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Zinātnisko rakstu krājumā iekļauti VIII starptautiskās zinātniski praktiskās konferences "Vide. Tehnoloģija. Resursi" raksti.
Rakstu tematika saistīta ar vides kvalitāti, tās kontroli un nodrošināšanu, piesārņojuma novēršanas tehnoloģijām, tīrāku ražošanu, ilgtspējīgo lauksaimniecību, dabas resursiem, degradēto teritoriju atjaunošanu, vides izglītību un ilgtspējīgo attīstību. Tiek pētītas atjaunojamās enerģētikas problēmas. Rakstu krājumā pārstāvēti referāti, kas ir saistīti ar datorzinātnes, matemātikas, mehānikas un mehatronikas pielietošanu vides zinātnes un citu nozaru problēmu risināšanā.
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COMPUTER SCIENCE

BRAIN CANCER ANTIBODY DISPLAY CLASSIFICATION

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Abstract. *This article explores real data on brain cancer. This type of biological data has a few particularities like a great number of attributes – antibodies and genes. However the number of entries is rather small because the data have to be obtained from real patients. This process is time consuming and very costly. Due to that, this research provides detailed data description as well as analyzes their particularities, type and structure. Correspondingly, classification rules are also difficult to discover. This research is dedicated to finding applications of classification methods aimed at determining interconnections that could be used to classify brain cancer. Working exactly with such unique data has a great practical value, because the data obtained can be used in future to continue the research and in practical diagnostics with the possibility to offer the data to biologists for interpretation. To speed up the obtaining of interconnections, only important attributes were used. Various methods of interconnection determination were employed. Conclusions about this type of data analysis, obtaining classification rules and the precision of obtained rules are made and directions of future work are outlined.*

Keywords: *antibody display, classification, data mining, IF- THEN rules.*

Introduction

In the last few years the rapid development of computer systems has enabled performing even more complicated computing actions; thus data obtaining algorithms that can identify and classify various diseases have become very popular. One of the first works in this sphere is Golub et al. [1] research that is a basis for many other researches [2-4]. Different methods and the most popular gene expression data set description can be found in [5].

In the present work, the analyzed data are antibodies which are created as a response to some infectious disease microorganism, vaccine or another anti-gene and which react specifically to this particular anti-gene [6]. As a result, by creating antibodies, conclusions can be made whether a patient has been infected with particular disease. Such real data analysis and obtaining of important interconnections in classification is also done by biologists themselves [7], however the methods they are using differ a little from the methods used in the process of collecting and analyzing data.

Two methods of obtaining fuzzy rules were used in this paper - FURIA (An Algorithm For Fuzzy Rule Induction) and FLR (Fuzzy Lattice Reasoning) classifiers. The FURIA algorithm was proposed in 2009 by Hühn and Hüllermeier [8]. FURIA is a RIPPER algorithm modification, preserving all RIPPER [9] algorithm advantages, for example, a simple and well understood set of laws. In addition, it includes a number of modifications and extensions. FURIA obtains fuzzy rules instead of the usual strict rules, as well as an unordered rule set instead of the rule list. In addition, to address the problem of uncovered samples it uses an efficient method for stretching the rules. Combined with a sophisticated law induction method provided by the original RIPPER algorithm these improvements have led to a better rule induction algorithm for classification, which requires only a small increase in classification time. Authors have made extensive experiments that show that FURIA outperforms the original RIPPER algorithm, as well as other methods of obtaining fuzzy rules.

The FLR classifier was proposed in 2007 by Kaburlasos, Athanasiadis and Mitkas [10]. The FLR classifier is designed to obtain descriptive, decision-making knowledge (rules) in a mathematical lattice data. Training takes place both gradually and rapidly, calculating the disjunctions of interval conjunctions. In this article, the authors study the problem of ozone

concentration from both meteorological and air pollutant measurements. The FLR classifier induces rules from training examples, allowing a rise in the size of the diagonal of the rule to a maximum threshold. FLR is the Leader-Follower classifier, which learns quickly at a time, using the results of training. Data input order is vital. The total number of rules is not known a priori, but it is usually determined during the training period [10].
The first section of the paper describes the methods used and general principles underlying their work. The set of data used in the experiments is specified and compared to other publicly available databases. The second section discusses the experiments performed and their results. In conclusion, some observations about particular data set and directions of future research are provided.

Materials and methods

In the course of this study, experiments with real data of cancer research antibodies were performed. A short review of the data set is given in Table 1. Clearly biological data specifics can be seen – a great number of attributes and a rather small count of entries. There are also problems with data domination, which is a topical problem, because such biological data experiments are relatively expensive and complicated to perform. Important factor in cancer classification is the stage of the disease – the later the stage, the clearer it is to classify. However, in this research the stage has not been considered, as not all of the entries have this data provided. That is why 1229 attributes (genes) are used in experiments.

Table 1.

Brain cancer data set description

Number of attributes (genes)	1230	
Number of classes	2	Brain cancer (BrCa)
		Healthy donor (HD)
Number of instances	168	BrCa – 13
		HD – 155

The data set in the space of the two most important attributes determined (where 329 and 501 are two most relevant attributes) in the experiment is displayed in Fig. 1.

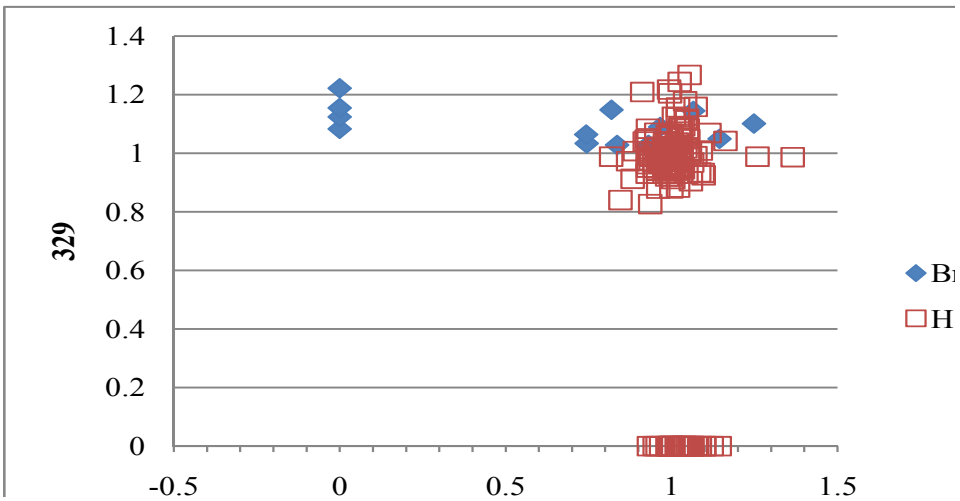

Fig. 1. **Brain cancer data set relevant attributes**

Let us describe the methods used in the experiments in more detail. Since six different methods were used in the classification and the first four of them - Ridor [11], PART[12], OneR [13] and JRIP (a version of RIPPER algorithm [15] that was created especially for

WEKA) are rigorous training methods in Weka and only the last two - FLR and FURIA are based on fuzzy rules, they also will be given extra attention.

Let us describe the FURIA algorithm. The representation of rules is as follows. A fuzzy selector $A_i \in I_i^F$ covers an instance $x = (x_1 ... x_n)$ to the degree $I_i^F(x_i)$. A fuzzy rule r^F involving k selectors $(A_i \in I_i^F), i = 1,...k,$ covers x to the degree [8]:

$$\mu_{r^F}(x) = \prod_{i=1...k} I_i^F(x_i). \quad (1)$$

Rule fuzzification. For the fuzzification of a ($A_i \in I_i$) it is important to consider only the relevant training data D_T^i, i.e., to ignore those instances that are excluded by any other antecedent [8]:

$$D_T^i = \left\{ x = (x_1 ... x_n) \in D_T \mid I_j^F(x_j) > 0 \, for \, all \; j \neq i \right\} \subseteq D_T \quad (2)$$

D_T^i is partitioned into the subset of positive instances, D_{T+}^i, and negative instances, D_{T-}^i. To measure the quality of a fuzzification, the rule purity will be used:

$$pur = \frac{p_i}{p_i + n_i} \quad (3)$$

where

$$p_i = \sum_{x \in D_{T+}^i} \mu_{Ai}(x)$$

$$n_i = \sum_{x \in D_{T-}^i} \mu_{Ai}(x).$$

Suppose that fuzzy rules $r_1^{(j)} ... \; r_k^{(j)}$ have been learned for class $\lambda_j . j$. For a new query instance x, the support of this class is defined by

$$s_j(x) = \sum_{i=1...k} \mu_{r_i^{(j)}}(x) \cdot CF(r_i^{(j)}) \quad (4)$$

where $CF(r_i^{(j)})$ is the *certainty factor* of the rule $r_i^{(j)}$. It is defined as follows:

$$CF(r_i^{(j)}) = \frac{2\frac{\left|D_T^{(j)}\right|}{\left|D_T\right|} + \sum_{x \in D_T^{(j)}} \mu_{r_i^{(j)}}(x)}{\sum_{x \in D_T} \mu_{r_i^{(j)}}(x)}, \quad (5)$$

where $D_T^{(j)}$ denotes the subset of training instances with label λ_j [8].

Let us describe the FLR classifier [10]. The main rules used in this algorithm are as follows.

Definition 1. A fuzzy lattice is a pair $\langle L, \mu \rangle$, where L is a crisp lattice and $(L \times L, \mu)$ is a fuzzy set with membership function $\mu : L \times L \to [0,1]$ such that $\mu(x, y) = 1$ if and only if $x \leq y$.

Definition 2. An inclusion measure σ in a complete lattice L is a real function $\sigma : L \times L \to [0,1]$ such that for $u, w, x, y \in L$ the following conditions are satisfied:

(C0) $\sigma(X, O) = 0, x \neq O$

(C1) $\sigma(x, x) = 1, \forall x \in L$

(C2) $u \leq w \Rightarrow \sigma(x, u) \leq \sigma(x, w)$ – The Consistency Property

(C3) $x \wedge y < x \Rightarrow \sigma(x, y) < 1..$

Proposition 3. If $\sigma : L \times L \to [0,1]$ is an inclusion measure on lattice L, then $\langle L, \sigma \rangle$ is a fuzzy lattice.

Proposition 4. If L is a (complete) lattice and $v: L \to R$ is a positive valuation (with $v(O) = 0$) then (1) $k(x,u) = \frac{v(u)}{v(x \vee u)}$ and (2) $s(x,u) = \frac{v(x \wedge u)}{v(x)}$ are inclusion measures.

Proposition 5. Let L_i be a totally-ordered lattice, let $v: L \to R$ be a positive valuation, and let $\theta: L_i^{\partial} \to L_i$ be an isomorphic function in L_i. Then a positive valuation function $\nu: \tau(L_i) \to R$ is given by $\nu([a,b]) = v(\theta(a)) + v(b)$.

Definition 6. Consider a product lattice $L = L_1 \times ... \times L_n$. Let $v_i : L_i \to R$ be a positive valuation function in the constituent lattice $L_i, i = 1,... N.$. Then the diagonal of an interval $[a,b] \in \tau(L)$, with $a \le b$, is defined as a non-negative real function $diag_p : \tau(L) \to R_0^+$ given by $diag_p([a,b]) = d_p(a,b), p = 1,2...$

Proposition 7. For $p = 1,2,...$ we have $diag_p([a,b]) = \max_{x,y \in [a,b]} d_p(x,y)$ [10].

Results and discussion

In the course of this work several experiments with various attribute importance methods available in software WEKA [14] were made to determine the number of important attributes that can be used in further experiments. As can clearly be seen, eight different combinations of methods were used to reach the goal – to obtain most important attributes, to narrow the data capacity that can be used to successfully perform classification several times. In every series of experiments 10 fold cross validation was used to get more accurate results with different methods and to make them less affected by coincidence. As a result, 75 attributes were found to be most important in this data set and all other experiments were performed with already narrowed data set.

To perform classification, classifiers based on interconnections that can be accessed in WEKA software were used. The results obtained are summarized in Table 2. In the first column the name of an algorithm is given; in the second – the number of correctly classified examples; in the third – the number of incorrectly classified examples; in the fourth – the accuracy of classification and in the fifth – the summarized number of obtained interconnections.

The last two methods - FLR and FURIA use fuzzy set theory to obtain the rules. As can be seen from the results, FLR reached the highest results - the classification accuracy of 95%.

Table 2.

Result of classification

Algorithm	Correctly Classified Instances	Incorrectly Classified Instances	Accuracy	Number of rules
Ridor	149	19	88.69%	1
PART decision	159	9	94.64%	2
OneR	160	8	95.24%	2
JRIP	152	16	90.48%	2
Fuzzy lattice Reasoning (FLR)	161	7	95.83%	7
FURIA	156	12	92.86%	5

Since in such real life problem one class has a significantly greater (155 against 13) number of entries, it is important to clarify which examples have been classified incorrectly. In Table 3 the results of classification are summarized by the value, how precise every attribute classifies entries of each class. We can see that the best score for the “Brain cancer” class is

shown by Fuzzy FLR classificatory, then PART decision algorithm, which by overall accuracy score takes the second place a little behind OneR algorithm. The results of other algorithms are not so good. Of course, the practical result is important here – if a patient who is perfectly healthy is classified as a cancer case, it definitely is no good, though the patient is not in danger. However, if the case is opposite: a cancer patient is classified as healthy, it is extremely dangerous, because often timely diagnosis of this disease provides recovery possibilities.

Table 3.

Algorithm confusion matrix

Classifier		Classified as		
		a= BR	b=HD	Classification accuracy for each class
RIpple DOwn Rule Learner(Ridor)	a=BR	2	11	15.38%
	b=HD	8	147	94.94%
PART decision	a=BR	7	6	53.85%
	b=HD	3	152	98.06%
OneR	a=BR	6	7	46.15%
	b=HD	1	154	99.35%
JRIP	a=BR	3	10	23.08%
	b=HD	6	149	96.13%
FLR	a=BR	9	4	69.23%
	b=HD	3	152	98.06%
FURIA	a=BR	2	11	15.38%
	b=HD	1	154	99.35%

Interconnections obtained as a result of classification are shown in Table 4. As displayed, various classifiers use different classification methods. That is why the resulted interconnections are with different attributes; however one of them, namely 329, dominates significantly. Prominently displayed are the differences of each algorithm in the rule induction process and the contents of the rules (see Table 4).

Table 4.

Rules

Classif.	**Rule**
Ridor	IF 329 <= 0.852165 THEN Category = Br
PART	IF 329 > 0.835414 AND 1142 <= 1.132913 THEN Category=HD
	IF 568 <= 0 AND 223 <= 0.851652 THEN Category=Br
ONE R	IF 329< 0.78095255 THEN Category=Br
	IF 329>= 0.78095255 THEN Category=HD
JRIP	IF 958 <= 0.837699 and 115 <= 0.845161 THEN Category=Br
	IF 329 <= 0 THEN Category=Br
FLR	IF 329 [0.835414, 0.8458] THEN Category=Br (CF = 0.74)
	IF 997 [0, 0.815175] and 115[0.845161, 0.853948] THEN Category=Br (CF = 0.77)
	IF 501 [1.024421, 1.028017]) THEN Category=HD (CF = 1.0)
	IF 87 [0, 0.803008] and 104 [1.259394, 1.283743] THEN Category=HD (CF = 1.0)
	IF 997 [1.021784, 1.026568] THEN Category=HD (CF = 1.0)

Classif.	Rule
FURIA	IF data in interval [0.0 1.7643473] [0.0 1.1474993] [0.0 1.2891427] [0.0 1.0846912] [0.744659 1.3009045] [0.0 1.0004329] [0.0 1.2837429] [0.6871632 1.108951] [0.0 1.1201585] [0.0 1.4158141] [0.0 1.6925139] [0.0 1.0963819] [0.0 1.2071105] [0.0 0.8506509] [0.9561629 1.1801563] [0.0 1.2243818] [0.9354909 1.3019569] [0.0 1.5064373] [0.0 1.0559155] [0.0 1.1105751] [0.0 1.2031143] [0.0 2.3868061] [0.0 1.2479679] [0.0 2.1671135] [0.8866751 1.0796594] [0.0 1.260543] [0.0 0.8510461] [0.0 1.3208536] [0.8985972 1.2919535] [0.9869045 1.840857] [0.0 1.2867797] ….. [0.9319126 1.2546412] [0.7294844 1.1581615] [0.0 1.1322578] THEN Class=Br, et al.

Conclusions and future work

As expected, the results are difficult to evaluate, because the number of cancer patients in the training data set is very small; even after performing 10 fold cross-validation the results are still not satisfactory, because the best result in classifying cancer patients is 69%, which means that only in a bit more than half of the cases in this classification has been correct. Due to that, it is necessary to use other methods for data classification.

However, it should be emphasized that the use of fuzzy classification methods produces higher-quality results and comparably the best result of the crisp methods of Brain Cancer classification is 53% as compared with 69% obtained by fuzzy method (FLR).

In general, it can be concluded that the FURIA algorithm shows worse results than FLR; however, to objectively assess capabilities of this algorithm it should be possible to make comparisons with other publicly available data sets whose classification results are publicly available. Of course, the main advantage of the fuzzy rule-based technique is the decision making process. Each person can easily and intuitively perceive the classification process, as it operates with IF -THEN rules, which are closer to the real, everyday language. In this situation rules inducted by FURIA are better understandable. So the main issue is classification accuracy or well understandable rules.

The directions of further research include studying other types of cancer separately and also researching all of the available types of cancer with data of healthy donors. It is necessary to continue research on different methods of important attributes selection to optimize the required work.

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Anotācija. *Šajā rakstā pētīti reāli smadzeņu vēža dati. Šāda veida bioloģiskajiem datiem ir savas īpatnības – liels atribūtu – gēnu, antivielu skaits. Toties ierakstu skaits ir neliels, jo datus nepieciešams iegūt no reāliem pacientiem, šāds process ir lēns un ar lielām materiālajām izmaksām. Tāpēc darbā dots izmantoto datu sīks apraksts, analizētas to īpatnības, veids un struktūra. Attiecīgi arī klasifikācijas likumu atklāšana šādos datos ir sarežģīta. Šis pētījums veltīts klasifikācijas metožu pielietošanai ar mērķi atrast likumsakarības, kuras būtu iespējams izmantot smadzeņu vēža klasifikācijā. Tieši darbam ar šādiem unikāliem datiem ir ārkārtīgi liela praktiska vērtība, jo tos iespējams nākotnē izmantot turpmāko pētījumu veikšanai, kā arī praktiskam pielietojumam diagnosticēšanā ar iespēju nākotnē tos piedāvāt arī interpretēšanai biologiem. Lai paātrinātu likumsakarību iegūšanu, tika izmantoti tikai nozīmīgie atribūti. Tika pielietotas vairākas metodes nozīmīgo atribūtu iegūšanā. Izdarīti secinājumi par šāda veida datu apstrādi, klasifikācijas likumu iegūšanu, iegūto likumu precizitāti, kā arī aprakstīti nākotnē plānotie darbi.*

FEATURE SELECTION APPROACHES IN ANTIBODY DISPLAY DATA ANALYSIS

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Abstract. *Molecular diagnostics tools provide specific data that have high dimensionality due to many factors analyzed in one experiment and few records due to high costs of the experiments. This study addresses the problem of dimensionality in melanoma patient antibody display data by applying data mining feature selection techniques. The article describes feature selection ranking and subset selection approaches and analyzes the performance of various methods evaluating selected feature subsets using classification algorithms C4.5, Random Forest, SVM and Naïve Bayes, which have to differentiate between cancer patient data and healthy donor data. The feature selection methods include correlation-based, consistency based and wrapper subset selection algorithms as well as statistical, information evaluation, prediction potential of rules and SVM feature selection evaluation of single features for ranking purposes.*

Keywords: *antibody display, classification, data mining, feature selection, ranking*

Introduction

In the last decade new technological advancements have made molecular diagnostics more accessible and it has become a popular and perspective field of research [1]. While gene, protein and antibody analysis and screening techniques are developed, the analysis techniques of the resulting data to extract new knowledge are less than satisfactory. The statistical approaches that are often used are demanding towards data and provide little useful information to help understand relationships between features and prognostic capabilities of features.

Antibody display data analysis is a relatively new approach and is less studied than other molecular diagnostics approaches but it has similar problems – high dimensionality (thousands of antibodies) and small numbers of instances due to high costs of experiments. Most classification methods are very sensitive to data dimensionality and the instance/feature ratio but the less sensitive ones are also shown to benefit from dimensionality reduction [2]. Therefore this study is dedicated to analyzing feature selection techniques known in data mining and investigating their performance in antibody display data.

Methods

The antibody selection can be performed using standard data mining techniques. All of the techniques can be divided into two major groups – subset selection and individual attribute ranking. Attribute ranking evaluates each attribute independently of others and does not consider dependencies between attributes. Subset selection in its turn searches for a set of attributes that together give the best result. The choice of the approach depends on the data features but subset selection has another advantage – it can provide more information about patterns in the data by explaining relationships between attributes. But subset selection methods and wrappers, in particular, have higher computation costs which can be an important matter in high-dimensional data.

Subset selection methods

Feature subset selection algorithms perform a search over the feature space to select the optimal subset. To perform the search they have to address four basic issues [3]:

- Starting point: starting with no features in the initial subset (*forward selection*) or starting with the full set of features (*backward elimination*);

- Search organization: consider each possible subset (*exhaustive search*) or locally changing the subset without returning to reconsider the change (*greedy search*); another possible approach is based on adding and removing a feature from the subset in each step to make the search more flexible (*stepwise selection*);
- Evaluation strategy: testing each feature of the subset individually (*filters*) against an evaluation merit or testing the whole subset (*wrappers*);
- Stopping criterion: lack of improvement on change, reaching the other end of the feature space or a particular subset size.

Correlation-based Feature Selector (CFS) is a filter algorithm that ranks feature subsets according to a correlation-based heuristic evaluation function that selects features highly correlated with the class feature and uncorrelated with each other [4]. It allows distinguishing features with a high predictive accuracy in the instance space that is not already covered by other selected features (the low inter-correlation of the selected features). The heuristic evaluation merit M for a subset S containing k features is calculated as shown in the Equation 1.

$$M_s = \frac{k\overline{r_{cf}}}{\sqrt{k + k(k-1)\overline{r_{ff}}}} \quad (1)$$

where r_{cf} is the mean correlation between features and the class attribute,
r_{ff} is the average correlation between features.

Classifier Subset Evaluator uses classification algorithms applied to full data sets (or a division of the full data set into training and testing subsets for one run) to evaluate feature subsets. They are very similar to *Wrapper Subset Evaluators* but in this case the term Wrapper Subset Evaluators is used to address strategy that uses classification algorithms to evaluate feature subsets and cross-validation to estimate classification accuracy while fundamentally both, the Classifier Subset Evaluator and the Wrapper Subset Evaluator, are considered being wrappers. In both cases the classification process is treated as a black box giving evaluation values [5]. In this study all classification algorithms used to evaluate final subsets are employed to evaluate feature subsets while searching for the best combinations.

Consistency Subset Evaluator (CSE) evaluates feature subsets by the degree of consistency in class values when the training instances are projected onto the set, i.e. the prevalence of one class in subsets that the data set is divided into by attribute values. This also means that feature values have to be discretized [6]. Consistency of a subset can never surpass that of the full set so the algorithm searches for the smallest subset which has the same consistency as the full set.

The consistency of a feature subset S in a data set with N instances is calculated using the equation presented by Liu [7]:

$$C_s = 1 - \frac{\sum_{i=0}^{J} |D_i| - |M_i|}{N} \quad (2)$$

where J is the number of distinct attribute value combinations,
$|D_i|$ is the number of occurrences of the i-th attribute value combination,
$|M_i|$ is the cardinality of the majority class for the i-th attribute value combination.

Ranking methods

Ranking feature search methods evaluate single features using various metrics and assign a rank to each feature based on the performance of the feature. Ranking methods can filter the top features based on the metric based on a predefined subset size. The evaluation metrics are usually based on statistical properties of features or the predictive potential of a feature.

One of the metrics used in ranking is *Chi-Square Statistic* that is calculated with respect to the class [8]. It also works with discrete data types. The statistic for a problem with k classes and N instances is calculated as shown in Equation 3.

$$\chi^2 = \sum_{i=1}^{2} \sum_{j=1}^{k} \frac{(A_{ij} - E_{ij})^2}{E_{ij}} \quad (3)$$

where A_{ij} is the number of instances in the i-th interval (with i-th value), j-th class,
E_{ij} is the expected frequency of A_{ij}, which is calculated as shown in Equation 4.

$$E_{ij} = \frac{R_i \cdot C_j}{N} \quad (4)$$

where R_i is the number of instances in the i-th interval,
C_j is the number of instances in the j-th class.

Another popular metric to evaluate features is *Information Gain* that is measured with respect to the class. Information Gain is used in decision tree induction and was introduced by J. R. Quinlan [9]. Prior to feature evaluation the numeric attribute values have to be discretized because this approach works with categorical data. This metric is based on the change of information entropy that would occur if the state of the information would change (some information is given) and can be calculated by subtracting conditional entropy of the class from its entropy. Entropy of a feature C is calculated as shown in Equation 5. Conditional entropy of a feature C if the state of feature A is given is calculated as shown in Equation 6.

$$H(C) = -\sum_{i=1}^{n} P(C = c_i) log_2(P(C = c_i)) \quad (5)$$

$$H(C|A) = -\sum_{j=1}^{k} P(A = a_j) H(C|A = a_j) \quad (6)$$

where $P(C=c_i)$ is relative appearance frequency of value c_i in feature C in the data set,
$H(C|A=a_j)$ is the entropy of feature C in the data subset where the value of attribute A is a_j.

Gain Ratio is another metric used to evaluate features in decision tree induction [9]. It is based on Information Gain metric and eliminates its weakness that occurs in data sets that have features with large numbers of unique values which are given preference over other possibly better features with fewer values. Therefore Gain Ratio divides Information Gain by entropy of the considered feature as shown in Equation 7.

$$GR(C, A) = \frac{H(C) - H(C|A)}{H(A)} \quad (7)$$

Another classification method that can be used as a basis for feature selection is the rule induction algorithm *OneR* [10]. It also discretizes numeric features (using minimum bucket size as the criteria) and evaluates each feature using its error rate. OneR generates one rule for each feature and evaluates how this rule classifies the data. This classification error is also used to rank features in this feature selection approach.

Relief algorithm [11] evaluates a feature by randomly sampling instances and analyzing two neighboring instances of same and different classes. This algorithm was not able to work with missing data and data sets that included three or more classes therefore it was improved resulting in *Relief-F* algorithm [12]. It is adapted to work with multi-class problems by finding one or more (k) neighboring instance $M(C)$ from each different class C and averages their contribution for upgrading estimates $W[A]$ weighting it with the prior probability of each class. The estimation of weight W of feature A when the sampled instance is R (which is sampled m times) and the nearest instance of the same class is H is conducted as shown in Equation 8 [13].

$$W[A] := W[A] - \sum_{j=1}^{k} \frac{diff(A, R, H_j)}{m \cdot k} + \sum_{C \neq class(R)} \frac{P(C)}{1 - P(class(R))} \sum_{j=1}^{k} \frac{diff(A, R, M_j(C))}{m \cdot k} \quad (8)$$

The number of the checked neighboring instances is determined by either predefining a number or the maximum distance. The difference $diff(A, I_1, I_2)$ for discrete features is one if the values of instances are equal and 0 if the values are different. The difference of numeric features is calculated as shown in Equation 9.

$$diff(A, I_1, I_2) = \frac{|value(A, I_1) - value(A, I_2)|}{max(A) - min(A)} \quad (9)$$

Another approach that can be used in feature selection is *Support Vector Machines* (SVM) that was proposed by Guyon et al. [1]. In feature ranking the feature evaluation is done by using the square of the weight assigned by the SVM. SVMs have the deficiency that they only work with binary classes therefore feature evaluation for multi-class problems is conducted by ranking attributes for each class separately using the one-vs-all method. SVMs build decision functions *D(x)* whose weights w_i are a function of a small subset of the training examples called support vectors [1]. The squares of sums of these weights assigned to features by support vectors are considered evaluation metrics in feature ranking.

Classification methods

To evaluate feature subsets, various classification methods are used – decision function classification using SVM, probabilistic classification using Naïve Bayes method, decision tree induction algorithm C4.5 and tree ensemble Random Forest. The choice of classification algorithms is based on a number of studies on gene expression classification techniques that deal with similar problems [14-17]. The best results have shown that SVM and Random Forests perform best on such specific data but C4.5 and other decision tree classifiers not only perform well but also allow extracting knowledge about feature relations; Naïve Bayes classification algorithm is a standard and best-performing probabilistic classification algorithm.

SVM builds a function of relevant features by assigning weights to them (irrelevant features are assigned weight 0) based on relevant instances (support vectors). The function is a hyperplane in the instance space that separates different classes with a maximum margin (distance from the hyperplane to the nearest instances). SVMs have various types and enhancements; this study employs an enhancement called *Sequential Minimal Optimization* (SMO) introduced by Platt [18] that is used for training support vector classifiers. It was also improved by Keerthi and Shevade [18]. This approach breaks training process into smaller, two-dimensional problems and reduces resource consumption comparing to large matrix computation needed for the classic SVM training. SVMs also use kernels to transform feature spaces where they search for hyperplanes. In this study the Polynomial kernel was used to represent dot products.

While SVMs only work with binary classes, the multi-class problem is solved using pairwise classification 1-vs-1 (*pairwise coupling method*) proposed by Hastie and Tibshirani [20].

Naïve Bayes classifier uses probabilistic knowledge to assign class values [21]. It assumes that features are conditionally independent (hence the naïve approach) and predicts the most probable class according to class probabilities that are calculated for class set C with value c and feature value vector X with values x as shown in Equation 10.

$$P(C = c|X = x) = \frac{p(C=c)p(X=x|C=c)}{p(X=x)} \quad (10)$$

C4.5 is a decision tree induction algorithm proposed by Quinlan [9]. The trees are constructed from a data set by dividing the training set into subset until a class value can be assigned to each subset. The tree construction starts with choosing a root node representing a feature that splits the initial data set into subsets according to its values. Then nodes are selected for the second level split and so on. The features are chosen based on evaluation using *Gain Ratio* (described previously). Random Forest is an ensemble of random trees [22]. Random trees are constructed considering a predefined number of randomly chosen features. In these experiments the Forest consists of ten trees each considering eleven features (this number *k* is determined based on the number of instances *N* in the data set using Equation 11).

$$k = \log_2 N + 1 \quad (11)$$

Then the class to assign to a new instance in classification process is chosen using the most frequent tree output.

Design of experiments

The experiments were carried out using a data set describing patient antibody displays that held 1230 attributes and 343 instances divided into classes 'melanoma patients' (188 instances) and 'healthy donors' (155 instances); the data were provided by Latvian BioMedical Research & Study Center. To determine the baseline error, a set of experiments was conducted using the full data set and performing classification with all methods (C4.5, Random Forest, Naïve Bayes and SVM).

The second step involves attribute selection by all of the methods described using 10 fold cross-validation that divides the data set into 10 subsets and performs attribute selection on data withholding one subset each time. The feature subset selection methods use greedy forward stepwise selection using both filter and wrapper strategies (as described earlier) and stop when the evaluation metric starts to decrease. Attribute subsets selected by subset selection methods are used complete (including attributes used in more than one fold) to assure robustness and avoid overfitting to specific data subset, whereas ranker methods rank all of the attributes and only a subset can be used in the experiments to reduce dimensionality. According to Golub et al. [23], the attribute subset size differences of data sets that contain 50, 100 and 200 attributes have a minimal impact if data sets hold microarray data with several thousand attributes and a much smaller number of instances. Considering similarities of gene microarray data and antibody display data the number of selected ranked attributes is set to 50 best attributes.

The selected antibody subsets are then evaluated using classification algorithms C4.5, Random Forest, Naïve Bayes and SVM and 10 fold cross-validation and the results are compared to baseline results.

Results and discussion

Overall experimental results show that the most appropriate classification algorithms for this data set are SVM and Random Forest, which had the lowest error rate in the most attribute subsets. The error rate in data subsets that were created using ranking approach had less deviation and mostly were around 20% the only outfitter being SVM classifier when applied to data set with dimensions reduced by SVM approach (the classification error being a little over 5%), which is a logical result. The classifier precision in data sets where subset selection was used varied more corresponding to classifier sensitivity to inter-feature relationships in the selected subset.

The obtained results evaluated by classification error (percentage of the incorrectly classified instances) in 10 fold cross-validation are given in Table 5. It shows classification errors of all classifiers in all data sets used in the experiments; the shaded cells show the best result for the data subset used in the experiments.

In almost all data subsets where wrapper technique was used to reduce dimensionality the best results were shown by the methods which were used in the wrapper indicating that choosing the right dimensionality reduction approach is very important because it can significantly improve the results but also decrease results if used improperly.

The performance of Classifier and Wrapper methods is similar because they both use classification algorithms when evaluating feature subsets. Wrapper-based feature subset selection showed the largest increase in classification accuracy for tree based classification methods (improvement in C4.5 being 18% and almost 5% in Random Forest. The best results for Naïve Bayes classification method were in the data subset selected by Classifier method. It

can be explained by the fact that it did not use cross-validation leaving more data for the method to be trained and it is crucial for Naïve Bayes to show good results.

Table 5.

Classification errors for data subsets

	Attri butes	Error (%)			
		C4.5	RF	SVM	NB
Baseline	1230	32,9446	23,9067	18,0758	25,3644
CFS	123	31,7784	19,8251	17,7843	21,8659
Classifier J48	6	17,2012	41,1079	45,1895	45,1895
Classifier RF	2	46,9388	47,2303	45,1895	44,898
ClassifierSVM	13	37,3178	35,8601	18,9504	32,07
ClassifierNB	7	29,7376	36,7347	41,3994	16,6181
Consistency	16	34,6939	31,7784	31,4869	38,1924
Wrapper J48	6	14,8688	41,1079	45,1895	38,484
Wrapper RF	1	42,8571	18,0758	44,0233	18,0758
Wrapper SVM	12	39,3586	34,6939	20,6997	40,2332
Wrapper NB	5	24,1983	31,4869	45,1895	19,242
Chi	50	32,3615	22,1574	23,0321	33,5277
GR	50	30,0292	21,5743	25,3644	37,3178
IG	50	32,07	22,449	25,656	33,5277
OneR	50	31,1953	38,484	26,8222	35,8601
ReliefF	50	32,9446	26,5306	25,656	32,9446
SVM	50	36,4431	23,3236	**5,2478**	27,1137

The best results using CFS and Consistency feature subset selection methods have been shown by SVM because the algorithm benefits from correlation reduction and it showed the best overall and baseline results. Correlation reduction in the features (CFS method) benefited all tested classification results showing better results than baseline although the feature set was reduced to 10% of the initial set meaning that the information in the data was preserved.
The use of Chi-square statistic only slightly improved the performance of the decision tree based classification methods that had the best increase in accuracy among ranker selected subsets when GainRatio and Information Gain metrics were applied. This is also understandable because these metrics are used in tree construction.
The evaluation of single feature predictive capabilities did not show any notable results the only accuracy increase being for C4.5 method. The ReliefF method also did not show any significant results in this data decreasing the classification accuracies. Notably dimensionality reduction using SVM feature evaluation method only showed an increase in classification accuracy for SVM classifier.
The methods that are scalable perform well on full data sets but they also benefit from the right feature selection methods (the accuracy of C4.5 improved by 18%, Random Forest by almost 6% and SVM by almost 13%). Another important aspect in favor of feature selection also with scalable methods is the reduction in computational resources. On average, the computation time decreased by half.
Most frequently chosen features are shown in Fig. 1; the antibodies are coded by their ID used in the study.

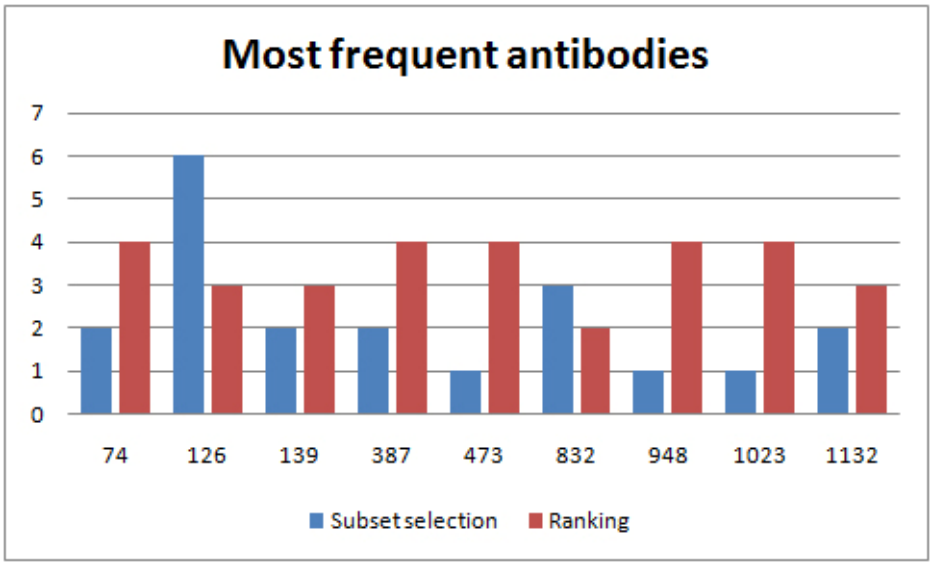

Fig. 1. **Frequency diagram of the most popular attributes**

The lighter columns show the occurrence frequency of the antibody in feature subsets chosen by subset selection methods; the darker columns show the number of occurrences in the top 50 antibodies of ranked lists.

Conclusions

Although accuracy fluctuations are greater in feature subset selection methods, the best results of all classification methods were shown in data subsets selected by these methods. Ranker methods show more stable results across all methods that would ease the selection of the right method, they do not show the best results.

The data subsets that were acquired using feature subset selection methods held less features than the selected threshold for rankers (50 best features) showing that the size of the feature subsets does not have to be large to build effective classifiers.

Overall experimental results show that data mining methods can be used to reduce antibody display data dimensionality for data analysis keeping the significant information intact and the accuracy does not suffer; on the contrary – the results even show some increase in accuracy and the computation resource consumption decreases.

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Anotācija. *Ar molekulārās diagnostikas rīkiem tiek iegūti specifiski dati, kuriem ir augsta dimensionalitāte, kas saistīta ar lielo apskatīto faktoru skaitu vienā eksperimentā, un neliels ierakstu skaits, kas saistīts ar augstajām eksperimentu izmaksām. Rakstā apskatīta dimensionalitātes problēma melanomas pacientu antivielu analīžu datos, šim mērķim izmantojot datu ieguves atribūtu atlases metodes. Tiek apskatītas atribūtu ranžēšanas atlases un atribūtu apakškopu izvēles pieejas, kā arī dažādu metožu veiktspēja, novērtējot izvēlētās atribūtu apakškopas ar klasifikācijas algoritmu C4.5, Random Forest, SVM un Naivā Baijesa palīdzību. Klasifikatoriem jāspēj maksimāli labi atšķirt vēža pacientu dati no veselo donoru datiem. Atribūtu atlases metodes iekļauj uz korelāciju un konsekvenci balstītās metodes un wrapper tipa apakškopu atlases metodes, kā arī atribūtu novērtēšanu, izmantojot statistiskās īpašības, informatīvuma novērtējumu, likumu prognozētspēju un SVM atribūtu atlases novērtējumu, ranžēšanas vajadzībām*.

CLUSTERING-BASED BEHAVIOURAL ANALYSIS OF BIOLOGICAL OBJECTS

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Abstract. *The article examines the problem of processing short time series for bioinformatics tasks using data mining methods in the field of pharmacology. The experiments were conducted using heart contraction (contraction and relaxation) power data that were obtained in experiments with laboratory animals with the goal of registering the power changes of heart contractions in different stages of experiment in a given period of time. The selected data were treated using data preprocessing technologies. The short time series were compared using various time-point similarity search methods using agglomerative hierarchical clustering, k-means clustering, modified k-means clustering and expectation-maximization clustering algorithms. Based on the clustering result evaluation the most suitable algorithm was chosen and the optimal number of clusters was determined for the least clustering error. The acquired clusters were used for to create cluster prototypes that aggregate the groups of similar heart contraction power objects. The article offers an examination of the errors produced by algorithms and methods as well as a discussion of the obtained clustering results using different evaluation methodologies. It also gives conclusions about the application of data mining methods in solving bioinformatics tasks and outlines further research directions.*

Keywords: *clustering short time series, clustering algorithms, cluster prototypes.*

Introduction

This article proposes a solution for bioinformatics experts for effective short time series processing using data mining methods and algorithms. In bioinformatics and pharmacology in particular the obtained data during large and time-consuming experiments are specific and voluminous. This data can be used to acquire new knowledge using data mining technologies, which can be used as a basis for result interpretation and improve the accuracy of the research results as well as obtain results in a shorter period of time and using less experiments that involve animals (laboratory rats).

The study uses the results acquired in experiments with animals [1, 2] that resulted in heart contraction power measurements. The animals were fed for eight weeks a specially prepared food that contained certain supplements that stimulated action of the heart. Each group of the animals was fed one of the supplement types for a certain period of time. The biological goal of this experiment was the creation of a pharmacological drug that prevents heart failure. Experiments with animal hearts that conform to European Union animal protection ethics rules [2] were carried out to achieve this goal. This resulted in measurements of heart contraction power in a given period of time or in "Isolated heart" [2] experiments. This experiment has three stages: preparation stage when a heart is placed into a special machine for life support and prepared for further experiments; occlusion – closure of blood vessels; reperfusion – opening of blood vessels. The goal of the pharmacological experiment is to determine the percentage of the dead tissue (necrosis) that depends on the types of supplements that were fed to the animals.

The data used in this study describe the occlusion period. The measurements of heart contraction power over a certain period of time can be viewed as short time series because the period of occlusion lasts for 40 minutes in each experiment with each heart. Using pharmacological equipment the intensity of measurement readings was set to 1 minute intervals because what matters is the structural changes over a period of time and not the frequency of the measurements. *ADInstruments* software used in experiments provides this type of data readings, dismissal of noisy data values and calculation of mean values of heart contraction power in a chosen period of time. As a result a data set vas obtained that included

certain number of period for each animal heart used in the experiment. For an obtained subset a set of data mining experiments was carried out to determine object membership to cluster and create prototypes that describe mean values of cluster in each moment of time based on the clusters.

Objective statement

This study is a part of an extensive research that is intended to develop a system to determine heart failure that would help bioinformatics and pharmacology experts to carry out experiments to determine the percentage of necrosis in 'Isolated Heart' experiments based on individual descriptive parameters like weight, food supplements and the parameters that describe the blood plasma. The development of this system would increase the speed of experiments while decreasing their costs and the number of animals used in them. This study is set to prove that application of data mining methods and algorithms is useful in solution of bioinformatics and pharmaceutical tasks. The goal of the study is to find groups of similar objects in the heart contraction data and patterns in them using data mining methods and algorithms so that these groups can be used in later experiments enabling classification of individuals based on their descriptive parameters. The following tasks have to be solved to achieve the goal: carry out the selection of equal numbers of periods for each individual; choose the most appropriate data preprocessing approach to the problem to be solved; find the most appropriate clustering approach; determine the most appropriate number of clusters based on the evaluation of the clustering error; create prototypes that describe similar objects in a cluster.

A series of researches involving choosing of a data normalization approach and using clustering algorithms used in this research has to be conducted to complete the set tasks. The restrictions of the research are related to the processing of short time series. When solving this type of tasks there are several problems associated with choosing methods and algorithms. They are mainly related to the issue of inability of traditional time series data processing methods and algorithms to solve such tasks related to the insufficient length of the time series. Therefore this type of tasks are solved using data mining technologies that provide the acquisition of new knowledge from the analyzed data.

The scientific novelty of the study is based on providing bioinformatics experts with the chance of analyzing heart contraction power data using data mining methods and algorithms by determining groups of similar objects.

The methods

A. Data normalization

This study uses two approaches for data normalization: Z-score normalization by standard deviation (ZSSD) [3] and demand normalization by life curve (LC) [4].

ZSSD is based on the calculations of time series mean value and standard deviation; the normalized value of each object T_i' is calculated using the following formula (1):

$$T_i' = \frac{T_i - \overline{T}_i}{\sigma_{T_i}}, \tag{1}$$

where T_i – value of the time series T in the moment i;

$\overline{T}_i$ – mean value of the time series;

σ_{T_i} – standard deviation.

When ZSSD is used the range of the normalized values includes both the negative and the positive values [3]. LC is calculated using the following formula (2):

$$y_i = \frac{x_i}{\sum_{j=1}^{n} x_j}, \tag{2}$$

where y_i – the normalized attribute value at the time moment i;
x_i – the value of time series x at the time moment i;
x_j – the value of time series y in the period n;
n – the time series duration (number of periods).

This approach is specifically suited for time series normalization. The normalized values belong to the positive range only [4, 5].

B. Clustering algorithms

The data set analyzed in this study does not contain any information about classes and their connection with the data. Therefore there is the necessity to apply data analysis, i.e. to find knowledge in the data that would help to determine groups of similar objects in the data and describe the relationships in these groups. The aggregation of the objects into clusters is implemented in a way that allows grouping the time series with similar structure based on one of the distance metrics.

K-means algorithm

The data set that consists of n objects is split based on predefined parameter, which determines the number of clusters in the data set, into k clusters where the similarity among objects of one cluster is larger than that of objects from different clusters. Each cluster has its own centroid or center of gravity that is calculated using the arithmetic average of the objects that belong to the same cluster using each attribute. In each iteration the algorithm assigns each object to the nearest centroid obtaining a cluster. Then the centroid is recalculated based on objects belonging to the cluster and the algorithm calculates objects' membership to the clusters. This process continues until centroids stop changing their memberships. To assign an object to the nearest centroid a distance metric *Euclidean distance* [6] is used. The only imperfection of the *k-means* algorithm is its dependency on the initial division because the centroids are assigned randomly and the initial position of clusters can be less than optimal. To avoid imprecision the given algorithm is run several times and the results are compared to each other to choose the best result. The result evaluation is carried out using sum of squares error that is calculated using the following formula (3):

$$E = \sum_{i=1}^{k} \sum_{x \in c_i} d^2(x, m_i), \tag{3}$$

where x – given multi-dimensional object;
m_i – multi-dimensional centroid of cluster c_i;
$d(\cdot)$ – distance function;
k – number of clusters.

The results can be interpreted when the best result of the algorithm is determined and the sum of squares is calculated [6, 7].

Modified k-means algorithm

At the beginning of the algorithm the range of the clusters has to be determined to make the process of clustering more effective and less time consuming. The optimal number of clusters has to be found in the range from 2 to maximum number of clusters. This maximum number should be large enough to precisely cluster the data set but also small enough to avoid the influence of noise on the results. Therefore the maximum number of clusters

$Max_{quantityofclusters}$ [5, 7] is calculated according to the theoretical assumption that the maximum number of clusters equals the square root of the number of records in the data set (4):

$$Max_{quantity\ of\ clusters} = \sqrt{n} \tag{4}$$

The calculation of the maximum number of clusters improves the speed of obtaining the desired results by saving time and calculation resources. Then the *modified k-means* algorithm works like *k-means* algorithm until it reaches the calculation of sum of squares error. The algorithm determines the number of clusters that produces the least error that is calculated by dividing the sum of distances *d* between each object and centroid (see Table 1) by the number c_n of records in the cluster (see Formula (5)). It produces the mean absolute error AE_i for each cluster.

Table 6.

Object distances to the centroids used for calculating mean clustering absolute error

Number of object	*Periods*				*Distance measure*
c	***T1***	***T2***	***…***	***T12***	***d***
c_1					d_1
c_2					d_2
…					…
c_n					d_n

Then the sum of mean absolute errors AE_n is divided by number of clusters C_n obtaining the mean absolute error *MeanAE* [5, 10] of clustering using the formula (6):

$$AE_i = \frac{d_1 + d_2 + \cdots + d_n}{c_n}, \tag{5}$$

where d_1, d_2, d_n – the distances from the corresponding record to the centroid;
c_n – the number of records in a cluster;
AE – the mean absolute error in a cluster.

$$MeanAE = \frac{AE_1 + AE_2 + \cdots + AE_n}{C_n}, \tag{6}$$

where C_n – the number of clusters;
MeanAE – the mean clustering absolute error.

This approach provides the analysis of distances between each object of the data set and centroids in each cluster and provides the calculation of average absolute error of clustering. This error is used for finding the number of clusters that is needed to cluster the data set.

Expectation maximization

Expectation maximization algorithm uses probability measure instead of a firm distance measure and analyzes distribution curves for each dimension where each point belongs to a specific cluster with a certain probability. This approach is called soft clustering, which means that clusters can overlap because they do not have strict borders. The algorithm is intended to use when borders of clusters are fuzzy. *Expectation maximization* algorithm calculates the expected value of a hidden variable for each record and then recalculates these values if they were of the observed variables that use the expected values. The work of the algorithm consists of two steps (E and M). In the *E-step* the algorithm calculates the sum of an expression that includes the expected logarithmic credibility value of the appended data against probability distribution. The *M-step* maximizes the expected logarithmic credibility value according to parameters [8, 9].

Agglomerative hierarchical algorithm

Agglomerative clustering algorithm belongs to the hierarchical clustering algorithms. The main working principle of the algorithm consists of stepwise object merging into groups. At the beginning each object represents a separate cluster. The nearest objects are merged first based on the minimum distance between them and later between farther objects and object groups. The process is run until all objects belong to the same group or cluster that signals the algorithm to stop. To determine the distance between two clusters and compose a distance matrix the "nearest neighbor" principle is used (7):

$$d_{\min}\left(S_l, S_m\right) = \min_{\substack{x_i \in S_l \\ x_j \in S_m}} d\left(x_i, x_j\right) \tag{7}$$

where $d(\cdot)$ – distance function;

S_l, S_m – two separate clusters;

x_i, x_j– two objects of different clusters.

