking into account the degree of shredding, it is enough to deepen the working body by 8...9 cm;
- the main part of rhizome diameter measurements lies within 12.5...18.5 cm; therefore, the required width of row processing is at least 20 cm;
- the diameter of the ground part varies widely: the main part measures 15...20 cm and reaches a maximum of 24 cm. This must be taken into account when choosing the method of shredding and the working body;
- the average value of the height of the ground part (cut height) is 15.2 cm, which meets the agrotechnical requirements for harvesting corn.

Analysis of the quantitative characteristics of the field surface by measurements in the rows showed:

- After harvesting corn, there remains a fairly significant amount of plant remains on the field, and the values of various parameters vary within fairly wide limits.
- The analysis of the total amount of plant remains shows that only 16.2 % of the plots (with an area of 2.8 m^2) are clean, that is, they do not have plant remains in the rows. The average number of them is 3.2, although in some areas their number reaches 10 or more.
- Whole stems must also be taken into account when choosing a method of freeing the field from plant residues, as they make up about 25% of the total amount of plant residues in the rows;

- The analysis of the location of the plant remains indicates that most (47 %) of the stems are located longitudinally (±10˚), while transverse ones occupy only up to 25 %.

B. Development of the construction of a combined cultivator-shredder of plant residues

Taking into account the results of the study of the condition of the surface of the field, it can be concluded that one of the rational solutions to the problem of freeing the field from plant residues without increasing energy costs for continuous milling of the surface is the use of strip milling (Fig. 3).

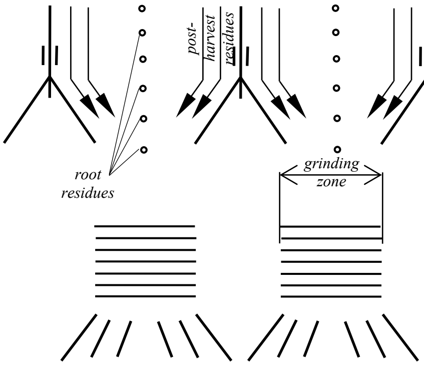

Fig. 3. Scheme of the work process

Therefore, the basis of the development is the task of qualitatively and economically preparing the field for sowing; ensure high-quality shredding and wrapping of plant remains of rough-stemmed crops with efficient use of energy spent on the drive of milling drums, and thereby achieve the possibility of increasing the width of the aggregate and its productivity; leave the field surface leveled and clean of plant remains.

The task is achieved by the fact that in the cultivator - shredder, which contains a frame - a beam, on which milling sections, hillers and flat disk knives are mounted, active working bodies are placed only in certain areas - in the shredding zones (along the sowing row). Shredding of residues along the entire front of the grip width is achieved with the help of hillers, which direct the stems and other plant residues left in the rows into the shredding zone. Flat disc knives are installed in order to prevent clogging of the hillers.

Due to the fact that shredding takes place only in the zone of the row, the energy for milling is used effectively (it is not used for soil cultivation in the rows). The leveling of the field surface is achieved by directing the soil with milling sections to different sides with the help of the guide ribs of the distribution board.

Cultivator - shredder of plant residues is shown in Fig. 4a – side view, during field cultivation after harvesting rough-stemmed crops; Fig. 4b - top view, location of working bodies.

Cultivator - shredder includes frame 2, on which milling sections 5, hillers 3 and flat disc knives are located.

Milling sections 5 include a chain transmission 4, a milling drum with L-shaped knives 6, a casing with a dividing shield 7. The shield 7 is made trapezoidal with guide ribs. Hillers 3 are spreading legs with guide wings, which are located in front of the milling sections in the rows. Flat disk knives 1 are placed along the axis of movement of the hillers. They rotate freely on the axles when rolling across the field.