Agglomerative clustering algorithm is often used to construct taxonomies because it uses a hierarchical approach. The result is a dendrogram that graphically demonstrates the succession of object merges in each step of the algorithm iteration [6, 7].

C. Prototypes of clusters

Prototypes of clusters are created based on clustering results. Each cluster is represented by its own prototype that characterizes mean values of the cluster in each period of time.

Results and discussion

The following software was used in experiments: *LabChart 7 View*, *Microsoft Excel 2010*, *Weka 3.6.3*, *OrangeCanvas 2.0* un *Statistica 8.0*.

Data and experiments

This study uses a data set that consists of 92 records; each object was described by 38 time periods of time that were read from the pharmacological apparatus using *ADInstruments* and *LabChart 7 View* software. The readings were made every 60 seconds over a period of 40 minutes; the first and the last readings were excluded. The mean values of heart contraction power in each period of time were expressed using mercury height (mmHg). The obtained short time series values were normalized using various normalization approaches to determine the most appropriate for the used data. The result of the readings were two data sets with different normalization results. Both data sets were clustered using each clustering algorithm. The obtained results were analyzed which provided the best clustering approach for the given task. The clustering results served as a basis to create prototype for each cluster.

Data preprocessing

Heart contraction data of 40 minutes were sampled for each animal using *LabChart 7 View*. Heart contraction power measurement graphs are shown in Fig. 1; the vertical dashed lines show the beginning and the end of the measurements. The beginning phase indicates occlusion and the end phase shows reperfusion. The tool provided data readings in the given period of time and exclusion of noise using a built-in mathematical analyzer. The prepared data were normalized using ZSSD and LC approach providing two data sets for further experiments.

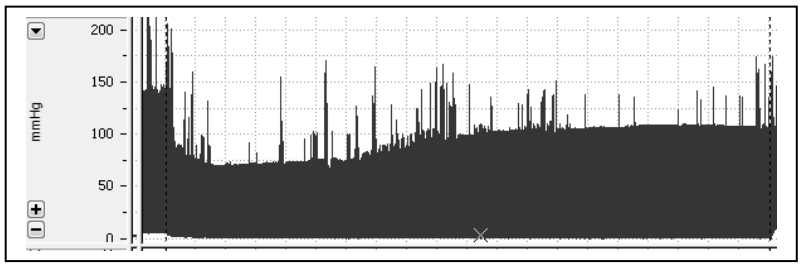

Fig. 2. **Heart contraction power (mmHg) measurements in a given period of time**

Data clustering

The experiments with each data set were repeated 20 times varying centroids based on the randomness principle. The results were evaluated using the distances between objects and centroids and distances between clusters. The sums of squares were calculated for different numbers of clusters as shown in Table 2.

Table 2.

Sums of squares errors for *k-means* algorithm

	Number of clusters							
Approach	2	3	4	5	6	7	8	9
ZSSD	141,67	138,42	128,36	125,89	122,64	120,56	116,34	113,92
LC	115,73	112,99	101,81	96,36	92,54	89,44	87,39	85,79

When *modified k-means* algorithm was used the absolute errors were calculated using formula (5) and the mean absolute errors of each cluster were calculated using formula (6); see Table 3 for results. The number of clusters was determined using evaluation of these results. The optimal number of clusters for this data set is 5 (see Fig. 3), which is represented by the minimum mean absolute error. The normalization approach was also chosen based on these errors.

Table 3.

Mean absolute errors using *modified k-means* algorithm

	Number of clusters							
Approach	2	3	4	5	6	7	8	9
ZSSD	1,233	1,192	1,158	1,150	1,128	1,095	1,093	0,946
LC	1,026	1,017	1,026	**0,59**	0,644	0,91	0,824	0,615

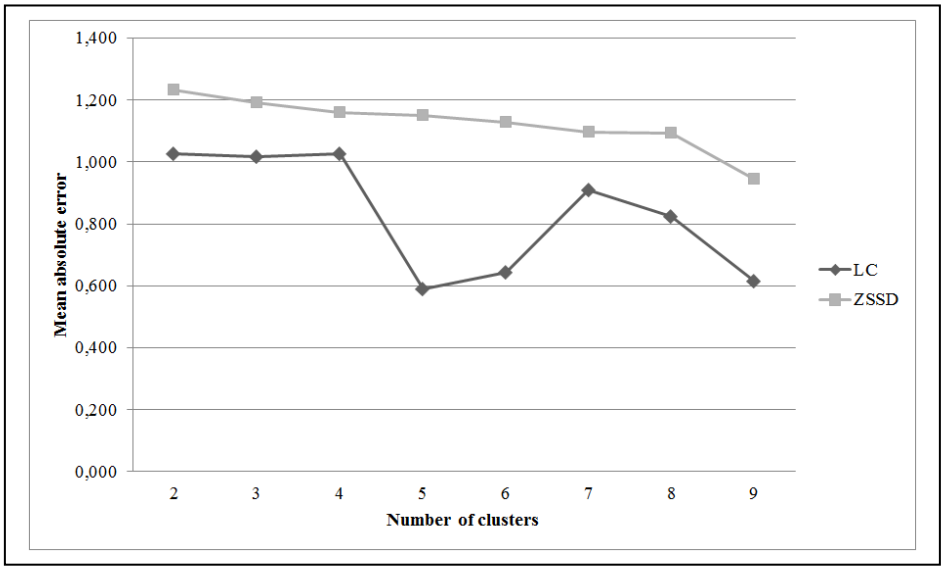

Fig. 3. **The choice of normalization approach and number of clusters using mean absolute error**

Expectation maximization algorithm found two clusters for each approach in the clustering process. The obtained logarithmic probabilities that evaluate the performance of the algorithm are shown in Table 4. The agglomerative hierarchical algorithm found three clusters for each approach using *Ward's linkage*. This Ward's linkage is based on increase in sum of squares of object distances between clusters and their centroids during merges. In the first case

(see Fig. 4, left) when the ZSSD was used the stopping criterion is distance in the range from 4.2 to 5 because this value is the maximum in the analyzed range of merges. There are three clusters expressed that describe this division.

Table 4.

Logarithmic probabilities for *expectation maximization* algorithm

	Number of clusters							
Approach	2	3	4	5	6	7	8	9
ZSSD	-49,64	-48,64	-47,93	-47,39	-46,36	-45,47	-45,25	-44,13
LC	144,49	145,40	148,42	149,06	150,06	150,32	151,13	150,87

In the approach that uses demand normalization using life curve (see Fig. 4, right) the stopping criterion is reached in the distance range between 3.8 and 5.8. There are two expressed clusters for this division.

Based on the clustering results the best results were shown by *modified k-means* algorithm using mean absolute error estimation. The results of this algorithm were used as basis for prototype construction (see Fig. **Error! Reference source not found.**). The obtained prototypes will be used in further research that will be based on merging heart's descriptive parameters (like weight of the heart, blood count etc.) with the clustering results.

The merging of the results is necessary to develop a system that would diagnose heart failure in the future.

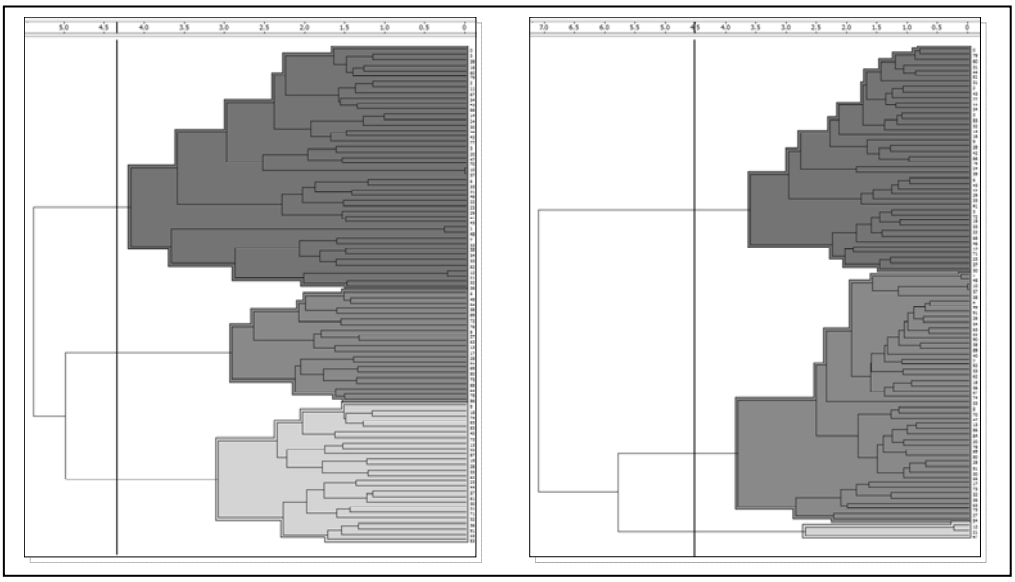

Fig. 4. **Clustering of the data set using hierarchical agglomerative algorithm using *Z-score normalization by standard deviation* (left) and *demand normalization by life curve* (right)**

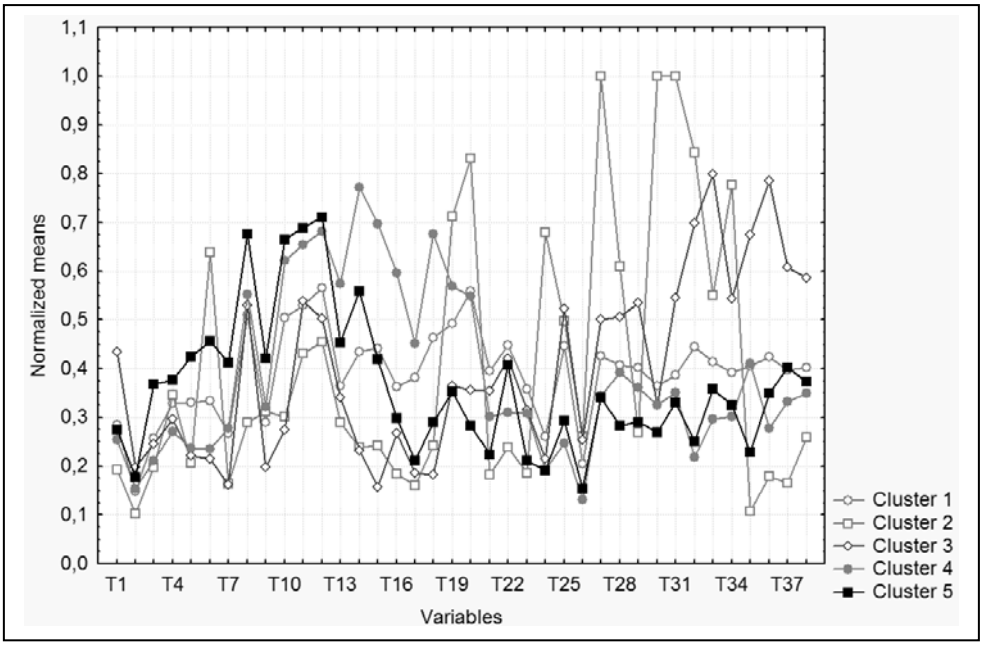

Fig. 4. **The prototypes obtained using *modified k-means* algorithm and demand normalization by life curve for five clusters**

Conclusions

The results of this study show that data mining methods and algorithms are useful when solving bioinformatics and pharmacology tasks that involve short time series.

The experiments show that the best results in normalizing heart contraction power data are acquired by normalization by life curve approach that can be explained by the fact that Z-score normalization by standard deviation normalizes values in positive and negative value ranges whereas normalization by life curve uses only values in the positive range.

Clustering algorithms showed different results. Expectation maximization algorithm showed a unitary trend when clustering both data sets: when the number of clusters grew the logarithmic probability, which is used when calculating the error of the algorithm, increases. The obtained results show that this algorithm is not suited for this type of tasks.

K-means algorithm also showed a unified trend in error evaluation. Two evaluation methods were used in this study: *distance to centroids* where the maximum (9) number of clusters was chosen in both data sets; and *distance between clusters* where the minimum (2) number of clusters was chosen. The results are not clearly interpretable therefore this algorithm is not suited for this type of tasks.

Agglomerative hierarchical algorithm showed similar trends assigning the same number of clusters using both approaches. Visual analysis of the dendrograms shows that the results of clustering are informative and visually interpretable. The analysis also shows that Z-score normalization by standard deviation has more advantages because the cluster distribution among objects is more even.

The results and the mean absolute error show that *modified k-means* algorithm is the most adequate of the analyzed clustering algorithms for this task. This algorithm showed the best results using normalization by life curve judging by mean absolute clustering error evaluation. Therefore the data set used to build prototypes was clustered using this approach and five clusters.

Based on the prototypes found in the data for each cluster the further experiments will revolve around determining connections between clustering results and the parameters describing animals like weight, blood count etc. There are plans to build a system that would help pharmacology experts to conduct experiments in heart failure diagnostics. The use of such

system would decrease the number of needed experiments, increase the efficiency of the results and save human and time resources.

Acknowledgements

The author thanks the lead researcher of the pharmaceutical pharmacology laboratory Dr. phrm. Edgars Liepins and researcher Janis Kuks of Latvian Institute of Organic Synthesis for the expressed interest and the provided research data on heart contraction power that were used for experiments in this study.

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Anotācija. *Darbā tika aplūkota problēma, kas saistīta ar īsu laika rindu apstrādi, risinot bioinformātikas uzdevumu farmakoloģijas nozarē, pielietojot datu ieguves metodes. Eksperimentiem tika izmantoti dati par sirds kontrakcijas (saraušanās un atslābšanas) spēku, kas iegūti eksperimentos ar laboratorijas dzīvniekiem, ar mērķi reģistrēt sirds kontrakcijas spēka izmaiņas dažādās eksperimenta stadijās noteiktā laika periodā. Atlasītie dati tika apstrādāti, izmantojot datu pirmapstrādes tehnoloģijas. Īsu laika rindu salīdzināšanai tika izmantotas dažādas punktveida līdzības meklēšanas metodes, izmantojot aglomeratīvo hierarhisko, k-vidējo, modificētu k-vidējo un maksimālās līdzības (EM) algoritmus. Balstoties uz klasterizācijas rezultātu novērtējumu, tika izvēlēts atbilstošākais algoritms un noteikts piemērotākais klasteru skaits, kas nepieciešams šīs datu kopas klasterizācijai, balstoties uz klasterizācijas vidējās absolūtās kļūdas novērtējumu. Pamatojoties uz iegūtajiem klasteriem, tika izveidoti paraugmodeļi klasteros, kuri apvieno līdzīgu sirds kontrakcijas spēka objektu grupas. Darbā tika izvērtētas pielietoto algoritmu un metožu radītās kļūdas. Salīdzināti iegūtie klasterizācijas rezultāti, pielietojot dažādu novērtēšanas metodiku. Izdarīti secinājumi par datu ieguves metožu pielietošanu bioinformātikas uzdevumu risināšanai, iezīmētas nākotnes vīzijas turpmākajiem pētījumiem.*

PROJECT MANAGEMENT KNOWLEDGE RETRIEVAL: PROJECT CLASSIFICATION

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Abstract. *Project management knowledge contains a wide range of information that can be accumulated from theory and practice. This knowledge is not always readily available to project manager and that can leave a significant impact on project management efficiency and success. Therefore, this knowledge is necessary to store in the project management knowledge repository and then to retrieve it when necessary. To find this knowledge it is necessary to define attributes for searching relevant projects and knowledge associated with these projects. The objective of this paper is to develop a set of project classification attributes that can be used to describe project characteristics and use them in similarity definition. The project classification attributes are defined as a part of the architecture of project management knowledge retrieval. They are identified by analyzing several project management methodologies and are validated by classifying twenty two empirical information technology projects.*

Keywords: *project management knowledge, project classification, knowledge retrieval*

Introduction

Project management (PM) knowledge includes a wide range of information that describes PM data, actions and processes. Use of the accumulated PM knowledge improves effectiveness and success of the project and PM [1][2][3] and reduces possibility of typical errors. Knowledge can be obtained from both theory and practice. Methodologies (e.g. PMBOK [4], PRINCE2 [5]), frameworks (e.g. RUP [6], MSF [7], SCRUM [8]), standards (e.g., ISO 9001 [9], CMMI[10], ISO/IEC, COBIT [11], ITIL [12]) and other guidelines provide the theoretical PM knowledge, but the practical PM knowledge is available from previous projects. This knowledge should to be stored and then retrieved for usage. In order to provide a project manager with actual knowledge it is necessary to find similar projects during the knowledge retrieval process. A project similarity could be determined by comparing project and project environment attributes.

The objective of this paper is to develop a set of the main project classification attributes that can be used to describe the project similarity during the PM knowledge retrieval process. Case-based reasoning (CBR) principles are used for the knowledge retrieval in the PM knowledge retrieval architecture. This architecture ensures theoretical and practical PM knowledge storage in the repository and knowledge retrieval according to the knowledge search area, the project attributes and similarity measurements of the project attributes. The proposed set of project attributes will provide project usage area independent project classification and similarity measurements.

In existing research on project classification focuses on project success characteristics and projects are classified according to the following characteristics: software vs. hardware, project scope, project outcome, technology uncertainty, type of usage, level of operation and type of basic technology [13]. Project also can be classified using two dimensions: technological uncertainty and complexity [14]. Classification using the method of working and the objective clarity has been proposed by [15]. In [16] three dimensions are used for project classification: customer, project and project keywords. These existing classifications are general and slightly subjective, but for the measurement of project similarity more detailed and specific classification attributes are needed. For this reasons, the set of project classification attributes has been elaborated in this paper.

This paper is divided in four sections. The material and method section has description of the PM knowledge retrieval architecture, importance of the project attribute in the PM knowledge retrieval and descriptive source of the project attribute. The set of the main project classification attributes is represented in the result section. An example of project classification according to the defined project attributes is shown in the discussion section and conclusions are provided in the last section.

Materials and methods

Architecture of PM knowledge retrieval

In order to support knowledge utilization in the PMIS configuration, the architecture of PM knowledge retrieval is elaborated in [17] and shown in Fig.1. This architecture has already been used for other PM knowledge retrieval. A principle of the CBR [18] has been used in design of the architecture of PM knowledge retrieval. CBR consists of the case library and four-step process: retrieve, reuse, revise and retain. The cases in PM knowledge are a) empirical knowledge C_j, j=1,..., m, that previously have been used in projects and b) PM methodologies, standards and best practices H_i, i=1,…, p . The cases can be described by the structured PM description in form of XCPM scheme [19]. Data structure, data and processes description have been ensured by this XCPM scheme. Also store of unstructured knowledge D has been allowed in the library.

The CBR process is managed using the client, which has three main modules. The first module is used to describe a new case using the set of project attributes A_{j+1}, where j+1 is used to identify the new case. The retrieve step is performed by the information retrieval module that is used to find the similar cases in the theoretical and practical case descriptions (P_t^H and P_t^C) according to the information search knowledge area M_s (e.g., risk management) and the defined similarities L_k, k=1,…, n. The sets of similar cases according to the new case j+1 and the search knowledge area M_s are denoted by $\mathbf{H_{j+1,s}'}$ and $\mathbf{C_{j+1,s}'}$ for theoretical and empirical knowledge, respectively, is the result of information retrieval. The information processing and display module performs CBR reuse and revise steps. This module collects and processes gathered information and displays it to the user.

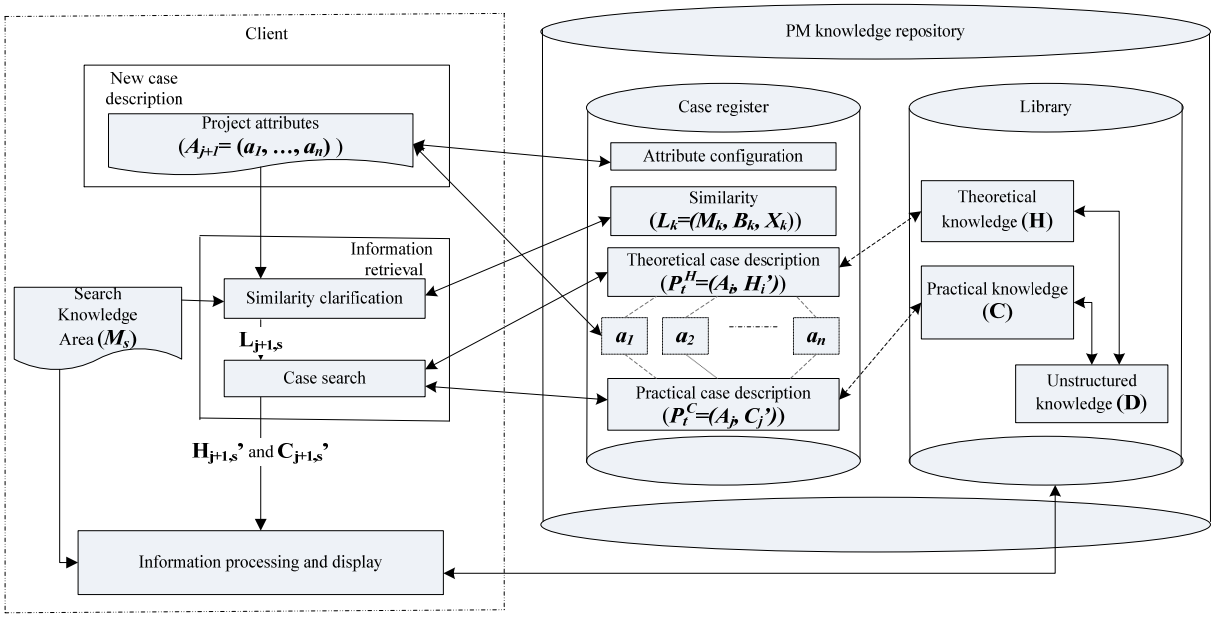

Fig. 1. **Architecture of PM knowledge retrieval**

Project attribute

In the proposed architecture the project attributes are main element in the PM knowledge classification and the similar case search (Fig.1). The default set of attributes and attribute values are established in this architecture, but predefined configuration can be edited, extended or reduced according to needs and area. During the similar case selection each attribute is defined the similarity measurement x_i ($X_k=(x_1, \ldots, x_n)$, n is count of attribute) that depends of the knowledge search area M_k and the knowledge type B_k (theoretical or practical). These similarity measurements are also configurable.

The characteristics of project and project environment have been defined with the project attributes. Description of these characteristics can be found in general PM methodologies such as PMBOK [4] and PRINCE2 [5]. In PMBOK the project environment information has been found as input data to a project charter development process or has been defined in the project charter. In [5] that describe PRINCE2 one charter is devoted to the project environment.

Information from PM methodologies PMBOK and PRINCE2 and existent project classifications [13] [14] [16] have been used for definition of the general project classification attributes.

Result

The general project attributes obtained from the methodologies and the existent classifications have been collected into Table 1. The resulting set of project attribute includes eighteen attributes that can be divided into six groups: type, product, size, organization, guidance and management/planning approach. The project type defines the way in which the project is being implemented and what kind of customer. The project product attributes are defined by product, it areas and how it is obtained. The project size is described by complexity, team size, project budget and duration. To describe the project execution organization should indicate its structure, size and basic work area. The project organization size can be measured with count of employers or turnovers. The guidance is three types: the PM methodologies, frameworks and standards; the government rules; and the project product related standards. The approach group attributes define the PM lifecycle and the estimation and cost approaches. The project attribute values must be clearly defined and classified in order to prevent the subjective assessment. For example, for the team size description better use classified values ‘less than 10’ and ’10 and more’ than values ‘small’ and ‘large’. Examples of the attribute values are given in Table 1.

Discussion

To demonstrate the project classification using the set of project attributes twenty-two projects have been classified. All of these projects are from the information technology area and have been developed in Latvia.

Further project classification according to the project attributes groups is analyzed.

According to the project type and client, projects are divided in five groups:

1) Outsourcing + government (9 projects);
2) In-house + commercial (1 project);
3) In-house + private (4 projects);
4) Outsourcing + private (6 projects);
5) In-house + government (2 projects).

The product in all projects belongs to the information technology area and the result is software. These projects have different project actions. According to the project product, the reviewed projects are divided in five groups:

1) Improvement + software + IT (7 projects);
2) Development + software + IT (11 projects);

3) Development and implementation + software + IT (2 projects);
4) Implementation + software +IT (1 project);
5) Development + software and process + IT (1 project).

Table 1.

Project classification attributes

Attribute	PMBOK	PRINCE2	Other resource	Possible values
Project type				
Project type	X	X		Outsourcing / In-house / Offshore National / International Internal / External
Client	X	X	[16]	Government / Private / Commercial
Project product				
Project action	X	X	[13]	Development / Maintenance / Improvement/ Implementation
Project product	X	X	[13]	Product / Service / Process
Area	X	X	[13]	Classified values (e.g., IT, Construction, Research etc.)
Project size				
Complexity		X	[13]	Mono- / Multi-discipline With / Without branches
Team size	X	X	[13]	Scalar
Project budget	X	X	[16]	Scalar
Duration		X	[16]	Scalar
Project organization				
Project organization structure	X		MSF	Functional / Weak matrix / Balanced matrix / Strong matrix / Project
Organization size		X		Scalar
Organization area		X		Classified values (e.g., IT, Construction, Research etc.)
Guidance				
Management methodologies	X	X	MSF	Classified values (e.g. PMBOK, PRINCE2, RUP, MSF, Agile, SCRUM, CMMI, ITIL, ISO9001)
Government rule	X	X	MSF	Classified values
Product related standards	X	X	MSF	Classified values
Management/planning approach				
PM lifecycle	X			Classified values (e.g. Waterfall, Iterative, Spiral, Agile)
Estimation approach		X		Expert / Functional point
Cost approach		X		Contract price / Fixed price per unit

The project size is described with four attributes where three attribute – team size, budget and duration – are scalar values and it values should be grouped into intervals. The team size values have been divided into two intervals: 'less than seven' and 'seven and more'. Analyze budget attribute values have been divided into five intervals: 'less than 10 000'; '10 000 – 50 000', '50 000 – 100 000', '100 000 – 500 000', '500 000 and more'. The project duration values have been divided into four intervals: 'less than six months', 'six month to a year', 'from a year to two years' and 'more than two years'. The reviewed projects are divided into eleven groups by the project size:

1) Multi-discipline + less than 7 + more than 500 000 + more than 2 years (2 projects);
2) Multi-discipline + less than 7 + 100 000 - 500 000 + 6 months to a year (1 project);
3) Multi-discipline + 7 and more + more than 500 000 + more than 2 years (1 project);
4) Multi-discipline + 7 and more + 100 000 - 500 000 + 6 months to a year (1 project);
5) Mono-discipline + 7 and more + 10 000 – 50 000 + less than 6 months (1 project);
6) Mono-discipline + 7 and more + 50 000 – 100 000 + 1 – 2 years (1 project);
7) Mono-discipline + 7 and more + 10 000 – 50 000 + 6 months to a year (1 project);
8) Mono-discipline + 7 and more + 50 000 – 100 000 + 6 months to a year (1 project);
9) Mono-discipline + less than 7 + 10 000 – 50 000 + less than 6 months (5 projects);
10) Mono-discipline + less than 7 + 10 000 – 50 000 + 6 months to a year (4 projects);
11) Mono-discipline + less than 7 + less than 10 000 + less than 6 months (4 projects).

The project organization is described with three attributes, these attributes characterizes project implementation organization. The organization size attribute is scalar values that have been measured with employer count and have been divided into two intervals: 'less than 100' and '100 and more'. According to the project organization the reviewed projects are divided in eight groups:

1) Project + 100 and more + IT (7 projects);
2) Project + less than 100 + IT (6 projects);
3) Project + less than 100 + education (1 project);
4) Project + 100 and more + manufacture (1 project);
5) Individual + less than 100 + IT (1 project);
6) Functional + 100 and more + energy (1 project);
7) Functional + less than 100 + government (2 projects);
8) Matrix + 100 and more + IT (2 projects).

The reviewed projects according to the used guideline are divided in eight groups:

1) None (9 projects);
2) ISO 9001:2008 (5 projects);
3) ITIL + ISO 9001:2008 (2 projects);
4) MSF + PMBOK + CMMI + ISO 9001:2008 + LVS (1 project);
5) ISO 9001:2008 + LVS (2 projects);
6) ISO 9001:2008 + EC rule + IEEE + LVS (1 project);
7) ISO 9001:2008 + ITIL + CMMI (1 project);
8) Scrum (1 project).

All twenty two projects use expert estimation approach, but they differ in the PM lifecycle and the cost approach. The reviewed projects are divided into seven groups by the used approaches:

1) Evolutionary + expert estimation + fixed price for unit cost (3 projects);

2) Evolutionary + expert estimation + contract price cost (2 projects);
3) Waterfall + expert estimation + contract price cost (4 projects);
4) Waterfall + expert estimation + fixed price for unit cost (9 projects);
5) Iterative + expert estimation + contract price cost (2 projects);
6) Agile + expert estimation + fixed price for unit cost (2 projects).

Full result of the reviewed project classification is shown Table 2. Explanation of values for the attribute groups is given in text above.

The project classification result shows that among the twenty two reviewed projects if they have been compared after all eighteen attributes there are no two similar projects. However, usually similar projects are not searched according to all attributes, but only after those that affect the searched knowledge area. For example, planning project activities user might only interest information about projects with similar product, project size, approaches and guidance. After these four groups of attributes can be considered that similar are project 6 and 7. According to project type, product and size similar are project 7 and 21. The project similarity can be evaluated by the various subsets of attributes.

Table 2.

Project classification

Project ID	Project attribute groups					
	Type	Product	Size	Organization	Guidance	Approach
1	1	1	1	1	2	1
2	1	2	3	1	2	2
3	1	2	2	1	2	3
4	2	1	1	1	2	4
5	3	2	5	6	3	4
6	1	2	9	8	1	4
7	4	2	9	2	1	4
8	4	3	10	2	1	2
9	1	1	4	2	4	5
10	1	1	10	1	5	6
11	4	2	11	2	1	3
12	3	4	11	3	1	4
13	4	2	6	2	1	3
14	3	1	11	8	1	4
15	5	3	11	7	1	1
16	3	2	9	4	1	1
17	3	1	7	2	6	3
18	1	1	9	1	2	6
19	5	5	10	7	7	4
20	1	2	8	1	5	4
21	4	2	9	5	8	2
22	1	2	10	2	3	4

Conclusion

The project attributes is one of the important input data in the PM knowledge retrieval. This paper defines the set of the main project attributes that can be used as basis for the classification of any project. These defined attributes will be used as the default set of attributes in the PM knowledge retrieval. To obviate the subjective assessment values of this attributes must be clearly defined and classified.

The main task for the attributes in the PM knowledge retrieval is to ensure search of similar project by comparison of the attribute values. Not always the similar projects are being sought for full set of attributes, but the subset of affected attributes is defined for the each search knowledge area.

Acknowledgment

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THE MATHEMATICAL MODELING OF Ca AND Fe DISTRIBUTION IN PEAT LAYERS

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Abstract. *Bogs have been formed by an accumulation of peat - a light brown-to-black organic material, built up from partial decomposition of mosses and other bryophytes, sedges, grasses, shrubs, or trees under waterlogged conditions. The total peatlands area in Latvia covers 698 918 ha or 10.7% of the entire territory. Knowledge's of peat metals content are important for any kind of peat using. Experimental determination of metals in peat is very long and expensive work. Using experimental data mathematical model for calculation of concentrations of metals in different points for different layers can help to very easy and fast to find approximately concentration of metals or trace elements.*

The results of the research show that concentrations of trace elements in peat are generally low. Concentrations differ between the superficial, middle and bottom peat layers, but the significance decreases depending on the type of mire.

The mathematical model for calculation of concentration of metals in different points for different 3 layers in peat blocks is developed. As an example, mathematical models for calculation of Ca and Fe concentrations have been analyzed.

Keywords: *finite difference method, heavy metals, peat bog.*

Introduction

Peat is a mixture of plant remains in different stages of decay consisting in five main groups of organic compounds: proteins, lipids, hydrocarbons, pigments and lignin [1]. Peat can be totally or poorly humified, depending on the level of decomposition and formation that its parent plants have undergone. Peat is classified primarily as fibric, hemic or sapric peat. With fibric peat being the least decomposed and containing large amounts of undecomposed fibers, hemic peat is being moderately decomposed, and sapric peat being the most decomposed. Peat has ability to bind trace elements which depends of peat structure and composition. Climatic conditions may be the principal factor favouring peat formation. Regional climate, the nature of the vegetation, water pH, and degree of metamorphosis may affect the characteristics of the peat. [2]

Trace elements accumulated in peatlands have two main natural sources:

1) atmospheric deposition of soil dusts and aerosols (the only source in ombrotrophic mires); and
2) the incorporation as particulate matter or in solution via runoff and ground waters (by mineral dissolution or desorption of compounds previously accumulated in the environment). [1]

Main anthropogenic pollution sources are atmospheric particles, wastewaters, results of changes in environmental conditions such as changes in pH value [1]. Although at trace levels some heavy metals are essential for plants and animals, at higher concentrations they become dangerous for any form of life [3].

The mechanisms for sorption of metal ions on peat include physical adsorption, ion exchange, chelating, lone pair electron sharing, chemical reaction with phenolic hydroxyls and similar species [4, 5]. There are some limitations in the use of peat as sorbent material. Natural peat has a low mechanical strength, a high affinity for water, poor chemical stability and tendency to shrink.

Experimental chemical analyses of heavy metals in peat usually are expensive and not always easy to use. Mathematical models which based on real results are more easy to use for practical determination of necessary elements.

Using experimental data the mathematical model for calculation of concentration of metals in different points for different 3 layers (peat blocks) is developed. In study was considered averaging and finite difference methods for solving the 3-D boundary-value problem in multilayered domain. A specific feature of these problems is that it is necessary to solve the 3-D boundary-value problems for elliptic type partial differential equations (PDEs) of second order with piece-wise diffusion coefficients in three layer domain.

In study process was developed a finite-difference method for solving of above mentioned boundary-value problem of the type with periodical boundary condition in x direction. This procedure allows reducing the 3-D problem to a system of 2-D problems by using circulant matrix [6].

Materials and methods

Peat. Peat samples have been carried out in Knavu peat bog in East Latvia, Vilani district. Total area of Knavu bog is 1240.6 ha and maximum depth of peat is 5.55 m. Peat layer forms hummock and hollow peat. The sampling sites in peat bog have been chosen in natural not drained part of bog.

The peat samples (0.34 m long monoliths) were put in polyethylene film. The first slice (+3 to 0 cm) is corresponded to the living plant material on the bog surface. For survey of the metal concentration in the peat in the studied bog in four peat bores were sampled using a peat sampler ($\varnothing$ = 0.08 m). Excess surface vegetation was removed *in situ* to facilitate penetration of the peat surface. Samples of peat were taken to a depth of 3 m.

Study of metals in peat samples has been carried out using air dry peat. All analysis has been performed using A class vessels, calibrated measuring instruments and equipment. Analytical quality reagents have been used without further purification.

For preparation of solutions high purity deionized water has been used throughout. All chemicals used in study were of high purity. Glass and quartz vessels utilized in the study have been pre-cleaned by treating with $K_2Cr_2O_7$ and concentrated sulfurous acid mix. All peat samples have been analyzed in triplicate.

Metals were determined after acid digestion. Peat samples were digested heating 1.5 g of peat with 15 mL conc. HNO_3 at 95 ^{0}C for 2 hours. Samples were filtered through filter which previously has been washed with 0.5% conc. HNO_3 solution, and then the filtrate was diluted to the volume of 65 mL with deionized water. Ca and Fe concentrations were measured by inductively coupled plasma optical emission spectrometer OPTIMA 2100 DV ICP/OES from PerkinElmer.

A mathematical model

The process of diffusion we will consider in 3-D parallelepiped

$\Omega = \{(x, y, z): 0 \le x \le l, 0 \le y \le L, 0 \le z \le Z\}.$

The domain Ω consists of multilayer medium. We will consider the stationary 3-D problem of the linear diffusion theory for multilayered piece-wise homogenous materials of N layers in the form

$\Omega = \{(x, y, z): x \in (0, l),\ y \in (0L),\ z \in (z_{i-1}, z_i)\},\ i = \overline{1, N}$

Where $H_i = z_i - z_{i-1}$ is the height of layer Ω_i, $z_0 = 0$, $z_N = Z$.

We will find the distribution of concentrations $c_i = c_i(x, y, z)$ in every layer Ω_i at the point $(x, y, z) \in \Omega_i$ by solving the following partial differential equation (PDE):

$$D_{ix}\partial^2 c_i / \partial x^2 + D_{iy}\partial^2 c_i / \partial y^2 + D_{iz}\partial^2 c_i / \partial z^2 + f_i(x, y, z) = 0, \quad (1)$$

where D_{ix}, D_{iy}, D_{iz} are constant diffusions coefficients, $c_i = c_i(x, y, z)$ - the concentrations functions in every layer, $f_i(x, y, z)$ - the fixed sours function. The values c_i and the flux functions $D_{iz}\partial c_i / \partial z$ must be continues on the contact lines between the layers $z = z_i, i = \overline{1, N-1}$:

$$c_i|_{z_i} = c_{i+1}|_{z_i},\ D_{iz}\partial c_i / \partial z|_{z_i} = D_{(i+1)z}\partial c_{i+1} / \partial z|_{z_i},\ \ i = \overline{1, N-1} \quad (2)$$

where $i = \overline{1, N-1}$.

We assume that the layered material is bounded above and below with the plane surfaces $z_0 = 0, z = Z$ with fixed boundary conditions in following form:

$$c_1(x, y, 0) = C_0(x, y),\ c_N(x, y, Z) = C_a(x, y) \text{ - the boundary conditions of the first type} \quad (3)$$

where $C_0(x, y)$, $C_a(x, y)$ are given concentration-functions.

We have two forms of fixed boundary conditions in the x, y directions:

1) the periodical conditions by $x = 0, x = l$ in the form

$$c_i(0, y, z) = c_i(l, y, z), \partial c_i(0, y, z) / \partial x = \partial c_i(l, y, z) / \partial x, \quad (4)$$

2) the symetrical conditions by $y = 0, y = L$

$$\partial c_i(x, 0, z) / \partial y = \partial c_i(x, L, z) / \partial y = 0. \quad (5)$$

For solving the problem (1 - 5) we will consider conservative averaging (AV) and finite difference (FD) methods. These procedures allow to reduce the 3-D problem to some 2D boundary value problem for the system of partial differential equations with circular matrix in the x - directions.

The AV–method with quadratic splines

The equation of (1) is averaged along the heights H_i of layers Ω_i and quadratic integral splines along z coordinate in following form one used [7]:

$$c_i(x, y, z) = C_i(x, y) + m_i(x, y)(z - \bar{z}_i) + e_i(x, y)G_i\left((z - \bar{z}_i)^2 / H_i^2 - 1/12\right) \quad (6)$$

where $G_i = H_i / D_{iz}$, $\bar{z}_i = (z_{i-1} + z_i)/2$, m_i, e_i, C_i are the unknown coefficients of the spline-function, $C_i(x, y) = H_i^{-1}\int_{z_{i-1}}^{z_i} c_i(x, y, z)dz$ are the average values of $c_i, i = \overline{1, N}$.

After averaging the system (1) along every layer Ω_i, we obtain system of N equations of 2-D PDE

$$D_{ix}\partial^2 C_i / \partial x^2 + D_{iy}\partial^2 C_i / \partial y^2 + 2H_i^{-1}e_i + F_i(x, y) = 0, \quad (7)$$

where $F_i = H_i^{-1}\int_{z_{i-1}}^{z_i} f_i(x, y, z)dz$ are the average values of $f_i, i = \overline{1, N}$.

From (3) follows

$$3m_1H_1 = 6(C_1 - C_0) + e_1G_1 \quad (8)$$
$$3m_3H_3 = 6(C_a - C_3) - e_3G_3$$

From (2), (6) we obtain following system of $N-2$ algebraic equations for determining e_i:

$$2e_{i-1}G_{i-1}(G_i+G_{i+1})+e_i((G_i+3G_{i-1})(G_i+G_{i+1})+(G_i+3G_{i+1})(G_i+G_{i-1}))+ \\ +2e_{i+1}G_{i+1}(G_i+G_{i-1})=6(C_{i+1}-C_i)(G_i+G_{i-1})-6(C_i-C_{i-1})(G_i+G_{i+1}) \quad (9)$$

where $i=2,\overline{N-1}$.

From the system of algebraic equations (2 - 9) can be obtained e_i depending of $C_i, i=\overline{1,N}$.

In the case $N=3$ (three layers) we have:

$$e_i=e_{i,1}C_1+e_{i,2}C_2+e_{i,3}C_3+e_{i,0} \quad (10)$$

$$m_i=m_{i,1}C_1+m_{i,2}C_2+m_{i,3}C_3+e_{i,0},\ i=1;2;3,$$

From (7), (10) follows the system of three PDE

$$\begin{cases} D_{1x}\partial^2C_1(x,y)/\partial x^2+D_{1y}\partial^2C_1(x,y)/\partial y^2+2H_1^{-1}e_1(x,y)+\widehat{F}_1(x,y)=0 \\ D_{2x}\partial^2C_2(x,y)/\partial x^2+D_{2y}\partial^2C_2(x,y)/\partial y^2+2H_2^{-1}e_2(x,y)+\widehat{F}_2(x,y)=0, \\ D_{3x}\partial^2C_3(x,y)/\partial x^2+D_{3y}\partial^2C_3(x,y)/\partial y^2+2H_3^{-1}e_3(x,y)+\widehat{F}_3(x,y)=0 \end{cases} \quad (11)$$

where $\widehat{F}_i(x,y)=F_i(x,y)+2H_1^{-1}e_{i,0}, i=1;2;3$.

The Finite Difference method

For solving 2-D problems we consider a uniform grid $(N_x\times(N_y+1))$:

$$\omega_h=\{(x_i,y_j),\ x_i=ih_x,\ y_j=(j-1)h_y,\ i=\overline{1,N_x},\ j=\overline{1,N_y+1},\ N_xh_x=l,\ N_yh_y=L\}.$$

Subscripts (i,j) refer to x,y indices, the mesh spacing in the x_i,y_j directions are h_x and h_y. The PDEs (11) can be rewritten in following vector form:

$$D_x\partial^2C/\partial x^2+D_y\partial^2C/\partial y^2-AC+\widehat{F}=0 \quad (12)$$

where D_x, D_y are the 3-d order diagonal matrices with elements D_{1x}, D_{2x}, D_{3x} and D_{1y}, D_{2y}, D_{3y}, C is the 3 order vectors-column with elements C_1, C_2, C_3, $\widehat{F}$ is also the vectors-column with elements $\widehat{F}_1, \widehat{F}_2, \widehat{F}_3$, and matrix A is in following form:

$$A=-2\begin{pmatrix} e_{1,1}/H_1 & e_{1,2}/H_1 & e_{1,3}/H_1 \\ e_{21}/H_2 & e_{22}/H_2 & e_{23}/H_3 \\ e_{3,1}/H_3 & e_{3,2}/H_3 & e_{3,3}/H_3 \end{pmatrix}.$$

The equation (12) with periodical conditions for vector function C in the uniform grid (x_i,y_j) is replaced by vector difference equations of second order approximation:

$$AA_jW_{j-1}-CC_jW_j+BB_jW_{j+1}+\widehat{F}_j=0, \quad (13)$$

where $W_j, \widehat{F}_j, i=\overline{2,N_y}$ are the $M\times N, (M=N_x)$ order vectors-column with elements $C_{k,i,j}\approx C_k(x_i,y_j)$, $\widehat{F}_{k,i,j}=\widehat{F}_k(x_i,y_j)$, $i=\overline{1,M}, k=1;2;3$, $AA, CC, BB=AA$ are the 3 block-matrices of M order circulant symmetric matrix. The circulant matrix

$$A=\begin{pmatrix} a_1 & a_2 & \dots & a_M \\ a_M & a_1 & \dots & a_{M-1} \\ \dots & \dots & \dots & \dots \\ a_2 & a_3 & \dots & a_1 \end{pmatrix}$$

can be given with its first row in the form $A=[a_1,a_2,...,a_M]$. The calculation of circulant matrix (matrix inversion and multiplication) can be carried out with MATLAB using simple formulae for obtaining the first M elements of matrix.
The boundary conditions (5) are replaced by difference equations of first order approximation:
$C(x,h_y)=C(x,0)+O(h_y)$, $C(x,L)=C(x,L-h_y)+O(h_y)$.
The vectors-column W_j from (15) is calculated by Thomas algorithm [8] in the matrix form using MATLAB.

The numerical methods

The vectors-column W_j from (13) is calculated by Thomas algorithm in the matrix form using MATLAB.

$$W_j = X_j W_{j+1} + Y_j = 0,\ j = N_y(-)1 \qquad (14)$$

where X_j, Y_j are corresponding matrices and vectors, obtaining of following expressions

$$X_j = (CC_j - AA_j X_{j-1})^{-1} BB_j\ ,\ Y_j = (CC_j - AA_j X_{j-1})^{-1}(AA_j Y_j + F_j),\quad j = 2(1)N_y \qquad (15)$$

Here $X_1 = E\ \ Y_1 = 0\ \ W_{\bar{N}+1} = (E - X_{\bar{N}})^{-1} Y_{\bar{N}}$, $(\bar{N} = N_y)$

where

$$E = \begin{pmatrix} [1,0,...,0] & 0 & 0 \\ 0 & [1,0,...,0] & 0 \\ 0 & 0 & [1,0,...,0] \end{pmatrix}.$$

The inverse matrix of

$$A = \begin{bmatrix} A11 & A12 & A13 \\ A21 & A22 & A23 \\ A31 & A32 & A33 \end{bmatrix}$$

$B = A^{-1}$, $(BA = AB = E)$ is in the form

$$B = \begin{bmatrix} B11 & B12 & B13 \\ B21 & B22 & B23 \\ B31 & B32 & B33 \end{bmatrix}$$

where is obtained from the following MATLAB file [8]:
function[B11,B12,B13,B21,B22,B23,B31,B32,B33]=apg3(A11,A12,A13,A21,A22,A23,A31, A32,A33).

Results and discussion

Average concentrations of Ca and Fe in peat of the Knavu bog are shown in Fig. 1. The profile of concentration changes for metals at first may be influence their biogenic recycling and low mobility of these elements considering also the changes of the water table. Changes of concentrations of studied elements in all points have similar characters - concentrations very fast decreases with depth increasing.

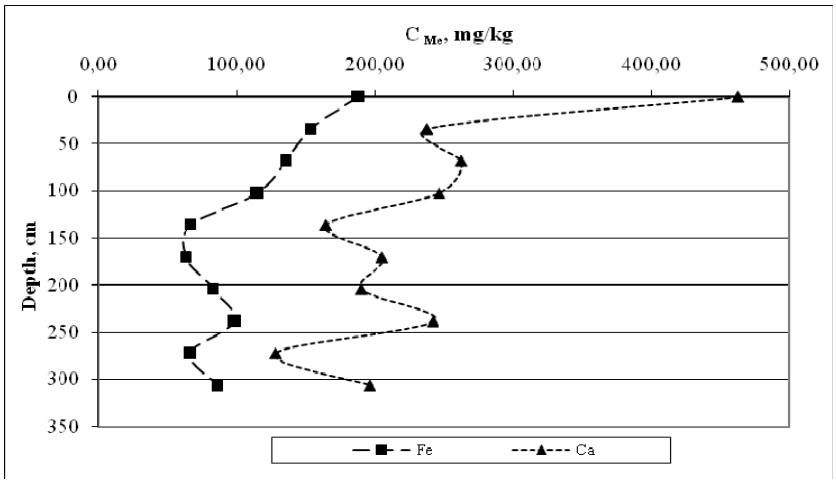

Fig. 1. **Fe and Ca concentrations (mg/kg) in peat core**

The numerical results

On the top of the earth ($z = Z$) we have the measured concentration ***c*** *mg/kg* x10^2 of metals in the following nine points in the (x; y) plane:

1) for **Fe:**

$c(01., 0.2) = 1.69$; $c(0.5, 0.2) = 1.83$; $c(0.9, 0.2) = 1.72$; $c(0.1, 0.5) = 1.70$; $c(0.5, 0.5) = 1.88$; $c(0.9, 0.5) = 1.71$; $c(0.1, 0.8) = 1.71$; $c(0.5, 0.8) = 1.82$; $c(0.9, 0.8) = 1.73$,

2) **for Ca:**

$c(0.1, 0.2) = 3.69$; $c(0.5, 0.2) = 4.43$; $c(0.9, 0.2) = 3.72$; $c(0.1, 0.5) = 4.00$; $c(0.5, 0.5) = 4.63$; $c(0.9, 0.5) = 4.11$; $c(0.1, 0.8) = 3.71$; $c(0.5, 0.8) = 4.50$; $c(0.9, 0.8) = 3.73$.

This date are smoothing by 2D interpolation with MATLAB operator, using the spline function.

We use following diffusion coefficients in the layers:

1) **for Fe** (C0 = 0.66):

$D1z = 10^{-3}$; $D2z = 0.38\ 10^{-3}$; $D3z = 0.22\ 10^{-3}$;

2) **for Ca** (C0 = 1.30) :

$D1z = 10^{-3}$; $D2z = 1.875\ 10^{-3}$; $D3z = 0.1333\ 10^{-3}$:

The diffusion coefficients in (x, y) directions are:

$D1x = D1y = 310^{-4}$; $D2x = D2y = 410^{-4}$; $D3x = D3y = 510^{-5}$.