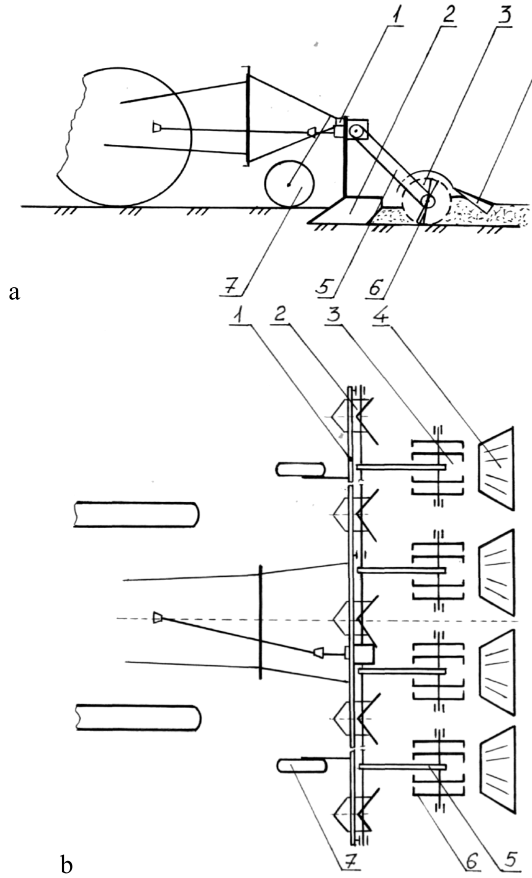

Fig. 4. Milling shredder of root and leaf-stem residues: a-side view; b-view from above.

The cultivator - shredder of plant residues works in this way. When moving the machine along the rows of the field after harvesting coarse-stemmed crops, the hillers 3 move between the rows, loosening the soil and transporting the stalks and other plant remains left after harvesting to the shredding zone (up to the row), where they are grind by the knives 6 of the milling sections 5 and mixed with soil. A flat disc knife 1, which cuts long stems, prevents the hillers from clogging with plant remains. Thanks to this, plant remains fall only on the side walls of the guide “wings” of the hillers, which are used to move freely. The milling drum works in the shredding zone. Soil and plant residues thrown by the knives hit the casing of the milling section and with the help of the guide ribs of the shield 7 are distributed along the front of the unit's movement, leveling the field surface.

This design was developed and tested at the higher education institution "Podilskyi State University", and its design and method of field preparation are protected by patents of Ukraine u200803382.

IV. Conclusions

1. The presence of a large amount of plant residues both in the row and between the rows greatly complicates soil cultivation and worsens the further use of the field, which requires operations to free the field from coarse harvest residues, in addition, taking into account the fibrous

structure of corn stalks, it can be concluded , that for shredding the post-harvest remains of corn, it is necessary to use working bodies that would cut (and not tear) the stalks, ensure a sufficient degree of shredding, good wrapping and mixing with the soil. Milling working bodies are best suited for this.

2. The arithmetic mean deviation of the root height and the range of heights indicate that for processing the root system, taking into account the degree of shredding, it is enough to deepen the working body by 8...9 cm, i.e., to such a depth, it is necessary to carry out processing with active working bodies in the rows.

3. The main part of rhizome diameter measurements lies within 12.5...18.5 cm; therefore, the required width of row processing is at least 20 cm.

4. The location of the vast majority of plant remains along the row indicates that it is best to use L-shaped knives that chop the stem across or at an angle to the longitudinal axis of the stem.

5. The design of the machine is proposed, which combines active (milling) working bodies (in the row zone) for effective shredding of plant residues and passive ones (paws equipped with hillers) designed to loosen the soil in the inter-row area and send the residues to the row zone for shredding. The use of cutters only in the shredding zone allows you to significantly increase the width of the grip, and therefore the productivity of the unit, while achieving the required quality of shredding.