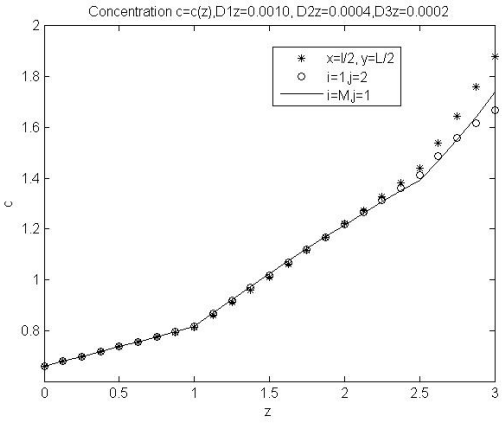

Fig. 2. **The distribution of Fe concentration *c* depending of vertical coordinate *z* in three points: *x = l/2, y = L/2; i=1, j=2; i=M (x=1), j=1***

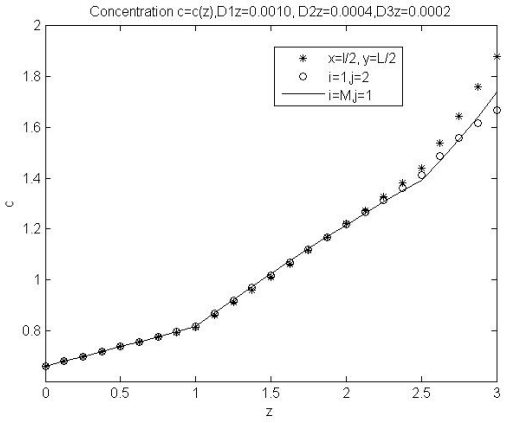

Fig. 3. **The distribution of Ca concentration *c* depending of vertical coordinate *z* in three points: *x = l/2, y = L/2; i=1, j=2; i=M (x=1), j=1***

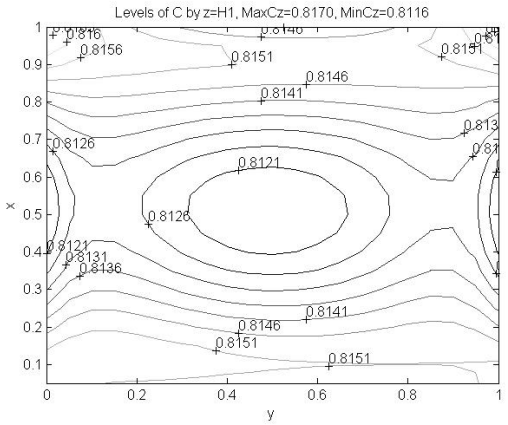

Fig. 4. **The distribution of Fe concentration *c* in the (*x; y*) plane (Levels of *c*) by *z* = *H*1**

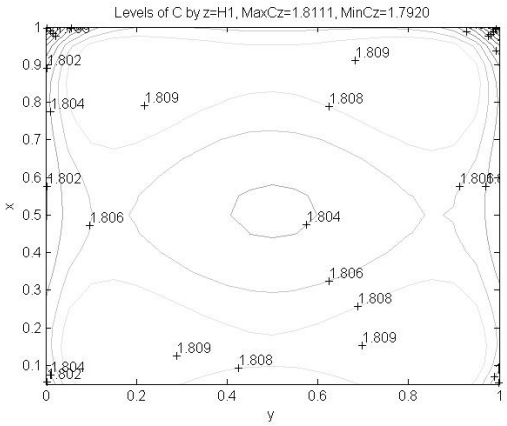

Fig. 5. **The distribution of Ca concentration *c* in the (*x; y*) plane (Levels of *c*) by *z* = *H*1**

In the Fig. 2 and Fig. 3 we can see the distribution accordingly of Fe and Ca concentration c depending of vertical coordinate z in three points, in Fig. 4 and Fig. 5 – the distribution of concentration c in the (x, y) plane by $z = H_1$ accordingly for Fe and Ca.

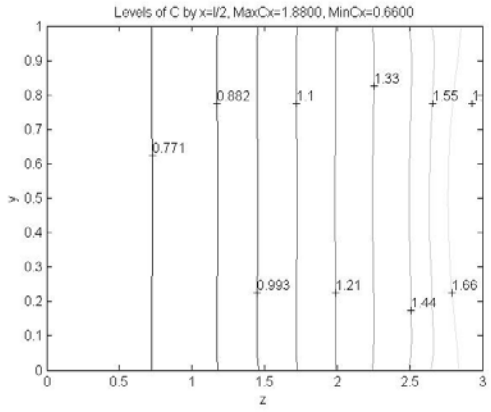

Fig. 6. **The distribution of Fe concentration *c* depending of vertical coordinate *z* by *x* = *l/2***

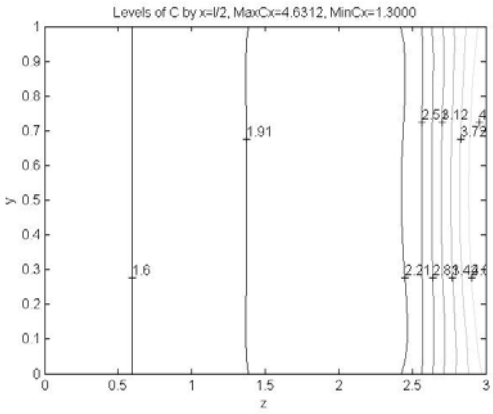

Fig. 7. **The distribution of Ca concentration *c* depending of vertical coordinate *z* by *x* = *l/2***

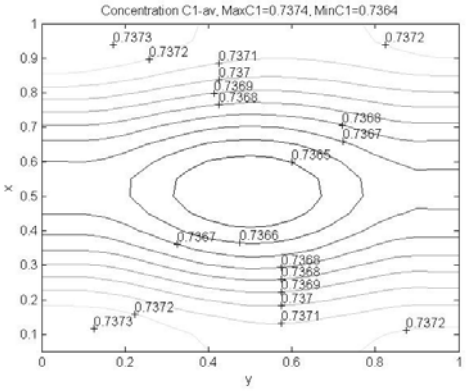

Fig. 8. **The distribution of averaged values C1 in first layer for Fe concentration**

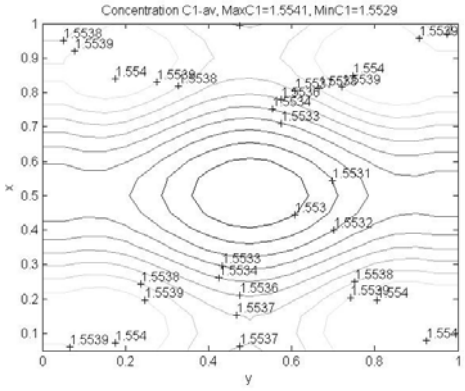

Fig. 9. **The distribution of averaged values C1 in first layer for Ca concentration**

In Fig. 6 and Fig. 7 – the distribution of c in the (z, y) plane by $x = l/2$ accordingly for Fe and Ca, and the distribution of averaged values C_1 in the first layer accordingly for Fe and Ca – in Fig. 8 and Fig. 9.

Conclusions

The biggest concentrations of heavy metals are at the top layers of peat. Concentrations of Ca and Fe very fast decreases with depth increasing. Elements concentration in peat profiles confirms with respect to the possibility of using trace elements concentration as indicator of the region and global environmental pollution.

The 3D diffusion problem in N layered domain described by a boundary value problem of the system of PDEs with piece-wise constant diffusion coefficients are approximate on the 2D boundary value problem of a system of N PDEs. This algorithm is used for solving the problem of metal concentration in the 3 layered peat block ($N = 3$). The total advantage and attainment of an averaged method for engineering calculations is determined from the number of grid points in every of three layers. The efficiency of this method is obtained due to simple algorithms for calculations of circulant matrix. Mathematical modeling results and practical data are very similar and it means that mathematical model have practical application in real determination of trace elements concentrations.

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INTELLECTUAL GEOINFORMATION SYSTEM FOR EARTH SCIENCES

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Abstract. *A new technology was elaborated, combining a geoinformation system (GIS) and GIS-oriented algorithmic methods of artificial intellect (AI).*
Numerous thematic layers for geosciences, obtained from Russian and international scientific sources, were imported into the GIS.
Technology and software for integration of AI methods within the GIS in the form of the Centralized Catalogue of Geodata Processing Algorithms (CCGPA) was developed.
A GIS visualization subsystem was created to provide interaction between the GIS and its users. It performs geodata layers visualization, map operations, geodata set management, execution of CCGPA-stored algorithms and representation of application results.

Keywords: *geoinformation system, geodata, Earth sciences, artificial intellect.*

Introduction

The fundamental problem of complex analysis of georeferenced data (geodata) is the development of a geographic information system (GIS) and artificial intellect (AI) for the creation of an integrated geinformation environment for thematic data retrieval, storage, and processing. The present research is aimed at the integration of data on geography, geology, geophysics, geoecology, and other Earth sciences in the comprehensive problem-oriented GIS including the intellectual environment for geodata analysis [1].

Materials and methods

The main goals of the present research are:

- The development of an intellectual GIS for Earth sciences;
- Creation of new AI methods and algorithms for recognition, classification and clusterisation and their integration with the GIS environment and geodata bases.

ArcGIS 9.3.1 software package developed by Environmental Systems Research Institute (ESRI) was used for the creation of the basic GIS environment.
Numerous thematic layers for geosciences were obtained from Russian and international scientific sources and imported to the GIS geodata base.
The main information sources were:

- Institutes of the Russian Academy of Sciences (RAS);
- World Data Centers (WDC) of the World Data System (WDS);
- United States Geological Survey (USGS);
- British Geological Survey (BGS);
- German Research Centre for Geosciences (GFZ);
- Institut de Physique du Globe de Paris (IPGP);
- Institute for Environment and Sustainabilityof the European Commission Joint Research Centre (IES EC JRC);
- International Association of Geomagnetism and Aeronomy (IAGA);
- International Institute for Applied Systems Analysis (IIASA).

Presently the GIS geodata base includes over 200 thematic layers arranged within 17 data categories including Geodesy and Cartography, Geology, Geophysics, Glaciology, Hydrology, Remote Sensing, Mineral Deposits, Meteorology and Climatology, Pedology, Political Geography, Industry, Agriculture, Biogeography, Ecology. The cartographic base is formed with digital terrain maps at 1:1 000 000 scale. All thematic geodata layers are stored as GIS-projects on database servers providing remote access via Internet.
Examples of visualization of different thematic geodata layers in the GIS are shown in Fig. 1.

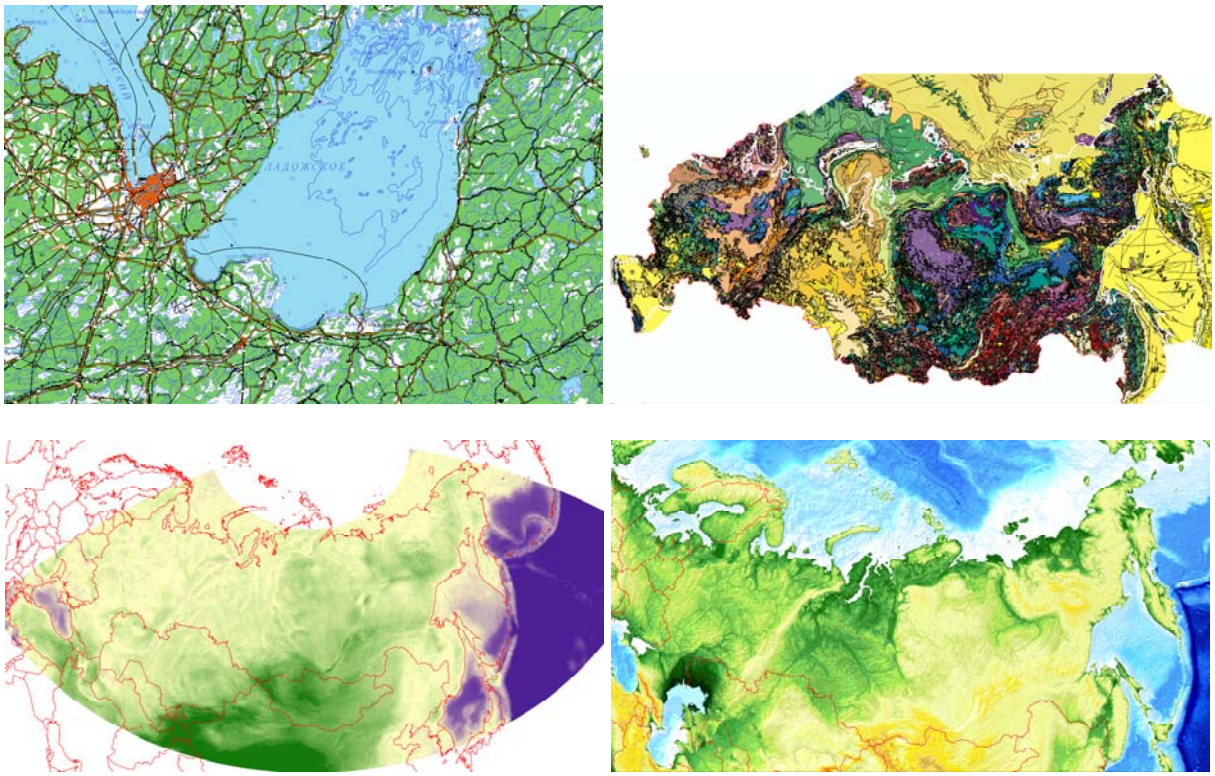

Fig. 1. **Visualization of thematic geodata layers in GIS: (top, left to right) topographic map (fragment, 1 : 1 000 000), geological map (1 : 5 000 000); (bottom, left to right) Bouguer gravity disturbancies (5'), digital elevation model ETOPO1 (1')**

In order to integrate AI methods and algorithms within the GIS a new technology was elaborated. This advanced approach is implemented in the form of the Centralized Catalogue of Geodata Processing Algorithms (CCGPA) [2]:

- The CCGPA is a GIS subsystem providing access to algorithms, which are executed centrally by a GIS-server;
- Users can choose available algorithms from the CCGPA or upload new algorithms to the CCGPA themselves;
- Each new algorithm is checked and published by an administrator and becomes available to other users.

The advantages of this technology are:

- Possibility to upload new algorithms to the CCGPA;
- Possibility to execute a sequence of algorithms on several geodata sets;
- Minimal requirements to user workstation: all computations are performed by the server;
- Access to the CCGPA from any Internet node.

The CCGPA is implemented in three-level architecture as the GIS subsystem [3] on the base of *ArcGIS Server* technology (Fig. 2).

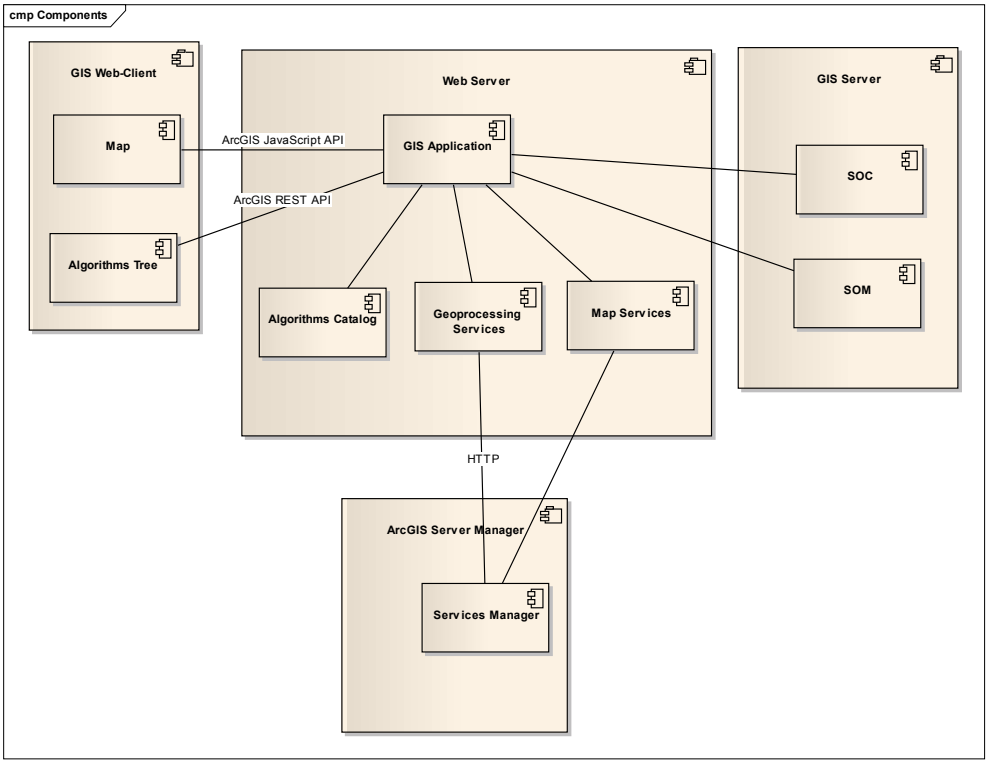

Fig. 2. **Architecture of CCGPA**

The CCGPA is managed by a GIS administrator using *ArcGIS Server Manager* application. The administrator publishes algorithms as *Geoprocessing Services*, which become available to GIS users.

The component *Algorithms Catalog* is responsible for uploading by users of new algorithms and their storage before inclusion in CCGPA. For uploading algorithms a client application opens a special form.

The client application is implemented via *ArcGIS JavaScript API* and includes a component for operations with algorithms (*Algorithms Tree*). When a user launches *GIS Application* via *ESRI REST API*, this component receives a list of *Geoprocessing Services* with the information about them and fills a user's *Algorithms Tree*.

ArcGIS JavaScript API allows to execute the algorithms with the user-specified parameters and returns the results to the client application for visualization.

Geodata processing is performed by the components *Server Object Container (SOC)* and *Server Object Manager (SOM)* of the GIS-server.

To provide interaction between the GIS and its users a GIS visualization subsystem was created. It performs geodata layers visualization, map operations, geodata set management, execution of CCGPA-stored algorithms and representation of application results.

The basic part of the GIS visualization subsystem includes a GIS application, implemented as a web-application. This GIS web-application can be launched at a user's Internet enabled workplace without installation of any additional software. It supports an interface between the GIS, its geodata base, the CCGPA, and remote users.

The user interface of the GIS web-application is represented in a browser window by the following elements (Fig.3):

1. *Map* window, with minimap subwindow to ease navigation
2. *Panel of Instruments* for map operations;

3. *Data*, *Algorithms*, *Results* tabs;
4. *Title* and *Information* line.

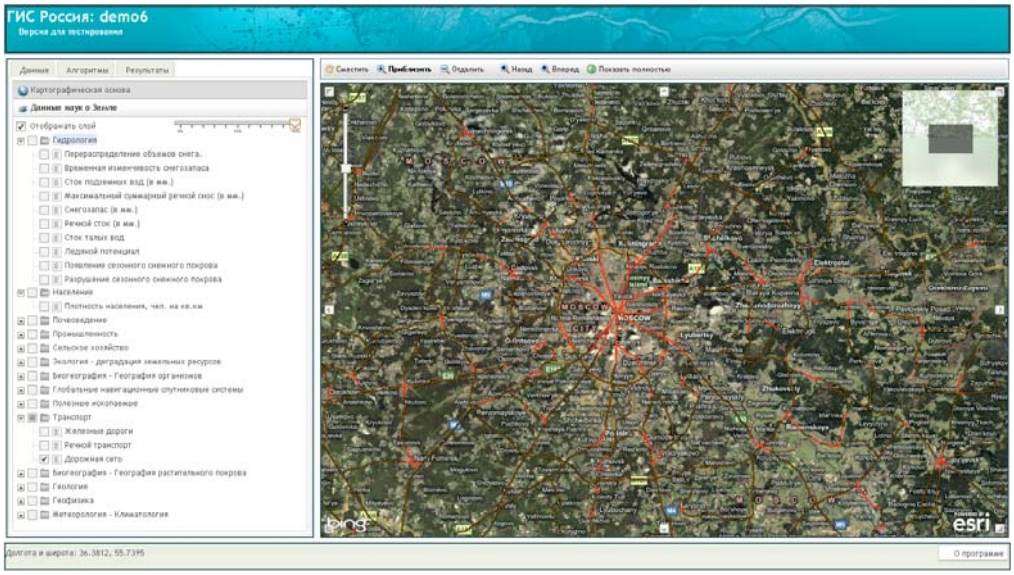

Fig. 3. **User interface of GIS web-application**

The *Data* tab contains a tree of thematic geodata layers available for visualization, including conventional signs and legend. A user can switch the layers on and off by placing or removing a tick in the appropriate box.
Geodata layers chosen by a user in the *Data* are visualized in the *Map* window.
The *Algorithms* tab contains a tree of algorithms available in the CCGPA.
The *Results* tab contains a list of layers created as results of application of chosen algorithms to chosen thematic geodata layers.
It is possible to choose either digital terrain maps at 1:1 000 000 scale stored in the GIS geodata base, or web mapping service applications (*Google Maps*, *Bing Maps*, *Imagery*, *etc*.) as a cartographic base (Fig. 4).
A user can apply to thematic geodata layers visualized in the *Map* window all instruments and operations contained in the *Panel of Instruments* (Fig. 5).

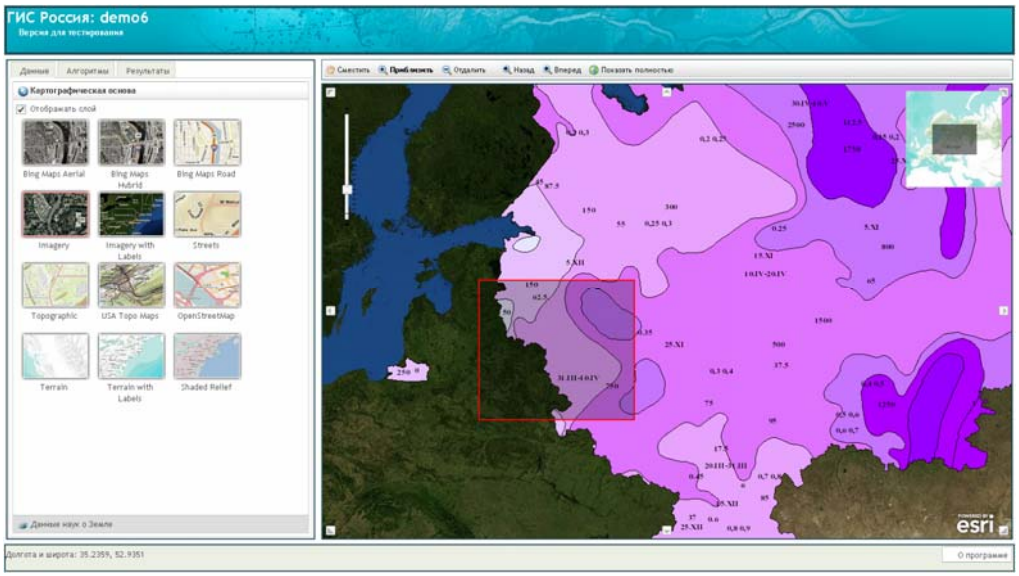

Fig. 4. **Choosing a cartographic base**

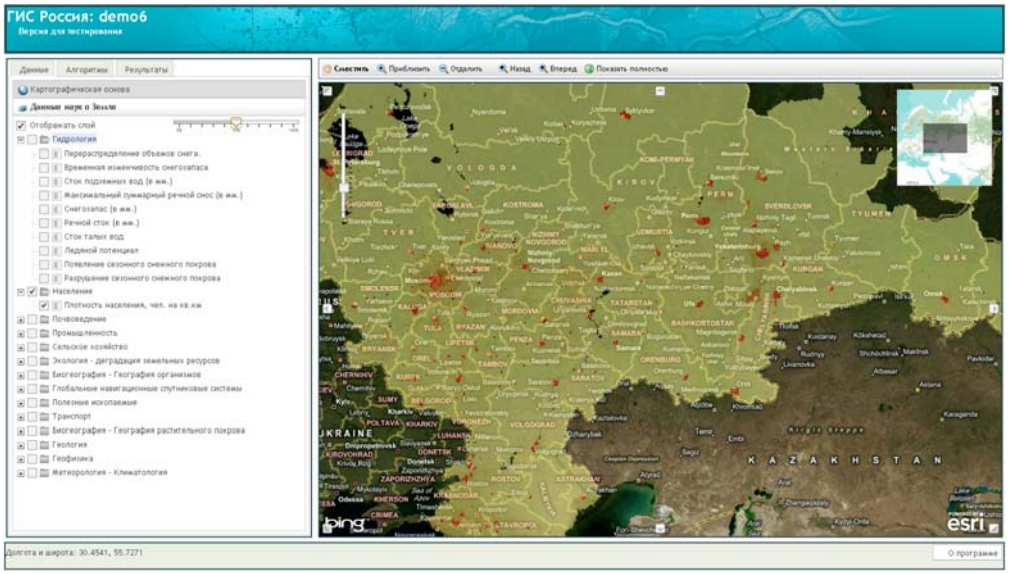

Fig. 5. **Overlaying several geodata sets and changing transparency**

Results and discussion

The developed theory and methods of AI must become not only an integral, but the main core of a modern GIS [4, 5]. At the present time GIS provide only limited opportunities for general analysis of geodata handled. At the same time, among the scientific community, dealing with the Earth sciences data, the requirement of more profound and comprehensive data analyzing and processing is constantly growing. Application of AI methods not only brings the analysis of initial geodata to the higher scientific and practical level, but provides scientifically based recommendations on interpreting the results obtained. The evaluation of natural environment and risk is a task of identification of a complex character of potentially dangerous situation on the basis of huge data volumes of environmental monitoring. The AI methods, developed by the GC RAS, are presently applied to seismology, volcanic activity monitoring, search and interpretation of anomalies in geophysical fields, detecting of signals on various types of times series records, to solving geodynamic problems, *etc*.

On the base of the CCGPA technology an algorithmic shell was constructed in the frame of the GIS, ensuring the intellectual capacity of GIS environment. The shell comprises a set of customizable algorithms for geodata processing and decision making based on geostatistical and AI methods.

CCGPA is a set of algorithms of universal character bound by the common formal framework. It contains fundamental solutions of classic tasks of data analysis: clustering and search of linear structures in stationary multidimensional arrays, construction of smooth skeletons, search of signals and morphological analysis in time series. Fig. 6 demonstrates the results of application of the *K-means* clustering algorithm stored in the CCGPA to geophysical data sets.

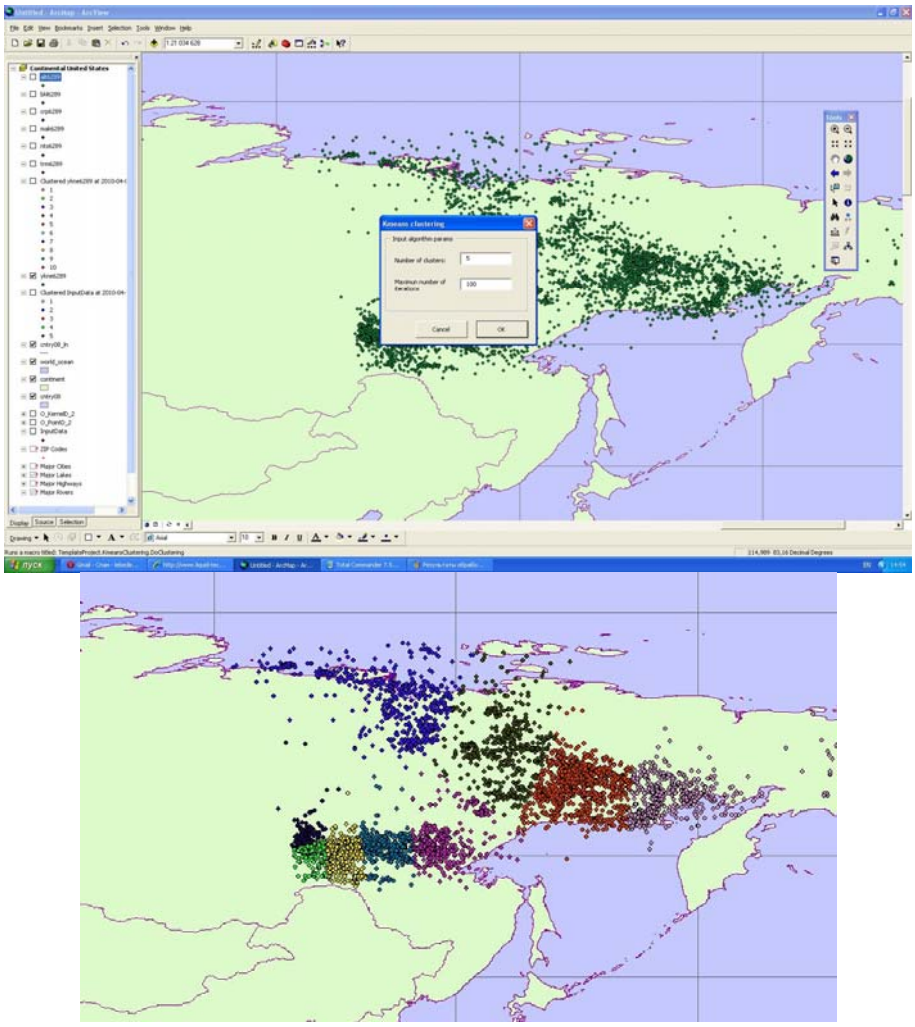

Fig. 6. **Application of CCPGA-stored *K-means* clustering algorithm: (top) input data (earthquake epicenters, Eastern Siberia, 1962-1989) and algorithm parameters window; (bottom) results (clusters are marked in colors)**

Conclusions

Application and complex integration of AI methods and algorithms within the unified geinformation environment are the key features of the discussed intellectual GIS. GIS technologies, based on generalization and complex processing of geodata, in combination with appropriately adjusted AI algorithms stored in the CCPGA, provide efficient automation of Earth sciences data analysis and forecasting for fundamental and applied scientific research.

The interaction between the GIS and remote users is provided by the GIS visualization subsystem. It includes the GIS application, implemented as the web-application, which can be launched at a user's Internet enabled workplace without installation of any additional software. The GIS visualization subsystem supports an interface between the GIS, its geodatabase, the CCGPA, and remote users. Thus the problem of geodatabase publication and interface between data, CCGP and remote users was solved.

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USING OF INFORMATION TECHNOLOGIES TO IMPROVE THE SPATIAL UNDERSTANDING OF STUDENTS

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Abstract. *It is possible to improve the development of students' spatial thinking with various information technologies. We can improve students understanding with three dimensional models, created in the CAD program and special processing it in PowerPoint in the program, together with drafting in three planes. Gradually solving tasks in planes and explaining it in three dimensional models, the solution of concrete task is much clearer, because it is possible to look a situation together in planes and 3D models.*
The students of three faculties were polled that cognize the students' opinions about teachers teaching methods in descriptive geometry lessons and analyze spatial understanding of students.
A possibility to use information technologies to improve a descriptive geometry lectures have been researched in this work.
The most important information about working out methodological materials has been generalized in discussion part.
The results of research show that lectures with information technologies using improve students' understanding of solved tasks during the lectures.

Key words: *descriptive geometry, handouts, multimedia, spatial understanding.*

Introduction

Spatial thinking is especially developed in many specialists preparation for practical activities. The high level of spatial thinking is necessary for many technical subjects understanding at different learning steps.
The disadvantages in spatial thinking development are seen in mastering of descriptive geometry.
So there has been worked out the methodology for descriptive geometry mastering in learning process using multimedia technologies.
These technologies allow not only to master learning material, but as well to improve the students' level of understanding during the lecture. Using multimedia technologies it is possible to move spatial objects and so to make the lecture more perceived and understandable in short time. Multimedia technologies are more often used in learning process and they can be considered as an integral part of learning process.
So it is necessary to change learning methods including multimedia technologies into the learning process. In the descriptive geometry it is possible to animate or move spatial models and accordingly to depict on the screen.
Research aim: to clarify the multimedia technologies influence on students' spatial understanding.
Research hypothesis: using multimedia technologies at descriptive geometry lectures students' spatial understanding has been improved.

Materials and methods

In the research participated to 172 students from Latvia University of Agriculture Forest Faculty, Faculty of Engineering and Faculty of Rural Engineering.
In experiment were two groups: control and experimental. In control group a themes of descriptive geometry (Projection of a point; projection of a line; projection of a plane; relations between a point, a line and a plane; change of projekction planes; intersection of a

line (plane) and a plane; intersection of a plane and a surface; intersection of a surfaces) explained on a blackboard, and in experimental group - use of multimedia.
Author use Auto CAD and PowerPoint software for lecture development. Materials have published at E-studies environment, too. Author has made the combated descriptive geometry study courses with interactive e-learning elements.
When the students of each group had write opinion survey about descriptive geometry themes, which has been considered during the lecture. Opinion survey is created for check of understanding a concrete theme of a lesson.
The results of research are processed by software SPSS. In order to find out a statistically significant difference between control and experimental groups was conducted Mann-Whitney test between groups.

Results

At first, it was found out how substantially are differences of understanding in descriptive geometry between control and experimental groups, conducted Mann-Whitney test between groups.
The hypothesis was advanced, that understanding in descriptive geometry is equal in both groups.
Table 1 (understanding) result shows that comparing the data on two groups according to the grouping variable group, it can be concluded that there are significant differences between control and experimental groups $p = 0.000 < 0.05$ ($p = 95$ %).
So between control group and experimental group exist differences of understanding in descriptive geometry. On a figure 1 it is possible to see control and experimental groups percentage understanding of the concrete complete theme.

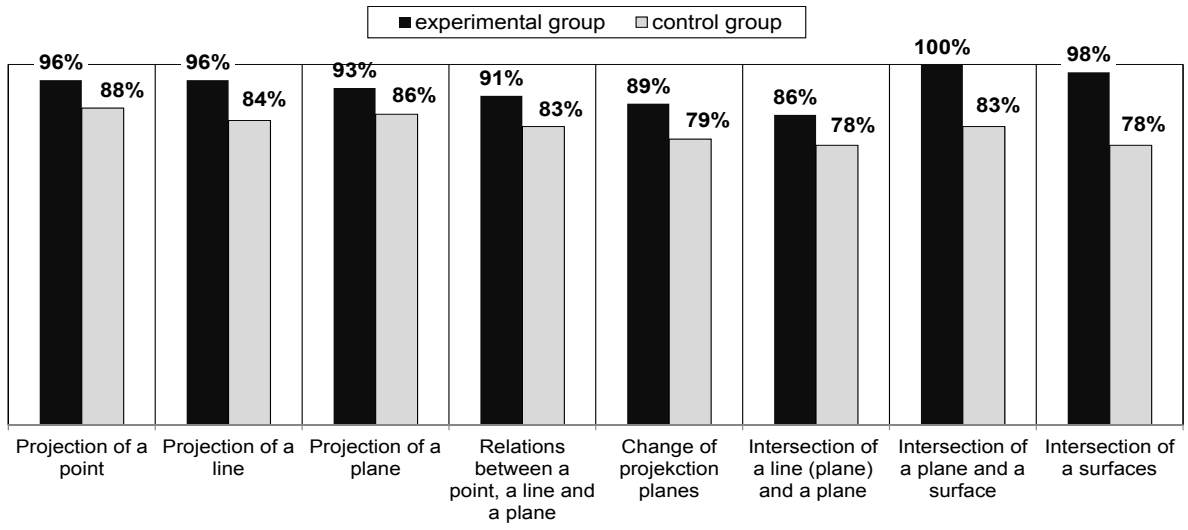


Fig. 1. **Control and experimental groups differences of understanding**

Secondly, was found out how substantially are differences of incomprehension in descriptive geometry between control and experimental groups.
The hypothesis was advanced, that incomprehension in descriptive geometry is equal in both groups.
Table 1 (incomprehension) result shows that comparing the data on two groups according to the grouping variable group, it can be concluded that there are significant differences between control and experimental groups $p = 0.000 < 0.05$ ($p = 95$ %).

Table 1.

Test results

	understanding	incomprehension
Mann-Whitney U	79206.000	2136.500
Wilcoxon W	185236.000	5539.500
Z	-7.709	-3.961
Asymp. Sig. (2-tailed)	0.000	0.000

So between control group and experimental group exist differences of incomprehension in descriptive geometry.

Discussion

Spatial thinking can be considered as a mental peculiarity of any person which provides the orientation in the space – visible or imaginary [1].

Spatial thinking is a kind of mental activity, providing the forming of spatial images and using them in the process of fulfilling practical and theoretical tasks [2].

Spatial thinking is formed at all steps of ontogenesis under the influence of different teaching/ learning affects [3].

Developing of imagination is the most important condition to master the skill of descriptive geometry and reading the draught and graphic activity in general. At the same time teaching descriptive geometry is one of the most important means to develop imagination [4].

The most important principle directed to the learning process is the following: at the beginning of mastering new material of descriptive geometry students are taught the elementary methods, which are characterized by additional base on visual aids, and then the methodology has to provide changing the teaching ways so, that a student made images without any additional base, that is mentally, by imagination. The students' transition from activities with additional base to mental in the process of imagination reveals a regularity, which means, that in the process of mastering any knowledge a great role plays the transition from actual activities or activities with visual aids to mental ones, that is to activities in mind.

This transition should be done in time. If the students are taught the "visual" methods of learning activity too long, not including imagination, if can complicate the development of their spatial imagination [5].

Perception is a complicated system of receiving and transforming information, which provides the organism with an ability to reflect the objective reality and to take one's bearings in the surrounding world.

Visual perception includes various sources of information besides those, which are perceived by eyes, when we are looking at the object. In the process of perceiving, as a rule, is included the knowledge about object got from the previous experience and this experience is not limited by vision. It one more time underlines the active process of perception [6].

To form imagination it is necessary to master understanding, because understanding determines the content of image. Spatial imagination as regards to thinking is an initial base, condition of development, but at the same time forming the notions demands to master them, to master facts in advance. If can be said, that the process of forming spatial imagination about geometrical objects is realized on the base of knowledge about them [7].

Spatial thinking is one of thinking kinds which is characterized as the whole of cognitive skills. These skills include: declarative and perceiving forms of knowledge, as well various cognitive processes, which are used to transform and combine or to operate the knowledge in other way. In the base of cognitive process are included all knowledge, skills, experiences, which are used to think, discuss, solve problems, organize, plan and take the decision.

Cognitive processes give a possibility to solve personal, social and international problem systematically, avoiding the repeated attempts and mistakes [8].
Spatial thinking as well as other kinds of thinking, is based on thinking operations, but its content is formed by spatial dimension. By thinking process is understood: analysis and synthesis, comparison, classification, systematization, generalization, abstraction, concretization.
Analysis is a thinking operation, which helps to break a phenomenon into smaller parts, separate elements or groups, and as a result to get much simpler phenomenon, a group of elements or parts which understanding by its sense is clear.
Conducting descriptive geometry lectures, it is necessary to provide a possibility to break a complicated spatial task into its smaller parts and as well to provide the usage of preliminary obtained knowledge and skills in fulfilling the corresponding parts task. For example, at lectures in which are considered complicated figures (Figure 3) it is necessary, first of all, to break it them into basic elements, that is, to consider what straight lines and planes this figure consists of, or what straight lines or planes are presented in the real size, or the angles formed by these planes or straight lines are in the real size (Figure 2); and only after that to start solving the task. Such task organization assists the improvement of spatial thinking, because is formed the deep understanding what angles, planes and straight lines mutual position, and only after that is analyzed in what kind of task fulfilling in addition to the concrete task soloing methods and ways we can use features of these basic elements.

Pyramid		Prism	
Straight line ✚ General position ➢ ... ✚ Special position ➢ Level • horizontal ... • frontal ... • profile ... ➢ Projecting • horizontal projecting... • frontal projecting... • profile projecting...	*Plane surfaces* ✚ General position ➢ ... ✚ Special position ➢ Level • horizontal ... • frontal ... • profile ... ➢ Projecting • horizontal projecting... • frontal projecting... • profile projecting...	*Straight line* ✚ General position ➢ ... ✚ Special position ➢ Level • horizontal ... • frontal ... • profile ... ➢ Projecting • horizontal projecting... • frontal projecting... • profile projecting...	*Plane surfaces* ✚ General position ➢ ... ✚ Special position ➢ Level • horizontal ... • frontal ... • profile ... ➢ Projecting • horizontal projecting... • frontal projecting... • profile projecting...

Fig. 2. **Complicated figures break into basic elements**

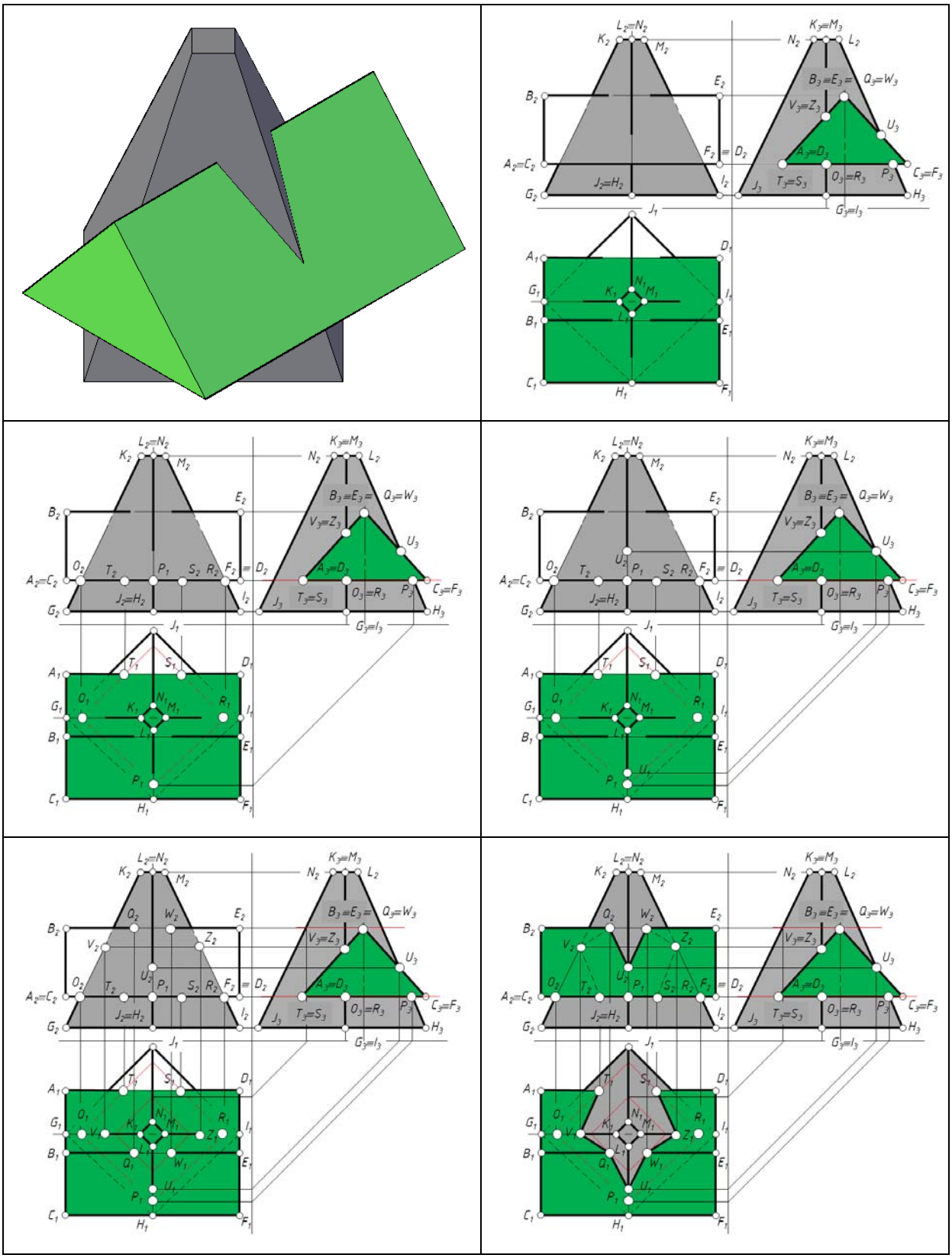
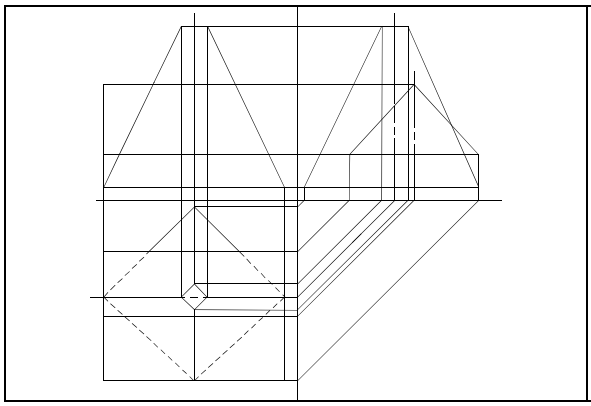


Fig. 3. **Example of complicated figures**

For better observe bases of the theory - it in the form of definition should be told, passing significant words which to students should be entered in the definition (Figure 4).



Intersections between prism and pyramid basic elements find with..... ..... method

Intersections between the basic elements of special position.....

Intersect lines find connecting..... .... .

Fig. 4. **Definition of complicated figure solving**

These operations are better with handouts employed in lectures. Correspondingly, the thinking operation of *synthesis* has been revealed, which is interpretated as different phenomena, their parts or separate group elements combining into are operation or as well as the close interaction of these elements in one phenomenon.
Having considered above mentioned examples, we can see when during the synthesis operation are realized invisible spatial activities either in practice, forming the understanding about existing phenomena (angles a real size links), or, forming understanding about space. Separate activities, mastered knowledge and new skills are united, forming new skills by the quality, which include spatial thinking skills too.
Analysis and synthesis are realized with the help of other thinking operations. As one of those thinking operations is *comparison*, which is expressed as determination of compared objects, phenomena and facts. Also comparison is understood as the determining or reviewing of united criteria. To visualize the operations of comparison in the spatial context let us consider the same task. In this task it is necessary to review, that there are two cross points of basic elements, which are found not using special methods, because are crossing the special planes with the special straight line, the difference is only in the location of these basic elements. In one case are crossing the profiles of projected prism planes BCEF with the profile of pyramid straight line LH, but in the second case are crossing the same profiles of projected prism planes ABDE with the front pyramid straight line GK. Both in the first and in the second case the cross point is looked for in the planes of profiled projections, because the prism profiles of projected planes are represented as a straight line. This kind of activity is expected to have definite difficulties, the realized comparison is happening in reflection and demands the great efforts of operative memory, and especially, if in the previous experience have not been understood the mutual features of planes and straight line positions. Before solving such kind of task there should both experience and skills to determine the cross point of basic elements.
Classification is the next thinking operation, which is much more difficult than comparison, because it demands to unite objects, phenomena or operations into groups according to their similarities. When a student, comparing, have understood the essence of all projected, leveled and common basic elements positions, he is already able to classify them, and according to this classification to know, not comparing, that all cross points of projected planes with straight lines are seen in the planes of projections, in which these planes are reflected as straight lines or in front of which these planes are perpendicular. Classification gives a possibility to release the operative memory, and as a result to improve other mental activity.

As well on the map the represented information is classified and reflected according to the group of space objects.
Systematization is similar to classification, which is expressed as dividing the whole into parts. Systematization in the spatial dimension provides the mutual ties and consequences of regularities in general, and thus forming the necessary task or thinking algorithm and having understood it, is formed a possibility to look at the fulfilling task from the other point of view.
Generalization as a thinking operation is unification according to common features. And in the result the solving of different spatial problem situations, the algorithm can be similar.
Abstraction as one of the most difficult phenomenon of thinking process, because is connected with clearing up of essential features, and in the result are formed regularities. Fulfilling the task, in the base of which is the comprehension of know spatial regularities promotes more perfect understanding of definite question, and thus appears a possibility to form new knowledge, regularities, spatial experiences and skills. In the result of abstraction a student is able to see the distinct lines, where they must be and how they could look like. Fulfilling such kind of tasks the manipulations happen mainly in the mental dimension. Running into difficulties to imagine any process or an object, it is very effective to use modern computer technologies, which allow visualizing both an object and a process itself in the space.
Concretization is understood as using of general knowledge not only for matching any definite example to corresponding regularity, but as using corresponding regularities in the fulfilling of definite task and forecasting the results. It is very important for students to know at least one of the methods to solve the task, to be able to use it in any task and understand the essence of these methods in space.

Conclusions

- Between the control group and experimental groups in Descriptive Geometry exist differences of incomprehension and understanding.
- Using of multimedia technologies in lectures gets better the students' spatial understanding.
- Using of special handouts helps students to break objects in basic elements and understand the theme better.

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RESEARCH OF COMPUTERIZATION AND IMPLEMENTATION OF THE E-PRESCRIPTION FOR INDIVIDUAL PHARMACIES

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Abstract. *The paper deals with establishment, implementation and development of electronic prescription or e-Prescription in context with e-Health solutions. It includes introduction of a numerous innovative solutions, which are to be committed for data information flow, data management and functionality as well as of establishment of a new feasible communication forms between doctors, patients and pharmacists. The aim of the study is to describe some technical aspects and functionality of implementation of e-Prescription system for medical institutions, patients and pharmacies; and, calculation of the total cost of implementation (TCI) for Latvian individual pharmacies. Several expecting financial aspects, which have encompassed evaluation of TCI, calculating payback time, ROI, NPV, and IRR are to be calculated. On the bases of these financial calculations, the primary investment of implementation of e-Prescription for individual pharmacies and initial costs are determined. Impact on individual parts of TCI with the scope to individual pharmacy size, location, existence or absence of formal information strategy has calculated. According to collected data, research paper shows how proposed electronic system is going to implement among Latvian individual pharmacies.*

Keywords: *electronic prescription, Latvian individual pharmacies, total cost of implementation.*

Introduction

With the advent of information technology pharmacy has been touched with a new paradigm, which is underpinned in 2006 by Introductory Handbook. This handbook is devoted to and emphasized pharmacy practice approach that should be carried out by doctors, patients, and pharmacies. Necessity of new paradigm is pointed out on a Foreword of Introductory Handbook and it can sound as following:

Pharmacists should move from behind the counter and start serving the public by providing care instead of pills only. There is no future in mere act of dispensing. That activity can and will be taken over by the internet, machines, and/or hardly trained technicians. The fact that pharmacists have an academic training and act as health care professionals puts a burden upon them to better serve the community than they currently do.

This new approach has named ***pharmaceutical care.*** On the bases of given definition International Pharmaceutical Federation (FIP) gives a key definition of pharmaceutical care.

Pharmaceutical care is the responsible provision of drug therapy for the purpose of achieving definite outcomes that improve or maintain a patient's quality of life.