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Reorganization business management model for increasing the competitiveness of Real estate management companies in Latvia through Merger and Acquisition transactions

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Abstract. **Research background: Globalization, the impact of geopolitical conditions, the rapid rise of inflation, and the rapidly changing conditions intensifies competition between companies, which influence companies think about expanding their services. Economic survival forces companies to think about reorganizations through mergers and acquisitions. Companies consider mergers and acquisitions as a strategy for product market expansion to improve competitive advantage, however, achieving the expected success through mergers and acquisitions poses serious challenges to company management and does not provide the expected value from these transactions. Acquisitions and mergers without reorganization business management model may not deliver the expected benefits.**
Purpose of the article: to present a reorganisation business model to enable Latvian Real estate service companies to implement the product market expansion strategy through acquisitions and mergers and reorganisation processes.
Methods: A monographic and descriptive method was used to analyse the theoretical aspects of company strategies, secondary data analysis and expert interview were used to describe the situation of real estate management service industry, but quantitative research method such as analysing of statistical data of the apartment maintenance companies, in connection with the comparative, analytical, deductive, logical approach method was used in this research.
Findings & Value added: Real estate management companies in Latvia face the conditions created due to the influence of globalization and geopolitical conditions - market limitations to expand. Companies, their managers have not enough knowledge of reorganization process, and many other factors about properly conducted reorganization transactions, incl. about acquisitions, due diligence, transaction progress, therefore companies need a reorganization business management model suitable for reorganization transactions

Keywords: mergers and acquisitions, product market expansion strategy, Latvian real estate service companies, reorganization business management model.

I. INTRODUCTION

The expansion of the range of services is relevant in every business and in every industry, and the companies are constantly forced to adapt to changing business, and their economic and strategical conditions.

Real estate management companies in Latvia face the conditions created due to the influence of globalization and geopolitical conditions - market limitations to expand, so the development of these companies is not possible without a product market expansion strategy, which can be implemented through reorganization transactions.

The purpose of this research is to present a reorganisation business model to enable Latvian Real estate service companies to implement the product market expansion strategy through acquisitions and mergers and reorganisation processes.

Initially a review of competitiveness of companies will be presented in line in the context of the reorganization process. This topic has been dealt with by a number of authors in the competitiveness of companies, such as Michael Porter [28], [29] who created the foundations of modern competition theory and the concept of competitiveness, so much so that today the volume of literature and researches about competitiveness is continuing to grow [6], [31]. This paper seeks to retrieve the importance of reorganization for companies in order to better adapt to competition changes [11], [12], but study

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shows achieving product-based competitive advantage is a key task for a company [8].

Despite those worldwide studies [4], [5], [13], [15], [16], [36] show that approximately 80% of transactions do not meet expectations, acquisitions and mergers are complicated transaction projects, therefore mismanaged they may not deliver the expected benefits [1], [3], [20-22], [26].

Before describing reorganization model based on several findings [3], [20], [22], [24], [26], [30], [34] the authors present research findings on product market expansion strategy, based on H. Igor Ansoff [27] as a less risky strategy [33], [37] for real estate service provider companies.

In addition to the basic characteristics of the reorganisation model, the description of Latvian real estate service companies will be presented in scope of their need to carry out reorganisation as product expansion strategy, based on an expert interview. As will be seen, the reorganisation model presented, is based on the complete 10 criteria, from which some as most essential are - company strategy, reorganisation leader, appropriate and professional team, plan for the implementation of the reorganisation and product market expansion strategy, performing of reorganisation transaction and integration or restructuring of acquired company, according to the literature reviewed.

II. Methods

The purpose of this research is to present a reorganisation business model to enable Latvian Real estate service companies to implement the product market expansion strategy through acquisitions and mergers and reorganisation processes.

To achieve the goal of the research, three tasks were set:

a) to analyse the theoretical basis of competitiveness and of companies in the context of the reorganization process;

b) to describe the companies operating in the industry of real estate management services in Latvia;

c) to develop reorganization business management model for real estate management companies in Latvia suitable for reorganization transactions.

The research question: How reorganization business management model created for real estate management companies in Latvia can help to carry out reorganization transactions?

The results of the application the monographic and descriptive method were used to analyse the theoretical aspects of merger and aquation transactions and company strategies, secondary data analysis and expert interview were used to describe the Real estate management service industry.

An expert interview was created as a semi-structured interview. In expert interview authors used following questions and themes for discussion like:

a) what are the main problems from experience for possibilities of increasing the competitiveness of real estate management companies in Latvia?

b) which factors influence Real estate management service companies of the Republic of Latvia to carry out reorganization transactions and restructuring of the company?

c) Do Real estate management companies in Latvia need reorganization business management model for reorganization transactions?

III. Results and Discussion

A. Characteristics of increasing the competitiveness of companies in the context of the reorganization process

Michael Porter [28] created the foundations of modern competition theory and the concept of competitiveness - the prosperity of a country depends on its competitiveness, which is based on the productivity with which it produces goods and services.

In [29] it is stated that in today's hyper-competition conditions, it is critical for companies to understand the dynamic of external conditions and their impact on the possibilities of increasing competitiveness. Fierce competitive conditions can lead companies to liquidation, so company managers must guide companies to improve efficiency and financial performance [6].

Several authors [11], [12] point out that companies need to implement reorganization in order to better adapt to changes. Companies implementing reorganization should take into account that the necessary financial resources must be foreseen [11].

The business strategy of reorganization, mergers and acquisitions can be an opportunity for companies to increase their competitive advantages, improve their position in relation to customers and suppliers [24].

Achieving a product-based competitive advantage is the main task of any company [8] and in today's hyper-competitive environment, it is very important for companies to understand the dynamics of the environment and its role in creating competitive advantages [30]. By implementing the product market expansion strategy, it allows the company to achieve competitive advantage [8].

Companies do not operate in isolation and constantly compete with other firms to increase profits in the battle for customers and market share [23]. Fierce competition conditions increase the probability of a company's bankruptcy and liquidation, but to prevent the company from going out of business, competition encourages company managers to improve the company's efficiency and financial performance [6].

B. Characteristics of the Product market expansion strategy

Several authors [19], [34] have recognized that no core business is eternal, or that every product has its own life cycle.

COVID-19 pandemic, increasing of energy prices, supply chain disruptions, financial crisis pose a threat to business continuity, therefore companies are facing pressures for their very survival [9], and resilience does not just relate to the ability of a system to “bounce back” after an impeding event, but also to the capacity to adapt and transform [38].

The influence of increasing competition, customer complexity, and market turbulence is creating a latent hazard for the sustainability of established buyer–seller relationships [7] and the same the latter factors influence relationship between service provider and customer in service businesses and product market competition can have dramatic and far-reaching consequences for individual firms [14].

In [36] is indicated that strategy is the core of corporate competitiveness. By choosing product development strategy, offering new products and services to existing customers, this is less risky strategy, and corresponds to the needs of customers [33], [37] and according to [18] service synergies in relation to related services, the goal of related services is generating economic savings.

The mathematician and business manager H. Igor Ansoff has created Product market matrix, which was published in the Harvard Business Review in 1957 [29]. The Matrix is used to evaluate the level of risk of growth strategies for existing products and markets comparing with new products and markets [28], and is presented in Table 1.

TABLE. 1 ANSOF'S PRODUCT MARKET EXPANSION MODEL [28], created by authors)

Markets	Products: Existing	Products: New
Existing	*Market penetration* 1	*Product development* 3
New	*Market Development* 2	*Diversification* 4

Increasing risk

*= Relative risk 1=LOW 4=HIGH

As visible in Table 1, there are several product and market expansion strategies at both the market and product levels, depending on whether the market and product are new or existing.

Those companies whose strategy is based on offering one type of product or service can achieve an increase in market share, but up to a certain limit, because the market is as big as it is. At this stage, the company's strategy should be based on either:

a) market expansion, or

b) expanding the range of services.