Pharmacists, being effective health care team members, may need skills and attitudes enabling them to assume many different functions. The concept of the "seven-star pharmacist" was first introduced by World Health Organization (WHO) and can be taken up by FIP on 2000 in its general policy statement on Good Pharmacy Education Practice, which should cover such roles: caregiver, decision-maker, communicator, manager, life-long learner, teacher and leader.

According to Introductory Handbook, term researcher is added in it as an eight`s function. With the naked eye there can be able to see that, in order to realize pharmacy paradigm, it should be necessary to introduce a numerous innovations into practice, which should be entailed by Information and Communications Technologies (ICT). In addition, pharmacist in

his everyday work ought to be engage in management, a system, which is complicated to manage.

Concept of e-Prescription

European Commissioner for Digital Agenda, Neelie Kroes stated [1]: “e-Health is our key to more sustainable healthcare - it's as simple as that. There's literally no other way to pay for and manage the workload our systems will experience in the coming years. And given that e-Health initiatives like telemedicine are leading to a safer, longer and higher quality of life - the question isn't whether to invest. The question is - where do I sign up?”

The clear answer would have consisted of establishing interoperable e-Health services for all stakeholders; in which, one certain and main part would be electronic prescription information system (IS), so called e-Prescription.

e-Prescription means a medicinal prescription, i.e. a set of data like drug ID, drug name, strength, form, dosage and/or indication(s), provided in electronic format. This is understood as the prescription of medicines using software, the electronic transmission of the prescription from the Prescriber (the Health Care Professional or Doctor) to a dispenser (e.g., pharmacy or Pharmacist), where the prescription is electronically retrieved, and the medicine is given to the patient (e.g., e-dispensation) and information about the dispensed medicine(s) is reported electronically.

Decision on creating e-Health solutions in Latvia was undertaken into an effect on 17th August, 2005 when e-Health guidelines and related documents having been accepted by the Cabinet of Ministers, issuing an order Nr. 560 which documented “e-Health Guidelines”. While another important linked up document named “Architecture of the Information Systems of the Health Sector” describes high level architecture for systems, which have to be ensured the realization of e-Health Program [2].

e-Prescription information flow

In order to improve the quality of patients’ health care, in which one important part should be pharmaceutical care, there are going to be unfolded and maintained Electronic Health Card (EHC) record. There where will be summarized and kept together basic data from all available sources picked up from patient`s different medical records into one common data basing information system. Opening patient`s EHC medical personal, wherever it would be located will be able to access to patient`s data, diseases, diagnoses, diseases tests, vaccines, patents used medicine and more other necessary information for treatment and recovery of the patient health.

e-Prescription [3] means substituting existing documents` flow of the paper format between medical institutions and pharmacist with electronically created documents; therefore, establishing electronic based services for doctors, patients and pharmacists. Accessibility by all parties to the so call drug journal can to be depended from each group before-given priority level.

e-Prescription will be integrated into e-Delivery system [4] as a part of a common centralized data exchange unit, from where medical institutions and pharmacies will be able to connect through their local information system or, for instance, through using WEB portal. As an advantage of this integrated based solution it should right to mention that each patient would be able to get access to his/her health care information as well as to pharmaceutical care information, especially to prescribed drugs. There is behaviorally speaking evidence for creating a new relationships and communication among doctors, patients and pharmacists, which are to be supposing on cooperation and partnership.

Implementation of e-prescription can be touched with clinical data flow (treatment data), financial information flow and administrative data flow. These information flows [5] should be ensure accomplishment of such a main functions of e-Prescription:

1. Maintenance and distribution of pharmacy goods classificatory for recipes` medicine, sold without prescription medicines` and for the medical devices.
2. Reception of the data from Health Payment Centre (HPC) on the rights for reimbursable drugs and the medicine device to be invoiced.
3. Opportunities to modify and added e-Prescription rights from administrative interface.
4. Opportunity among pharmacies to receive information about e-Prescription (based on patients ID) and to be registered e-prescription into the system for prescriptions full or partial hand out, using pharmacies IS or e-Health portal.
5. Opportunity for doctors to prescribe electronic prescriptions using medical institution IS or e-Health portal.
6. Patients and physicians data access rights to checked by EHC system.
7. Payment information of processing of using e-Booking systems financial module.
8. Patients work with their recipes (using e-Health portal) in order to see prescription to be prescribed to patient and patients medical supplies to be received.

e-Prescription functionality

Introduction of e-Prescription in Latvia and; therefore, its implementation costs, as from pharmacies wholesaler or pharmacies chains till individual pharmacies point of view are closely related of introduction of national e-Health system into one integrated unit. As mentioned before, it provides creating a conceptual development of the e-Health and IS architecture into one unified single national-wide level. That means, having been integrated separate IS sectors together with records of national significance (CSDD, URL, VZD, PMLP etc.) into one integrated IS [2]. Thus, creating a single e-Environment is related to have access to both health care and pharmaceutical care information.

Organization which is responsible for introduction of e-prescription in Latvia is the Centre of Health Economics (CHE) attracting from ERAF budget (2007-2013) 7 408 000 EUR for the first stage. There will in this first stage be intended to be introduced EHC (1 668 000 EUR); health integration platform (941 000 EUR); e-Prescription, e-Appoinment (appointment with a doctor), e-Refer (refer to doctor) (all total 2 126 000 EUR) [6].

e-Prescription can be used for and getting access to: (1) prescription of the conventional recipe; (2) prescription of the special recipe; (3) information about prescribed medicine within EHC IS; (4) to emergency medicine IS; (5) vigilance reports; as well as (6) business intelligence.

All above mentioned are integrated through Electronic Message Exchange (EME) to e-Prescription electronic service. The functionality [6] of the e-prescription is shown on Fig. 1.

As can been seen from Fig.1. e-Prescription IS can basically has ensured prescription circulation between doctor, pharmacist and patient.

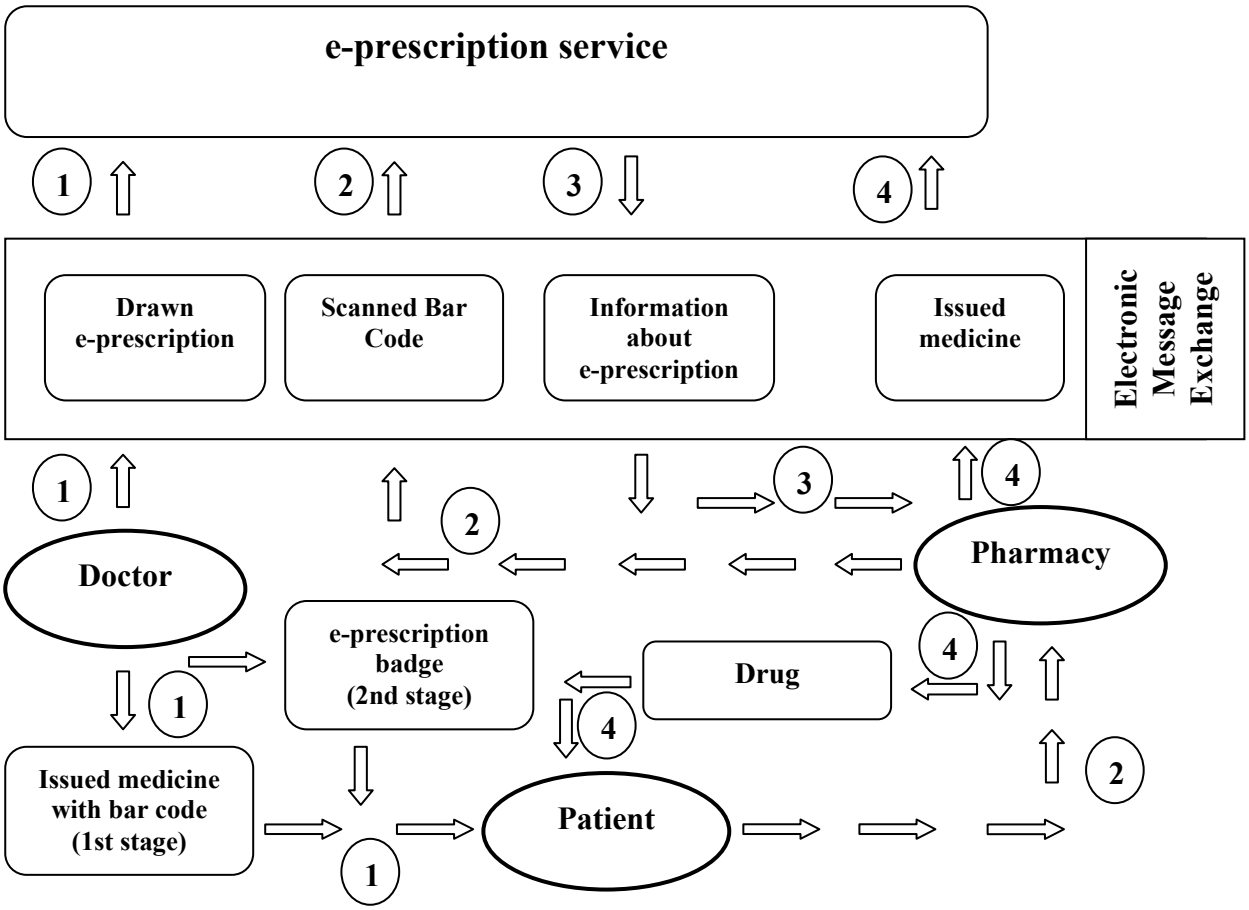

Fig.5. **The functionality of the e-prescription**

Research object and tasks

On April 30, 2010, the number of pharmacies are decreased reaching 846: among them 124 pharmacies - pharmacist as one of the owners of the pharmacy; 87 pharmacies - pharmacist as an owner of the pharmacy; 216 pharmacies - pharmacists, assistants of pharmacist, persons with other education or collective body of pharmacy. There are 427 individual pharmacies, which mainly are located in region towns and region small rural areas. These pharmacies are the object of the research, which means, approximately a half from the total number of all Latvian pharmacies. The rest 418 pharmacies belong to the pharmaceutical chains, which are mainly located in 9 cities – Riga, Jūrmala, Jēkabpils, Jelgava, Daugavpils, Liepaja, Ventspils, Valmiera un Rēzekne, as well as, in large regional cities.

Our task was to be sizing up how Latvian regional towns` and regional small rural areas individual pharmacies realizes current provision of law at pharmaceutical care, how the owners of the pharmacies look forward on introduction of ICT for expected introduction of electronic prescription. Comparing to other pharmacies individual pharmacies mainly are located at region small rural areas where the density of the population is low, but the serving area broad.

Problems will be risen for these pharmacies, if small pharmacies should be to financed introduction of pharmacy IS and its further integration to e-Prescription by themselves. Initially, paper format prescription will be anticipating together with electronic prescription. For long term both electronic and paper format might to be economically unprofitable for government. Thus, small pharmacies should be ready to up-to-date their operations. Having

unable to do that, it can take negative impact on an availability of the medicine and health care at rural region areas. Due to transport problems, not all countryside population will be able to go to the nearest regional city for necessary medicine, So, two main research tasks has been risen on issuing:

1. Performing questionnaire survey, define pharmacies attitude and readiness towards pharmaceutical care.
2. Counting all primary costs, consist with introduction of electronic prescription and possible consequences.

Costs express analysis for ICT systems introduction

One of the key points of introduction of ICT system for Latvian individual pharmacies is capital budgeting. From the business point of view, the introduction of the new IS ought to have got an additional profit or at least cost decrease for individual pharmacies. Operations around individual pharmacies we cannot evaluate from the business perspective. Calculation on capital budgeting is based on project management and we assumed that ICT system introduction is looking a project.

Once the potential capital budgeting has been identified its evaluation is based on the following methods. First method is to calculate **net present value** (NPV), which relies on discounted cash flow (DCF) techniques. To implement this approach it should be proceed as follows. (i) Find the present value of each cash flow, including both inflows and outflows, discounted at the ICT systems cost. (ii) Sum these discounted cash flows and this sum is defined as the ICT systems NPV. (iii) If NPV is positive, ICT system should be accepted, while, if the NPV is negative, it should be rejected.

The equation for the NPV is as follows:

$$NPV = \sum_{t=0}^{n} \frac{CF_t}{(1+r)^t}$$

where, CF_t - is the expected net cash flow at period t, Ls

r - is the ICT system`s cost of capital or discount coefficient

t - is its life (in years)

Net cash flow at period t is as follows:

$$CF_t = NI_t + Dep_t$$

where, NI_t - is net profit at period t, Ls

Dep_t - depreciation at period t, Ls

Net profit calculation which is based on gradually table calculation method can be transformed in one common equation where corporate income tax is to consider as a function:

$$NI_t = NOI_t - Dep_t - I_t - T(NOI_t; Dep_t; I_t)$$

where, NI_t - net profit at period t, Ls

NOI_t – operating profit including depreciation at period, t, Ls

Dep_t - depreciation at period t, Ls

I_t – interest payments at period t, Ls

$T(NOI_t; Dep_t; I_t)$ - corporate income tax at period t as a function of operating profit, depreciation at period t, and interest payment at period t in Ls.

Second method is to calculate the ICT system **payback time**. Third, **the return on investment** (ROI) and, fourth, **internal rate of return** (IRR).

Primary investment that anticipates initial costs for hardware and software has been estimated in range from 1 500,- to 3 000,- Ls. Calculations is based on the smallest monthly maintenance costs 35,- Ls and coefficient of discount 0.05.

Original calculations show that there are not expected not substantial costs decreases nor revenue increases. In fact, the introduction of the ICT system will not be able to create an

additional cash flow for individual pharmacies. There are restrictions in legislation in Latvia on issuing the licenses for pharmacies operations` depending from the number of local inhabitants. That is the answer why in rural areas unlike large cities there is only one pharmacy with permanent number of its clients. It is potentially impossible substantially increase a number of its clients. As a result, individual pharmacies are not a unit of business in its normal sense. Thus, the public authorities` decisions in case of introduction of ICT system are important for them.

Calculating capital budgeting there is evaluated individual pharmacies cash flow at ten-year period starting from introduction of the ICT system from ground. It is based on and to be depending from current annual profit (profit before introduction of the ICT system).

If current annual profit does not cover 50% from primary investment then there is anticipated to take credit from bank at 5-year period with an interest rate from five to 10%. Calculation shown on Table 1 illustrates necessary current profit derived from foregone income for three different groups (for all groups NPV>0). (j) Foregone income is less than 20% from total annual profit. Individual pharmacies belonging to this group, whatever is the primary investment, will not touch with problems of introduction of the ICT system. (jj) Foregone income is more than 20%, but less the 50%. Individual pharmacies belonging to this group are under discussion. (jjj) Foregone income is between 50% and 100% from annual profit. Individual pharmacies belonging to this group are impossible to introduce ICT system and e-prescription, also.

Table 1.

Necessary current profit, grouped, as foregone incomes, after systems introduction

Primary investment, Ls	Current profit, in Ls, if foregone income after system`s introduction (NPV>0)		
	≥50% <100%	≥20% <50%	<20%
1500	**>650**	>1300	**>3850**
2000	**>700**	>1450	**>4250**
2500	**>750**	>1550	**>4700**
3000	**>800**	>1700	**>5050**

On the basis of this calculations, there can be predicted that the introduction of the system is not possible at all, if current profit is less than 650,- Ls. Moreover, financially weak individual pharmacies have currently incomplete infrastructure and introduction of the system charges higher investments for them. That means, after 10 year period the new system will create losses and will go bankrupt those pharmacies whose current profit does not today reach 800,- Ls. Pharmacies with annual profit, which from 1 300,- Ls to 1 700,- Ls are also threatened and introduction of the new system is under consideration. In general, this system could be introduced at pharmacies, whose current profit reaches beyond 3 850,- Ls. Capital budgeting research has been established a fact that taking a credit from bank marginally influence the data shown on Table 2. Because, in relation to primary investment there are comparatively high operating costs, which annually are 420,- Ls or 14% to 28% of current investment.

Figure 2 shows sample of 36 provincial towns` and countryside pharmacies turnover in Latvian lats from the population of 427 pharmacies.

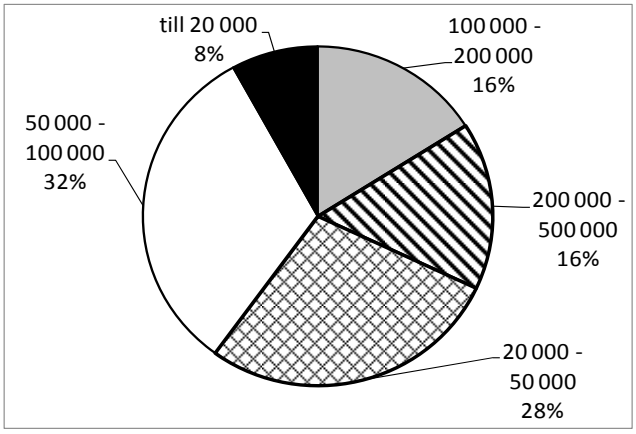

Fig. 6. **Provincial towns` and countryside pharmacies turnover in lats**

In order to perform an express analysis the data is proportionally taken based on the pharmacies annual turnover, see Figure 2. Having into account express analysis and expert estimate, the potential profit depending from the pharmacies turnover has calculated. This is of course depended from different additional collateral factors: space rent, salary etc. As a result, there has a first approximation of estimated profit depending from pharmacy turnover see Table 2.

Table 2.

Number of pharmacies and estimated profit depending from pharmacies turnover

Nr	Turnover of pharmacy and percentage from total number of pharmacies	Number of pharmacies	Estimated profit
1.	to 20 000 (8%)	34	Not
2.	20 000 – 50 000 (28%)	120	Not
3.	50 000 – 100 000 (32%)	137	to 3 000
4.	100 000 – 200 000 (16%)	68	3 000 – 5 000
5.	200 000 – 500 000 (16%)	68	5 000 – 10 000

Conclusions

From the financial point of view introduction of the system is not possible for 36% (8% + 28%) from total number of pharmacies. Moreover, financially weak pharmacies have incomplete infrastructure and introduction of the system charges higher investments to them. These pharmacies cannot increase their situation simply borrowing money from bank, because in relation to primary investment there are existed comparatively high operating costs, which annually constitute 14 to 28% from primary investment. Planning system would be successfully introduced by pharmacies whose profit reaches 3 850,- Ls. Problems will be risen for 34% all registered pharmacies or 68% individual registered pharmacies in Latvia.

It is quite clear that large half of individual pharmacies will not separately be ready to introduce necessary innovations in their practice. The given research of pharmacies has also shown that large half of pharmacies have only a weak sense on above mentioned innovations and necessity of establishment of the system. After study of the problem, there would be several solutions: joint venture of pharmacies, government support, attraction of EU structural funds etc.

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THE CHOICE OF METRICS FOR CLUSTERING ALGORITHMS

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Abstract. *Methods of data analysis and automatic processing are treated as knowledge discovery. In many cases it is necessary to classify data in some way or find regularities in the data. That is why the notion of similarity is becoming more and more important in the context of intelligent data processing systems. It is frequently required to ascertain how the data are interrelated, how various data differ or agree with each other, and what the measure of their comparison is. An important part in detection of similarity in clustering algorithms play the accuracy in the choice of metrics and the correctness of the clustering algorithms operation.*

Keywords: *metric, clustering algorithms.*

Introduction

Nowadays the concept of *regularity or similarity* is acquiring more and more attention in the representation of intelligent data processing system operation. In many cases it is necessary to ascertain in what manner the data are interrelated, how various data differ or agree with each other, and what the measure of their comparison is. In various dictionaries the term *regularity* or similarity is interpreted as similarity, conformity with a law or conclusion by analogy. Regularity can be considered determined correctly if it explains the results of all experiments that relate to the given area of operation.

The main purpose of metric learning in a specific problem is to learn an appropriate distance/similarity function. Metric learning has become a popular issue in many learning tasks and can be applied in a wide variety of settings, since many learning problems involve a definite notion of distance or similarity [1]. A metric or distance function is a function which defines a distance between elements of a set [2, 3]. A set with a metric is called a metric space. In many data retrieval and data mining applications, such as clustering, measuring similarity between objects has become an important part. Normally, the task is to define a function Sim(X,Y), where X and Y are two objects or sets of a certain class, and the value of the function represents the degree of "similarity" between the two. Formally, a distance is a function D with nonnegative real values, defined on the Cartesian product X x X of a set X. It is called a metric on X if for every x,y,z ε X:

- D(x,y)=0 if x=y (the identity axiom);
- D(x,y) + D(y,z) ≥ D(x,z) (the triangle inequality);
- D(x,y)=D(y,x) (the symmetry axiom).

A set X provided with a metric is called a metric space.

Distance metrics overview

Euclidean distance is the most common use of distance – it computes the root of square differences between coordinates of a pair of objects:

$$D_{XY} = \sqrt{\sum_{k=1}^{m}(x_{ik} - x_{jk})^2} \quad (1)$$

Manhattan distance or city block distance represents distance between points in a city road grid. It computes the absolute differences between coordinates of a pair of objects:

$$D_{XY} = \sum_{k=1}^{m} |x_{ik} - x_{jk}| \quad (2)$$

Chebyshev distance is also called Maximum value distance. It computes the absolute magnitude of the differences between coordinates of a pair of objects:

$$D_{XY} = \max_k |x_{ik} - x_{jk}| \tag{3}$$

Minkowski distance is the generalized metric distance:

$$D_{XY} = \left(\sum_{k=1}^{d} |x_{ik} - x_{jk}|^{1/p}\right)^p \tag{4}$$

Note that when p=2, the distance becomes the Euclidean distance. When p=1 it becomes city block distance. Chebyshev distance is a special case of Minkowski distance with p=∞ (taking a limit). This distance can be used for both ordinal and quantitative variables.
The distance measure can also be derived from the correlation coefficient, such as the Pearson correlation coefficient. Correlation coefficient is standardized angular separation by centering the coordinates to its mean value. It measures similarity rather than distance or dissimilarity:

$$r_{ij} = \frac{\sum_{k=1}^{d}(x_{ik}-\bar{x}_i)(x_{jk}-\bar{x}_j)}{\sqrt{\sum_{k=1}^{d}(x_{ik}-\bar{x}_i)^2 \sum_{k=1}^{d}(x_{jk}-\bar{x}_j)^2}}, \tag{5}$$

where $\bar{x}_i = \frac{1}{d}\sum_{k=1}^{d} x_{ik}$. Noticing that the correlation coefficient is in the range of [-1, 1], with 1 and -1 indicating the strongest positive and negative correlation respectively, we can define the distance measure as

$$D_{XY} = (1 - r_{ij})/2 \tag{6}$$

When using correlation coefficients for distance measures, it should be taken into consideration that they tend to detect the difference in shapes rather than to determine the magnitude of differences between two objects.
In order to illustrate different metrics the following two points will be applied: point X has coordinate (1, 2, 3, 4) and point Y has coordinate (5, 6, 7, 8).
For example, the Euclidean distance between point X and Y is:

$$D_{XY} = \sqrt{(2-3)^2 + (3-5)^2 + (4-7)^2 + (5-9)^2} = 5{,}5$$

The Manhattan distance between point X and Y is:

$$D_{XY} = |2-3| + |3-5| + |4-7| + |5-9| = 10$$

The Chebyshev distance between point X and Y is:

$$D_{XY} = max\{|2-3|, |3-5|, |4-7|, |5-9|\} = max\{1,2,3,4\} = 4$$

The Minkowski distance of order 3 between point X and Y is:

$$D_{XY} = (|2-3|^3 + |3-5|^3 + |4-7|^3 + |5-9|^3)^{1/3} = \sqrt[3]{100} = 4{,}6$$

The correlation coefficient between point X and Y. The mean value of each object is:

$$\bar{x}_X = \frac{1}{4}(2+3+4+5) = 3{,}5$$

$$\bar{x}_Y = \frac{1}{4}(3+5+7+9) = 6$$

$$r_{XY} = \frac{(2-3{,}5)(3-6)+(3-3{,}5)(5-6)+(4-3{,}5)(7-6)(5-3{,}5)(9-6)}{([(2-3{,}5)^2+(3-3{,}5)^2+(4-3{,}5)^2+(5-3{,}5)^2][(3-6)^2+(5-6)^2+(7-6)^2+(9-6)^2])^{0{,}5}} = \frac{4{,}5+0{,}5+0{,}5+4{,}5}{\sqrt{5\times 20}} = 1$$

The summary of the metrics under consideration is shown in Table 1.

Table 1.

Proximity measures and their applications

Measure	Metric	Examples and applications
Euclidean distance	Yes	K-means with its variants
Manhattan distance	Yes	Fuzzy ART, clustering algorithms
Chebyshev distance	Yes	Fuzzy C-means clustering
Minkowski distance	Yes	Fuzzy C-means clustering
Pearson correlation	No	Widely used as the measure for microarray gene expression data analysis

Cluster analysis method

As a data mining function, clustering can be used as a standalone tool to gain insight into the distribution of data, to observe the characteristics of each cluster, and to focus on a particular set of clusters for further analysis [4, 5]. Clustering is one of the most fundamental issues in data recognition. It plays a significant role in searching for structures in data. It may serve as a pre-processing step for other algorithms, which will operate on the detected clusters.

In general, clustering algorithms are used to group some given objects defined by a set of numerical properties in such a way that the objects within a group are more similar than the objects in different groups. Therefore, a particular clustering algorithm needs to be given a criterion to measure the similarity of objects, how to cluster the objects into groups. The k-means clustering algorithm uses the Euclidean distance to measure the similarities between objects [5]. Both iterative algorithm and adaptive algorithm exist for the standard k-means clustering. K-means clustering algorithms need to assume that the number of groups (clusters) is known a priori.

The standard k-means clustering algorithm is a general clustering algorithm to cluster N objects into m groups of the given number m. The method minimizes the total squared Euclidean distance D of the form:

$$D = \sum_{i=1}^{N} \sum_{j=1}^{m} M_{ij} \left\| x_i - c_j \right\| \qquad (6)$$

where x_i ; i=1, 2, … N are the N objects and c_j ; j=1, 2, … m are the m centres. M_{ij} is the cluster membership function, which is defined by N×m matrix of 0's and 1's with exactly one 1 per row that identifies the groups to which a given object belongs. In this algorithm, the similarity of objects is defined by the Euclidean distance: the smaller distance between two objects is, the more similar they are. The algorithm works in this way. At the beginning, the m centres c_j are set to some initial data points. If the training data was not ordered in any way, the first m training data is usually chosen as the initial set of function centres. Otherwise, m data points would be selected randomly. At step 2, each of the training patterns is assigned to the closest centre. At step 3, the centres are adjusted by taking the arithmetic average in each cluster group. Steps 2 and 3 will be repeated until each training pattern stays in its group, i.e., no reassignment of any pattern to a different group than its previous group (see Table 2.).

An important step in clustering is to select a distance metric, which will determine how the similarity of two elements is calculated.

Drawbacks of k-means clustering

The term «cluster analysis» actually comprises a set of different classification algorithms. A common question frequently asked by researchers is: how to organize the data observed into clear structures? A viewpoint exists that unlike many other statistical procedures, methods of cluster analysis are commonly used when the researcher has not got any prior hypotheses

regarding classes but is still at the descriptive stage of investigation. It should be noted that cluster analysis determines the most possible meaningful decision [6].

Table 2.

K-means clustering procedure

Step 1. Initialise the function centres
Set the initial function centres to the first m training data or to the m randomly chosen training data.
Step 2. Group all patterns with the closet function centre
For each pattern x_i, assign x_i to group j*, where
$\left\| x_i - c_{j^*} \right\| = \min_j \left\| x_i - c_j \right\|$
Step 3. Compute the sample mean for the function centre
For each group c_j, $c_j = \frac{1}{m_j} \sum_{x_i \in group\ j} x_i$
where m_j is the number of patterns in group j.
Step 4. Repeat by going to step 2, until no change in cluster assignments

Cluster analysis is used to automatically generate a list of patterns by a training set. All the objects of this sample are presented to the system without the indication to which pattern they belong. The cluster analysis is based on the hypothesis of compactness. It means that methods of cluster analysis enable one to divide the objects under investigation into groups of similar objects frequently called clusters or classes. Given a finite set of data *X*, the problem of clustering in *X* is to find several cluster centres that can properly characterize relevant classes of *X*. In classic cluster analysis, these classes are required to form a partition of *X* such that the degree of association is strong for data within blocks of the partition and weak for data in different blocks.

Similar to other clustering algorithms, k-means clustering has many drawbacks:

- Cluster number, k, must be determined beforehand.
- It is difficult to determine the contribution each attribute makes to the grouping process, since it is assumed that each attribute has the same weight.
- By using the same data, we may never know the real cluster. If the number of data is a few, by inputting data in a different order, a result may be a different cluster.
- In case there are not many numbers of data, the cluster will be significantly determined by the initial grouping.
- Weakness of arithmetic mean is not robust to outliers. As a result, the centroid may be pulled away from the real data by very far data.
- It is sensitive to initial condition, since different initial condition may lead to different result of cluster. The algorithm may be trapped in the local optimum.
- As a result one gets a circular cluster shape which is based on distance.

Materials and methods

The purpose of the experimental part was to test the operation of the k-means algorithm by applying different metrics. Three different metrics have been chosen: Euclidean distance, Manhattan distance and Pearson correlation. In the course of the experiments in order to determine cluster centres in k-means clustering algorithm sequentially all three metrics have been used. The results obtained have been analyzed and the clustering correctness has been tested.

During the experiment the well-known Fisher's IRIS data set was employed [7], containing three species classes of 50 elements each: setosa, versicolor and virginica. Each species has

four attributes: SL - sepal length, SW - sepal width, PL - petal length, PW - petal width. However, it is uncommon to use this data set in cluster analysis, since the data set contains only two clusters with rather obvious separation. One of the clusters contains the Iris setosa species, while the other cluster contains both Iris virginica and Iris versicolor and is not separable without the species information Fisher used.
The experimental part has been carried out in Matlab environment [8].

Results and discussion

The results of the experiments are shown in Table 3.

Table 3.

Clustering results by applying different metrics

Distance	Euclidean	Manhattan	Correlation
Cluster centres	50.06 34.28 14.62 2.46 68.50 30.74 57.42 20.71 59.02 27.48 43.94 14.34	50 34 15 2 57 27 42 13 65 30 54 19	0.68 0.24 -0.29 -0.63 0.62 -0.35 0.34 -0.61 0.69 -0.23 0.20 -0.66
Cluster1 contains:	Records from cluster 1 – **50** Records from cluster 2 – 0 Records from cluster 3 – 0	Records from cluster 1 – **50** Records from cluster 2 – 0 Records from cluster 3 – 0	Records from cluster 1 – **50** Records from cluster 2 – 0 Records from cluster 3 – 0
Cluster2 contains:	Records from cluster 1 – 0 Records from cluster 2 – **48** Records from cluster 3 – **2**	Records from cluster 1 – 0 Records from cluster 2 – **39** Records from cluster 3 – **11**	Records from cluster 1 – 0 Records from cluster 2 – **47** Records from cluster 3 – **3**
Cluster3 contains:	Records from cluster 1 – 0 Records from cluster 2 – **14** Records from cluster 3 – **36**	Records from cluster 1 – 0 Records from cluster 2 – **4** Records from cluster 3 – **46**	Records from cluster 1 – 0 Records from cluster 2 – **3** Records from cluster 3 – **47**
Correct-ness:	For cluster 1 – **100 %** For cluster 2 - **96 %** For cluster 3 - **72 %**	For cluster 1 – **100 %** For cluster 2 - **78 %** For cluster 3 - **92 %**	For cluster 1 - **100 %** For cluster 2 - **94 %** For cluster 3 - **94 %**

The above table shows that all metrics correctly recognize cluster 1 records. Cluster 2 records are best recognized by Euclidean distance, whereas cluster 3 records – by correlation. The following figure in the form of a chart shows potentialities of different metrics in clustering (see Fig. 1.).

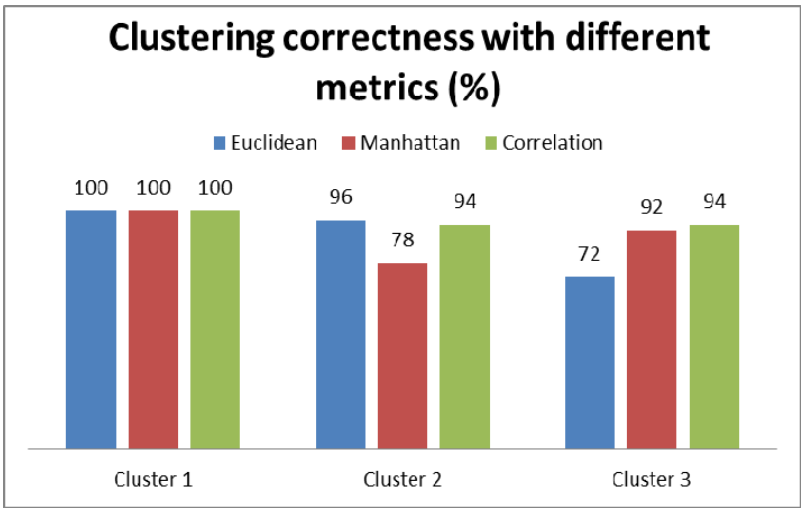

Fig.1. **Clustering correctness**

The visualization of clustering may be useful when analyzing results. For data visualization purposes, 2D projections can be used showing the distribution of particular parameters with respect to each other, while dendrogram graphs are normally used for visualization of the formation of clusters (see Fig.2., Fig.3. and Fig.4.).

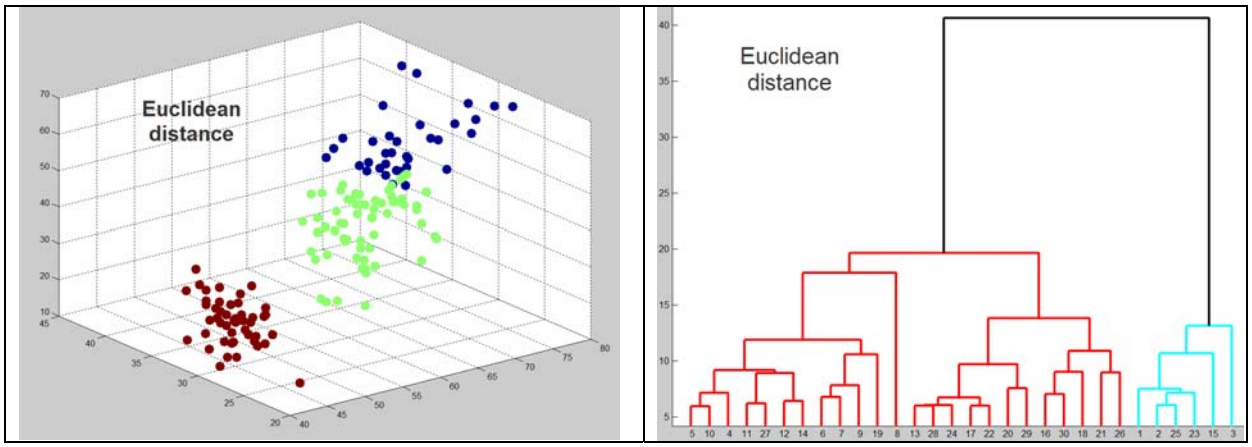

Fig.2. **Clustering results for Euclidean distance**

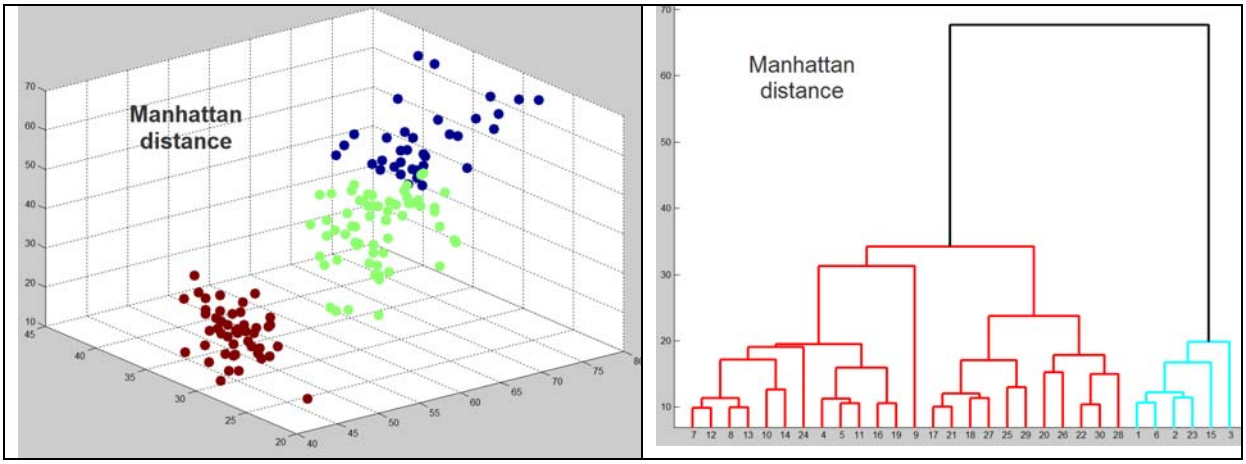

Fig.3. **Clustering results for Manhattan distance**

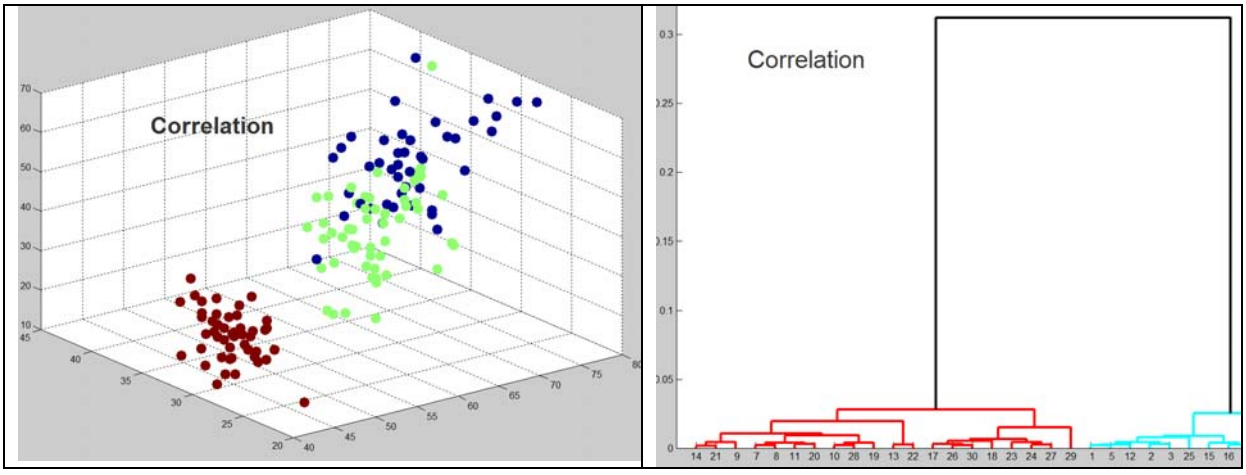

Fig.4. **Clustering results for Correlation**

Conclusions

Based on the tables and figures it can be concluded that the results obtained by applying all three metrics are very similar. None of the metrics shows dominance that could allow to consider it as the best metric. Traditionally Euclidean distance is used in clustering algorithms, however, the choice of other metric in definite cases may be disputable. It depends on the task, the amount of data and on the complexity of the task.

Further research will be dedicated to the analysis of the evaluation of clustering results' correctness.

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Anotācija

Metrikas izvēle klasterizācijas algoritmiem

Intelektuālās analīzes datortehnoloģijas patlaban piedzīvo uzplaukuma periodu. Tas galvenokārt saistīts ar jaunu ideju realizēšanos vairāku zinātņu nozaru saskarsmes punktos tādos kā mākslīgais intelekts, statistika, datu bāzu metodes u.c. Daudzos gadījumos ir nepieciešams kaut kādā veidā klasificēt datus vai atrast likumsakarības tajos, tāpēc jēdziens „likumsakarība" iegūst arvien lielāku nozīmi intelektuālās datu apstrādes sistēmu kontekstā. Bieži ir nepieciešams noskaidrot – kādā veidā dati ir saistīti savā starpā, kāda ir dažādu datu līdzība vai atšķirība, kāds ir šo datu salīdzināšanas mērs. Tādiem nolūkiem var izmantot dažādus klasterizācijas algoritmus, kas datus sadala grupās pēc noteiktiem kritērijiem – metrikas. Ar metriku šajā kontekstā tiek saprasta distance (attālums) starp klasterā ietilpstošajiem punktiem.

Darbā tika pārbaudīta klasiskā klasterizācijas algoritma k-means darbība ar dažādām metrikām: Eiklīda attālumu, Manhetenas attālumu un Pīrsona korelācijas koeficientu. Eksperimentu gaitā k-means klasterizācijas algoritmā klasteru centru noteikšanai secīgi tika izmantotas minētās trīs metrikas. Iegūtie rezultāti tika analizēti un tika pārbaudīts klasterizācijas korektums. Tradicionāli klasterizācijas algoritmos izmanto Eiklīda attālumu, taču citas metrikas izvēle atsevišķos gadījumos var būt diskutējama. Tas atkarīgs no risināmā uzdevuma, datu apjoma un sarežģītības. Tika konstatēts, ka klasterizācijas rezultāti visu triju metriku izmantošanā ir ļoti līdzīgi. Nevienai no izvēlētajām metrikām nebija izšķirīga pārsvara, kas varētu garantēti pasludināt to par labāko.

V

MECHANICS, MATERIAL PROPERTIES

COMPARISON OF POZZOLANIC ADDITIVES FOR NORMAL AND HIGH STRENGTH CONCRETE

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Abstract. *Microsilica is widely recognized as a "benchmark" for pozzolanic products. Although microsilica is an industrial byproduct, it has recently become very expensive. Four different pozzolanic additives were compared by the authors of this study. Two of the additives were commercially available products – microsilica by Elkem and Centrilit NC by MC Bauchemie. The other two additives were produced under laboratory conditions. Both of them were clay-based materials. Compressive strength was determined after 7, 28 and 155 days. The objective of this research was to determine alternatives to microsilica and evaluate pozzolanic additives performance in normal and high-strength concrete*.

Keywords: *compressive strength, metakaolin, microsilica, pozzolanic reaction.*

Introduction

Pozzolanic additives are the materials that can improve concrete properties such as concrete strength, durability and impermeability. They are used either as partial substitutes of Portland cement or as an addition [1]. The main component of pozzolanic additives is usually active SiO_2 in the amorphous phase. Pozzolanic reaction is a simple acid-based reaction between calcium hydroxide ($Ca(OH)_2$) and silicium acid (H_4SiO_4) [2]. Mechanism of pozzolanic reaction between microsilica and calcium hydroxide in water solution has been investigated particulary by Grutzeck *et al* [3]. According to this study, during the first hour of getting in contact with water, gel is formed on the surface of microsilica particles that is rich in silicium and poor in calcium. In presence of water microsilica particles form agglomerates. After a while, the gel on the surface of microsilica particles dissolved and microsilica agglomerates started reacting with calcium hydroxide thus forming calcium hydrosilicates. In the presence of cement the above mentioned mechanism becomes more complicated. In this case, microsilica absorbs lime containing water, forms silicium-rich gel and consumes most of the available water. Gel particles clump together and fill the voids between the cement particles and agglomerates in bigger masses. Within the first 15 minutes up to one hour, calcium hydrosilicate particles that do not contain water are enclosed by microsilica gel. In case of ordinary concrete, approximately 3 hours later discrete calcium hydroxide crystals are formed in pores, however when pozzolanic admixtures are used such weak crystals are not formed because excess lime reacts with the surface of silicium-rich gel thus forming calcium hydrosilicates, which is a stronger binder phase than calcium hydroxide. The reactivity of pozzolans is closely linked to the silicate and alumosilicate content in the amorphous phase as well as to the fineness of the material (surface area available for reaction). The influence of superplasticizer on the performance of concrete is reviewed in this paper as well. Previously, the influence of superplasticizer was studied by many authors [4; 5]. At present, superplasticizers play an important role in concrete mix composition (especially in case of high and ultra-high strength concrete), where reduction of water amount is necessary to obtain higher compressive strength. When dry particles are mixed with small amount of water, the electric charges upon the solid particles tend to cause their aggregation and prevent free distribution of the water between solid particles, thus preventing ultimately an optimal repartition of the hydrates formed between the particles. Superplasticizer lowers the surface tension of water. Superplasticizer addition to water is mandatory to allow penetration of the fluid in between the solid particles. A high level of fluidity can be maintained in spite of the

low water content by the use of only small amounts of superplasticizers. Better pumping behavior for better shuttering or mold injection and a high-strength final concrete can be obtained. The kinetics of chemical mechanisms and the structural organization of particles and their cohesion are deeply influenced by superplasticizers even in small quantity.

Materials and methods

Local raw materials, commercially available pozzolanic additives, and laboratory produced pozzolanic additives were used in this study. The materials used in this study are: Portland cement CEM I 42,5; coarse aggregate 5/20; coarse aggregate 2/12; sand 0/4; dolomite powder; microsilica 920D (Elkem); Centrillit NC (MC Bauchemie); metakaolin; dehydroxilated illite clay; polycarboxilate-based superplasticizer; water. Chemical composition of pozzolanic materials (similar materials were used in this study) was earlier determined by other authors [6;7;8]. The results are given in the Table 1.

Table 1.

Chemical composition of Portland cement and pozzolans

	Mass percentage							
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O+K_2O	SO_3	LOI
Portland cement	21,0	4,63	2,26	65,6	1,18	0,94		0,99
Metakaolin	52,1	41,0	4,32	0,07	0,19	0,89		0,6
Illite clay	54,83	19,05	6,0	9,39	1,77	3,65	2,9	1,48
Microsilica	92,0	0,7	1,2	0,2	0,2	2,0		3,0

Nine concrete mixes were produced by using four different pozzolanic additives. Dolomite powder was applied as filler for the reference mix. Two additives were commercially available: Microsilica 920D from Elkem and Centrillit NC (alumosilicate in slurry form) from MC Bauchemie. The other two were prepared under laboratory conditions from natural clay minerals, the first of those being kaolinite clay (not found on the territory of Latvia) and the second being illite clay (widely found in Latvia). Clay was dried at the temperature of 100°C and burned at the temperature of 700°C, by using the algorithm shown in Fig. 1. Metakaolin was obtained from kaolin – a sedimentary rock that contains hydrated alumosilicate $Al_4(OH)_8(Si4O_{10})$ [9]. In the calcination process at 600°C kaolin starts losing crystalline water and transforms into amorphous metakaolin. At the temperature above 900°C metakaolin turns into glassy phases, such as cristobalite (SiO_2) and mullite (Al_6Si2O_{23}), which no longer possesses any pozzolanic reactivity [10].

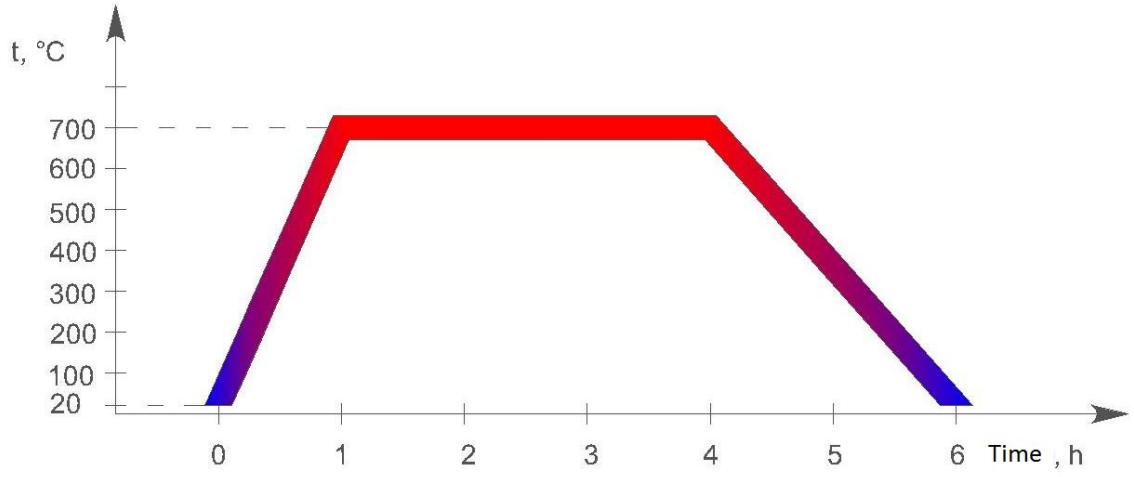

Fig. 1. **Temperature regime for clay dehydroxillation**

After the process of calcination the materials were ground in the planetary ball mill for 7 minutes. Concrete compositions were mixed in the activating mixer according to the following procedure: all dry materials were mixed till a homogenous mixture was built (approximately for 1.5 min). Then water and superplasticizer were added in two steps. During the first step approximately 60% of water was added. During the second step the rest of the water and the full amount of superplasticizer were added. This procedure was used to achieve a more effective use of the superplasticizer, since superplasticizer can be absorbed by the dry aggregate thus reducing the plasticizing effect. Duration of wet mixing was approximately 5 minutes.

Concrete mix compositions, testing procedure

Nine different concrete mixes were produced. Five mixes were produced without adding superplasticizer and four mixes contained superplasticizer. The water/cement ratio for the first five mixes was 0.61 and for the rest four mixes – 0.48. Concrete mix composition is given in Table 2.

Table 2

Concrete mix compositions

Material	DP	MK	IC	MS	CNC	DP/SP	MK/SP	MS/SP	CNC/SP
Portland cement 42,5 R	350	350	350	350	350	350	350	350	350
Coarse aggregate 5/20 mm	500	500	500	500	500	500	500	500	500
Coarse aggregate 2/12 mm	500	500	500	500	500	500	500	500	500
Sand 0/4 mm	750	750	750	750	750	750	750	750	750
Dolomite powder	80					80			
Metakaolin		80					80		
Dehydrox. illite clay			80						
Microsilica				80				80	
Centrillit NC					80				80
Superplasticizer						7	7	7	7
Water	212	212	212	212	212	169	169	169	169
W/C	0,61	0,61	0,6	0,61	0,61	0,48	0,48	0,48	0,48

DP – dolomite powder; MK – Metakaolin; IC – illite clay; MS – Microsilica; CNC – Centrillit NC; DP/SP – dolomite powder, mix with superplasticizer; MK/SP – metakaolin, mix with supeplasticizer; MS/SP – Microsilica, mix with superplasticizer; CNC/SP – Centrillit NC, mix with superplasticizer.