The service companies` strategy would be the most suitable product development strategy, offering new products and services to existing customers, which is less risky, and which also corresponds to the needs of customers, because the customers to whom cleaning companies already provides cleaning services for premises, all have different types of facilities, all of which require engineering communications management services.

C. The Real estate maintenance service industry of Latvia

Real estate management services in Latvia are offered by several types of merchants:

a) Providers of housing management services, for which the management of apartment buildings is the main type of business;

b) Premises and territory cleaning service providers who have expanded their range of services with real estate - apartment building management service;

c) Real estate brokerage service providers who have expanded their range of services with apartment building management services;

d) Real estate developer companies that build multi-apartment houses of the new project and continue to manage and manage these houses.

The real estate management service industry in Latvia is wide and due local market specifics, due strong competition between companies, due small market, companies not specify to only one service, but provides similar, familiar services, to achieve higher competitiveness.

The product market expansion strategy in the service industry is important because customers want to use and use a variety of similar, synergistic services, such as commercial building management, premises and territory cleaning, engineering crew, therefore the company that can offer a full range of services will have greater advantages to expand its market share [37].

D. Reorganization business management model for increasing the competitiveness of Real estate management companies in Latvia through reorganization transactions

Acquisitions and mergers are complicated, mismanaged they may not deliver the expected benefits. Several authors [1-5], [10], [13], [15], [17], [20], [22], [25], [27], [32], [35] indicates that a large number of reorganization deals fail and companies do not expect the expected benefits, while a McKinsey study shows that 80% of reorganizations fail and about 10% cause serious damage to the company [4], [5], [10], [13], [15], [35].

It would be important for companies, their managers and leading employees to first understand the process of reorganization transactions, the course of its implementation, which could help to avoid failures, as well as the planning of the reorganization process should be done correctly, starting with the development of the reorganization strategy and its implementation plan.

After the reorganization, managers begin to deal with the burning problems that need to be solved urgently, but in solving the burning problems, the managers miss several opportunities for business development. One of the biggest success factors is to create a future company`s strategy - where the company wants to go in the future and not just focus on the problems of the past [31].

In [35] it is recommended to use the following approach when implementing the reorganization process:

Before the reorganization, the 3 S principle, denoted as: Strategy, Structure, Selection. In the course of the reorganization, the 3 C principle, denoted as: Communication, Compassion, Clarity. After the reorganization, the 2 T principle, denoted as: Transfer, Transition.

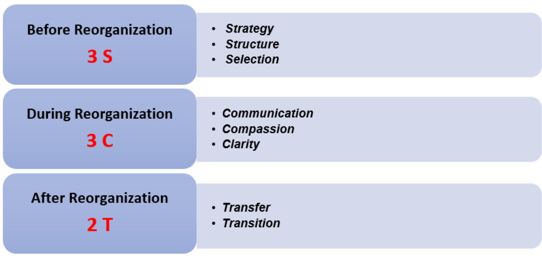

Fig.1. Principles for implementing reorganization (from [34] created by authors)

As visible in Figure 1, reorganization, as well as acquisition and merger transactions, should be seen as a big project with a holistic approach, which includes the beginning, implementation and completion of the project, or the post-reorganization stage.

Authors chose the expert interview as a method for the research to evaluate the real estate service companies' industry, to find out industry essential main problems and to understand companies' possibilities to expand their business and necessity to expand their services. As expert was chosen a professional expert in the field of real estate management service industry, who has worked for several years in the largest building management companies in Latvia. During the interview authors tried to find answers to following questions:

a) what are the main problems from experience for possibilities of increasing the competitiveness of real estate management companies in Latvia?

b) which factors influence Real estate management service companies of the Republic of Latvia to carry out reorganization transactions and restructuring of the company?

c) Do Real estate management companies in Latvia need reorganization business management model for reorganization stage?