Cone slump test results varied a little depending on different pozzolanic additives yet all the time stayed within the limits of the class S3. By applying superplasticizer it is possible to reduce the w/c ratio while maintaining the same cone slump result as without the superplasticizer. The effect of superplasticizer is also manifested through better dispersion of fine particles in the mix. Compressive strength was determined at the age of 7, 28 and 155 days. The pressure was applied at the rate of 0.75 MPa/s. Concrete samples were hardening under water at the temperature of 20^{o}C for 28 days; during the remaining time hardening happened in the air at 20^{o}C. Mixes without superplasticizer and with the w/c ratio of 0.61 were considered as normal-strength concrete mixes and mixes where superplasticizer was used and the w/c ratio was 0.48 were considered as high-strength concrete mixes.

Testing results and discussion

Four different pozzolanic admixtures: microsilica, metakaolin, Centrillit NC and dehydroxilated illite clay were compared with the reference mix containing dolomite powder. The same concrete mixes were produced with and without superplasticizer. The results of compressive strength at 7, 28 and 155 days for the samples that did not contain superplasticizer can be seen in Fig. 2 and Fig. 3. The results demonstrated that in the first five

experimental series (without superplasticizer) the compressive strength at the age of 7 days varied from 26.6 MPa for the reference mix to 40.4 MPa for the samples containing metakaolin.

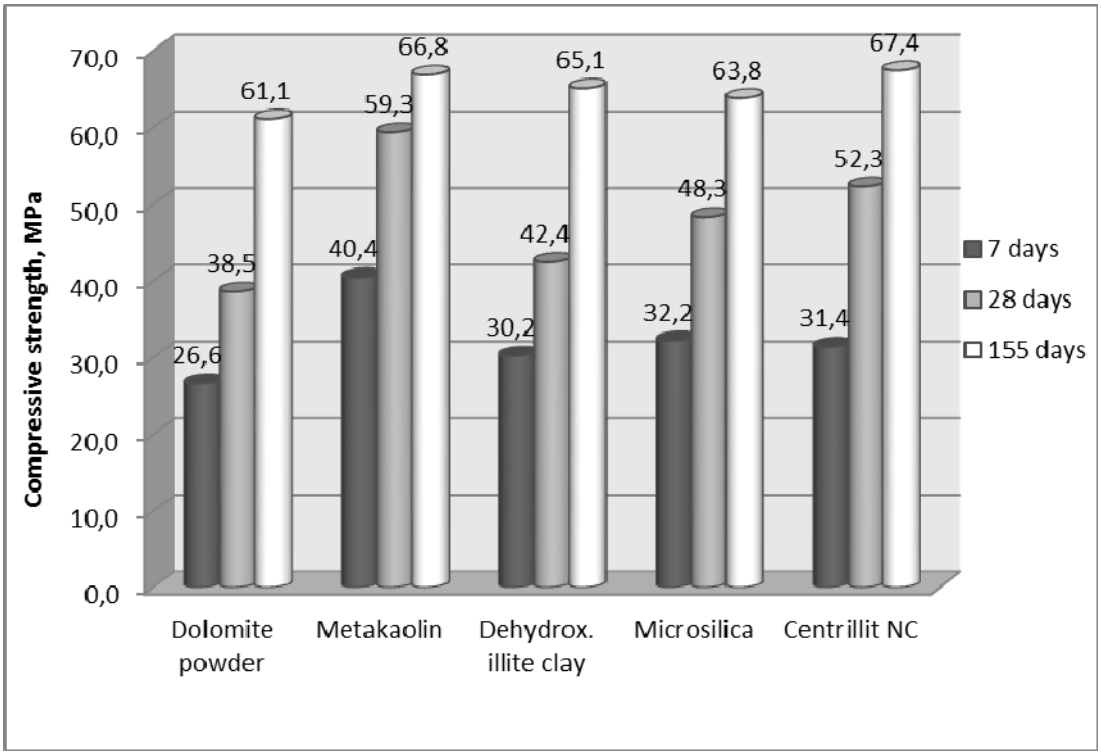

Fig 2. **Compressive strength of normal strength samples without superplasticizer**

Results for dehydroxilated illite clay, microsilica and Centrillit NC at the age of 7 days were very similar: 30.2MPa, 32.2MPa and 31.4MPa accordingly. Rapid strength gain for metakaolin can be explained by high content of Al_2O_3 and high reactivity with calcium hydroxide. At the age of 28 days the highest compressive strength of 59.3 MPa was obtained for metakaolin thus proving its high pozzolanic reactivity. The difference in compressive strength compared to the reference mix was as high as 54%. The lowest strength increase (4.9% compared to the reference mix) was for the dehydroxilated illite clay. Testing of samples at the age of 155 days showed that compressive strength increased from 12.6% for metakaolin mix to 58.7% for the reference mix showing that metakaolin tends to use most of its potential in the shorter term. The final 155 day strength varied from 61.1 MPa for the reference mix to 67.4 for Centrillit NC. Microsilica with the indicator 63.8 MPa demonstrated the second result after the reference mix, which proved that it is not possible to fully use its potential without good particle dispersion in the mix and that a high range superplasticizer should be used to obtain good microsilica particle dispersion.

The next experimental series where superplasticizer was applied and the w/c ratio was decreased to 0.48 showed the results that can be seen in Figure 3. At the age of 7 days the compressive strength varied from 40.1 MPa for the reference mix to 52.3 for the samples containing metacaolin, once again proving metacaolin's high early strength development. In comparison to samples without superplasticizer and with higher w/c ratio from the previous five series, strength increase at the age of 7 days is from 8.0% for the samples with metacaolin to 55.9% for the samples with microsilica. At the 28th day the highest compressive strength was for microsilica and metakaolin – 73.0 MPa and 68.4 MPa respectively. Finally, at the age of 155 days the dolomite powder samples reached compressive strength of 75.3 MPa, while indicators for metakaolin were 89.6 MPa, for microsilica – 99.1 MPa and for Centrillit NC –

79.2MPa. The reasons for lower compressive strength for Centrillit NC could be the fact that it was in the slurry form – at a 50/50 proportion with water and because of the possible segregation the distribution of the material in the volume might have been uneven.

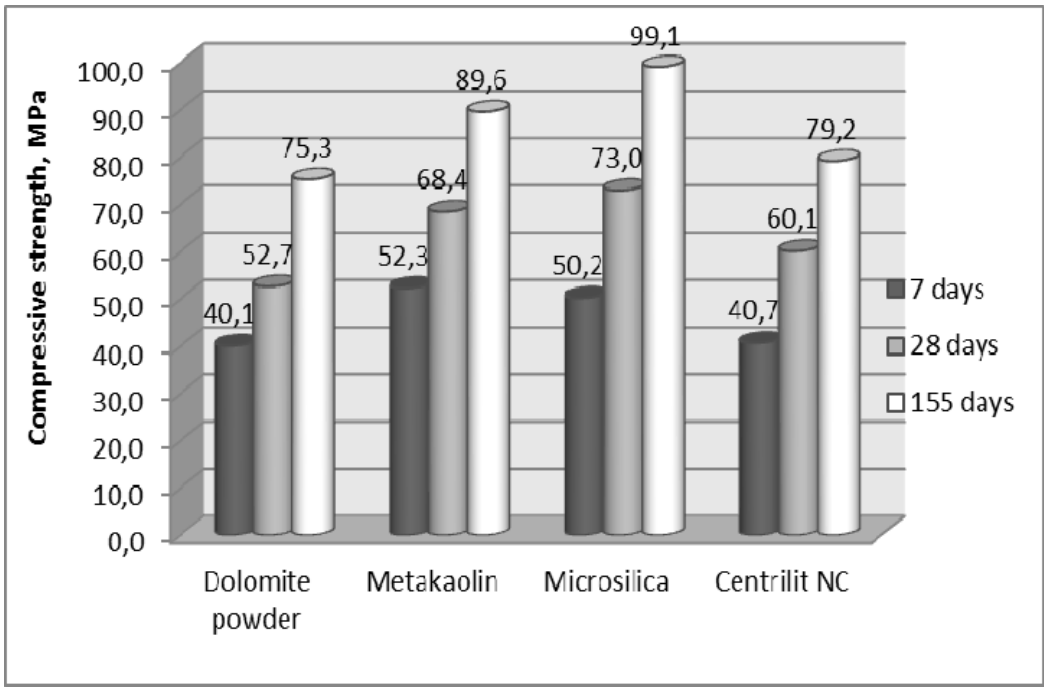

Fig 3. **Compressive strength of high strength samples with superplasticizer**

Conclusions

- Specimens were tested at three different ages of 7; 28 and 155 days. Normal strength concrete samples (series without superplasticizer) at the age of 28 days showed strength increase from 10.1% to 54% compared to the reference mix, showing the positive effect on compressive strength increase by all used additives. The highest gain of compressive strength was demonstrated by the specimens with metakaolin.
- This study demonstrated that without superplasticizer alumosilicate-based additives (metakaolin, and Centrillit NC) perform better than microsilica.
- Dehydroxilated illite clay recorded a 10.1% gain in compressive strength compared to the reference mix showing that after the dehydroxilation at 700^{o}C this type of material can also exhibit pozzolanic properties.
- In the series of experiments for high strength concrete microsilica demonstrated the highest compressive strength at the age of 28 days, which can be explained by better fine microsilica particle dispersion in the concrete mix.

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DYNAMIC RESPONSE OF TOWER STRUCTURES

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Abstract. *The present study focuses on the tower type structures response to the dynamic loads. The study analyzes the possible mode shapes regarding to tower structure. The estimation of mode shapes and their dependence from structural changes was made for an existing tower structure. To get an acceptable tower's vibration level and avoid possibility of resonance effect from usual serviceability loads it was evaluated options to change natural frequencies of the structure. It is performed existing 36m high sightseeing tower dynamic analysis and proposed potential solutions to increase critical natural frequencies of the structure. In this study to obtain dynamic parameters of the sightseeing tower structure have been used finite element models and calculation techniques.*

Keywords: *dynamic parameters, frequency, mode shapes, steel tower, vibrations.*

Introduction

The environment is affected when structures are being built and this can happen in a several ways. One of the aspects is amount of materials used for the construction of structure. To save a natures recourses, energy and due to economical reasons the steel tower type structures nowadays are getting remarkably flexible, low in damping and light in weight. Traditionally for such type of structures dynamic analysis are performed and dynamic parameters such as fundamental frequencies, mode shapes and damping ratios are found to evaluate wind induced vibrations and effects on the structure. Even most advanced and comprehensive codes concentrate mainly on these issues, including the Eurocodes. In case of the steel lattice sightseeing towers with low natural frequency of the structure human and structure interaction could play a role in the tower design. Human walking induces dynamic and time varying forces. Those forces have components in vertical, lateral and longitudinal directions. The lateral forces are a consequence of the sideway oscillation of the gravity centre of a human's body while stepping alternatively with the right or left foot forwards [1]. Published data on dynamics loads quote that pedestrian vertical and longitudinal walking on stationary pavements fundamental frequency is 2.0 Hz for normal walk, 1.7 Hz for slow walk and 2.3 for fast walk. Horizontal fundamental frequency is 1.0 Hz for normal walk, 1.85 Hz for slow walk and 1.15 for fast walk [2]. In a case of the tower structure there is an interest in horizontal and longitudinal component of the pacing frequency. Recently, there has been growing tendency to construct light weight foot bridges. Due to experienced problems in some of those structures with lateral vibrations there have been performed studies about phenomenon of synchronous lateral excitation. It is noted that humans are much more sensitive to lateral vibration than vertical one. Even if horizontal vibration is only 2-3 millimeters lateral motion affects balance and pedestrians tend to walk with their feet further apart which increases the lateral force imparted by individuals. In order to maintain balance, pedestrians tend to synchronize their footsteps with the motion of the structure. This instinctive behavior ensures that dynamic forces are applied at the resonant frequency of the structure and increase the motion even more. As the motion increases also increases the synchronization between pedestrians. It will not go infinity but reaches a steady state by people stopping when motion becomes too uncomfortable [3]. It is presumed that the same

processes will take place on the sightseeing towers. Wind forces will promote initiation of the lateral motion and because of adaptive nature of the human beings lateral vibration will have a self exited nature until some point.

Study and methods

There are several important aspects for the sightseeing towers. Firstly it should be esthetically pleasing, incorporated and consistent with the surrounding environment, comfortable stairs for the public use. In the general these aspects are governing the towers shape and structure. Unlike industrial steel towers the sightseeing towers structures will be more complicated and new aspects can rose during the designing process. The main purpose of this study is to identify whether a light weight sightseeing tower with particular steel structure is susceptible to the human induced excitation. In this paper there are analyzed possible mode shapes and corresponding fundamental frequencies of the existing steel core sightseeing tower. There is evaluated potential to change fundamental frequency of the tower by making amendments to the structure itself.

The studied steel core sightseeing tower is located in Dzintari, Jurmala city, Latvia (Fig. 1). It is open for public since 15th of May 2010. Total height of the tower is 36.48m. All elements – inner and outer core, platforms, and stairs are made of steel except the wooden cladding on the facades of the steel cores. The structural configuration of the tower is provided in Fig. 2. Structure consists of braced inner core with dimensions 1500x1500mm made from tubes with cross section 200x200x8 and outer core with dimensions 4240x4240mm made from tubes with cross section 140x140x5. Outer core does not have any vertical bracing as this was requested by architectural concept. Inner and outer cores are connected only with steel stairs.

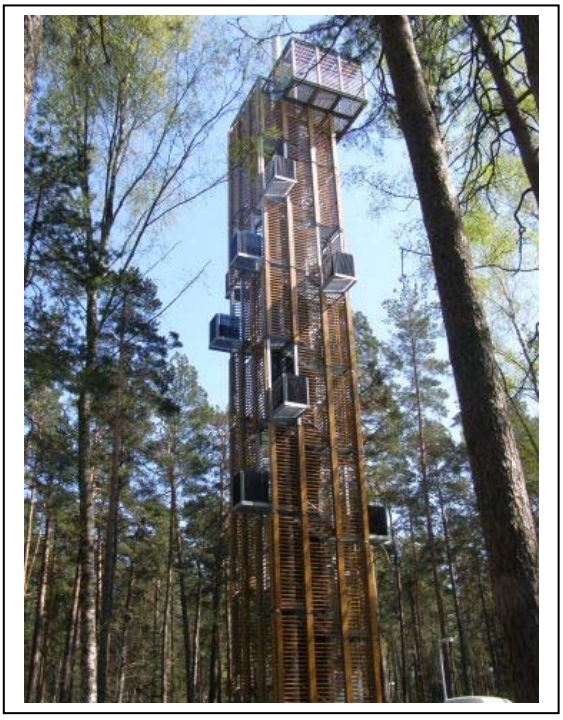

Fig.1. **Sightseeing tower in Dzintari**

Since the tower was opened for public there have been complaints about tower excessive vibration. The human perception of vibration is very sensitive and reaction is substantially psychological. There for it should be analyzed whether these vibrations are realistic or just perceived by the human visual stimuli.

The literature [5] provides a recommendation whenever fundamental frequencies are close to a critical range (from point of view of the pedestrian excitation) to use a more precise numerical model, because hand formulas and simplified methods are not enough for assessment of fundamental frequencies. The finite element software is widely spread and accepted as more precise numerical model. To evaluate degree of vibration there was established fundamental frequencies and critical mode shapes of the existing tower using three dimensional finite element models created by structural analysis software STRAP 12.5. This software also was used to assess how the changes in the structure of tower affects the fundamental frequencies and mode shapes.

To determine structural system fundamental frequency and mode shapes by solving undamped free vibration equation [4]:

$$[M]\{\ddot{u}\} + [K]\{u\} = 0 \quad (1)$$

where M is the mass matrix, K is the stiffness matrix, $\ddot{u}$ is the acceleration vector and u is the displacement vector, for extraction of eigenvalues the structural analysis software uses subspace iteration technique.

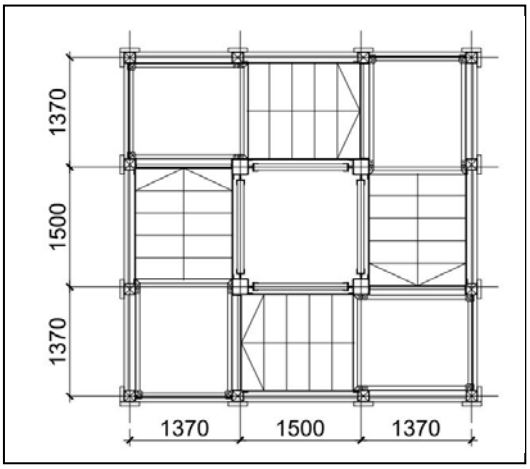

Fig.2. **Plan of the Sightseeing tower in Dzintari**

Tower was modeled step by step to evaluate main component influence on its fundamental frequency. The created finite element (FE) models of the tower are summarized in table 1.

Table 1.

FE models of the tower

Model Nr.	Description	Inner core dimensions (mm)	Outer core dimensions (mm)
1.	Only inner core	1500x1500	-
2.	Inner and outer core	1500x1500	2870x2870
3.	Inner and outer core	1500x1500	4240x4240
4.	Inner and outer core	1500x1500	5610x5610
5.	Inner and outer core	1500x1500	6980x6980
6.	Inner and outer core, stairs	1500x1500	4240x4240
7.	Inner and outer core, stairs, eccentric platforms	1500x1500	4240x4240
8.	Only inner core	2000x2000	-
9.	Inner and outer core	2000x2000	3370x3370
10.	Inner and outer core	2000x2000	4740x4740
11.	Inner and outer core	2000x2000	6110x6110
12.	Inner and outer core	2000x2000	7480x7480

During the creation process of the FE models and their evaluation for the base model was taken the behavior of the model Nr. 6 with inner core, outer core and stairs but without eccentric platforms. Outer core of the tower behaves more as unbraced in vertical direction. On this base more simplified models were created without any bracing in outer core façades and the last tower platform created as horizontal diaphragm.

Results

For all twelve FE models fundamental natural frequencies were calculated and summarized in table 2. There were established first three critical mode shapes which are the same for all twelve FE models (Fig. 3).

Table 2.

Calculated fundamental frequencies of the tower

Model Nr.	1st mode (Hz)	2nd mode (Hz)	3rd mode (Hz) Torsional mode
1.	1.521	1.521	6.051
2.	0.874	0.874	2.777
3.	0.874	0.874	2.031
4.	0.874	0.874	1.589
5.	0.874	0.874	1.301
6.	1.506	1.511	2.010
7.	1.279	1.296	1.914
8.	1.955	1.955	6.376
9.	1.151	1.151	3.206
10.	1.131	1.131	2.434
11.	1.111	1.111	1.917
12.	1.09	1.09	1.561

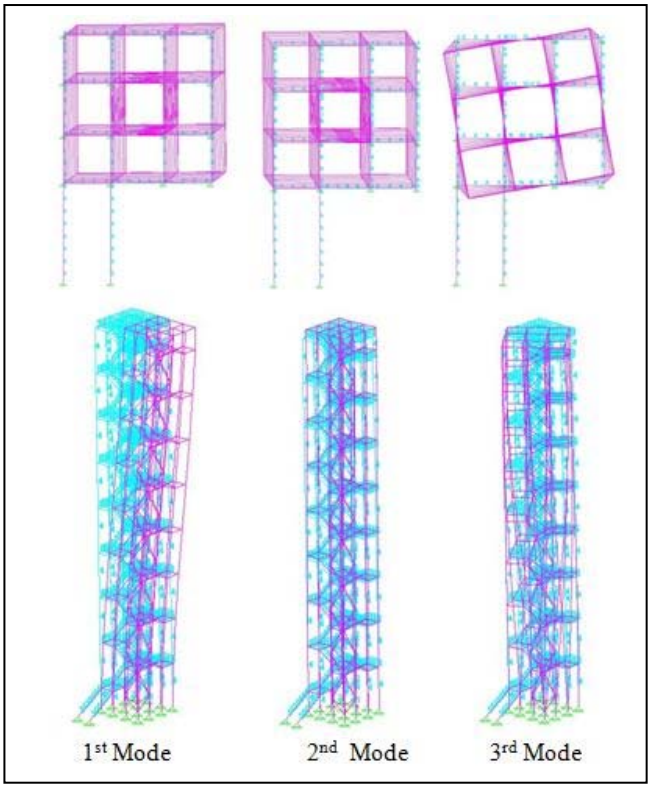

Fig.3. **Mode shapes for the FE model Nr. 6**

As it was expected the first and second mode shape fundamental frequencies mainly depend on the internal core stiffness (see FE Nr. 1-5 and Nr. 8-12). Adding the outer core whose stiffness was relatively small because of the vertical bracing absence the first and second mode shape fundamental frequency basically did not change and outer core acts more like a mass which decreases frequency of the entire tower. FE model Nr. 6 and 7 results shows that stairs provides some degree of restraint for the transversal directions and increase fundamental frequencies for the first and second mode shapes comparing to the models without stairs.
By analysing these results the most changes in the fundamental frequency was notified in the torsional mode shape (3rd mode shape). Adding the outer core to the structure dramatically decreased fundamental frequency and it is sensitive to the outer core placement with regards to the inner core. To demonstrate the outer core placement with regards to the inner core, both cores stiffness and mass influence on the torsional mode shape fundamental frequency it is proposed to find the equivalent square hollow box cross section with the same mass as the actual tower cross section mass and equivalent square hollow core cross section with the same torsional stiffness as the actual tower cross section torsional stiffness (see Fig. 4).

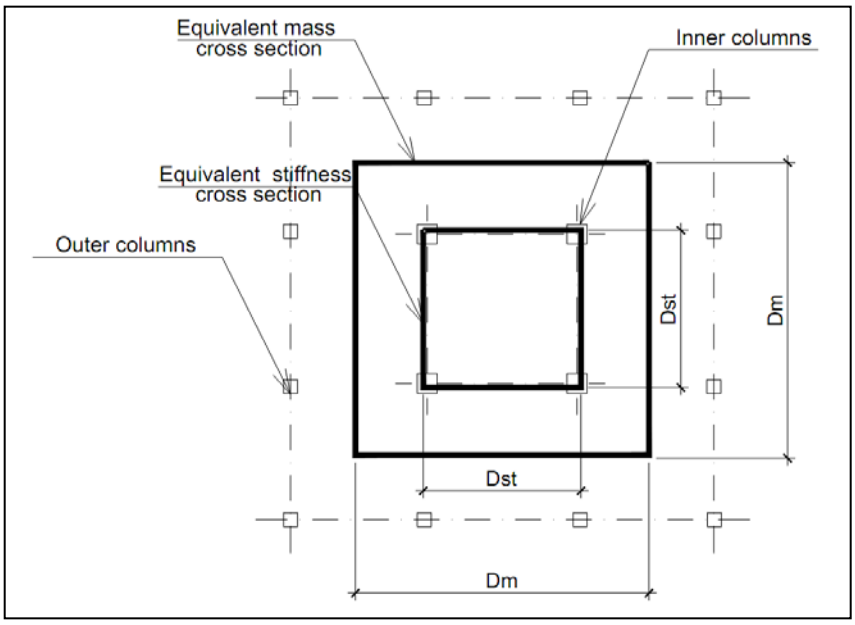

Fig.4. **Tower equivalent mass and stiffness cross sections**

Stiffness and mass cross section dimensions Dm and Dst coincides in case of FE models Nr.1 and Nr. 8 where tower is modeled only with one core. For the rest of the models where outer core as well as inner core was modeled, the equivalent cross section dimensions Dm and Dst do not coincides. In this particular tower case the inner core stiffness is higher because of the vertical bracing. Therefore dimension Dst is closer to the inner core width dimension. The Fig. 5 shows that if ratio Dm/Dst is growing the fundamental frequency is rapidly decreasing. Respectively when the mass around the centre of the tower is distributed further and stiffness is concentrated closer to the centre of the tower, there is a rapid decrease of the fundamental frequency for the torsional mode shape and it could lead to the critical range where tower is susceptible to the resonance effects induced by the human structure interaction.
Keeping in mind the above chart FE model Nr. 6 was amended and added vertical bracing to the outer core. Increasing outer core stiffness the ratio Dm/Dst came close to value 1.00 and torsional mode fundamental frequency rose to 6.06 Hz.

For the FE model Nr. 7 which is modeled to most precisely reflect the existing tower with added eccentrical platforms and cladding elements, as it was expected the fundamental frequency decreased due to additional mass.

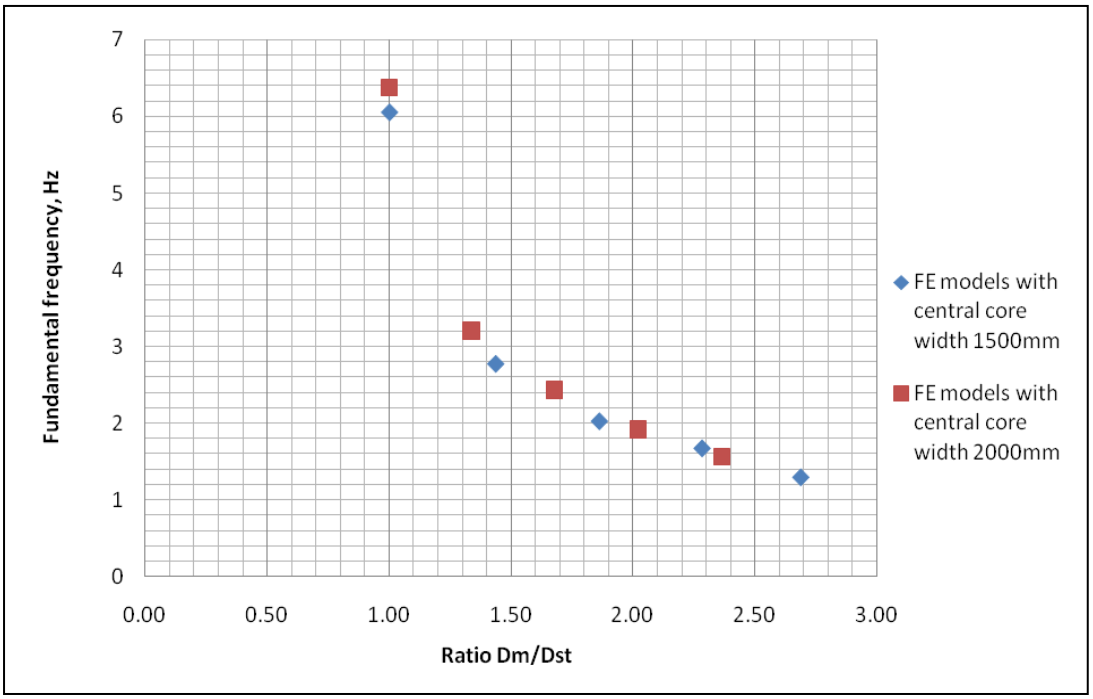

Fig.5. **Fundamental frequency of the third mode shape (torsional) dependence from the ratio Dm/Dst**

Conclusions

All tower models' fundamental frequencies f of 1st and 2nd mode shapes and tower models' with two different stiffness cores fundamental frequency f of 3rd mode shape lie in an interval $1.15\text{Hz} \leq f \leq 2.3$. The tower being within this interval makes it susceptible of excitation by harmonic of pedestrian excitation. In conclusion the existing tower should be the object for the further dynamic assessment to pedestrian movement.

The tower with two structural cores and internal core being remarkably stiffer, increase of outer core perimeter leads to the decrease of the tower fundamental frequency for 3rd (torsional) mode shape. It is suggested to link this effect with changes of stiffness and mass ratio in the structure.

By adding additional elements around the tower's inner core (dimension 1500x1500mm) the fundamental frequency for the 1st and 2nd mode shape decreases by 43% but for the 3rd mode shape it decreases by 54-78%. The author considers it is because the tower stiffness and tower mass changes according to the different relationships.

By adding an additional vertical bracing to the outer core it is possible to bring fundamental frequency of 3rd mode shape out of the critical range.

Summary

The first three mode shapes susceptible of excitation by harmonic of the pedestrian movement are critical to the tall sightseeing steel towers that have more than one structural core with different degree of stiffness in respect to each other.

Published data for the tower and human interaction are thin therefore further research is required which includes load models for pedestrian streams, possible design modifications by

increasing fundamental frequencies or development of low cost damping devices to reach the vibration comfort range in terms of the acceleration.

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OPTIMIZATION OF PARAMETERS OF HEATING ELEMENTS FOR FLOOR PANEL OF PIGLETS RESTING PLACES

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Abstract. *The article deals with problem solving of mathematical physics using the method of separation of variables optimizing heating element – optimizing water tube parameters (tube material, radius, insulation thickness, choosing appropriate surrounding environment). For ensuring piglets comfort, concrete floor panels heated by electric current or hot water are used. If an electro-heated cable in the panels body is placed, than amount of heat conducted from the cable is the same along all the length of the cable. If hot water circulating through tube is used, than amount of heat energy taken off the heater decreases along its length. The aim of the research is to create the mathematical model of a water tube, were water temperature is gradually decreasing. This model is needed to make precise calculations of the heating panel for piglets, to ensure equal temperature distribution over the upper surface of the panel, taking into account mathematically calculated temperature decrease of the heat source.*

Keywords: *mathematical modeling, heated floors, water tube.*

Introduction

New born piglets together with the sow are kept. The optimal surrounding air temperature for a sow is about 16…20°C, but for new born piglet during the first days of their life the temperature in its lairs has to be within the limits of 32…36°C. Gradually the lair's temperature must be decreased until 22…24°C when piglets are two months of age and weaned [Priekulis et al., 1992]. That means that comfortable surrounding temperature for sows and piglets is different despite the fact that during first days they are kept together. Therefore in cold winter countries like Latvia piglets resting place local warming ought to be used.

For local warming heating panels are usually used. They can be made from different materials and using different production technologies. The energetic efficiency of the panels will result from the integrated insulation which minimizes the downward heat emission and from the even distribution over the panel. To improve evenness of the temperature distribution it is necessary to make precise mathematical model of the heating panel and then to check it experimentally. Nowadays very popular are plastic pads which are filled in with water, but the evenness of the temperature is not so good [MIK, 2009], as it can be achieved using tubes with hot water placed into some kind of solid material, in our examples we used data for concrete, but there is a possibility to use another materials (with lesser abrasive properties) [Zoric. M. et al., 2009]. The energy consumption of the calculated concrete panel is lower than the most popular panels in the market is as well, comparing 320 W m^{-2} [MIK, 2009], to 290W m^{-2} at the same working temperatures. In terms of energy cost this leads to the enormous energy economy and decrease of CO_2 pollutions as well.

Materials and methods

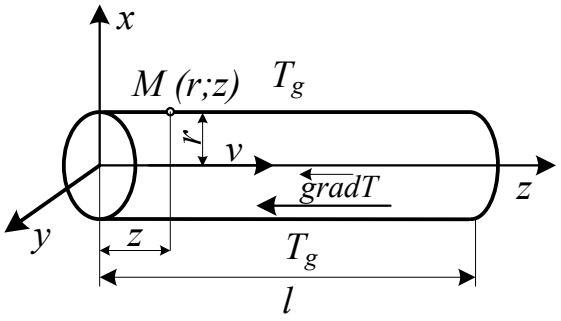

Fig.1. **Pipe element for calculation of temperature drop over the fluid flow in the tube**

Assuming, that tube is being bathed by environment, which temperature T_0 and flowing into the tube fluid temperature $T_1>T_0$ (the fluid gives the heat energy to he surrpunding environment). These processes can be described with equation (1) [Riekstins, 1969]:

$$a\Delta T - \vec{v}gradT = 0. \quad (1)$$

For concrete problem formulation it is necessary to give boundary conditions. According to our task, the fluid flows into the tube with temperature T_1 (2):

$$T|_{z=0} = T_1. \quad (2)$$

Conditionally we can accept that outflow fluid temperature is equal to surrounding air temperature (3):

$$T|_{z\to\infty} = T_0. \quad (3)$$

It is necessary to formulate the third type boundary conditions as well for the tube surface (4).

$$-\lambda\frac{\delta T}{\delta r}\Big|_{r=R} = \alpha(T|_{r=R} - T_0), \quad (4)$$

where

α- heat transfer coefficient, W m^{-2} K^{-1};

λ_2 - thermal conductivity, W $(m\ K)^{-1}$.

Now we have defined the problem of mathematical physics, which contains equation (1) and border conditions (2-4). For solving such a problem, we will use the method of separation of variables. In cylindrical coordinate system the Laplace operator is written in a form:

$$\Delta = \frac{1}{r}\frac{\delta}{\delta r}\left(r\frac{\delta}{\delta r}\right) + \frac{\delta^2}{\delta z^2} = 0. \quad (5)$$

So, equation (6) is a stationary equation, which contains conditions of fluid flow:

$$\frac{1}{r}\frac{\delta}{\delta r}\left(r\frac{\partial T}{\partial r}\right) - \frac{\vec{v}}{a}\frac{\delta T}{\delta z} + \frac{\delta^2 T}{\delta z^2} = 0. \quad (6)$$

The solution of the problem we will look for as sum of endless row (7):

$$T(r,z) = T_0 + \sum_k R_k(r)\cdot Z_k(r). \quad (7)$$

Inserting representation (7) into the basic equation (6), accordingly substituting $\frac{\partial R_k}{\partial r} = R'_k$ and $\frac{\partial Z_k}{\partial z} = Z'_k$.we will get the following:

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial(T_0+\sum_k R_k(r)Z_k(z))}{\partial r}\right) - \frac{v}{a}\frac{\partial(T_0+\sum_k R_k(r)Z_k(z))}{\partial z} + \frac{\partial^2(T_0+\sum_k R_k(r)Z_k(z))}{\partial z^2} =$$
$$= \frac{1}{r}\frac{\partial}{\partial r}\sum_k \left(r\cdot(R_k'\cdot Z_k)\right)' - \sum_k \frac{v}{a}R_k Z_k' + \sum_k R_k Z_k'' =$$
$$\sum_k \frac{1}{r}Z_k(R_k' + rR_k'') - \frac{v}{a}R_k Z_k' + R_k Z_k'' = 0 \qquad (8)$$

The solution of the equation (8) is found only in case, when each member of the sum row is equal with zero:

$$\frac{1}{r}Z_k\left(R_k' + rR_k''\right) - \frac{v}{a}R_k Z_k' + R_k Z_k'' = 0 \qquad (9)$$

Now, dividing equation (9) with$R_k Z_k$, we can get equation were the right side is dependant from one argument, and the left side from another argument (10):

$$\frac{1}{r}\frac{R_k'}{R_k} + \frac{R_k''}{R_k} = \frac{v}{a}\cdot\frac{Z_k'}{Z_k} + \frac{Z_k''}{Z_k}. \qquad (10)$$

To get 2 equations with one unknown, we need to compare it with free chosen constant μ_k^2 (11):

$$\begin{cases} \frac{1}{r}\frac{R_k'}{R_k} + \frac{R_k''}{R_k} = \mu_k^2 \\ \frac{v}{a}\cdot\frac{Z_k'}{Z_k} + \frac{Z_k''}{Z_k} = \mu_k^2 \end{cases} \qquad (11)$$

After algebraic changes we obtain two second order differential equations (12):

$$\begin{cases} rR_k'' + R_k' + \mu_k^2 rR_k = 0 \\ Z_k'' + \frac{v}{a}\cdot Z_k' + \mu_k^2 Z_k = 0 \end{cases} \qquad (12)$$

The first system's (12a) equation is special case of the general equation (13) which is called Bessel equation:

$$r^2 R''_k + r\,R'_k \pm (\mu_k^2 r^2 - v^2)R_k = 0, \qquad (13)$$

where v is numeral parmeter, in our case $v = 0$.
The solution of the Bessel equation is expressed with Bessel functions $J_v(\mu_k r)$. According to it the solution of the equation (12a) is:

$$R_k(r) = A_k \cdot J_0(\mu_k r) + B_k \cdot Y_0(\mu_k r), \qquad (14)$$

$$Y_0 = 0 \Rightarrow B_k \cdot (\mu_k r) = 0, \qquad (15)$$

$$R_k(r) = A_k \cdot J_0(\mu_k r), \qquad (16)$$

where A_k is free chosen integration constant;
$J_0(\mu_k r)$ - Bessel function, when parameter $v = 0$.

The equation (12b) is the 2nd order differential equation with constant coefficients, dividing it with Z_k, and making substitution $\frac{wc\rho}{\lambda} = 2\beta$ it is written in the following form (17):

$$Z_k''(z) - 2\beta Z_k'(z) - \mu_k^2 Z_k(z) = 0. \tag{17}$$

The general solution of the equation (17) is:

$$Z_k(z) = C_k e^{\xi_1 z} + D_k e^{\xi_2 z}, \tag{18}$$

where C_k and D_k are free chosen integration constants,

ξ- particular value.

$$\xi_1 = \beta + \sqrt{\beta^2 + \mu_k^2} \tag{19}$$

$$\xi_2 = \beta - \sqrt{\beta^2 + \mu_k^2} \tag{20}$$

Further process for solution finding is being made: the expressions (18) and (16) are inserted into the equation (7), the equation (21) is obtained. The equation (21) is being inserted into the boundary conditions (2, 3) in consecutive order. To satisfy boundary conditions (2), no restrictions are introduced. The boundary conditions (3) can be satisfied, only when $z \to \infty$, then $e^{(\beta+\sqrt{\beta^2+\mu_k^2})z} \to \infty$, it means, that we have to assume $C_k = 0$, to satisfy boundary conditions (3). The following is obtained:

$$T(r,z) = T_0 + \sum_k J_0(\mu_k r)\left(D_k e^{(\beta-\sqrt{\beta^2+\mu_k^2})z}\right), \tag{21}$$

where -D_k is free chosen constant $A_k \cdot D_k$

As we see from equation (21) we do not know free chosen constants μ_k and D_k.

To determine free chosen constants μ_k we will use side surface boundary conditions (4), the equation (21) is inserted into the boundary conditions (4):

$$\begin{gathered} -\lambda \sum_k D_k \left[-J_1(\mu_k R)\right] \cdot \mu_k \cdot e^{\left(\beta-\sqrt{\beta^2+\mu_k^2}\right)z} = \\ \alpha\left(T_0 + \sum_k D_k \cdot [J_0(\mu_k R)] \cdot e^{(\beta-\sqrt{\beta^2+\mu_k^2})z} - T_0\right). \end{gathered} \tag{22}$$

After row of algebraically changes we obtain:

$$\mu_k = \frac{\alpha}{\lambda} \cdot \frac{J_0(\mu_k R)}{J_1(\mu_k R)}. \tag{23}$$

As Bessel function argument is dimensionless, than $[\mu_k] = [m^{-1}]$, to introduce into the solution Biot number $\frac{\alpha}{\lambda} \cdot R = b$, we need to multiply equation (23) with R:

$$\mu_k R = \frac{\alpha}{\lambda} \cdot R \cdot \frac{J_0(\mu_k R)}{J_1(\mu_k R)}. \tag{24}$$

We will mark $\mu_k R$ as X_k:

$$X_k = b \cdot \frac{J_0(\mu_k R)}{J_1(\mu_k R)}. \tag{25}$$

So we have got the transcendental equation for particular value determination.

Now it is needed to determine D_k, to obtain it we will put general equation (21) into the boundary conditions (2), when $z \to 0$:

$$T(r;0) = T_1 = T_0 + \sum_k J_0(\mu_k r) \cdot D_k e^{\left(\beta - \sqrt{\beta^2 + \mu_k^2}\right)z} = \\ - T_0 + D_1 J_0(\mu_1 r) + D_2 J_0(\mu_2 r) + D_3 J_0(\mu_3 r) + \cdots + D_k J_0(\mu_k r). \quad (26)$$

Using properties of the particular functions' scalar multiplication multiplying with $rJ_0(\mu_k r)$ and integrating, we obtain (27):

$$\int_0^R rJ_0(\mu_k R)(T_1 - T_0)dr = D_k \int_0^R rJ_0{}^2(\mu_k r)^2 dr. \quad (27)$$

The equation above enables to get solution for D_k as division of two integrals:

$$(T_1 - T_0)\frac{\int_0^R rJ_0(\mu_k r)dr}{\int_0^R rJ_0{}^2(\mu_k r)^2 dr} = D_k. \quad (28)$$

Now we need to develop function into a row (29), where trigonometrically functions are taken for Furje rows:

$$1 = \sum_k C_k J_0(\mu_k r), \quad (29)$$

where - C_k is Furje coefficient.
From equation (28) it is seen, that:

$$D_k = (T_1 - T_0)C_k; \quad (30)$$

$$f(r) = \sum_k C_k J_0(\mu_k r), \quad (31)$$

where $f(r)$ – whatever function, which can be impulse function as well.
Now we need both equations (29 and 30) to multiply with $rJ_0(\mu_k r)$ and integrate from "0" to "R".
The particular function I_k is obtained:

$$I_k = \frac{R^2}{2}\left(J_0{}^2(\mu_k R) + J_1{}^2(\mu_k R)\right). \quad (32)$$

and

$$C_k = \frac{2J_1(\mu_k R)}{\mu_k R\left[J_0{}^2(\mu_k R) + J_1{}^2(\mu_k r)\right]}. \quad (33)$$

Results and discussion

The solution for determination the temperature drop during the fluid flow through the tube is obtained:

$$T(r;z) = T_0 + 2(T_1 - T_0)\sum_{k=1}^{\infty} \frac{J_1(\mu_k R) \cdot J_0(\mu_k r) \cdot e^{(\beta - \sqrt{\beta^2 + \mu_k^2})z}}{(\mu_k R)\left[J_0{}^2(\mu_k R) + J_1{}^2(\mu_k R)\right]}. \quad (34)$$

According to this equation, it is possible to calculate temperature drop during fluid flow through the tube at the different conditions. In the figure 1, different cases of the fluid flow are presented, three curves are being compared, when diameter of the tube and heat transfer coefficient is changeable, and other parameters remain constant.
From the picture it is seen, that temperature decrease of the fluid (in our case water) is exponentially dependant from the tube length. Three cases for simulation were chosen (diameter value 1 cm, 1.5 cm, 2 cm). In the first case temperature drop during the 1 m fluid flow through the tube is 1.01%, in the second and third cases 0.67% and 0.50% respectively. The value of the heat transfer coefficient was changed theoretically, but further it is necessary to make train of experiments to determine heat transfer coefficient dependency on tube

diameter and other important parameter as flow speed, fluid type and surrounding environment.

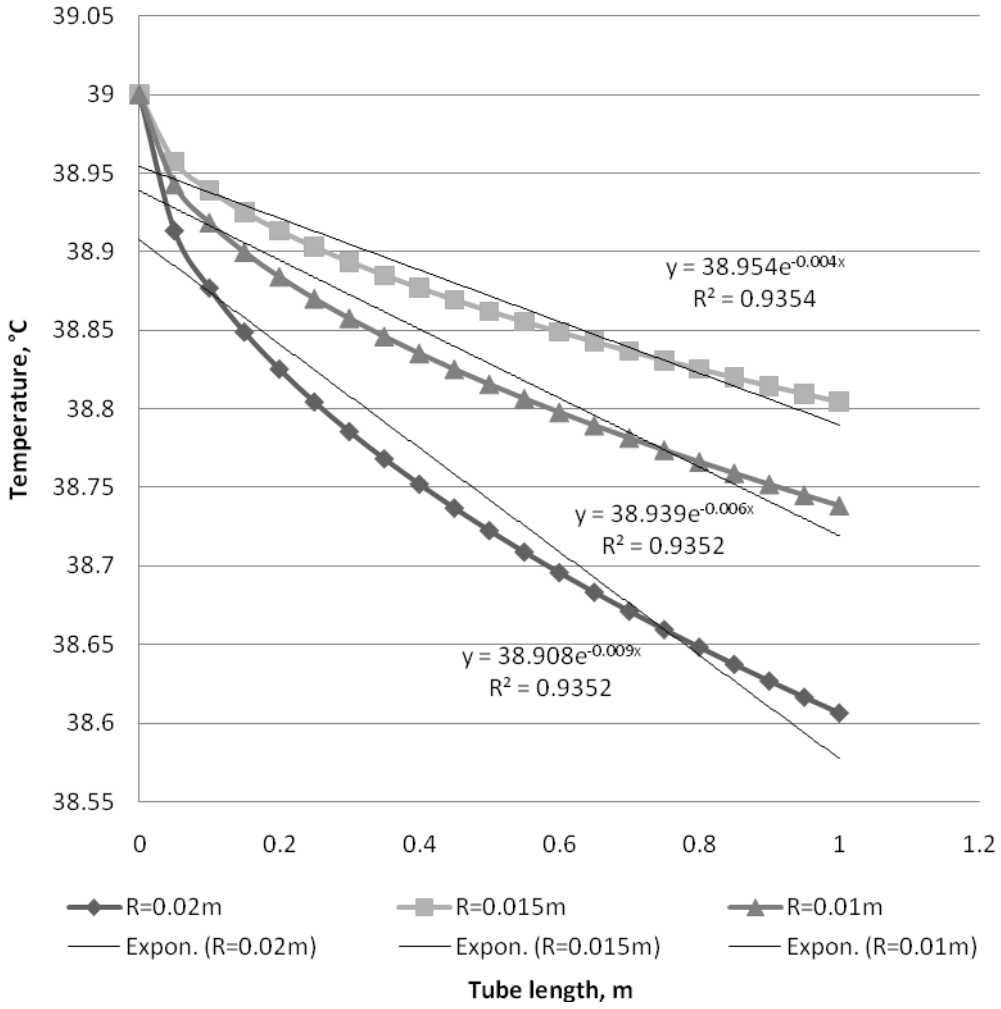

Fig. 1. **Fluid flow through the water tube with different diameters**

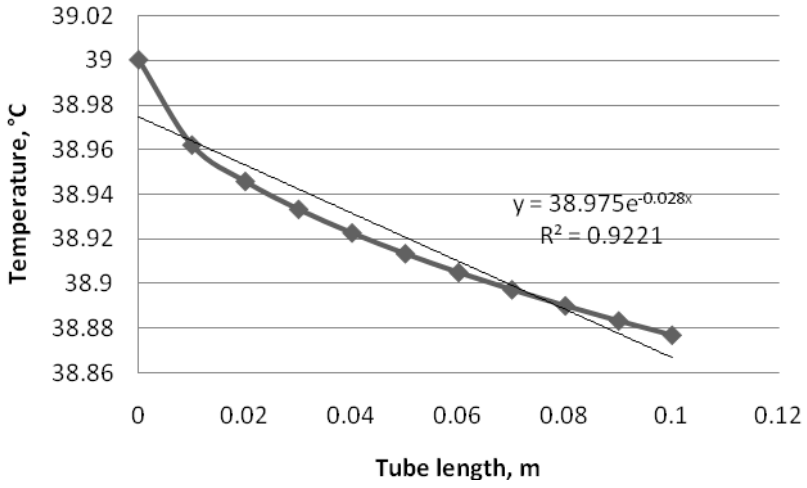

Fig. 2. **Temperature drop of the fluid during the first 10 cm flow**

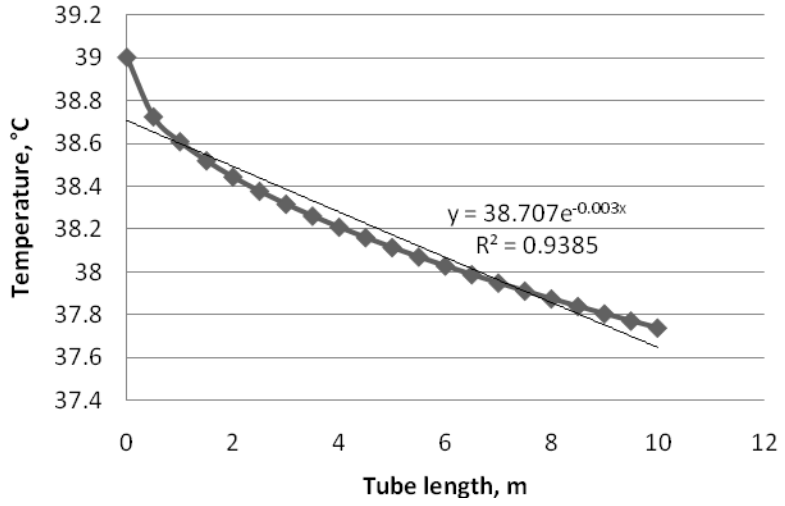

Fig. 3. **Temperature drop of the fluid during the 10 m flow**

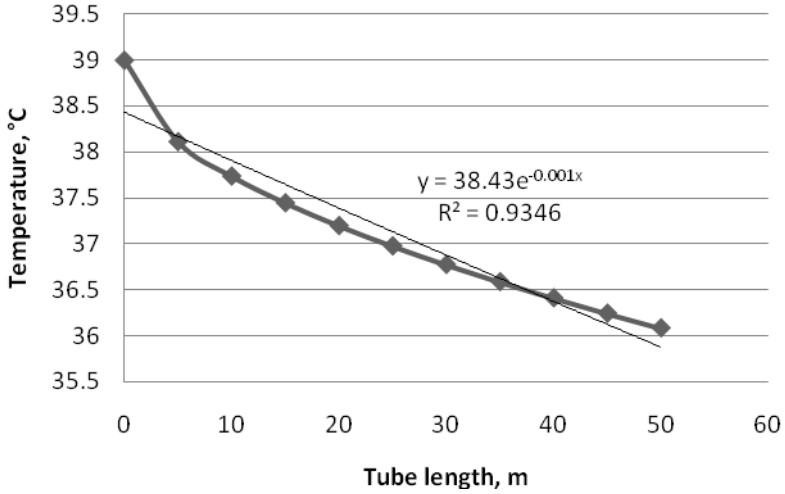

Fig. 4. **Temperature drop of the fluid during the 50 m flow**

Comparing figures two, three and four. We can see the tendency of the temperature drop depending on the fluid flow distance, for example, when fluid flows 10 cm the temperature drop of 0.32% occurs, but when distance is ten times greater, the temperature drop only for 1.01% appears, when we speak about longer distances, then at 50 m distance it will be 3.24%. Using obtained formula it is possible to calculate the temperature drop of fluid at different fluid flow distances. Using previously obtained formulas [Zagorska V., et al. 2010], it is possible to make the model of the heating panel for various materials, flow rates, surrounding environment parameter values.