An expert interview shows following results:

The real estate maintenance service industry is complicated, the Latvia market is narrow for expansion with existing products, there are several options for such companies – to carry out product expansion strategy and to start offer new services, such like engineering communication services, cleaning of commercial premises, maintenance of commercial premises, or to buy another company which already has experience in those similar services, which will be more effective as to start new business types from beginning. As market in Latvia is small, the companies compete with each other and reorganization transactions are as one of possibility to expand their business.

In recent years in Latvia, three of the largest merger transactions in the sector of real estate management companies, are as follows, visible in Table 2:

TABLE 2. ACQUITION AND MERGER IN REAL ESTATE MAINTENANCE COMPANIES' SECTOR IN LATVIA (2022-2024) [25] created by authors

No.	Transaction, involved companies	Year	Kind of Product market expansion strategy
1	Buyer: Civinity group companies: SIA Civinity Mājas and SIA Civinity Mājas Jūrmala Seller: SIA LABO NAMU AĢENTŪRA SIA VBS serviss. SIA Home master	2022	*1) Expansion of services, by acquiring real estate management service companies* *2) Expansion of services, by acquiring engeneering service companies*
2	Buyer: SIA HAGBERG Seller: SIA TERMEX (engineering services)	2023	*1) Expansion of services, by acquiring engineering service companies*
3	Buyer: SIA City Service Sellers: SIA NĪA NAMI, SIA Nebruk Jelgava and SIA Jauntukums	2024	*1) Expansion of services, by acquiring real estate management service companies*

Based on the findings obtained during the research, the findings obtained during the expert interview, the studies of theoretical aspects, the authors develop business management model for reorganization, which is visible in Figure 2.

The reorganization business management model developed by the author within the product market expansion strategy is based on the following 10 main criteria:

1. Develop a company strategy. In the strategy, define what product market expansion strategy needs to be implemented. By what means will the product market expansion strategy be implemented:

a. The company itself will build the expansion of existing products, offering synergistic services to customers

b. The company will acquire an existing business to implement its product market expansion strategy

2. Finances. Does the company have the available funds to acquire an existing business to implement a product market expansion strategy?

3. Choose a potential acquisition company. If it is possible for the company to implement the product market expansion strategy through an acquisition transaction, search the market itself or instruct investment agencies to search for or approach potential acquisition companies.

4. Get to know the acquisition company and conduct its in-depth research.

5. Create a team. In order to successfully implement a reorganization and an acquisition or merger transaction, it is necessary to select a team that will work on the implementation of the reorganization and the implementation of the product market expansion strategy according to the plan.

6. Carefully develop a plan for the implementation of the product market expansion strategy and prepare the implementation plan of the product market expansion strategy in detail according to the principle:

a) Involve competent specialists

b) Define all necessary actions to implement the plan

c) Set deadlines for each task of the plan

d) Appoint those responsible for the implementation of the plan

7. Thoroughly familiarize yourself with the industry in which the acquiring company operates and identify all the nuances that should be known before implementing the transaction.

8. Get to know the essence of the business to be acquired.

9. To implement the purchase transaction.

10. Integrate or restructure the acquired company.

The most common mistakes and failures occur precisely because of this factor. Consultants believe that they have successfully completed their work with the completion of the closing phase of the transaction because the transaction has been implemented, but the acquiring company faces a reality after the acquisition is completed.

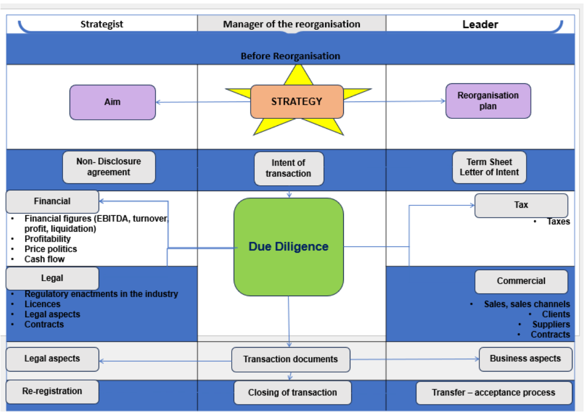

Fig.2. Reorganization business management model (created by authors)

As visible in Figure 2, the reorganization business model provide that there should be one main manager - the manager of the reorganization transaction or project, who must have strategic thinking and leadership abilities.