Conclusions

1. Formulas (33), (34) and (25) make the mathematical model of a tube with fluid flowing inside it at boundary conditions (2) to (4).
2. They enable to calculate the temperature drop, during the fluid flow at certain values of the parameters included into the formulas.
3. These calculations enable to analyze coherence among different parameters of a water tube.

4. It is necessary to determine heat transfer coefficient dependence on the tube diameter, fluid flow speed and surrounding environment experimentally, using well known equations.

Acknowledgment

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STRUCTURE AND PHASE CHANGES IN NATURAL AND SYNTHETIC MAGNESIUN ALUMINIUM SPINEL

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Abstract. *Natural spinel crystals from Ural and Pamir deposits and synthetic magnesium aluminium spinel single crystals with different stoichiometry ($MgO{\cdot}nAl_2O_3$) grown by Verneuil method were used. The photoluminescence (PL), its excitation (PLE) and optical absorption of stoichiometric and nonstoichiometric magnesium aluminium spinel crystals containing the chromium and manganese ions and defects produced by fast neutron irradiation(fluence up to $10^{20}cm^{-2}$, E>0.1 MeV) are investigated. The broadening of R- and N-lines takes place in synthetic stoichiometric spinel. Structure of synthetic nonstoichiometric spinels (n>1) has to be more disordered, since in addition to the site exchange the so called stoichiometric vacancies are present in the structure. The R- and N-lines broadening takes place after spinel crystals irradiation by fast neutron too. The neutron irradiation causes increasing of the spinel inversion. Furthermore the great deviation from stoichiometry leads to the local structure of α-Al_2O_3 formation around Cr^{3+} ions. The orange emission band at 570 nm is belonging to complex center "Mn^{2+}-F^+ (or F centre)".*

Keywords: *magnesium aluminium spinel, neutron irradiation, absorption and luminescence spectra.*

Introduction

Magnesium aluminium spinel is mixed oxide with high melting temperature at 2135 ºC . It has good thermal and mechanical properties, high hardness and low electrical loss. $MgAl_2O_4$ thin film is a possible candidate for the development of integrated humidity sensors [1]. Spinel single crystals are used for substrate in integrated electronics [2], they are known as laser materials [3-6]. Since magnesium aluminium spinel is highly resistant to neutron irradiation it is considered to be a candidate material for fusion reactor application such as dielectric windows for radio – frequency heating systems and insulators for magnetic coils [7-11]. Oxide spinels have attracted great attention in the field of Earth science because of their importance as constituent minerals in many igneous and metamorphic rocks [12].

The spinel belongs to double oxides of the $X^{2+}(Y^{3+})_2O_4$ type, where X is Mg^{2+}, Fe^{2+}, Mn^{2+} or other bivalent ions, and Y is Al^{3+}, Fe^{3+}, Cr^{3+}, Mn^{3+} or other trivalent ions. Magnesium aluminium spinel $MgO{\cdot}nAl_2O_3$ (if stoichiometric, n=1) is a cubic-type face centred crystal. The elementary cell consists of 8 formula units XY_2O_4. Oxygen ions create a close-packed arrangement with 64 tetrahedral and 32 octahedral interstices per cell. If eight bivalent ions occupy eight tetrahedral (A) sites, and 16 trivalent ones – 16 octahedral (B) sites, the spinel is described by the space symmetry group O^7_h and is called "normal". For the "inverse" spinel, a half of the trivalent (Y) ions is located in the tetrahedral position; the other part of Y and X ions is usually statistically distributed between the octahedral positions. If we use an inversion parameter i, the chemical formula of magnesium aluminium spinel may be expressed by $^{IV}(Mg_{1-i}Al_i)^{VI}[Mg_{-i}Al_{2-i}]O_4$,where $^{IV}( )$ and $^{VI}[\ ]$ represents the tetrahedral (A sites; 8a) and the octahedral sites (B site;16d). Assuming i = 1, we obtain a formula $Al[MgAl]O_4$ for the inverse spinel.

Transition metal ions in magnesium aluminium spinel nave been studied extensively, and their optical spectra in the infrared and visible part of a spectra are satisfactorily understood. Nevertheless, there is little information about the influence of fast neutron radiation on impurities behavior. The paper presents investigations of the of the structure and phase changes in natural and synthetic magnesium aluminium spinel crystals containing transition metal ions (Cr, Mn) and irradiated by fast neutron.

Materials and methods

Natural spinel crystals from Ural and Pamir deposits and synthetic magnesium aluminium spinel single crystals with different stoichiometry ($MgO \cdot nAl_2O_3$) grown by Verneuil method were used. Crystals labelled as 'Mn' have been doped with manganese. Chromium ions are used as a sensitive probe for absorption and luminescence spectra investigation.

Micro (Cr, Mn, Fe) and macrocomponent (Mg, Al) quantities have been detected by the instrumental neutron activation analysis technique [13]. Concentrations of some impurities (mass %) are given in Tab.1. The Tab. 2 presents the results of the determination of the macrocomponents in the magnesium-aluminium spinels. Sample thickness was in the range of 0.5–1 mm.

Table 1.

The concentration of the impurities in the spinel, mass %

Notation	Cr	Mn	Fe
Black	$1.5x10^{-3}$	23	1.2
Pink	$2x10^{-3}$	2.9	0.31
Dark pink	$8.0x10^{-2}$	0.1	$3x10^{-2}$
Middle pink	$7.0x10^{-2}$	0.1	$6x10^{-2}$
Lilac	$9.8x10^{-5}$	0.02	1.31
$MgO \cdot Al_2O_3$ (1)	$0.43x10^{-4}$	$0.3x10^{-4}$	$1x10^{-3}$
$MgO \cdot Al_2O_3$ (2)	$0.41x10^{-4}$	$0.16x10^{-4}$	$8.1x10^{-4}$
$MgO \cdot 2Al_2O_3$	$1.25x10^{-4}$	$0.17x10^{-4}$	$4x10^{-4}$
$MgO \cdot 2.8Al_2O_3$	$0.99x10^{-4}$	$0.2x10^{-4}$	----
$MgO \cdot Al_2O_3$ (MA 1:1 Mn 0.1)	$4.3x10^{-4}$	0.015	$1.2x10^{-4}$
$MgO \cdot 2.5Al_2O_3Mn0.1$	$\leq 1x10^{-4}$	$3.0x10^{-2}$	$1.4x10^{-2}$

Table 2.

The contents of the macrocomponents of $MgO \cdot nAl_2O_3$

Notation	Introduced	Obtained
$MgO \cdot Al_2O_3$ (MA 1:1)	1:1	1:0.9
$MgO \cdot Al_2O_3$ (MA 1:1)	1:1	1:1.5
$MgO \cdot 2Al_2O_3$ (MA 1:2)	1:2	1:1.7
$MgO \cdot 2.8Al_2O_3$ (MA 1:2.8)	1:2.8	1:2.5

Luminescence spectra of spinel crystals have been measured at liquid nitrogen temperature with an SPM-2 monochromator having a diffraction grating of 651 lines per mm. Crystals were excited by a high pressure xenon lamp (DKSEL-1000) connected to a monochromator (ZMR-1) with a quartz prism. Monitoring was carried out with a photomultiplier tube (FEU-119) using a synchronic detection method.

The neutron irradiation was performed in the Latvian 5MW water-water research reactor. The fluence of fast neutrons with an energy > 0.1 MeV was in the range of 10^{14} - 10^{20} cm^{-2}. The accompanied γ-irradiation with average energy 1.1 MeV gave an absorption dose of 0.33 Gy. The irradiation temperature was 293 K. A cadmium filter was used for thermal neutron absorption.

The optical absorption spectra were measured with a double-beam spectrophotometer "Specord M-40" (Karl Zeiss Jena) operating in the wavelength region of 200–900 nm (50000–11000 cm^{-1}). Optical measurements before and after irradiation were carried out at 293 and 80 K temperature.

Results and discussion

Fig. 1 shows the absorption spectra of $MgO{\cdot}Al_2O_3$ single crystals before and after fast neutron irradiation. After irradiation there appears an intense absorption on the long edge and occurs the characteristic maximum at 535 nm. The intensity of this peak grows with fast neutron fluence increasing.

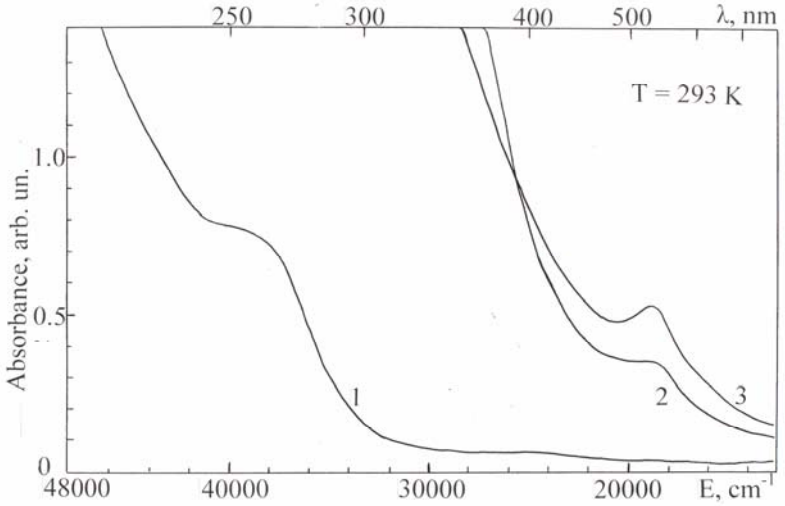

Fig.1. **Absorption spectra of $MgO{\cdot}Al_2O_3$ single crystals:**
1. before irradiation, 2. after fast neutron $\Phi=10^{16}cm^{-2}$, 3. $\Phi=10^{20}cm^{-2}$

The neutron irradiations of crystal with great deviation from stoichiometry (n> 2.5) have just the opposite absorption spectra (Fig. 2). Before irradiation the crystal is transparent. After irradiation at fluence $\Phi=10^{16}cm^{-2}$ in absorption spectra there is observed intensive absorption at $\lambda<280$ nm and bands at maxima 305, 355 and 470 nm. The same effect gives neutron irradiation of the α-Al_2O_3:Cr crystal. The band's location, which has been produced by neutron irradiation for α-Al_2O_3:Cr is similar to $MgO{\cdot}2.8Al_2O_3$ (Fig.2, curve 4).

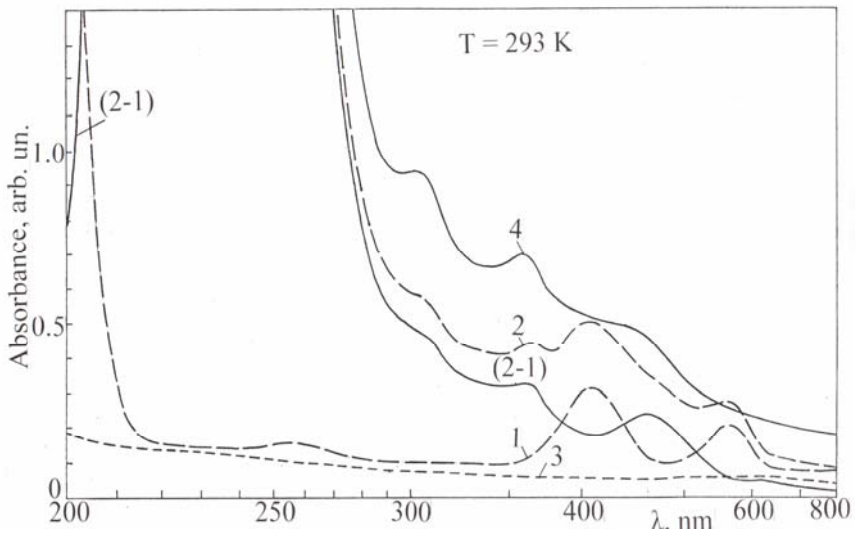

Fig. 2. **Absorption spectra of α-Al_2O_3:Cr:**
1. before irradiation, 2. after fast neutron $\Phi=10^{16}cm^{-2}$ irradiation, (2-1). additional absorption spectrum, 3. $MgO{\cdot}2.8Al_2O_3$ single crystals before irradiation, 4. after fast neutron $\Phi=10^{16}cm^{-2}$

The photoluminescence spectra of natural and synthetic magnesium aluminium crystals with different stoichiometry are given in Fig. 3. In the natural spinel spectra (Fig.3, solid line)

some zero-phonon lines were observed in the region of the Cr^{3+} ions electron transition $^2E_g \rightarrow {}^4A_{2g}$: R-lines (684.7 and 684.5 nm) predetermined by Cr^{3+} ions, which replace Al^{3+} ions in the octahedral sites of the spinel lattice; N-lines (686.0, 688.2, 690.9 and 692.3 nm) related to the Cr^{3+}ions, which local symmetry differs from symmetry of sites occupied by Al^{3+} in normal spinel.

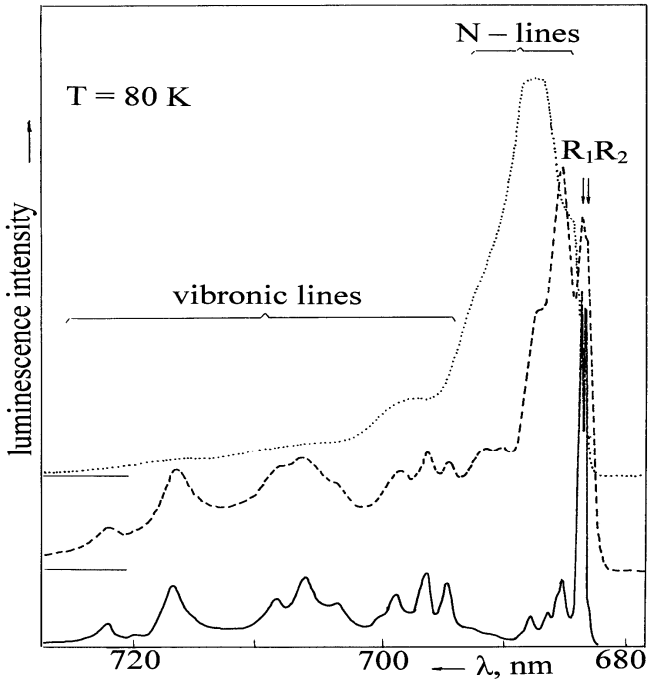

Fig.3. **Photoluminescence spectra of magnesium aluminium spinel. Solid line – natural spinel, dashed line – synthetic crystal $MgO \cdot Al_2O_3$, dotted line - synthetic crystal $MgO \cdot 2.8Al_2O_3$**

The broadening of R- and N-lines takes place in synthetic stoichiometric spinel (Fig. 3, dashed line). Structure of synthetic nonstoichiometric spinels (n>1) has to be more disordered, since in addition to the site exchange the so called stoichiometric vacancies are present in the structure. Therefore, the numbers of different versions of cation location in the 2nd coordination sphere increases. Moreover, an absence of a cation affects Cr^{3+} ion stronger than Mg^{2+} substituted for Al^{3+}. The number of Cr^{3+} ions with normal arrangement becomes negligible. As a consequence, in the luminescence spectra of a nonstoichiometric spinel one can observe the highly broadened bands with rather intensive N-lines and without signs of R-lines (Fig.3, dotted line). The broadening of R- and N-lines takes place after spinel crystals irradiation with fast neutrons [14]. The photoluminescence spectra of $MgO \cdot 2.8Al_2O_3$ crystal is shown in Fig.5b. Before irradiation (Fig. 5b, curve1) spectrum consists of so-colled N-lines only [15]. After irradiation by fluence $\Phi = 10^{16} cm^{-2}$ there appears two broad bands 470 and 580 nm (Fig.5b, curve 2). The Cr^{3+} luminescence spectrum completely changes (the luminescence spectra are observed at λ_{ex}= 400 nm). Luminescence spectra of the irradiated $MgO \cdot 2.8Al_2O_3$ crystal have been compared to that of α-Al_2O_3:Cr crystal. Position of the sharp lines of irradiated $MgO \cdot 2.8Al_2O_3$ crystal coincides with the R_1 and R_2 lines position for α-Al_2O_3:Cr crystal. Taking into consideration that N – lines intensity is closely associated with the inversion parameter, it is possible to state that neutron irradiation causes increasing of the spinel inversion. Furthermore at high deviation from stoichiometry in magnesium aluminium spinel around the Cr^{3+} ions the local structure of α -Al_2O_3 is observed.

In absorption spectra of manganese containing nonstoichiometric magnesium-aluminium $MgO{\cdot}2.5Al_2O_3$ spinel, bands at 367,430,451 550 and 610 nm are observed. Stoichiometric $MgAl_2O_4$ single crystal has the more complex shape. Apart from the above mentioned sharp lines two broad bands with maxima 390 and 555 nm as well as 260 nm band are found out. For Mn^{2+} ($3d^5$-configuration) the net stabilization energy is zero kkal/mol [16], therefore, Mn^{2+} ions equally possibly are situated in tetra- or octasites. Figure.4 shows photoluminescence excitation spectra of $MgO{\cdot}Al_2O_3$:Mn0.1 crystal at λ_{lum}= 520 nm and λ_{lum}= 700 nm.

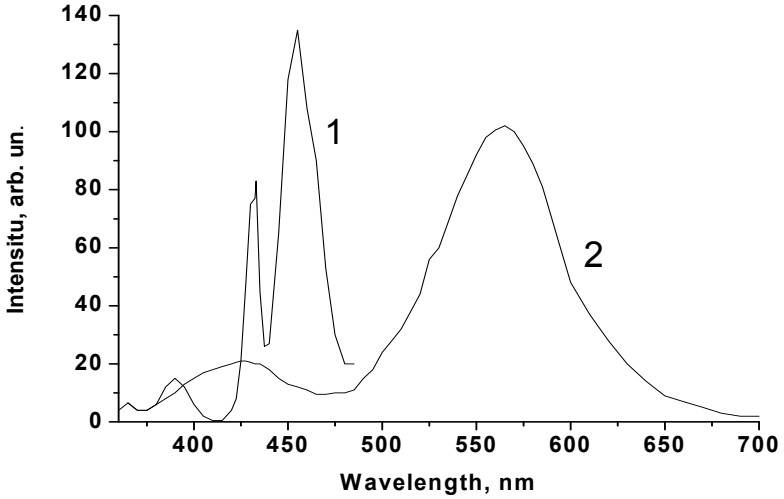

Fig.4. **Photoluminescence excitation spectra of $MgO{\cdot}Al_2O_3$:Mn0.1 crystal:**
1 - λ_{lum}= 520 nm, 2 - λ_{lum}= 700 nm

The spectra obtained at 520 nm showed two sharp lines at 433 and 455 nm, but for λ_{lum}= 700 nm there are observed two broad lines 565 and 430 nm, which correspond to energies of the $^4A_{2g} \rightarrow {}^4T_{2g}$ and $^4A_{2g} \rightarrow {}^4T_{1g}$ transition of Cr^{3+} ions. Shapes of the excitation spectra of stoichiometric and nonstoichiometric spinel are identical. But the relationship between band intensity and manganese concentration differs from sample to sample according to its composition. In contrast to synthetic spinel an emission band with a maximum at 625 nm has been found in natural spinel (dark and middle). An emission band with fine structure around 640 nm has been revealed in natural lilac colored spinel in addition to the band at 510 nm [17]. Photoluminescence spectra of $MgO{\cdot}Al_2O_3$: crystal containing 0.1 mass% of manganese is given in Fig.5a. Before irradiation spectra contain only Cr^{3+} impurity bands. After irradiation there appears a broad emission band, which spreads from 500 to 800 nm (λ_{ex}= 470 nm). Band at 520 nm is connected with Mn^{2+} ions occupying tetrahedral site in spinel structure. Green emission has been observed in synthetic stoichiometric and nonstoichiometric spinel with manganese impurity [18].

After irradiation a band at 570 nm appears in photoluminescence spectra of $MgO{\cdot}Al_2O_3$: crystal containing 0.1 mass% of manganese (Fig. 5a). This band appears only at low temperature in pattern containing manganese. Evidently, that the broad emission line 500-800 nm is connected with intrinsic defects, but peak 570 nm - with complex centers, because it appears after neutron irradiation only in the crystal containing manganese impurity.

A model which explains the observed features is that Mn^{2+} impurity ions are perturbed by presence of a nearby F or F^+ center (anion vacancies in the spinel can capture one or two electron to form F^+ and F centers [19]). The presence of a nearby F or F^+ center may modify the environment at the Mn^{2+} impurity site to produce an effective increase in the crystal field. In additional to the shift in energy, the perturbation induced by the F or F^+ center can increase

the oscillator strength by introducing odd components to the crystal field, or by exchange coupling between the F or F^+ center and the Mn^{2+} impurity. The enhancement of the oscillator strength by the exchange interaction has been previously observed between F centers and transition metal impurity ions in MgF_2, $MgAl_2O_4$ and MgO [20-24]. As the concentration of F and F^+ centers increased, the number of perturbed manganese sites also increased, so that the excitation peaks became more intense as a function of neutron dose. Since orange emission is attributed to Mn^{2+} in octahedral coordination, it is possible to assume that the band at 570 nm belongs to a complex center "Mn^{2+}-F^+ (or F centre)".

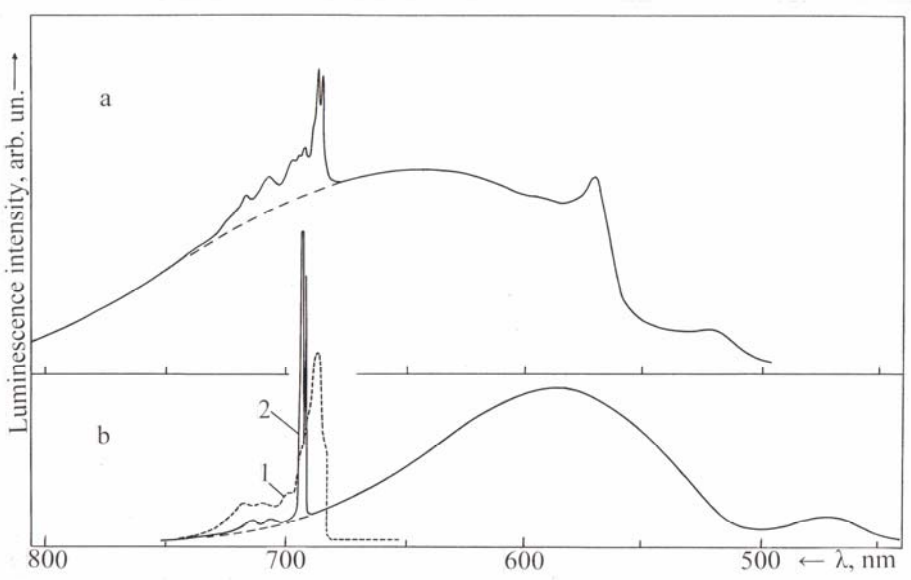

Fig.5. **Photoluminescence spectra of $MgO{\cdot}Al_2O_3$:Mn0.1 (a) and $MgO{\cdot}2.8Al_2O_3$ (b) crystal irradiated by fast neutrons. T = 80 K**

Summary

The photoluminescence (PL), its excitation (PLE) and optical absorption of stoichiometric and nonstoichiometric magnesium aluminium spinel crystals containing chromium and manganese ions and defects produced with fast neutron irradiation fluence up to $10^{20}cm^{-2}$ (E>0.1 MeV) are investigated. Natural spinel crystals from Ural and Pamir deposits and synthetic magnesium aluminium spinel single crystals with different stoichiometry ($MgO{\cdot}nAl_2O_3$) grown by Verneuil method were used. Micro (Cr, Mn, and Fe) and macro component (Mg, Al) quantities have been detected by instrumental neutron activation analysis technique. Chromium ions are used as a sensitive probe for absorption and luminescence spectra investigation.

In the natural spinel spectra some zero-phonon lines were observed in the region of the Cr^{3+} ions electron transition $^2E_g \rightarrow {}^4A_{2g}$: R-lines predetermined by Cr^{3+} ions, which replace Al^{3+} ions in the octahedral sites of the spinel lattice; N-lines related to the Cr^{3+}ions the local symmetry, which differs from symmetry of sites occupied by Al^{3+} in normal spinel. The broadening of R- and N-lines takes place in synthetic stoichiometric spinel. The R- and N-lines broadening takes place after spinel crystals irradiation by fast neutrons, too. Taking into consideration that N – lines' intensity is closely associated with the inversion parameter, it is possible to state that neutron irradiation causes increasing of spinel inversion. Furthermore the great deviation from stoichiometry leads to the local structure of α-Al_2O_3 formation around Cr^{3+} ions.

The orange emission is attributing to Mn^{2+} in octahedral coordination, it is possible to assume that the band at 570 nm belongs to a complex center "Mn^{2+}-F^+ (or F centre)".

Acknowledgment

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CONDITIONS OF FUEL FILLING DISPENSER TROUBLE – FREE OPERATION

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Abstract. *Regularly on the filling stations (FS) there are failures at priming of transport vehicles, when a driver, driving away after priming, forgets to smuggle out of a pistol from the mouth of filling tank of car. Thus, at wedging of pistol in the tank of car, there are not only breaks in a chart a pistol is a hose but also serious destructions of fuel filling dispenser (FFD). In the present paper the mathematical model of functioning of chart is considered vehicle - fuel filling dispenser. From the analysis of the got model, if a car begins motion with the undrawn pistol out of a fuel tank, the geometrical parameters of chart are determined vehicle - fuel filling dispenser, at which slipping out of pistol or his wedging will be in the mouth of tank which possible consequences are considered for (tearing away of pistol from a hose, tearing away of hose from corps of filling vehicle, break of hose, deformation of fuel filling dispenser). The geometrical parameters of chart are determined fuel filling dispenser, at which "forgetfulness" of driver will not result in damages of fuel filling dispenser f, and there will be slipping out of pistol from the mouth of fuel tank of car.*

Keywords: *fuel filling dispenser, fuel tank wedging, friction coefficient.*

Introduction

One of the main dangers in the process of fuel filling dispenser (FFD), is connected with the situation when a vehicle leaves the dispenser with filling pistol in the tank. This happens at most filling stations (FS). In this case, the car often drives off only from filling pistol when on the hose is safety cutoff clutch/valve (SCCV), or with the whole column, if the bursting SCCV is not installed or it does not work that leads to severe damage: Loss of FFD and damaging the car, and even ignite because of depressurization of FFD.

Fig.1. **The accident that occurred due to not pulled out of a tank a filling pistol**

Fig.2. **Safety cutoff clutch/valve (SCCV)**

The interest to SCCV has grown into a stable demand in many countries their use is mandatory. On the hardware market FFD most widely represented bursting SCCV production Emco Wheaton (USA), OPW (USA), Elaflex (Germany) and others (see Fig. 2.) with a force at break: 160-170 kg [5].The main the lack of some SCCV PTP associated with the method and location of installation: valve fails to break if the load angle of 90 °. That is, if

the car is near to the body of FFD or not from the fuel, the valve does not work, because the axial load on the valve in this case is missing.
The publication, based on an analysis of the technological scheme of the FFD, used for housing construction, the hose and the filling pistol is a recommendation on the location of the vehicle when it is fueling the body with respect to FFD, which ensures trouble-free situation, if the car after filling drives off from the FFD with inserted into the tank filling pistol.

Materials and methods

Fig.3. **Filling pistol**

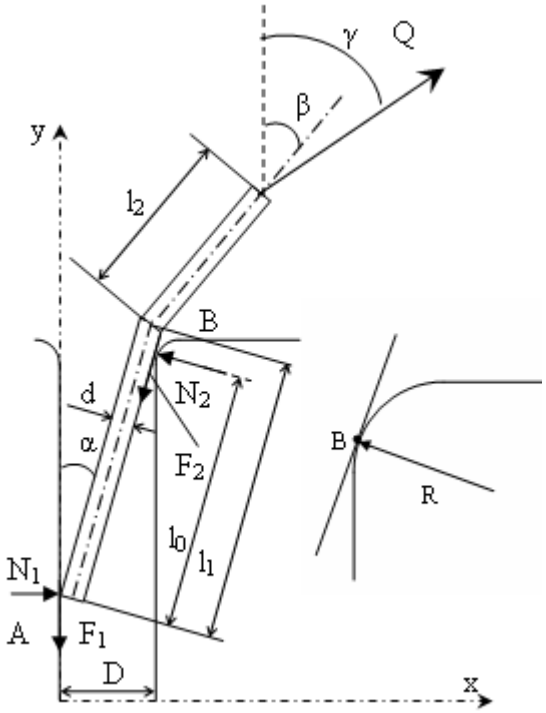

Fig. 4. **Design model**

The reaction F_1 and F_2 directed opposite to the outer movement of the pistol. Let us write the equation describing the relationship of geometric dimensions:

$$d\cos(\alpha) + l_1 \sin(\alpha) = D + R(1 - \cos(\alpha)) \tag{1}$$

Filling pistol and car's tank geometrical dimensions:
l_1 = 230÷260mm, l_2 = 200÷270mm, d = 20÷25mm, D = 40÷50mm, α = 2÷7°, β = 13÷20°
When a pistol is not moving, the contact point a pistol and filler cap are considered as hinges, restricting movement pistol in two directions (x and y). To find the unknown quantities N_1, N_2, F_1 and F_2 solve the hyperstatic system[2,3,6]. Equation of equilibrium of body:

$$\begin{aligned}
&\sum \vec{x} : N_1 - F_2 \sin\alpha - N_2 \cos\alpha + Q\sin(\gamma) = 0 \\
&\sum \vec{y} : -F_1 - F_2 \cos\alpha + N_2 \sin\alpha + Q\cos(\gamma) = 0 \\
&\sum M_A : -F_2 d + N_2 l_1 - Q \cdot l_1 \left(\frac{l_2}{l_1} \sin(\gamma - \beta) + \sin(\gamma - \alpha) \right) = 0
\end{aligned} \tag{2}$$

F2 reaction is found from the canonical equation (excluding the transverse force)[2,3,6]:

$$\delta_{11}F_2 + \delta_{1Q} = 0$$
$$\delta_{11} = \frac{l_1}{ES},\ S = \frac{\pi d^2}{4}\left(1 - \left(\frac{d_0}{d}\right)^2\right),$$
$$\delta_{1Q} = -\frac{l_1}{ES}Q\cos(\gamma - \alpha) \tag{3}$$
$$F_2 = Q\cos(\gamma - \alpha)$$

From 1-3 we find the reaction N_1, N_2, F:

$$N_1 = Q\frac{D\left[\cos(\alpha-\gamma) - \cos(\alpha+\gamma)\right] - l_2\left[\sin(\beta)\cos(\alpha)\cos(\gamma) - \sin(\gamma)\cos(\beta)\cos(\alpha)\right]}{D\sin(\alpha) - l_1\cos(\alpha)^2}$$
$$N_2 = Q\frac{\left\{D\cos(\alpha) + l_1\cos(\alpha)\sin(\alpha)\right\}\left[\cos(\alpha-\gamma) - 1\right] + l_2\left[\cos(\gamma)\sin(\beta) - \sin(\gamma)\cos(\beta)\right]}{D\sin(\alpha) - l_1\cos(\alpha)^2} \tag{4}$$
$$F_1 = Q\frac{l_1\cos(\alpha)\left[\cos(\alpha-\gamma) - \sin(\gamma)\sin(\alpha) - \cos(\gamma)\cos(\alpha)\right] + l_2\sin(\alpha)\left[\sin(\beta)\cos(\gamma) - \sin(\gamma)\cos(\beta)\right]}{D\sin(\alpha) - l_1\cos(\alpha)^2}$$

Reaction of F_1 and F_2 can not be more the frictional forces F_{f1} and F_{f2}. Module the frictional forces can be expressed through of the normal reaction N_1 and N_2:

$$F_1 = F_{f1} = N_1 f_1$$
$$F_2 = F_{f2} = N_2 f_2 \tag{5}$$

In relations (5) f_1 and f_2 - the coefficients of friction, respectively, in sections of the contact with the neck of filling tank and the pistol. In overall case $f_1 \neq f_2$.
From relations (3) and (4) implies that if:

$$F_1 \geq F_{f1} = N_1 f_1 \tag{6}$$

then at the contact point A is a necessary condition under which a possible move at this point, and accordingly, if:

$$F_2 \geq F_{f2} = N_2 f_2 \tag{7}$$

then at the contact point B is a necessary condition under which a possible move at this point. From (3) - (7) we can define the angle γ, which may slip the pistol by the throat filling the tank, respectively, in sections of the contact A and B. For the numerical example:
l_1 = 23 cm, l_2 = 20 cm, D = 5 cm, d = 3 cm, α = 5°, β = 65°, $f_1 = f_2$ = 0.3
To simplify the comparison of all the forces are built as a function by the angle γ in Figure 5. As is evident from the graphs in Figure 5 at point A at a smaller angle γ, are the conditions under which filling pistol's motion is possible at this point. Mean the filling pistol starts moving when in the point B are the conditions for the movement at this point.

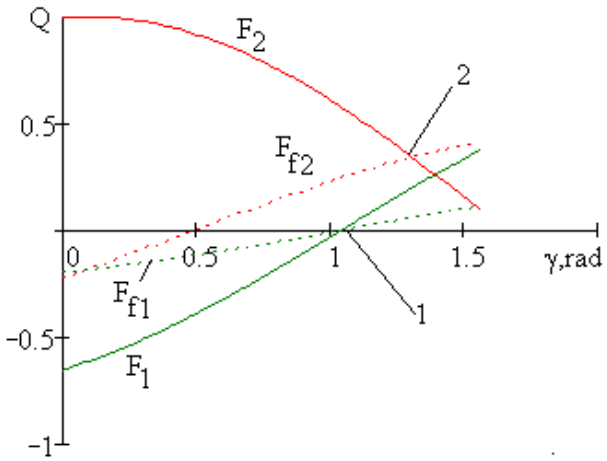

Fig. 5. **Dependence of the forces F_1, F_{f1}, F_2, F_{f2} by the angle γ**

For the limiting case where $F_1 = F_{f1} = N_1 f_1$ and $F_2 = F_{f2} = N_2 f_2$, have five equations (2), (3) and (5) with five unknowns: reaction of N_1, N_2, F_1, F_2, and the angle γ. The problem is statically defined. Determined by the normal reaction of N_1 and N_2:

$$N_1 = Q\frac{f_2\sin(\alpha)\cos(\gamma)+\cos(\alpha)\cos(\gamma)-f_2\sin(\gamma)\cos(\alpha)+\sin(\gamma)\sin(\alpha)}{f_2\cos(\alpha)+f_1 f_2\sin(\alpha)+f_1\cos(\alpha)-\sin(\alpha)}$$
$$N_2 = Q\frac{f_1\sin(\gamma)+\cos(\gamma)}{f_2\cos(\alpha)+f_1 f_2\sin(\alpha)+f_1\cos(\alpha)-\sin(\alpha)} \quad (8)$$

For the third equation of system (2) we obtain:

$$(1.973\cdot\cos(\gamma)-1.250\cdot\sin(\gamma))\cdot Q[l_1-0.3d]d+-Q\cdot l_1\left(\frac{l_2}{l_1}\sin(\gamma-\beta)+\sin(\gamma-\alpha)\right)=0 \quad (9)$$

which allows us to determine the greatest value of the angle γ, which is still possible to balance the pistol in refueling the tank. If the value of the angle γ is less than the value determined by equation (9), the pistol will slip out of filling tank.
For the adopted numerical values of the pistol in Fig. 6 provides a solution to (9), which implies that the movement of the pistol is possible at an angle $\gamma_{max} < 69^0$

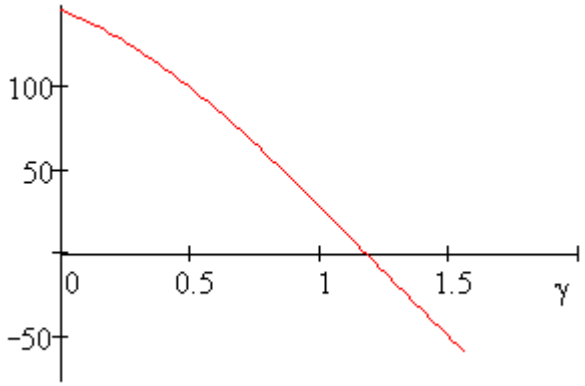

Fig. 6. **Graphical solution of equation (9)**

Results

Knowing the angle γ_{max} in Figure 7 can approximately determine the minimum distance L_{min}, which should be raised from the housing dispenser car at a fuel filling dispenser (FFD) to avoid jamming the pistol in refueling the tank, if the driver forgot to pull out after filling the the pistol out of filling the tank.

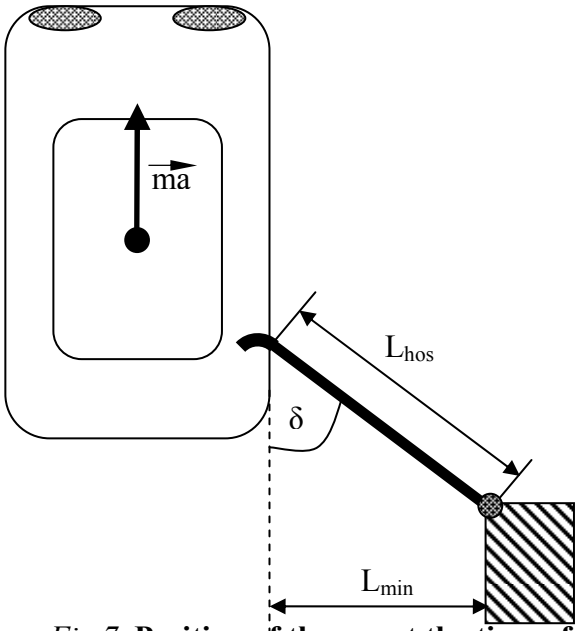

Fig.7. **Position of the car at the time of slipping or jamming the pistol**

$$L_{\min} \geq L_{hos} \cdot \sin(\delta_{\min}), \qquad \delta_{\min} = 90 - \gamma_{\max} \tag{10}$$

At the beginning of the pistol motion (could be the beginning of motion) force the tension hose can be calculated by the formula:

$$q_{hos} = F_{f1} \cdot \cos(\gamma) + F_{f2} \cdot \cos(\gamma - \beta) = N_1 f_1 \cdot \cos(\gamma) + N_2 f_2 \cdot \cos(\gamma - \beta) \tag{11}$$

where: N_1 and N_2 calculate by formula (8).

If at the time when the movement becomes possible tensile strength hose is more than the limit (q_{hos}>160-170 kg), the pistol will remain in the tank and explode safety cutoff clutch/valve. If the SCCV is not operable or not it will damage the FFD. Calculate conditions could be the beginning of pistol motion, remember that at this moment the tension force the hose does not exceed the allowable.

Conclusions

In this paper we analyze the process of jamming the pistol in the neck of the fuel tank. It can be concluded in order to avoid jamming is necessary to reduce friction coefficient at the contact points a pistol and the neck of the fuel tank. The most effective and easily implemented way to avoid the jamming is to increase the distance from the car before fuel filling dispenser.

Acknowledgment

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NATURAL FIBRE TEXTILE NANO-LEVEL SURFACE MODIFICATION

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Abstract. *A variety of applications requires production of textile materials with specially designed surface properties. Surface coating by metallic materials have attracted a lot of attention due to their special surface properties, such as UV-absorbsion, antimicrobial, anti-fungicidal and ect. The paper describes the process of vacuum evaporation and magnetron sputtering of copper layers on cotton textile materials and analysis of the metal coated textile surface morphology by laser laboratory complex. The textile samples have been finished by magnetron sputtering and vacuum evaporation technologies and tested for bonding strength, light reflection and light passing properties. The paper presents and discusses the results of the experiment.*

Keywords: *copper, cotton, magnetron sputtering, vacuum evaporation, textile.*

Introduction

Nanotechnology brings us a step closer towards materials with specific individual properties and represents a shift away from the catalogue range of standard materials. Surfaces emancipate themselves from the underlying material, developing clearly defined additional functions that can differ fundamentally from the substrate material. The goal of nanotechnology is a consistent usage of the minimum amount of raw material and energy, from an economic and ecological point of view, in the long term "nano" is a winning factor. The use of nanotechnology offers ecological and economic advantages for energy efficiency and the conservation of resources. [1]

It is important to take a life-cycle approach to evaluate the environmental as well as human health impacts at each stage of a nano-enabled product's life cycle (Fig.1.) before arriving at any conclusions regarding the product's potential environmental benefits or drawbacks.

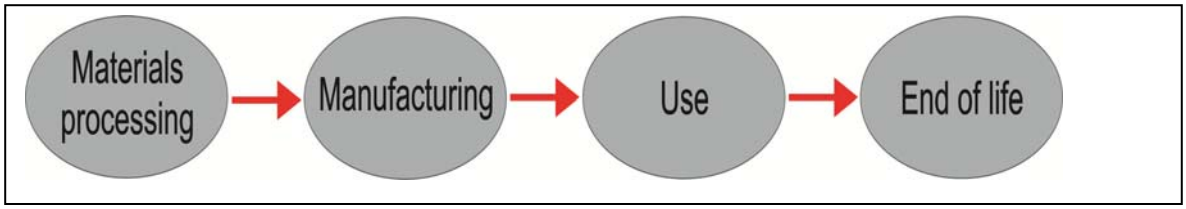

Fig.1. **Product life-cycle**

Manufacturing process requires energy, but creation of nano-level textile coatings needs a shorten process time which reduces energy consumption. At present manufacturing processes for the production of nanomaterials are not standardized, but are in an evolutionary stage, changing constantly. The techniques for textile surface modification generally are grouped in two major categories: chemical and physical. Physical methods are based on usage of non-chemical forces to control deposition of functional material on the textile surface. [2] Having the ability to control the surfaces of a natural fibers offers great rewards that go far beyond pure economics as natural fibers are renewable and biodegradable resources. [3]

At present consumers are becoming increasingly aware of the hygienic life style and there is a necessity and expectation for a wide range of textile products finished with biocide properties. One way to avoid the microbial degradation of textile fibres, limit the incidence of bacteria and fungi, and protect users, is the treatment of textiles with antimicrobial agents, such as silver and copper. Man has been exploiting the natural antimicrobial properties of copper since the dawn of civilization. It has been demonstrated clearly in many scientific studies conducted over several decades that copper reduces contamination of the most toxic species of bacteria, fungi and viruses, and inhibits its growth.

Copper is considered to be safe for humans, as demonstrated by the widespread and prolonged use by women of copper intrauterine devices (IUDs). [4] Animal studies have demonstrated that copper fibers do not possess skin sensitizing properties. These findings are in accordance with the very low risk of adverse skin reactions associated with copper. [5,6] In contrast to the low sensitivity of human tissue (skin or other) to copper, microorganisms are extremely susceptible to copper [7,8]: copper surface kills over 99.9% of bacteria (*Escherichia coli, Enterobacter aerogenes, MRSA*, *Pseudomonas aeruginosa, Staphylococcus aureus)* for 24 hours. [9]

Materials and methods

Object of investigation. Commercial woven 100% plain wave cotton fabric with surface linear density 276.19 g/m2 from yarns of linear density 9.2 tex has been used in the experiment. The thickness of the textile fabric is approximately 0.25 mm; the measurement was taken by the textile fabric thickness tester ("TH-25", "Zapadpribor", Ukraine).

Pre-treatment of textile fabric. The ability of a particular construction textile fabric to hold treatment depends on the level of cleanness of its surface i.e. oils, waxes, sizes applied in yarn and fabric manufacturing processes, dust and dirt particles contaminant the surface of the fabric must be removed to provide good interfacial contact between fiber surface and deposited product.

The previous research evince that evenness of copper coating and copper concentration amount on sample of materials deviated from physical pre-treatment time in 80% acetone solution, the results of the experiment show that 5 minutes is the optimal immersing time in acetone solution. [10] It means that after immersing in acetone solution for 5 minutes the copper was well distributed on the fabric surface and more copper was deposited on the surface. [10]

Three different methods to increase adhesion force are under inspection: 1) to remove dust and organic matter from the surface of woven cotton fabric the samples were washed at temperature 90°C with detergent without optical brighteners, 2) after samples were immersed in 80% acetone solution at room temperature for 5 minutes, and were washed twice with distilled water (ISO 9001, ISO 14001), the drying step was carried out on a horizontal surface, 3) surface modification by plasma.

Surface modification by plasma. Low temperature plasma treatment is a quite new technology for the natural fiber textiles; plasma is essentially a dry process providing modification of the top nanometer surface. [11] The advantages of plasma technology are its potential environmental friendliness and energy conservation benefits in developing high-performance materials. [11] It offers many advantages against wet techniques: there are no harmful chemicals, wet processes, wastewater, and mechanical hazards to textiles, etc. In addition it has a specific impact on the surface and gives surface some properties that cannot be obtained by conventional techniques. [12]

The plasma treatment as activation method of the surface of cotton fabric is used to improve copper adhesion to the fabric surface followed by the deposition of the metallic layers by vacuum evaporation technology. The results of our previous research evince that plasma

activation of the materials surface followed by the deposition of the metallic layer by vacuum evaporation positively influences copper concentration on the surface and copper coat evenness. [13]

In vacuum evaporation technology, plasma treatment and coating with copper, is a two-stage process. It is possible significantly simplify this process, by the method of magnetron sputtering, which unites the two processes mentioned above in one. This is a quick, ecological process, practically without yielding any waste and characterized by high repeatability, stability and efficiency.

Vacuum evaporation technology. In high-vacuum evaporation ($1*10^{-4}$ – $5*10^{-5}$ mm Hg) chamber „UVN – 2U" alternating current electrical heating is used to melt, gasify and evaporate copper. Then the copper vapour travels to the surface of textile material and gradually cools. Vacuum conditions prevent the collision of the evaporated functional particles with the background gas or other unwanted particles. As "UVN-2U" uses a point-source to evaporate the coating material and copper melting and evaporation temperature is rather high (>1400 ºC) for cotton fibres, to protect cotton fibres from high temperature is used special protective screen. Short exposure time (1 to 2 seconds) is sufficient to get a thin copper layer without destruction of substrate material from natural fibres. Experimental results show that during one exposition (1 second) 60-70 nm thick film of copper is formed on the surface of cotton fabric sample. [10]

Magnetron sputtering technology. Magnetron sputtering is a plasma coating process whereby sputtering material is ejected due to bombardment of ions to the target surface. The vacuum chamber of the PVD coating machine is filled with an inert gas - argon. By applying a high voltage, a glow discharge is created, resulting in acceleration of ions to the target surface and a plasma coating. The argon-ions will eject sputtering materials from the target surface (sputtering), resulting in a sputtered coating layer on the products in front of the target.

Non-contact method of surface examination. In order to get a detailed insight into the change of the surface properties and develop a tool for comparative analysis the surface of the sample has been examined with the laboratory laser complex. The experiment has been carried out by the laser beam, changeable angles between falling and reflected light beams were -20°, -15°, 5°, 10°, 15°, and 20° degrees. Measurements of the reflected light, that show how changes the textile surface morphology after it coating with copper. [10, 13]

The passing light has been measured by laboratory laser complex that makes it possible to determine the evenness level of the copper layer and the copper layer changes after exploitation impacts (Fig.2.).

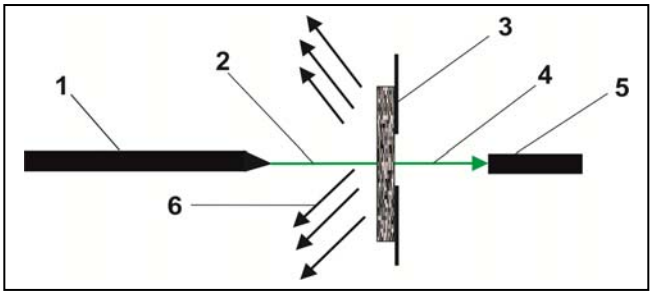

Fig.2. **Laboratory laser complex for the measuring of passing through light:**
1 – laser; 2 – incident laser beam; 3 – textile sample on holder; 4 – passing laser beam; 5 – detector of passing light; 6 – scattered light

Results and discussion

Copper particles can be deposited onto cotton fabrics by vacuum evaporation and magnetron sputtering technologies.

The results of the research show that vacuum evaporation has such disadvantage as low bonding strength of functional coating with the substrate surface. [10,13] In our experiments we have achieved the twofold increase of surface adhesion after pret-treatment immersing in 80 % acetone solution for 5 min and surface modification by low pressure plasma, but still exploitation of textile have a considerable influence on the copper layer. [10,13]

The samples have been washed in order to observe the see effects of exploitation processes on the copper coated textile samples finished by magnetron sputtering technology. Before washing and after samples of all washing times were measured passing through and reflected coherent light. The received passing light measurement results show, that light passing of the textile material samples covered with copper is only 48% in comparison to the light passing of the uncovered materials, after the first washing it is 60%, and after the second washing ~ 63%.

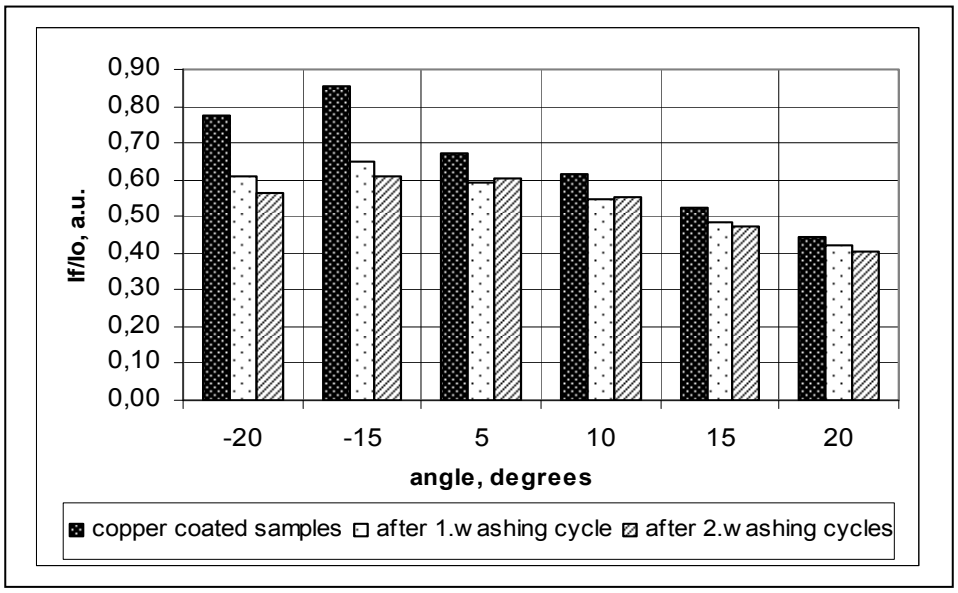

Fig.3. **Reflected light of coated samples before and after washing**
(a.u. – the level of light intensity, rationed to maximum)

The graph (Fig.3.) describes the measurement results of the reflected light by non-contact method of surface examination show similar results as passing light measurements. The graphs of Fig. 3 shows as well that the amount of reflected light decrease rapidly after the first washing, especially for small angles. It means that a part of the deposited copper was washed out during the first washing procedure and regular light reflection of the copper film diminished. The graph also shows that the effect of the second washing is insignificant; i.e. the unsteady copper particles were washed out during first cycle, and adhesion of the remaining particles is sufficient to resist repeating washing processes cycles.

The results of the experiment evince that reflected and passing light show that measurements of reflected and passing light can be applied to trace the metal covered fabric surface changes from exploitation impacts.

Summary

Application of nanotechnology offers ecological and economic advantages for energy efficiency and the conservation of resources. Magnetron deposition of nanolevel metal coatings on the textile surface reduces energy consumption in comparison with expenditures of the resources in traditional textiles finishing processes.

Vacuum evaporation and magnetron sputtering are physical methods based on application of non-chemical forces for deposition control of functional material on the textile surface.

Laser laboratory complex measurements of reflected and passing through covered material light can be applied to trace the unevenness of deposited metal film on the covered fabric surface and its changes from exploitation impacts.

Ability to add additional properties to the surfaces of natural fibers and textiles offers not only environmental and economic rewards, but solve problems connected with global resources shortening as natural fibers are yearly renewable and fully biodegradable resources.

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A METHOD FOR DETERMINATION OF SPECIFIC ELECTRICAL RESISTANCE OF STEEL AND NANO-COATING SPUTTERED ON IT

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Abstract. *The paper describes methods developed to determine specific electrical conductivity and relative magnetic permeability of cylindrical steel items and nano-coatings deposited on them by sputtering. Research enables development of a new method for determination of thickness of vacuum deposited nano-coating that is based on application of skin effect.*

Keywords: *electrical resistance, magnetic permeability, nano-coating thickness, skin effect, steel.*

Introduction

Development and implementation of technologies of sputtered protective nano-coatings require control over a thickness of the coatings which usually vary between 0.5-5μm. Traditionally, the thickness is determined using a scanning optical or electron microscope that implies destruction of a sample, it has to be sawn, polished, etched and then measured. Authors' previous experience tells that a preparation of one sample takes 2 -3 hours. It is necessary to develop less time consuming methods. The coatings contain metals; increase in the thickness also increases electrical conductivity. Therefore, the determination of the thickness could be based on electrical conductivity measurements. However, this approach has problems because steel is good electrical conductor, its resistance is comparable to that of electrical contacts and leads, the thickness of the coating is small in comparison to a size of a coated part and impact of the coating on total electrical conductivity of the part is negligible. The solution could be based on skin effect: at sufficiently high frequencies electrical charge only flows through a thin layer on the top of a conductor, electrical conductivity can become significant and can be measured. Therefore impact of the coating on total electrical conductivity can be significant and its value can be indicative of the thickness of the coating. To determine it, electrical and magnetic curve values have to be known. [1], [2], [3], [4]
The purpose of the paper is to develop methods for determination of specific electrical conductivity and relative magnetic permeability of steel and a nano-coating for electrical measuring of nano-coating thickness.

Materials and Methods

Determination of the specific electrical conductivity

Experiments are performed using a steel tube with length l=153mm and inside/outside diameter d_1/d_2= 6/8mm. To ensure good electrical contact, copper wires are soldered to both ends of the tube. HP 4284A 20Hz- 1MHz LCR-meter is used to measure electrical resistance. The electrical resistance of the tube is

$$R = \frac{l}{\kappa \cdot A}, \quad (1)$$

where κ is specific electrical conductivity, A – cross-section of charge flow area.

If high frequency *f* alternate current is charged through the tube, the depth of the skin effect [1], [2]

$$\delta = \frac{1}{\sqrt{\pi \cdot \mu_0 \cdot f \cdot \kappa \cdot \mu}}, \tag{2}$$

where μ- relative magnetic permeability of steel, $\mu_0=4\pi\cdot10^{-7}$H/m- magnetic constant.
In this case we can assume that the charge flows only through outer layer of the tube with depth δ and density of the current is the same in all points of this layer. Cross sectional area of the charge flow (represented in grey in Figure 1)

$$A = \pi \cdot (d_2 - \delta) \cdot \delta \tag{3}$$

This equation is valid if $\delta \le (d_2/2 - d_1/2)$. From expressions (1) - (3) follows

$$R = \frac{l}{d_2 \cdot \sqrt{\frac{\pi \cdot \kappa}{\mu_0 \cdot \mu \cdot f}} - \frac{1}{\mu_0 \cdot \mu \cdot f}} \tag{4}$$

and

$$\kappa = \frac{\mu_0 \cdot \mu \cdot f}{\pi \cdot d_2^2} \cdot \left(\frac{l}{R} + \frac{1}{\mu_0 \cdot \mu \cdot f} \right)^2. \tag{5}$$

To use equation (5), we need to know electric resistance R only for the tube excluding resistance of the contacts and the leads. To find that, *one input of the meter* is connected to the copper wire soldered to the end of the tube, but the other input – *to a crocodile clamp that holds the tube.* Total electrical resistance R_k of the tube is measured in different sections with length from 0 to *l* at the constant frequency *f*. The acquired curve $R_k=R_k(l)$ allows to determine electrical resistance of the contacts and the leads (it is *l*=0).

Determination of the magnetic permeability of steel

In order to calculate κ, we have to know relative magnetic permeability of steel μ (see equation (5)). To determine it, solenoid coil with length *l*, diameter D<<*l*, number of turns N is used. The solenoid is wound on a dielectric tube, it does not have a core and its inductance is L_1 (see Figure 2). The steel tube used in the experiments is inserted in the solenoid. The tube has the same length as (or is a little longer than) the solenoid (see Figure 3). As relative magnetic permeability of steel μ>>1, inductance of the solenoid in this case is $L_2>L_1$.
Inductance of the solenoid without a core is:

$$L_1 = \frac{\mu_0 \cdot \pi \cdot N^2 \cdot D^2}{4 \cdot l}. \tag{6}$$

System, where solenoid and the tube inserted in it has the same length, can be considered parallel magnetic circuit with magnetic flux

$$\Phi = \Phi_1 + \Phi_2 = B_1 \cdot A_1 \cdot N + B_2 \cdot A_2 \cdot N, \tag{7}$$

where Φ_1- magnetic flux in the tube, Φ_2- magnetic flux in free space inside the solenoid. Using Ampere's circuital law, we can determine that inductance of a steel tube placed in long solenoid *(l>>D)* is

$$B_1 = \frac{\mu \cdot \mu_0 \cdot I \cdot N}{l}. \tag{8}$$

and in free space within solenoid

$$B_2 = \frac{\mu_0 \cdot I \cdot N}{l}, \tag{9}$$

where I – current passing through loops.

Cross sectional area of the steel tube (perpendicular to the longitudinal axis of the solenoid):

$$A_1 = \frac{\pi \cdot d_2^2}{4} - \frac{\pi \cdot d_1^2}{4}. \tag{10}$$

Cross sectional area of the free space (perpendicular to the longitudinal axis of the solenoid):

$$A_2 = \frac{\pi \cdot D^2}{4} - \left(\frac{\pi \cdot d_2^2}{4} - \frac{\pi \cdot d_1^2}{4} \right). \tag{11}$$

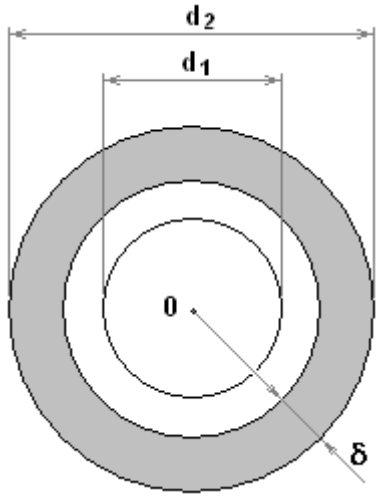

Fig.1. **Cross sectional area of the tube with high frequency current flowing through it**

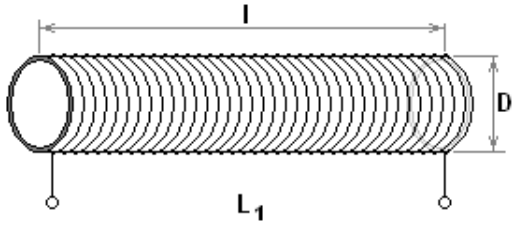

Fig.2. **Solenoid without a core**

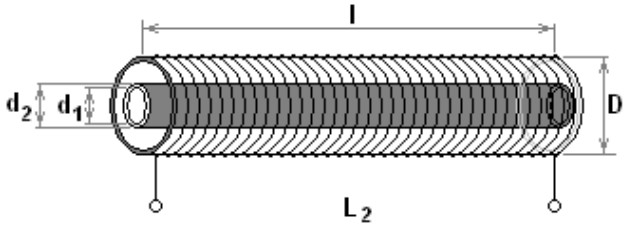

Fig.3. **Solenoid with the steel tube inserted in it**

Placing last four expressions in the equation (7), taking to account expression (6) and relation between magnetic flux Φ, inductance L and current through solenoid I

$$\Phi = L \cdot I, \tag{12}$$

We obtain inductance L_2 of the solenoid with the steel tube as a core is:

$$L_2 = \frac{\mu_0 \cdot \pi \cdot N^2 \cdot (d_2^2 - d_1^2)}{4 \cdot l} \cdot (\mu - 1) + L_1. \tag{13}$$

It follows that relative magnetic permeability of steel is

$$\mu = \frac{4 \cdot l \cdot (L_2 - L_1)}{\mu_0 \cdot \pi \cdot N^2 \cdot (d_2^2 - d_1^2)} + 1. \tag{14}$$

The steel tube described in the section 2.1. is used in the experiments. Inductance is measured with Peak Tech 2010 DMM multimeter. Before electrical measurements are taken, the tube is heated to 800^0C that exceeds Curie temperature for iron (768^0C). For this reason steel does not have lasting magnetization. During inductance measuring process, steel is not magnetized, therefore obtained μ value conforms to intensity of magnetic field H=0. Five solenoid coils of different length, diameter and number of turns are used for measurements.

To eliminate measuring errors, the method of partial derivation is applied. According to it, absolute error of relative magnetic permeability μ is

$$\Delta\mu = \sqrt{\left(\frac{\partial \mu}{\partial l} \cdot \Delta l \right)^2 + \left(\frac{\partial \mu}{\partial L_1} \cdot \Delta L_1 \right)^2 + \left(\frac{\partial \mu}{\partial L_2} \cdot \Delta L_2 \right)^2 + \left(\frac{\partial \mu}{\partial d_1} \cdot \Delta d_1 \right)^2 + \left(\frac{\partial \mu}{\partial d_2} \cdot \Delta d_2 \right)^2}, \tag{15}$$

where Δl- error of tube length measurement (0.5mm); ΔL_1 and ΔL_2 – measurement error of inductance of solenoid without a core and with the steel tube inserted (1μH); Δd_1 and Δd_2- measurement error of inside and outside diameter (0.1mm) of the steel tube.

The partial derivations in the equation (15) are obtained by derivation of the expression (14). Absolute error of specific electrical conductivity κ is:

$$\Delta\kappa = \sqrt{\left(\frac{\partial\kappa}{\partial\mu}\cdot\Delta\mu\right)^2 + \left(\frac{\partial\kappa}{\partial f}\cdot\Delta f\right)^2 + \left(\frac{\partial\kappa}{\partial d_2}\cdot\Delta d_2\right)^2 + \left(\frac{\partial\kappa}{\partial l}\cdot\Delta l\right)^2 + \left(\frac{\partial\kappa}{\partial R}\cdot\Delta R\right)^2}\ , \qquad (16)$$

where Δf- frequency measurement error (10Hz); ΔR- measurement error of electrical resistance of the tube (0.01Ω). Partial derivations of equation (16) are obtained by derivation of the expression (5).

Determination of specific conductivity of sputtered nano-coating

On the outside surface of the tube used in the above experiments Al-Ti-N nano-coating is deposited by sputtering in vacuum using electric arc and magnetron (equipment НВВ-66-И1, deposition time 30 min). At the same time Al-Ti-N coating is deposited also on dielectric film (one surface) that is placed in maximum proximity to the steel tube in a vacuum chamber. For the first approximation it is assumed that composition, structure and specific electric conductivity of the coating on the tube and on the dielectric film are the same. Rectangular slip sized 200mm by 12.5mm is cut out of the film and secured with crocodile clamps to the HP 4284A LCR meter. Specific electrical conductivity of the coating is

$$\kappa_2 = \frac{l}{R\cdot b\cdot h}\ , \qquad (17)$$

where *l* – length of the slip, width of the slip (12.5mm), h – thickness of the coating, R – electrical resistance.

Results and Discussion

Applying the method described in section 2.2., relative magnetic permeability μ=27.9±2.0 is determined for the particular type of steel. The comparatively small value of relative magnetic permeability of the steel is explained by a fact that before measurements were taken, the sample was heated above Curie temperature and as a result it does not have lasting magnetisation. Steel items are subjected to such heating during deposition of protective coating.

Equipment used to construct the curve depicting resistance-frequencies of the tube is shown in Figure 4 but the curve itself – in Figure 5. Resistance R values include electrical resistance of the tube, soldering, the copper leads and contacts that secure leads to the equipment. To determine electrical resistance of the tube, we measure resistance in its different sections with length 0 to 153 mm at the frequency 1MHz (see Fig. 6). The dependency of the resistance on the length of a section is shown in Figure 7. The total resistance of the tube with leads and contacts is 0.1141Ω (if *l*=153mm), but resistance of leads and contacts is 0.0498Ω (if *l*=0), that constitutes 43.6% of total value of the resistance. The resistance of the 153mm tube (without the leads and contacts) is 0.0643Ω. Assuming, that for this particular sample the proportion (43.6%) between resistance of the leads/contacts and the total resistance stays the same at different frequencies of alternating current, the curve shown in Figure 5 is recalculated excluding the resistance of the leads and contacts. Results of the calculations (points) and their margins of error are shown in Figure 8.

Placing at 1 MHz acquired resistance of the tube R=0.0643Ω in the equation (5), we calculate specific electrical conductivity for given type of steel: $\kappa_1=(1.01\pm0.32)\cdot10^6$ S/m**.**

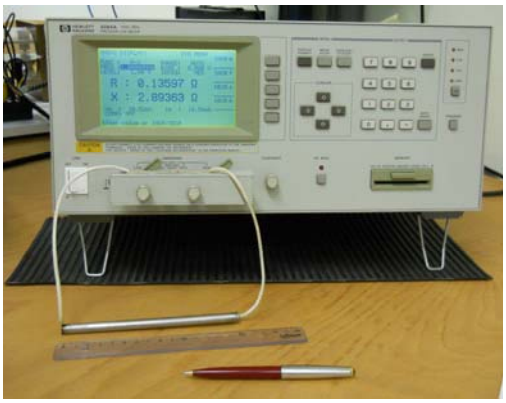

Fig.4. **HP 4284A 20Hz- 1MHz LCR meter with steel tube connected to it**

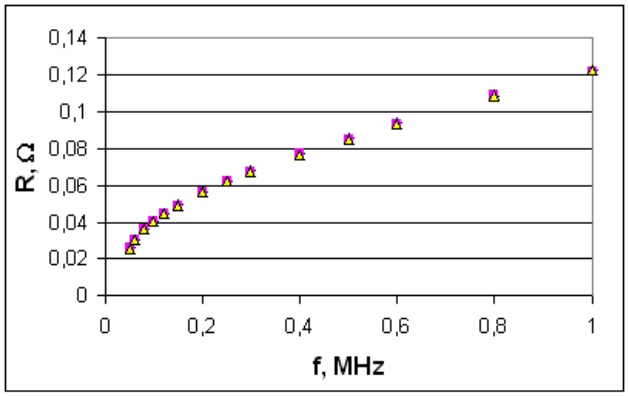

Fig.5. **Curve of electrical resistance frequencies of the steel tube with leads and contacts**

Fig.6. **HP 4284A 20Hz- 1MHz LCR meter with the connected steel tube, resistance of the 10 cm long section is measured**

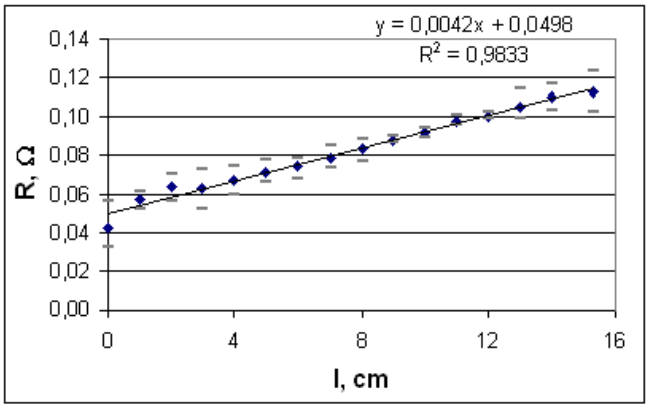

Fig.7. **Electrical resistance (at 1MHz) depending on the length of the section**

Knowing κ and μ for particular steel and using the equation (4), the curve of resistance frequencies can be obtained. In the Figure 8 it is shown as unbroken curve. Within margins of error it coincides with experimental data. This confirms that the model described in section 2 is right.

Using SEM HITACHI S-3000N equipped with BRUKER 133eV spectrometer, chemical compositions of the coatings on the steel tube (Table 1; Fig. 9) and the dielectric film (Table 2, Fig. 12) are determined. Comparing data from the tables, we conclude that chemical composition of titanium and nitrogen in both coatings is within measuring margins of error but composition of aluminum - differs. Since amount of aluminum is not big, we can assume that the chemical compositions of both coatings are approximately the same and the values of specific electrical conductivity κ_2 are also approximately the same. It is no exactly precise because during deposition process the steel tube is connected to negative electrical potential that in vacuum promotes positive metal and nitrogen ions reaching surface of the steel; the surface of dielectric film does not have such potential. Before deposition process the surface of the steel is subjected to ion bombardment that cleanses and heats it up to 800^0C improving quality of sputtered layer; it is not possible to perform this process with dielectric film. Therefore the composition, structure and properties of the coatings deposited on surfaces of the steel tube and dielectric film can vary.

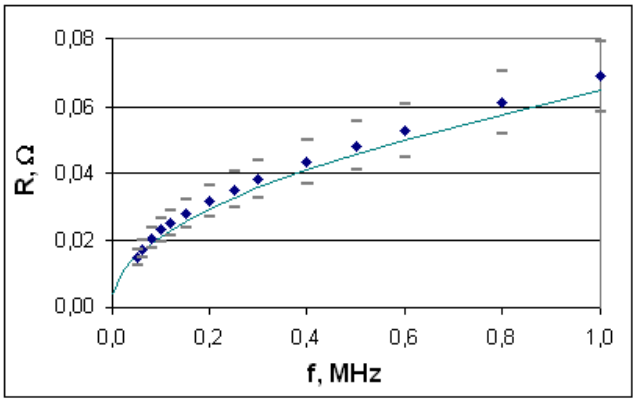

Fig.8. **The curve of electrical resistance frequencies of the steel tube** (without the leads and contacts)

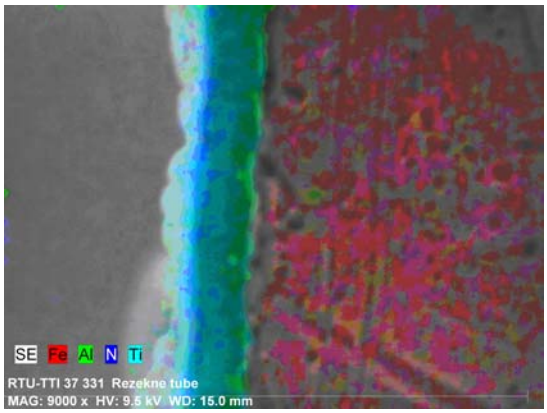

Fig.9. **Chemical composition of the nano-coating Al-Ti-N deposited on the steel tube; thickness of the coating 1.6μm**

Table 1.

Composition of nano-coating deposited on the steel tube

	Mass %	Atoms %
N	53,91±17	77,89±14
Al	2,49±1,3	2,06±1,6
Ti	43,59±16	20,05±12

Table 2.

Composition of nano-coating deposited on the dielectric film

	Mass %	Atoms %	Error %
N	61,32	82,48	32,5
Al	7,53	5,26	0,4
Ti	31,15	12,26	1,8

Dependence of electrical resistance of the dielectric film coating on the length of the slip *l* (see Fig. 10 and 11) is measured at frequency 1MHz. Difference in resistance measurements can be explained with a fact that coating do not adhere well to the dielectric film used in the experiments; it suffers local damage every time the crocodile clamps are attached, it is not possible to create same electrical contact between the coating and the crocodile clamps. It is indicated by tendency that shows increased electrical resistance with every repeated measurement.

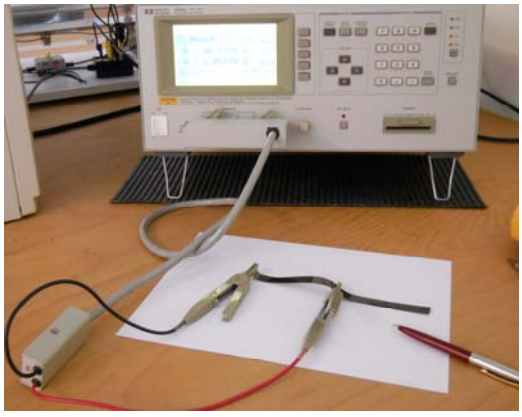

Fig.10. **Measuring electrical resistance of Al-Ti-N nano-coating deposited on the dielectric film**

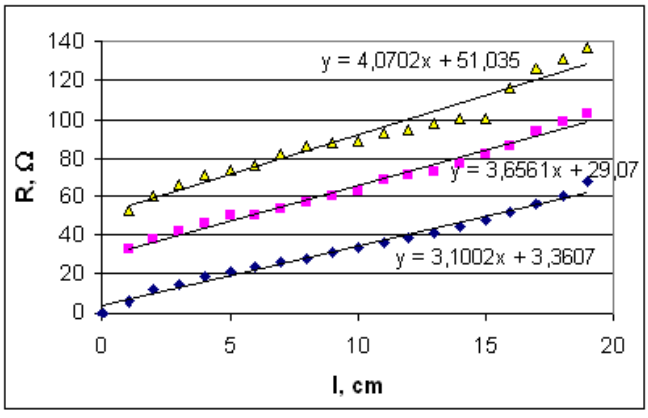

Fig.11. **Electrical resistance of Al-Ti-N nano-coating deposited on the dielectric film (at frequency 1MHz) depending on the length of the section of the slip**

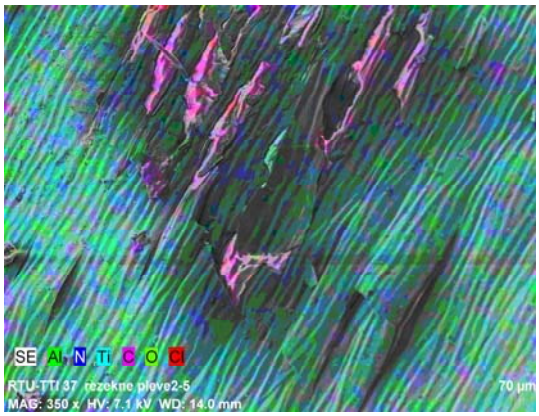

Fig.12. **Mechanically damaged Al-Ti-N nano-coating on the dielectric film; colors indicate its chemical composition**

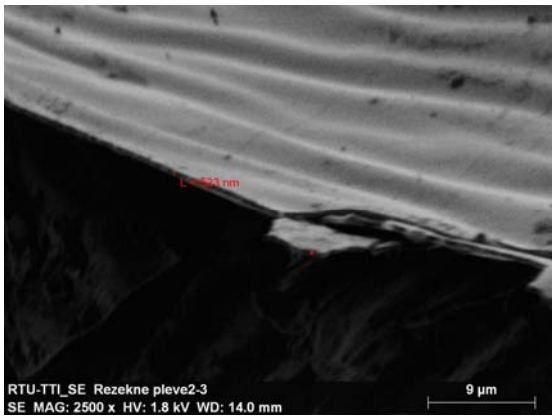

Fig.13. **Fragment of the Al-Ti-N nano-coating that has separated from the surface of the dielectric film; its thickness is 523nm**

Due to the poor adherence of the coating to the dielectric film, we cannot use traditional methods to measure thickness of the coating - polishing an edge of the film and measuring the thickness with a scanning electron microscope. The different solution is offered to take measurements: the coating on the dielectric film is mechanically damaged (see Fig. 12); then separated fragments of the coating with an edge towards an electron beam are located and their thickness measured (see Fig. 13). Statistically processing data from Figure 11, using the equation (17) and measured value of the thickness h=523nm, the specific electrical conductivity of the given Al-Ti-N nano-coating is determined $\kappa_2=(0{,}43\pm0{,}11)\cdot10^6$ S/m.
The scanning electron microscope is used to measure the thickness of the nano-coating deposited on the steel tube: that is 1.6µm (see Fig. 9). We conclude that simultaneously depositing coating on steel and dielectric surfaces, thickness of the coatings will be different (up to 3 times).

Conclusions

1. The method to experimentally determine specific electrical conductivity using high frequency current for steel (and other conductors) is developed. The method to determine relative magnetic permeability of steel is developed. It is established that steel used in the experiments has specific electrical conductivity $\kappa_1=(1{,}01\pm0{,}32)\cdot10^6$ S/m and relative magnetic permeability $\mu=27{,}9\pm2{,}0$.
2. Developed first approximation method for determination of the specific electrical conductivity of the nano-coatings. The specific electrical conductivity of the Al-Ti-N nano-coating deposited on the dielectric film is $\kappa_2=(0{,}43\pm0{,}11)\cdot10^6$ S/m.
3. The research offers opportunity to develop methods for measuring thickness of nano-coatings deposited on cylindrical conductors that are based on electrical measurements.

Acknowledgment

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CREEP BEHAVIOUR OF CONCRETE WITH GLASS WASTE MICROFILLER

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Abstract. *Every year there are several hundred tons of waste glass produced in Latvia. Glass can be re-used as a fine raw material and it presents a possibility to save natural, non-renewable materials. The use of glass powder in concrete production can make the construction industry more environmentally friendly. This paper examines the possibility of using glass powder as cement replacement in a new type of concrete. In the experiment, cement was partially (20% and 40%) replaced with glass powder. The long-term deformation (creep) of this new concrete was monitored. Three different concrete mixtures were batched. Specimens of 20% and 40% cement replacement were compared with the specimens made of standard concrete. The samples were tested in two extreme conditions: in one case they were kept in 100% humidity ensured by preventing the desiccation of the concrete, and in the other case samples were air-dried by preventing them from becoming wet. Compression strength and modulus of elasticity of 7 and 28 days old cubic samples was determined.*

Keywords: *compression strength, creep, glass powder, long-term deformations, modulus of elasticity.*

Introduction

In the last few years it has been recognized that one of the main sources of environmental pollution is waste. It has become a major environmental problem because many types of waste do not break down, that is, essential physical, biological and chemical changes do not take place. One of the possibilities of utilizing waste is recycling, which would not only save natural resources, but also decrease the amount of deposited waste. Glass waste requires recycling. Since there are different types of glass with different chemical compositions, there are also different possibilities of its use. In accordance with the decision of the European Committee, all simple incandescent lamps are to be replaced by fluorescent lamps until 2012, therefore after a couple of years the problem of their recycling and utilization will become more severe [1]. One of the solutions would be to recycle the lamp glass by using it in concrete production, where it can partly replace fine sand or cement and thus help create a new construction material. Using lamp glass powder (LGP) in concrete is an interesting possibility for economy on waste disposal sites and conservation of natural resources [2].

One of the main constituents of standard concrete is cement. Every year approximately 2.35 billion tons of cement are produced - that is almost 1 m^3 of cement for every person in the world. The carbon dioxide released into the atmosphere during the cement production process accounts for approximately 5-10% of the overall CO_2 production in the world. Its release into the atmosphere contributes to the global warming and the development of holes in the ozone layer. If the CO_2 production in cement factories could be decreased by 10%, the overall release into the atmosphere would decrease by 5.2%. Using waste glass as cement replacement in concrete construction sector is advantageous, as the production cost of concrete would decrease, and our industry would become more environmentally friendly [2].

The deformation characteristics of a material are just as important as its strength properties. Concrete is an important structural material used in every country of the world, in the oceans, under ground, and in virtually every type of construction. Moreover, the complexity of

structures and their size have continued to increase, and this has resulted in a greater importance of their deformation characteristics and in more serious consequences of their behavior [3]. One type of strain that plays a major role in successful and continuous use of structures is creep - deformations that appear due to long-term loading of the structural element. Under constant mechanical loading, the strain of concrete increases significantly with loading duration, the increase often reaching 2 to 3 times the value of the instantaneous strain [4]. Therefore, designers and engineers need to know the creep properties of concrete and must be able to take them into account in the structure analysis. After all, the end product of an engineer's endeavours is a structure whose strength is adequate, but not wastefully excessive, whose durability is commensurate with the conditions of exposure, and whose serviceability ensures fitness for the purpose. Consideration of creep is a part of a rational approach to satisfying these criteria. Deformation characteristics of materials are an essential feature of their properties, and a vital element in the knowledge of their behaviour. After all, it is the subject that matters: creep is important if its deformation increases with time under a constant stress [3].

The objective of this paper is to present the results of experimental investigations of the long-term deformation (creep) of concrete samples containing glass powder. Cement was substituted by weight with glass powder at rates varying from 20 to 40 per cent. The compressive strength and modulus of elasticity of concrete materials made with glass powder were studied and compared with those of standard specimens.

Materials and methods

One of the goals of the experiment was to find out whether the new concrete composition can be competitive and whether its physical and mechanical properties are equivalent to those of standard concrete. The object of this study was lamp glass powder (LGP) obtained from fluorescent lamp waste. The other raw materials used for this study were natural coarse aggregate, fine aggregate and normal cement CEM I 42.5 N (Kunda).

The experiment consisted of replacing cement with glass powder in amounts of 0, 20 and 40 per cent. Standard sample cubes 150x150x150 mm were produced in order to investigate the mechanical characteristics of the material (see Fig. 1). Concrete mixtures were cast into oiled steel moulds and compacted at the vibrating table. After two days the moulds were removed. Standard hardening conditions (temperature +20°C, RH > 95%) were provided. After the hardening period, the samples were measured and tested in standard conditions. Their compression strength was determined in conformity with LVS EN 12390-3:2002. A testing machine with accuracy +1% was used, and the rate of loading was 0.7 MPa/sec. The samples were tested at the age of 7 and 28 days. Compression strength and density of the hardened concrete were determined.

Fig. 1. **Specimens containing lamp glass powder**

Fig. 2. **Specimens with steel plates**

Fig. 3. **Creep lever test stand**

Creep experiments were carried out on prismatic 40x40x160 mm samples that had been weighted both before and after the test (see Fig. 1). The creep (time-dependent strain) was measured in hardened concrete specimens subjected to a uniform compressive load kept constant over a long period of time. Load was applied gradually in 4 steps and as quickly as possible. At the beginning of the test, the samples were 50 days old, and they were kept under constant load for 60 days. The constant compressive load was equal to 40% of the maximum strength of the concrete, which had been determined in destructive tests carried out on the cubic samples [4]. The tests were conducted in two extreme conditions. In one case no moisture exchange with the environment was permitted, which was ensured by protecting the specimens against desiccation, and in the other case drying was permitted under conventional conditions, by protecting the specimens against moisture [4]. In order to prevent humidity exchange between the specimen and the environment, the surface of the specimens was coated with two protective silicone layers. Before this sealing, four steel plates were centrally and symmetrically glued onto two sides of the test prism in order to provide a basis for the strain gauges. The distance between two plates was 50 mm. Two +/-0.01 mm precision strain gauges were symmetrically connected to each sample, and then the samples were put into a creep lever test stand and loaded (see Fig. 3). They were kept in a dry atmosphere of controlled relative humidity in standard conditions: temperature 23 ± 1ºC and relative humidity 25 ± 3%.

Results and discussion

The tests to determine creep, modulus of elasticity, density and compression strength were done on concrete cubes in which LGP was used to replace 0%, 20% and 40% of the cement weight. Experimental work made it possible to compare the strength of standard concrete samples and samples containing LGP. Strength tests were carried out after 7 and 28 days of hardening in standard conditions (see Fig. 4).

Concrete samples containing LGP as a microfiller displayed a reduction in compression strength when compared to the standard concrete samples. The concrete containing LGP showed lower strength in the first 7 days, but on the 28th day the strength increased and was very similar to that of standard concrete.

Fine glass powder caused a long-term hardening effect (see Fig. 5). Specimens with 40% cement replacement showed a 70.6% increase of compression strength, while the specimens with 20% cement replacement showed a 43.4% increase of compression strength. Standard specimens, however, showed only a 15.3% increase of compression strength.

Fig. 6 shows the density of concrete cubes. The average density of standard concrete specimens hardened in moist conditions was 2.278 kg/m^3, and the average density of dry-hardened specimens was 2.374 kg/m^3. The average density of concrete samples containing a 20% replacement of LGP was 2.267 kg/m^3 and 2.259 kg/m^3 respectively, and the average density of specimens containing a 40% replacement of LGP — 2.134 kg/m^3 and 2.251 kg/m^3. The average density of standard specimens hardened in moist conditions was larger by approximately 4.3%, and for specimens containing 40% cement replacement it was larger by

approximately 5.5%. The average density of moist-hardened specimens containing 20% cement replacement was, however, lower by approximately 0.35%. The difference between the densities of standard and 40% cement replacement concrete samples hardened in dry and moist conditions was approximately 6%. Between standard and 20% cement replacement concrete samples it was approximately 0.5% in dry conditions and approximately 4.8% in moist conditions. The density difference between 20% and 40% cement replacement concrete samples hardened in dry conditions was approximately 6% and between samples hardened in moist conditions it was approximately 0.35%.

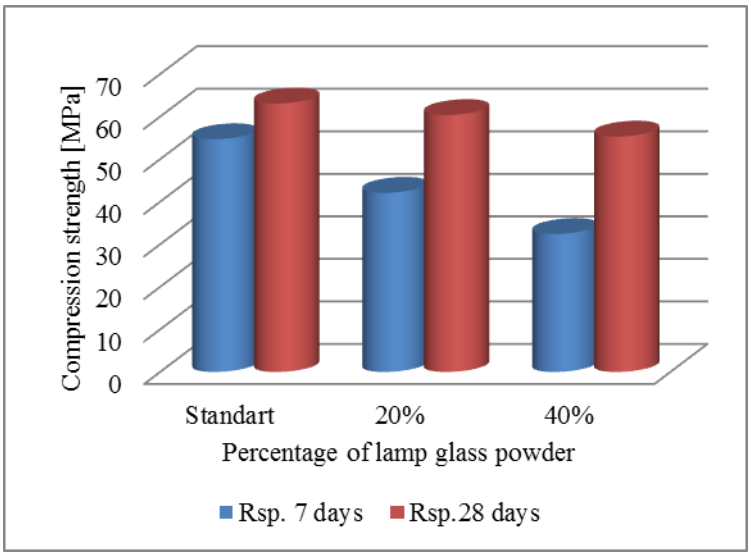

Fig. 4. **Compressive strength at 7 and 28 days [MPa]**

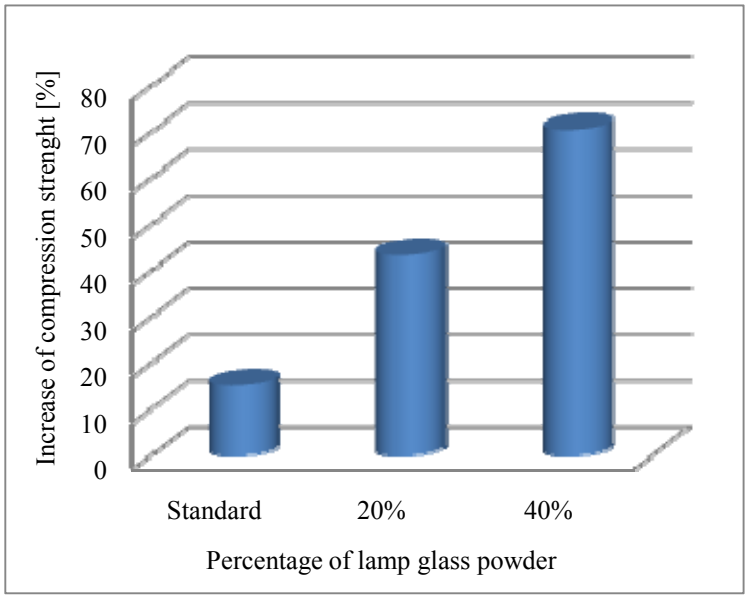

Fig. 5. **Increase of compression strength (from 7 days to 28 days) %**

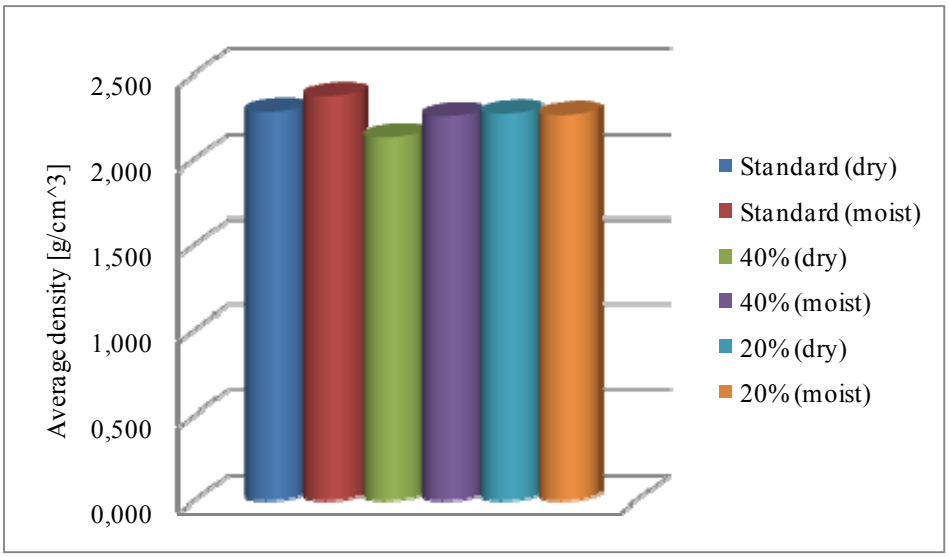

Fig. 6. **Average densities of different concrete**

The modulus of elasticity (see Fig. 7) was determined by measuring the deformations on the sides of the samples according to Hooke's law. For standard concrete the difference between samples hardened in moist and dry conditions is approximately 2.8%. For samples containing 20% cement replacement, this difference is approximately t is 12.4% and for samples with 40% cement replacement it is 27.4%. The comparison of the modulus of elasticity of standard concrete samples and samples containing a 40% cement replacement shows that for samples hardened in moist conditions this difference is 11.7%, while for samples hardened in dry conditions it is 32.6%. The corresponding differences between standard concrete samples and samples containing a 20% cement replacement is 2.9% and 16.3% respectively. The same tendency can also be seen from the stress-strain relation, which is a function of time (see Fig. 8).

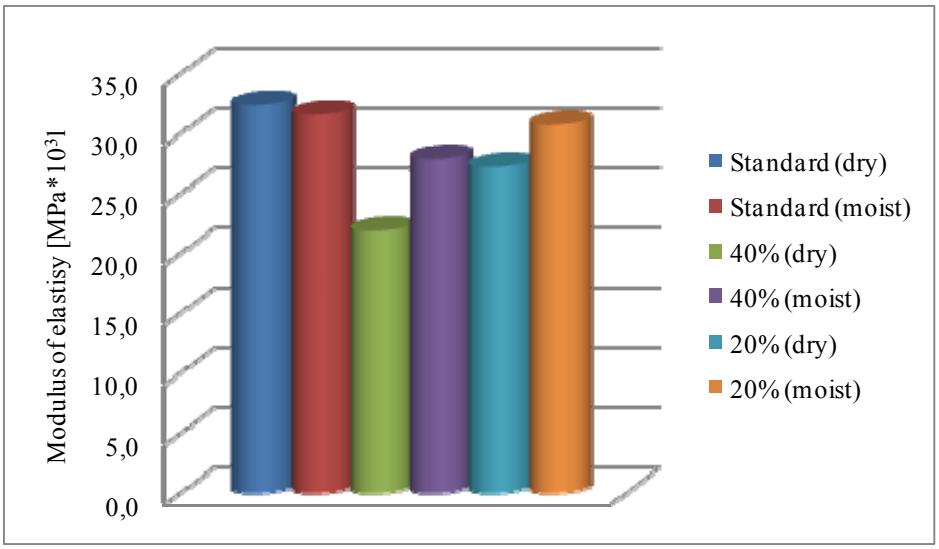

Fig. 7. **Modulus of elastisy of different concrete**

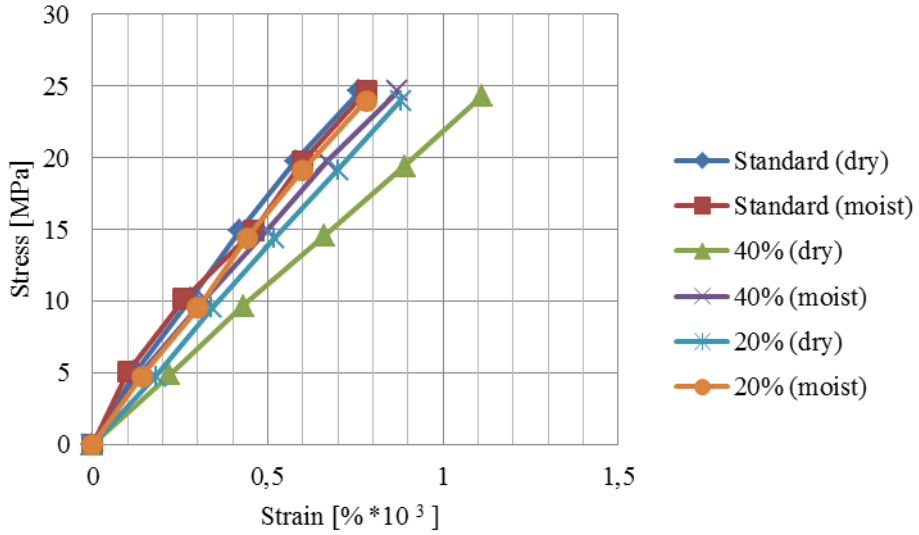

Fig. 8. **Relation between stress and strain**

The graph in Figure 9 shows linear creep — the stresses are almost proportional to the strain, and therefore the stresses do not reach the point of microcracking. From the gathered data it is evident that creep developed in standard concrete samples hardened in moist and dry conditions, whereas the smallest creep is exhibited by concrete samples containing a 20% cement replacement. The average difference between standard concrete samples hardened in moist and in dry conditions is approximately 4.2%. For samples containing a 40% cement replacement this difference is approximately 11.9%, and for samples containing a 20% cement replacement it is 13.5%. If we compare the average difference between the standard concrete samples and the ones containing a 40% cement replacement, we can see that for samples hardened in moist conditions this difference is 38.7%, and for samples hardened in dry conditions it is 38%. In comparison with the 20% cement replacement concrete samples, the difference is 46% and 41.4% respectively.

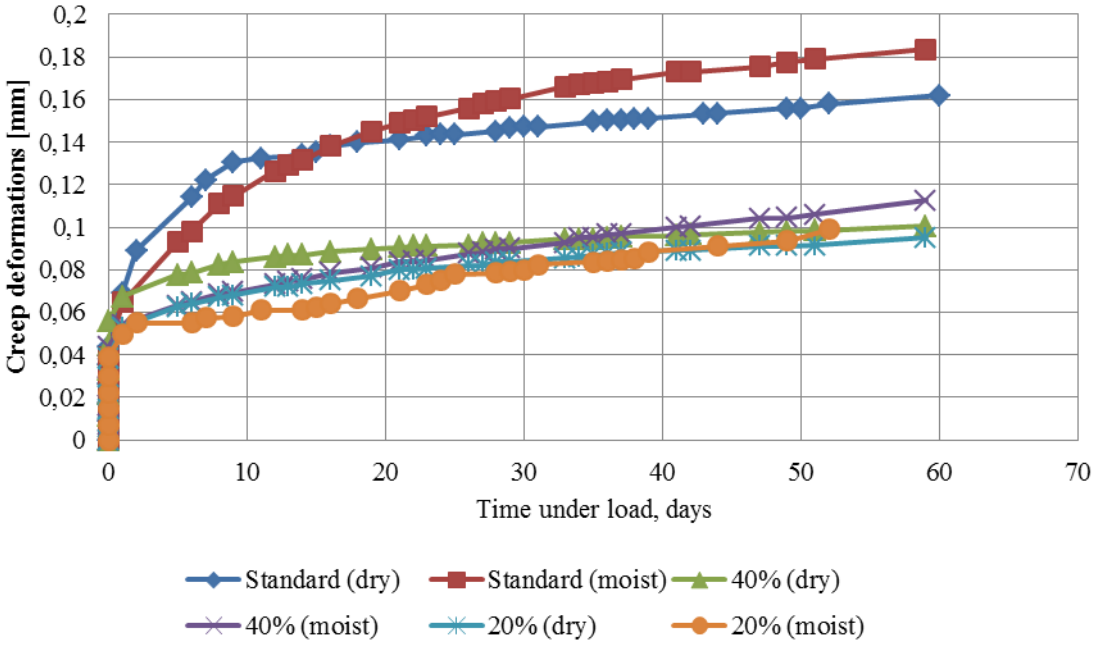

Fig. 9 **Creep of concrete**

The results of the experiments are presented in Table 1.

Table 1.

Physical and mechanical properties of concrete compositions

Specimen	Age, days	Density, kg/m^3 (dry)	Compression strength, MPa	Modulus of elasticity, GPa	Creep coefficient (60 days)
Standard	7	2297	55	32,5 (dry)	3,7 (dry)
Standard	28	2293	63	31,6 (moist)	4,7 (moist)
20%	7	2246	42	21,9 (dry)	2,5 (dry)
20%	28	2253	60	27,9 (moist)	2,54 (moist)
40%	7	2196	32	27,2 (dry)	1,8 (dry)
40%	28	2199	55	30,7 (moist)	2,1 (moist)

Conclusions

From the previously described tests, in which LGP was used as concrete microfiller instead of cement, the following main conclusions can be drawn: the lamp glass powder is available in significant quantities as waste and can be used for making concrete.

Long-term deformation testing was carried out, and the modulus of elasticity, the density and the compression strength of ordinary concrete and ones containing lamp glass powder were determined. Creep test results were summarized on the 60th day.

In the future the physical and mechanical properties of this new LGP concrete should be investigated in a more detailed way. Experimental results can be used to predict creep deformations. In order to decrease the dispersion of results, the number of specimens and tests should be increased.

This study proves that lamp glass can be successfully recycled and used in the production of concrete, thus potentially decreasing the amount of deposited waste and the use of cement, which would lead to a reduction of carbon dioxide release into the atmosphere.

Acknowledgement

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THE THERMAL CHARACTERISTICS OF GYPSUM BOARDS WITH PHASE CHANGE MATERIALS (PCM)

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Abstract. *Two types of PCM were investigated for use in phase change gypsum boards: salt hydrate and paraffin. The transition temperatures, or melting temperatures, of the PCM is near to standard or suggested room temperatures 20-21 °C for heating-dominated climates or 25-27 °C for cooling-dominated climates. Phase change gypsum boards were produced by using three different methods: simple immersion for 1 hour and direct incorporation of raw and microencapsulated PCMs in 5 and 10% of composition mass. PCM were tested and the effects of energy conservation of PCM gypsum boards were determined. Also some physical and mechanical properties were determined to investigate the effect of PCM addition to gypsum boards.*

Keywords: *phase change materials, PCM, gypsum board.*

Introduction

Overheat of indoor is a large problem not only in the southern countries, but it is becoming actual also in the Nordic countries as we saw in the last summer. In buildings with massive masonry or concrete walls, comfortable summer temperatures dominate due to the high heat capacity of components and assemblies. In contrast, buildings with modern lightweight constructions have little comparable heat storage, resulting in summers overheating as a major problem. The highly glazed surfaces in modern office buildings have an additionally significant influence here. Air condition, of course, is a solution, but it is electricity consumption and leads of peak periods of energy used. A possible answer to this problem is the emplacement of PCM, thereby increasing the thermal mass of buildings.