The reorganization business management model was approved in building management companies, of which: 1 company operates in Riga and Riga district, and 2 regional companies operating in regional cities.

The reorganization business management model provided for the improvement of the profitability of house management services, as well as the improvement of the content and quality of the provided house management service.

In order to organize the profitability of house management companies, within the framework of the reorganization business management model, many important measures were taken, the most important of which are:

- A new debtor control and debt collection policy was developed;
- A schedule of object surveys and a plan for its implementation were created;
- A technical department was established, which was responsible for the unified accounting of technical works, repair works, implementation of works and selection of technical personnel;
- A unified customer call center, register of complaints and submissions and quality control were introduced;
- A new accounting IT program was introduced and a new financial accounting system was created;
- Service pricing was identified - how much each service costs, whether the service fee corresponds to real expenses and whether the services are profitable;
- A decision was made to raise the price of the service to customers in order to stop the company from operating at a loss, and due this decision – companies financial results improved in possitive level.

Post-reorganization business model should be the future research thesis.

IV. Conclusions

1. Reorganization transactions are serious transactions that are time-consuming and also require financial resources to be allocated to it, however, worldwide studies [4], [5], [10], [13], [15], [35] show that approximately 80% of transactions do not meet expectations.
2. The results of the research, within the framework of the information obtained during the expert's interview, show that the internal, disorganized management problems of companies can prevent managers from successfully implementing reorganization and company restructuring plans.
3. To recommend the owners and managers of real estate management companies to use the product market expansion strategy and the reorganization management model to increase the competitiveness of the companies.

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Professor, leading researcher Dr.habil.geol. Gotfrīds Noviks
(15/09/1935 – 07/03/2024)

Professor Gotfrīds Noviks worked at Rezekne Academy of Technologies (RTA) since the establishment of the education institution. A lot of work was devoted to further development of the Academy. Professor Noviks was the scientist: habilitated doctor of geology, vice-rector of the Science and Studies Department, head of the Department of Natural and Engineering Sciences, creator of environmental engineering study programs and program director at the bachelor's, master's and doctoral levels. He prepared more than 320 scientific publications, obtained 25 authorship certificates, participated in more than 100 scientific conferences, led scientific projects and research groups. Professor was the initiator of the scientific conference "Environment. Technology. Resources" where the scientists and researchers from foreign countries and Latvia have been participating for many years. Professor's pedagogical experience lasted for almost 60 years. He was also the author of many textbooks which are still used in many countries of the world. Professor Noviks was the founder of rock physics, the author of the first textbook "Fundamentals of Rock Physics" which was the first one in this field in the former Soviet Union. He was the member of the International Water Federation (WEF) from 1995, the member of the ecological committee and ecological education committee from 1996, the member of the New York Academy of Sciences.

Gotfrīds Noviks was born in Ludza, graduated from Viļani Secondary School, later from Leningrad Institute of Mining, where he studied geology. In the scientific field, he worked at the Moscow Mining Institute in Russia, then at the Kabul Polytechnic Institute in Afghanistan for a short period. Afterwards he decided to return to Latvia, responding to an invitation to work in Rezekne. In 1994, Professor Noviks started to work at Rezekne Higher Education Institute (now Rezekne Academy of Technologies).

He worked at the Rezekne Academy of Technologies, led the scientific work, as well as enjoyed the hobbies that brought a lot of joy and inspiration for him. Gotfrīds Noviks once admitted that his hobby was kayak trips on rivers. His idea of ecological expeditions for 1st-year students of the environmental engineering still lives on. The first expedition was organized in 1997. Professor told that he liked reading books, cooking; he was interested in photography, enjoyed the nature with forests, rivers, and mountains as well.