Materials with good thermal storage capacity are typically solid and heavy. They store proportionally more heat as they become hotter. PCM materials use the energy stored in a phase transition, normally liquid/solid, to store thermal energy in a narrow temperature range. PCM uses special paraffin, hydrated salts or eutectic mixtures to absorb heat to stabilize room temperature in the human comfort range between 21°C - 26°C. During the day PCM absorbs surplus heat by melting the paraffin, hydrated salts or eutectic mixtures encapsulated in microcapsules. During the cooler night the heat is released and the paraffin re-crystallizes, ready for another cycle the following day.

Energy storage in the walls, ceilings and floors of buildings may be enhanced by encapsulation suitable PCM within these surfaces to capture solar energy directly and increase human comfort by decreasing the frequency of internal air temperature swings and maintaining temperature closer to the desired temperature for a longer period of time. Therefore the thermal mass of the building materials is increased by the latent heat, but indoor air temperature can be reduced [1-4].

The idea of improving the thermal buffer thought the application of phase change materials has been common knowledge for many years, but until now they are not widely distributed in building industry of developed countries and almost non-known in Latvia.

Shiley et al. [5] investigated impregnation of the wallboards with PCM which was achieved by immersing gypsum wallboards in a bath filled with a constant volume of PCM for 6–10 min. In experiments, the PCM absorbed by the gypsum was about 26% of total weight (saturation is about 30%). He proved that DSC tests could be used successfully to predict thermal performances of PCM wallboards.

Previous work has shown that wallboard can be successfully manufactured to contain up to 30 percent PCM, thus enabling this common building material to serve as a thermal energy storage device. The PCM wallboard was analyzed for passive solar applications and found to save energy with a reasonable payback time period of five years [6].
Athienitis et al. [7] presented the full-scale experiment results that demonstrated the application of PCM–gypsum boards in a passive solar building can bring down the maximum room temperature by about 4 °C during the day, thus preventing overheating, and during the evening and night (7–11 h in total) the surface temperature of the PCM gypsum board was approximately 3.2 °C higher than the surface temperature of the conventional wallboard so that heat was returned to the room.
Use of encapsulated PCM in building materials does not adversely affect the function of the construction material. Experiments with macroencapsulation failed due to poor conductivity of the phase change material where effective heat transfer was prevented. With microencapsulation, the dimensions are so small that this effect does not occur [8].
Hence, the aim of this work is to create a composition of comercially available gypsum and PCMs by using immersion, incorporation and encapsulation methods. Finally the mechanical, physical and thermal properties of created gypsum samples with PCM were determined.

Materials and methods

PCMs used

The latent heat stored during melting and freezing offers particular benefits. The key asset of PCMs is their high thermal storage capacity, which, for unit thickness, is many times that of conventional building materials like gypsum, concrete, etc. Common PCMs include paraffins, salt hydrates, alcohols, fatty acids, and synthetic materials.
Paraffins are waxes. They are readily availabe, inexpensive and melt at different temperatures relating to their carbon chain length with the general formula C_nH_{2n+2}. They are chemically stable, their volume increase upon melting is in the order of 10% of their volume; this is similar to that of many inorganic materials, but less critical as paraffins are softer and therefore build up smaller forces upon expansion. Paraffins are safe and non-reactive; they do not react with most common chemical reagents. Commercially available paraffins fromRubitherm RT21 and RT27 were used in this investigation [10]. The structure of paraffins taken with optical microscope with 40x magnification is shown in Fig. 1.

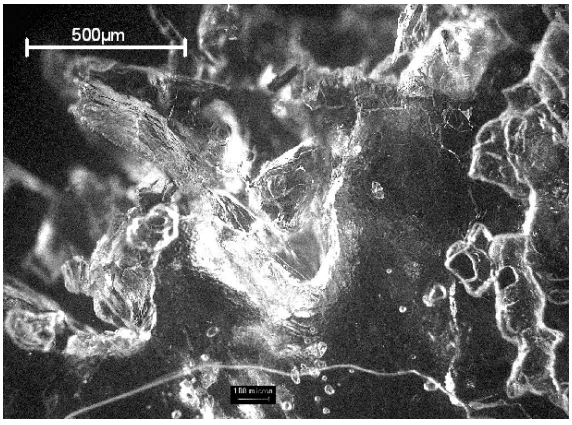

Fig.1. **Structure of paraffins**

Salt hydrates consist of salt and water, which combine in a crystalline matrix when the material solidifies. They are attractive materials for use in thermal energy storage due to high volumetric storage density, sharp melting point, show a lower volume change than paraffins and moderate costs compared to paraffin waxes. Among the disadvantages of salt hydrates is

that they can potentially seperate into different phases and thus show problems with cycling stability and show super-cooling because they do not start to crystallize at the freezing point. Commercially available salt hydrates from Rubitherm SP22 and SP25 were used in this investigation [10]. The structure of salt hydrates taken with optical microscope with 40x magnification is shown in Fig. 2.

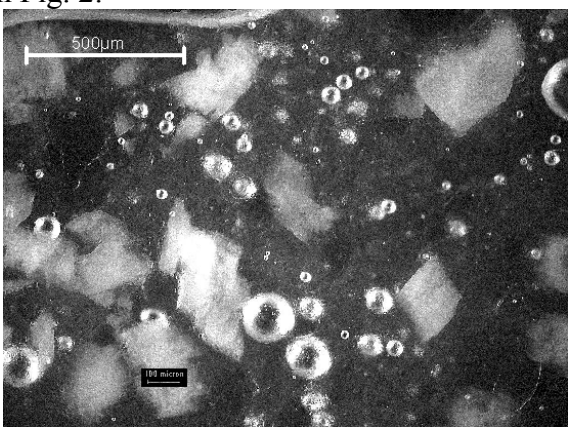

Fig.2. **Structure of salt hydrates**

Another product is encapsulated PCM, which prevents leakage of the material and improves the heat transfer. Encapsulations are classified according to their size as macroencapsulation and microencapsulation. In this paper are used two powder form microencapsulated paraffins DS5001 X and DS5008 X, with a typical crosslinked polymethyl methacrylate capsule diameter in the 2-20 μm range, produced by the company BASF [11]. The structure of microcapsules taken with optical microscope with 40x magnification is shown in Fig. 3.

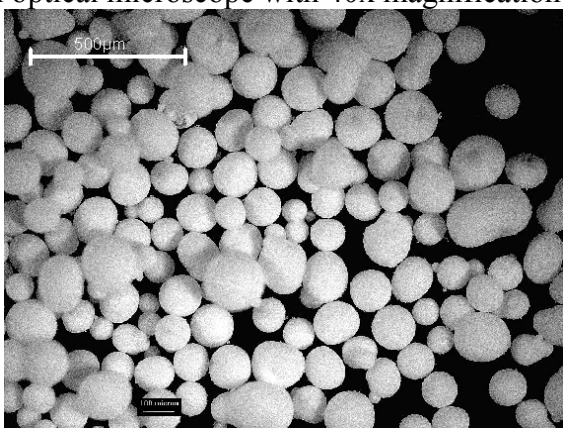

Fig.3. **Structure of microcapsules**

Thermo-physical properties of PCMs used in this paper are shown in Table 1.

Table 1.

Thermo-physical properties of PCMs [10, 11]

Property		RT21	RT27	SP22	SP25	DS5001 X	DS5008 X
Melting point (°C)		21	28	22	25	26	23
Density (kg m^{-3})	liquid	760	770	1430			
	solid	880	880	1490	1380		
Bulk density (kg m-3)						350	350

DSC analysis

Differental scanning calorimeter (DSC) analysis with heating rate of 1 °C/min was used to evaluate the thermal characteristics of PCMs. The results are summarized in Table 2.

Table 2

DSC analysis of PCMs

Material	Heat of fusion (J g^{-1})	Melting peak point (°C)	Temperature range (°C)
RT21	148.0	22.9	6.5 to 27.0
RT27	150.3	26.7	14.3 to 28.4
SP22	109.1	20.7	0.9 to 26.9
SP25	110.9	29.8	21.1 to 33.1
DS5001 X	99.8	26.9	18.7 to 29.1
DS5008 X	95.6	23.1	13.2 to 25.2

It is seen that the highest heat of fusion is for paraffins RT21 and RT27. For better performance of PCM usage for latent heat storage, it is relevant that the melting range is narrow and as close as possible to the melting point. The melting transitions which are shown in Fig. 4 for RT 27, SP25 and DS 5001 X are much sharper than for the rest ones, which means that they are more suitable for building applications.

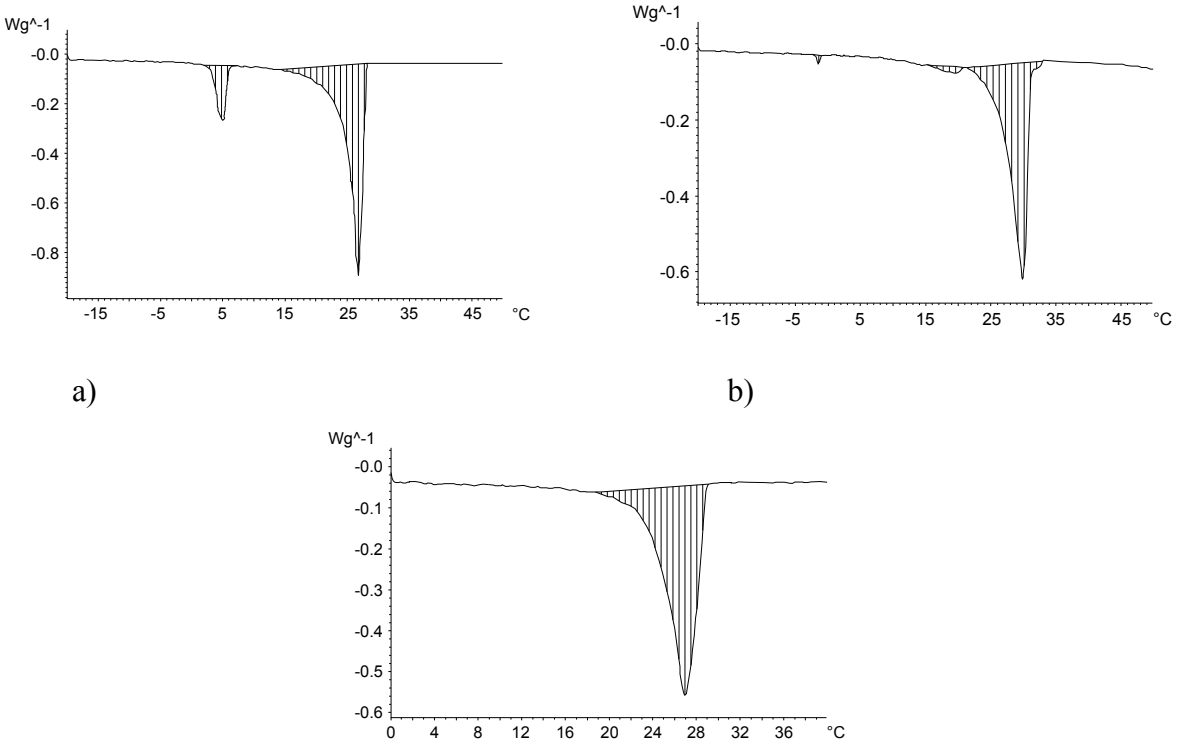

Fig.4. **DSC-measurements of PCMs**
(a – RT27, b – SP25, c – DS5001 X)

Experimental methods

Direct incorporation may be the most economical method, because very little additional process equipment is required. Paraffins and salt hydrates were added to local commercially available gypsum in 5 and 10% of compositions mass in the mixing process. Components were batched and then mixed in the laboratory drum mixer for 2 minutes.

In immersion method, the porous gypsum material was dipped into the hot melted paraffins and salt hydrates, which were absorbed into the pores by capillary action. After 1 hour the gypsum was removed from the liquid PCM and allowed to cool and the PCM remained in the pores of the gypsum.
Microencapsulated PCM in powder form was incorporated into the gypsum composition in 5 and 10% of mass.
To establish the influence of the PCM material on mechanical and physical properties of gypsum, standard testing methods were used. The mechanical and physical properties (flexural and compressive strength and material density) were determined after 7 days according to LVS 150:1998 /A1:2002. For the evaluation of thermal characteristics DSC analyses were performed for the several gypsum compositions.

Results and discussion

By immersing gypsum in PCM it was feasible to absorb 150 kg/m^3 SP22 or 11.4% of composition mass, 84.8 kg/m^3 SP25 or 6.8%, 303 kg/m^3 RT21 or 20.6% and 300 kg/m^3 RT27 or 20.4%. It is obvious that a higher mass ratio can be achieved by using paraffins than salt hydrates. The flexural, compressive strength and material density of gypsum immersed in PCM for 1 hour are shown in Table 3.

Table 3.

Mechanical and physical properties of gypsum samples immersed in PCMs

Property	Standard	SP22	SSP25	RT21	RT27
Density kg m-3	1120	1315	1245	1470	1470
Flexural strength MPa	4.1	1.8	2.1	3.7	3.9
Reduction %		55.5%	49.2%	9.4%	4.7%
Compressive strength MPa	7.4	3.7	4.3	7.2	7.1
Reduction %		49.9%	42.2%	2.9%	4.2%

It is seen that the flexural and compressive strength for salt hydrate gypsum samples are reduced for maximum of 55.5% compared to the standard gypsum sample. At the same time for paraffins the reduction in strength is maximum of 9.4 %.
The flexural, compressive strength and material density results for gypsum samples made by direct incorporation method with raw and microencapsulated PCMs are shown in Table 4.

Table 4.

Mechanical and physical properties of gypsum samples incorporated with PCMs

PCM mass of composition	Name	Density kg m^{-3}	Flexural strength MPa	Reduction %	Compressive strength MPa	Reduction %
0	Standard	1115	4.1		7.4	
5	SP25	1035	2.1	48.9%	3.4	53.7%
10	SP25	1015	1.8	55.5%	2.5	66.6%
5	SP22	1050	2.3	42.1%	3.0	60.1%
10	SP22	1020	0.9	78.9%	1.2	83.3%
5	DS5001	1025	3.7	9.7%	6.8	8.3%
10	DS5001	950	2.6	34.8%	5.3	28.0%
5	DS5008	1020	3.5	13.2%	6.2	16.9%
10	DS5008	970	3.2	20.0%	5.6	24.1%

Using direct incorporation method was concluded that paraffin cannot be mixed into gypsum with ordinary methods. It was obvious that salt hydrates are not suitable for direct incorporation method because the strength reduction for mass composition of 5% was maximum of 60.1%, but for 10% mass composition – 83.3%. The microencapsulated PCMs with 5% mass composition showed maximum of 16.9% strength reduction, but 10% - 34.8% strength reduction.

DSC analysis of immersed gypsum samples

DSC analysis which are shown in Fig. 5 of immersed gypsum samples SP 25 and RT21 were carried out with heating rate of 1 °C/min. The results show that paraffin after absorbtion still keeps the thermal properties and the gypsum sample has a heat of fusion of 26.4 J g^{-1} with the melting peak point of 24°C. Theoretical calculations showed that sample with absorbed PCM the heat of fusion should be 30.5 J g^{-1}, which could be explained by irregular PCM dissipation through the sample. Salt hydrates lost their thermal properties and showed only 1.4 J g^{-1} with melting point of 24.9 °C, but theoretically the heat of fusion should be 7.5 J g^{-1}.

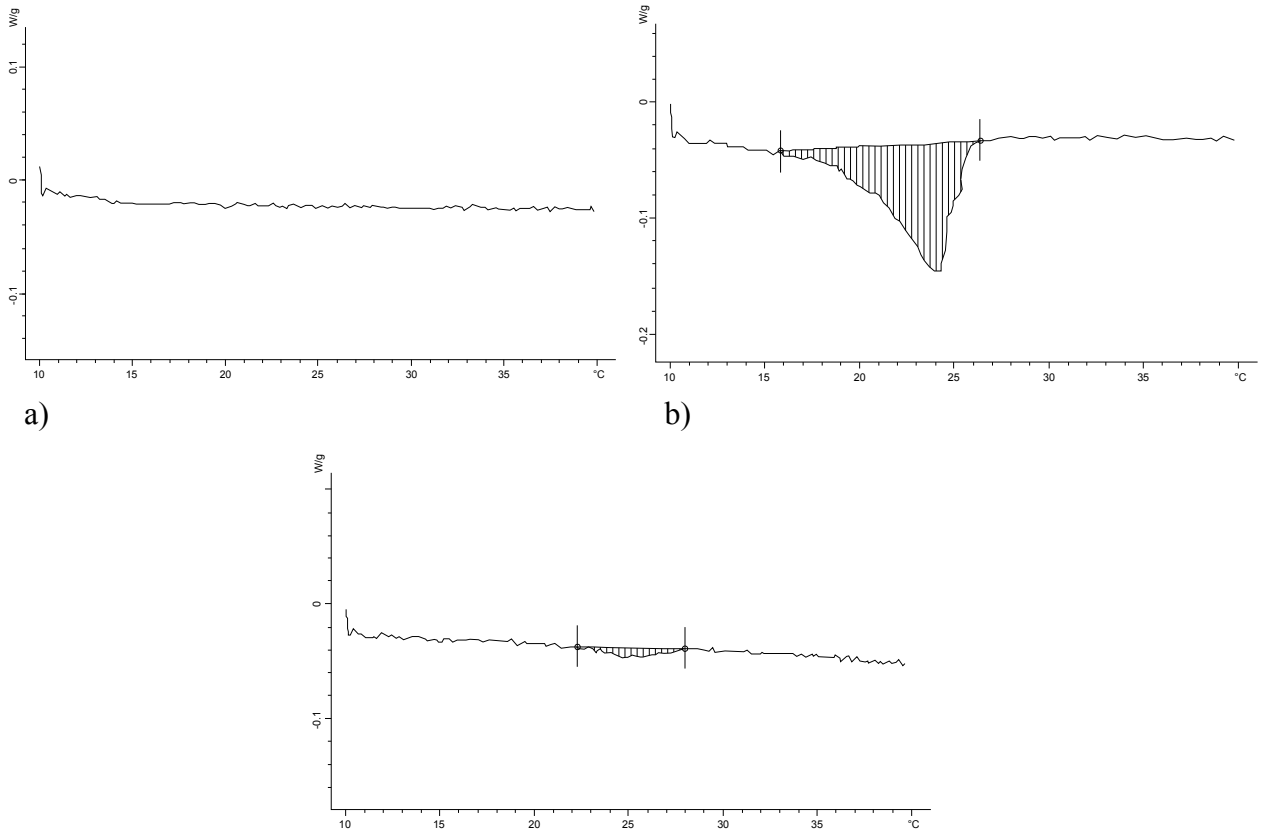

Fig.5. **DSC-measurements of gypsum samples**

(a – gypsum, b – gypsum immersed in RT21, c – gypsum immersed in SP25)

Conclusions

The heat of fusion for raw PCMs is higher of microencapsulated PCM, because of the inert polymer shell.

Although, the raw materials are not suitable for the direct incorporation method, because for paraffins there was a problem with mixing, but for salt hydrates the strength decrease was unacceptable high and the thermal properties were not stable due to changes of hydratation level of the chemical composition of PCM.

For the immersion method salt hydrates also decreased the strength unacceptably high, but paraffin showed good results with only 9.4% lost in strength and 26.4 J g^{-1} heat of fusion.
This investigation shows that potentially easy way of PCM incorporation in gypsum is microencapsulation with a polymer shell. Microencapsulation is the next aim for further research work.

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RENEWABLE RESOURSE INTEGRATION IN BIODEGRADABLE COMPOSITES

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Abstract. *For a variety of applications it is desirable to produce textile materials with specially designed properties. Reinforcing 2D and 3D woven structures for fibers reinforced polymer composites were developed from renewable natural fibers and tested in this research work. Results and discussion are presented in the paper.*

Keywords: *woven fabrics, reinforcement structures, fibers reinforced polymer composites, mechanical properties.*

Introduction

Textile materials as a components of laminated composites were used from 1960 [1]. Unfortunately high costs as a result of high share of manual labour in production and low resistance to loads in the third direction was the reason to investigate other solutions. 3D textiles were developed and first time as composite reinforcement were applied at 1970 [2]. In the course of time rapid development of applications took place and nowadays it is hard to imagine economic branch without exploitation of fibres reinforced polymer composites FRP [2]. Fabric reinforcements are used for improving FRP bent and stroke resistance. The other advantages of FRP are comparative low density and cost effectiveness, as well plasticity of textiles [3, 4]. For FRP production carbon, aramide and glass high modulus fibres are mainly applied as physical and mechanical properties of them are high and close to corresponding steel properties but density are less (Table 1). As disadvantages of mentioned fibres could be mentioned comparative high costs, low recyclability. For this reason where technical parameters allow less expensive, recyclable basalt or natural bast fibres are used [2].
Natural fibres are renewable, environmental friendly sources of raw materials with a low density; disadvantages of natural fibres are lower modules (Table 1), uneven fibres quality and low heat resistance. Local fibres resources are preferable – in Latvia these are flax and hemp fibres.

Table 1.

Main physical and mechanical properties of fibres for technical usage

	Basalt fibres	E – glass fibres	S – glass fibres	Carbon fibres	Aramid fibres	Flax fibres	Jute fibres
Density (g/cm^3)	2,63 – 2,8	2,54 – 2,57	2,54	1,78	1,45	1,4	1,46
Tensile strength (Mpa)	4100 – 4840	3100 – 3800	4020 – 4650	3500 – 6000	2900 – 3400	800-1500	400-800
Modulus (Gpa)	93,1 – 110	72,5 – 76	83 – 97	230 – 600	70 – 140	60-80	10 - 30
Elongation (%)	3,1	4,7	5,3	1,5 – 2	2,8 – 3,6	1,2 - 1,6	1,8
Filament diameter (mμ)	6 – 21	6 – 21	6 – 21	5 – 15	5 – 15	9,2 - 17,7	2 - 15

FRP mechanical properties are depended on mechanical properties of fibers and matrix, share of fibers and structure of reinforcing material, fibers/fabric adhesion to matrix, processing parameters.
Reinforcing textile structures in form of 2D or 3D fabrics could be produced by weaving, knitting, braiding, sewing, nonwoven or laminating technology. Weaving technology allows produced fabrics for composites starting from plain weaves (2D fabrics) till intricate composite 3D structures with interwoven and straight threads (Fig. 1).

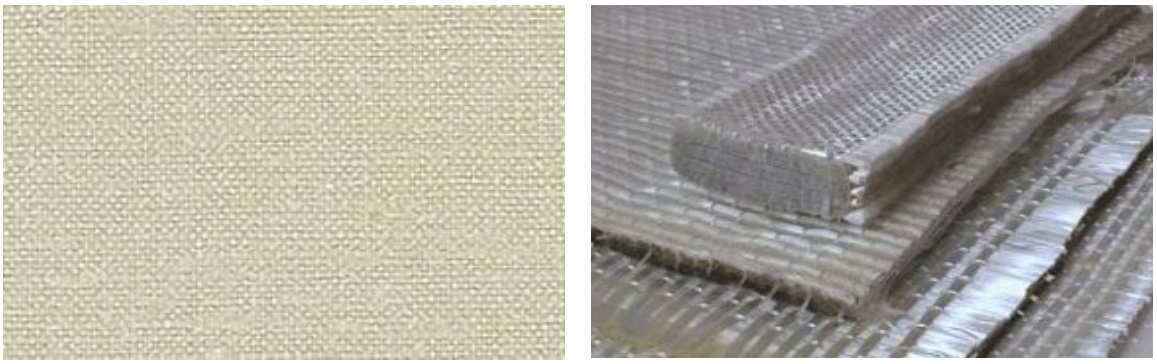

Fig. 1. **Composites reinforcing fabric weaves**:
plane weave (left), multilayer overlaid weave (right)

2D woven structures are executed in plain, panama, twill, satin, overlaid weaves depending on features of further application and processing. In FRP production processes 2D fabrics are spread out forming multi layer layouts filled with matrix resins. Impact on costs of manual labour in this technology is still high as a result FRP of this kind are quite expensive. Development of 3D reinforcing structures partially solves problem allowing exclude manual labour.

Materials and methods

Table 2.

Threads and weaves used in fabric samples processing

Thread type, fabric thickness	Flax			Jute			Jute/basalt
	2-layer plain weave	2 to 3-layer overlaid weave	Multi-layer overlaid weave 2/2	2-layer plain weave	2 to 3-layer overlaid weave	Multi-layer overlaid weave	Multi-layer overlaid weave 3/3
Flax, warp 582/2 tex	x	x					
Flax, warp 68/2 tex	x	x		x	x	x	x
Jute, warp 482/2 tex				x	x	x	x
Basalt, warp 68/2*2 tex							x
Flax, weft 382 tex	x	x	x				
Jute, weft 482/2 tex				x	x	x	x
Basalt, weft 68/2*2 tex							x
Fabric thickness, mm	3,84	3,84	3,85	5,35	5,32	5,33	5,35

Reinforcing 2D and 3D woven structures were developed corresponding to experiment plan (Table 2) and tested to investigate influence of warp and weft yarns combinations with weaves on fabric physical and mechanical properties.

Fig. 2. **Samples of woven reinforcement structures**
Two layer interwoven plain weave fabric (left), multi layer overlaid weave fabric (right)

7 different fabric structures in different weaves from natural threads are worked out and realized on hand loom (Table 2, Fig. 1 and Fig. 2). For the last structure natural jute threads are combined with the basalt threads (Table 2).

Fig.3. **Sample of the woven reinforcement structure.**
Flax multi-layer overlaid weave 2/2

For testing five 25 mm wide fabric samples were cut out and mechanical properties are tested on Instron tester in warp and weft directions with the distance between clamps 100 mm, testing velocity 10 mm/min. Results are shown in Table 3.

Results and discussion

Range of samples average surface density values are cover densities from 1210 to 2028 g/m^2, choices possibilities depending of final usage. From Table 3 and graphs in Fig. 5 and Fig. 6 are seen that the largest values of tensile stress and modules show samples with a jute/basalt multi-layer overlaid weave 3/3 tested in the weft direction (26,92 MPa and 0,81 GPa respetively), tensile stress for the same samples in warp direction is 1,7 times lower, module

1,93 times lower. Only a little lower values (26,19 Mpa) show samples from jute threads with 2 to 3-layer overlaid weave in weft direction that is 2,12 times more then in warp direction, module in weft direction exceed module in warp direction 2,57 times. For all three flax fabric samples tensile stress values in warp direction are slightly higher than in weft direction.

Table 3.

Physical and mechanical properties of woven fabrics under inspection

	Surface density (g/m2)	Thread direction	Tensile strenght, N	Tensile stress, MPa	Extension, mm	Modulus Gpa
1. Flax 2-layer plain weave	1353	Warp	1 793	18,63	10,4	0,18
		Weft	1 118	11,61	6,8	0,17
2. Fax 2 to 3-layer overlad weave	1866	Warp	1 606	16,73	5,5	0,31
		Weft	1 463	15,24	5,8	0,26
3. Flax multi-layer overlaid weave 2/2	1318	Warp	1 865	19,43	5	0,39
		Weft	1 376	14,33	4,4	0,32
4. Jute 2-layer plain weave	1210	Warp	1 284	11,81	15,8	0,08
		Weft	1 388	12,76	4,5	0,28
5. Jute 2 to 3-layer overlaid weave	2028	Warp	1 639	12,33	4,4	0,28
		Weft	3 483	26,19	3,6	0,72
6. Jute multi-layer overlaid weave	1755	Warp	1 721	12,87	4,2	0,31
		Weft	2 487	18,6	3,4	0,55
7. Jute/basalt multi-layer overlaid weave 3/3	1960	Warp	2 115	15,81	3,8	0,42
		Weft	3 600	26,92	3,3	0,81

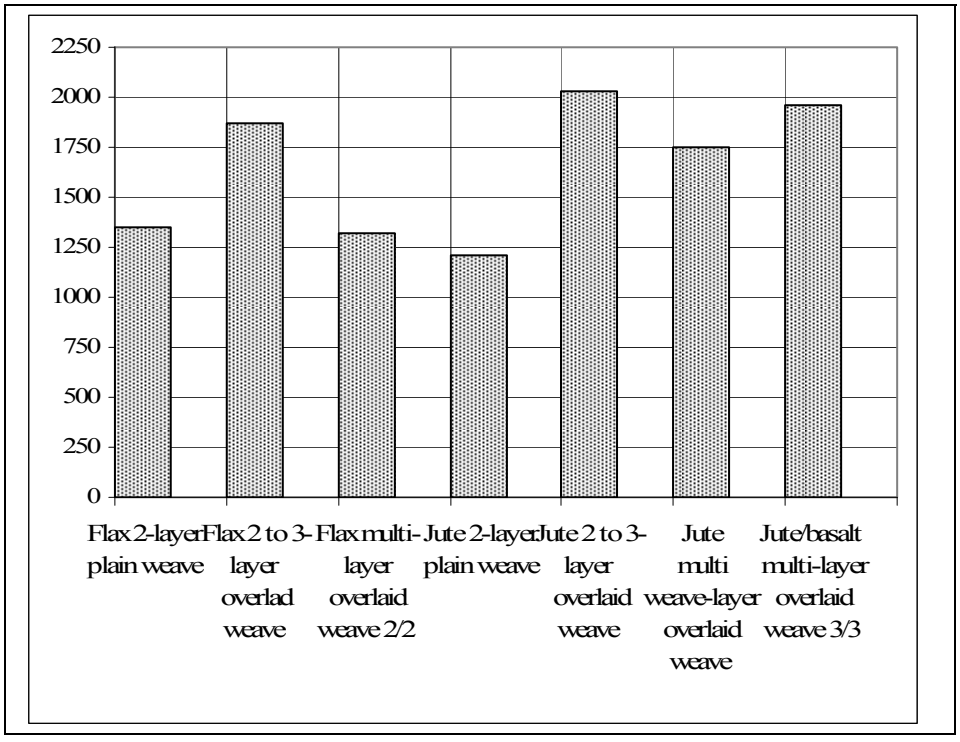

Fig. 4. **Surface density of woven samples**

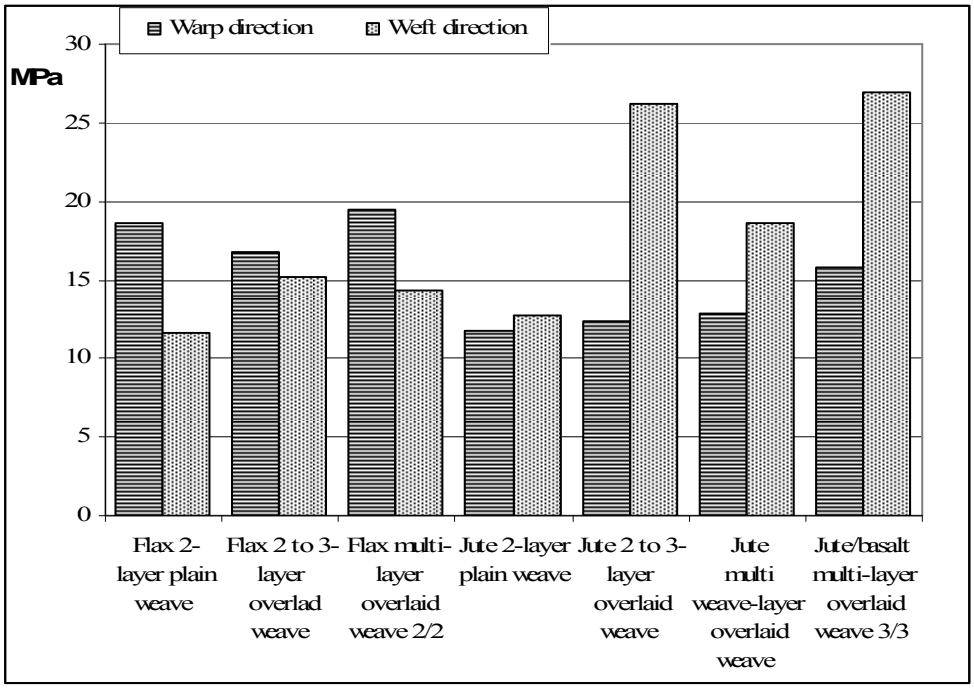

Fig. 5. **Tensile stress of woven samples (Mpa) in worp and weft direction**

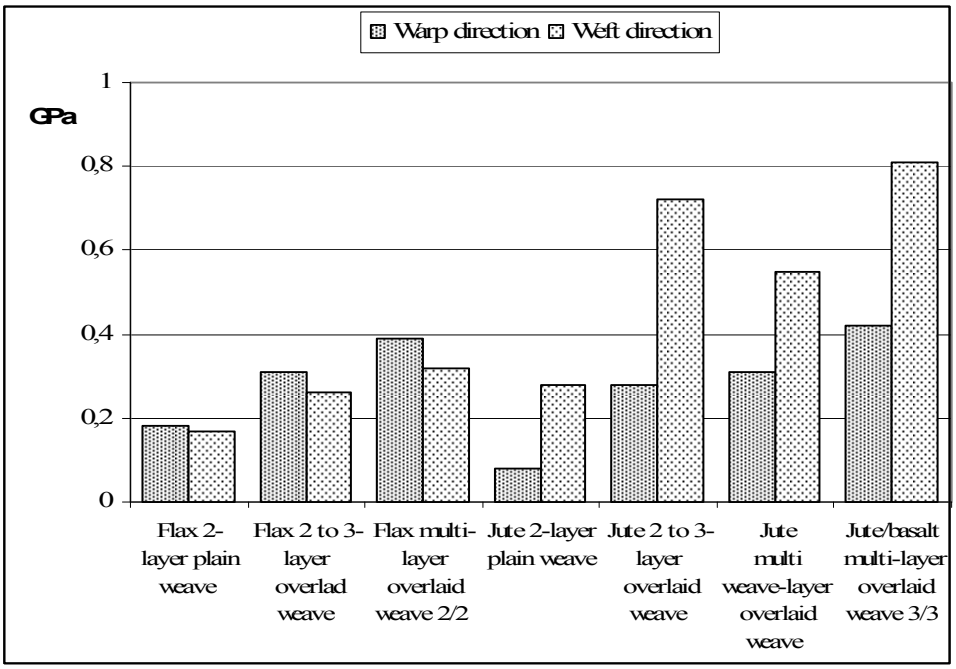

Fig. 6. **Samples Young's modules in warp and weft direction**

From Table 3 and graphs in Fig. 5 and Fig. 6 are seen that the largest values of tensile stress and modules show samples with a jute/basalt multi-layer overlaid weave 3/3 tested in the weft direction (26,92 MPa and 0,81 GPa respetively), tensile stress for the same samples in warp direction is 1,7 times lower, module 1,93 times lower. Only a little lower values (26,19 Mpa) show samples from jute threads with 2 to 3-layer overlaid weave in weft direction that is 2,12 times more then in warp direction, module in weft direction exceed module in warp direction 2,57 times. For all three flax fabric samples tensile stress values in warp direction are slightly higher than in weft direction.

Development of integrated FRP composition is possible if textile components has alongation close to that parameter of matrix. Too large elongation of reinforcing construction leads to situation in which only matrix some time overtake load, as a result composite mechanical properties is like corresponging matrix properties and such defects of composite structure as cracks arose. From graph in Fig. 7 obvious very high extension in warp direction of two layer plain weave sample from jute threads (close to 16 %) and high tensile extension of flax 2-layer plain weave. Reasonable seems last three structures with extension 4 % or less in both directions

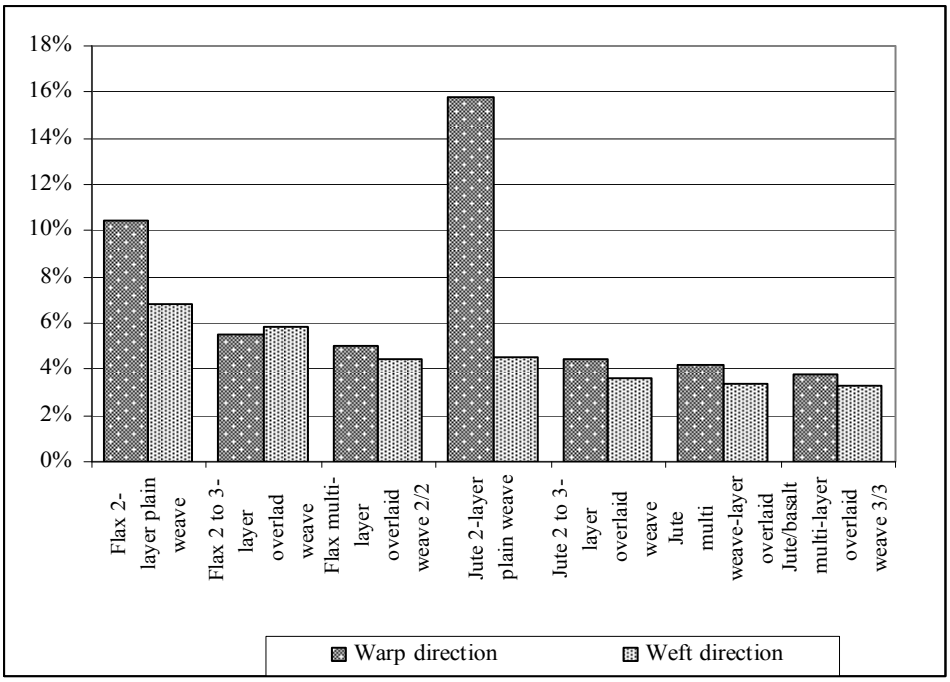

Fig. 7. **Samples tensile extension in warp and weft direction**

Summary

The technical textiles based composites are the rapidly developing light-weight engineering materials. The fabrics used in composites manufacture have to be especially engineered as a single-fabric system could impart reliability and performance of composite material.

Investigation of seven types of woven fabric structures from natural flax and jute threads interwoven with three different types of weaves show strong impact on fabrics investigated mechanical properties – tensile strength, extension and Young's module. Incorporation of basalt filament threads in weft system could substantially increase fabric mechanical properties in weft direction.

High tensile extension values in warp direction show 2-layer plain weave fabric samples, especially for fabric from jute threads.

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VI
ELECTRONICS AND MECHATRONICS

INSTALATION FOR INDUCTION HEATING FOR TESTING THERMO SENSORS

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Abstract. *With constant development and improvement of management systems in modern technological processes, in cars, in production lines and machinery and other fields are increasingly entering the use of different sensors. These sensors are tested on special test simulators, simulating the conditions for a long time close to their work. Often the temperature is in the range of 700-900°C. To achieve these temperatures, most environmentally safe and effective heating of the sensors can be achieved by induction heating of housing them. The object of this report is installation for induction heating system as part of the simulator to test the vibration and temperature thermal sensors.*

Keywords: *temperature sensor, induction heating, rectifier, width switching regulator, inverter.*

Introduction

Some of them work under harsh conditions such as high mechanical vibrations and high temperatures. These are mainly thermal sensors used in technological processes of heat in cars and others. Figure 1 shows a picture of some of the widespread thermal sensors car.

Fig. 1. **Picture of some of the widespread thermal sensors car**

Exibition

For specific application one of the most important requirements for the installation of induction heating is a broad range of regulatory power to set the temperature sensor on a particular algorithm or temperature changes widely in random.

The most used ways of power adjustment are:

- Adjustable Rectifier with a phase adjustment;
- Diode rectifier with DC pulse-width regulator;
- Frequency control of inverter with a consistent flickering circle.

Current requirements for mains ecology of a more sophisticated filter restricts the use of rectifier with phase control. Important factor is the power plant. Small dimensions and mass of the sensor and its housing need to be determined by low active power - 2-3 kW. On the other hand, to provide the necessary amplitude of mechanical vibration sensors in the inductor, it is oblong or rectangular shape and size much larger than the body of the sensor. In most cases, housing is non-magnetic metal, usually chrome-nickel alloys. Course received a very large air gap between the work piece and inductor defines low *cos φ*, therefore more reactive power and complete the circle. This fact determines the use of coherent flickering circle as ineffective. On the other hand switching regulator power 2-3 kW is the standard converter. For those reasons, he was elected DC / DC switching regulator power. Simplified block diagram of induction heating device is shown in Figure 2.

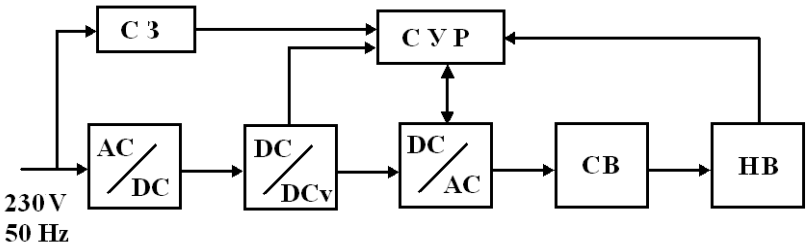


Fig. 2. **Simplified block diagram of induction heating device**

AC / DC - Not regulated rectifier
DC / DCv - impulse drive
DC / AC - Inverter
CB - unit agreement - RF transformer
HB - heating block
СУР - System management and regulation
СЗ - stabilized power

Adjustable DC power supply is realized by a diode bridge rectifier with capacitive filter and a switching regulator circuit of one-key buck converter.
Its principal scheme is shown in Figure 3.

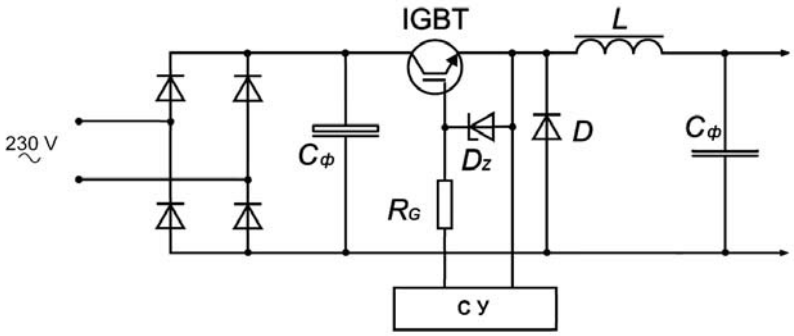


Fig. 3. **Schematic of a buck converter key**

The output voltage Uo depends on the duration of operation of transistors and diodes (impulse control), therefore the coefficient of filling of the control signal of the transistor.

$\gamma = t_{ON} / T$

t_{ON} - duration of the control pulse;

T - period of control signal.

The adjustment range of the output voltage is 150 to 300 V, and regulation is smooth. Tension can be set manually - by potentiometer or automatically - by request of the computer. In principle of operation of the pulse regulator has no specific features deriving from its particular application and therefore may not be his special attention.

Greater interest is the DC / AC converter. The main criteria for selecting circuit and transistors are reduced to power and operating frequency. In determining the optimal operating frequency has two conflicting characteristics. On the one hand small dimensions and thickness of the hull of the sensor requires a high frequency. On the other hand large air gap and non-magnetic metals require operation at lower frequencies. It is experimentally established that good technological effect is obtained at operating frequencies 65-75 kHz. For these frequencies and capacities up to 2-3 kW can be used all the schemes of resonant inverters. For less Transfer to and effective use of the matching transformer is selected half-bridge scheme resonant inverter. Pulse power source allows power regulation and implementation of the necessary equipment for such protections. This reduces the system requirements for the management of the inverter to control the formation of pulses with the required frequency. For these requirements the most inexpensive, is simple and reliable system management oscillator principle. Figure 4 shows the scheme of half-bridge oscillator resonant inverter.

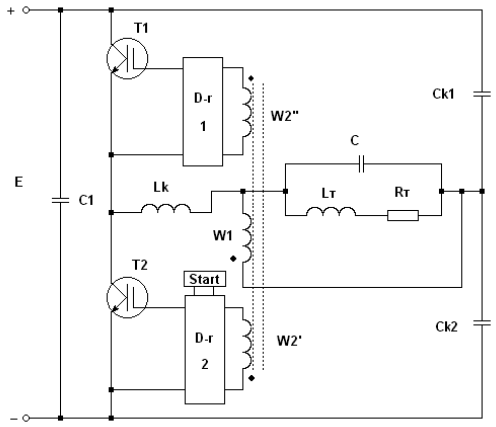


Fig. 4. **Scheme of the oscillator resonant half bridge inverter**

In principle of operation of the power scheme has no specific features. Interest is in the case of an oscillator control. The ruling scheme is limited to low-powered transformer feedback amplifiers to form governing impulses - drivers and starting device. The principle of operation is illustrated by timing diagram shown in Figure 5.

Feedback transformer has a primary coil connected in parallel to the freight flickering circle and two opposing same coiled coil secondary connected to the drivers. (Figure 4).

In the initial commissioning of the converter, starter drive (Start) produces a single impulse control Up to transistor T2. Pulse duration is less than half period of the highest possible operating frequency (Fig. 5). Transistor T2 is turned on, is brought energy to the load range and occurs oscillate process. The two secondary windings W2', W2'' transformer feedback appears sinusoidal signal phase shift of 180°. Under terms of cells marked in Fig.4 shows that W2'' is in phase with W1. Therefore, as Driver 2 is brought positive half-shaft and he formed

a steering impulse U_{GE2} for T2 (Fig. 5). To a driver shall be filed negative half-shaft of sine wave of W2' and T1 is blocked. Once the voltage range of freight and W1 changed its polarity to Driver 2 is brought negative half-shaft and worked transistor T2 is turned off. At the same time to the driver 1 is passed positive half-shaft and T1 is switched on. In the next period the process is repeated, but without starting pulse (Fig. 5).

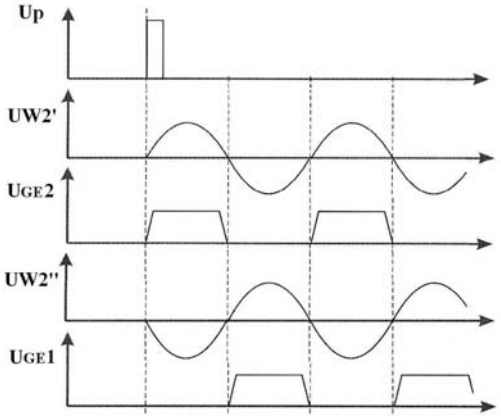
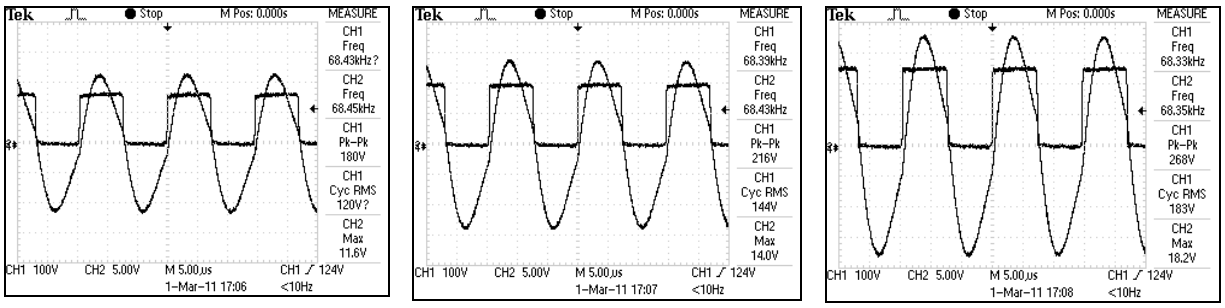


Fig. 5. **Timeline of the control circuit**

Management of transistors by a signal from the load range, with almost no logical processing provides self frequency of the inverter with the load. This self-ordination is both dynamic mode (during heating) and on initial start-up. That is what ensures reliable operation at relatively steady speeds of transistors in the entire process.
Examined for induction heating device for testing thermal sensors is constructed and operates in real terms.
To illustrate the mode of the inverter of Figure 6 shows oscillograms of the collector-emitter voltage of transistor T2 and the current in the diagonal of the inverter (during the two transistors).



a) b) c)

Fig. 6. **Oscillograms of the collector-emitter voltage of transistor T2 and the current in the diagonal of the inverter**

It is seen that switching transistor is at almost zero current, so there are no voltage peaks U_{CE}. Oscillograms were photographed in a different assignment of pulse DC source. In Figure 6a) is at minimum voltage Uo = 150V, 6b) - at 250V, and 6c) - intermediate voltage 200V. These figures confirm the strain of U_{CE} blocked transistor. It also includes increases in the current diagonal under increasing DC.

Conclusion

The realized system for induction heating in testing thermal sensors is shown in Figure 7. For easy installation in a constructive attitude, the loading range is exported in a separate box with a length of connecting wires 2.5 m.

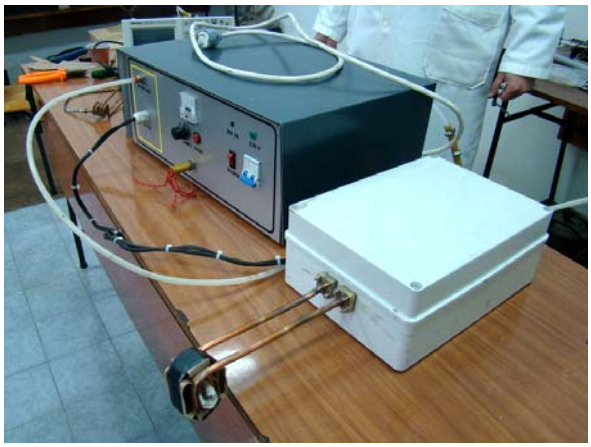


Fig. 7. **Arrangements for induction heating for testing heat detectors**

The device shows very good features in real working conditions as part of the tester thermal sensors vibration and temperature.

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DEVICE FOR MONITORING THE CONDITION OF THE NATURAL BACKGROUND

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Abstract. *Life on Earth arose and exists in terms of natural ionizing radiation. Environmental pollution with radioactive substances begins with the emergence of the nuclear industry. Proceeding from the accepted truth that there is no safe dose of exposure to radioactive radiation and accumulated over the years experience (more than 25 years), the author of this article provides an apparatus for monitoring the condition of the natural radiation background based on light and sound indication in all cases when there is increase toward "imperturbable" atmosphere.*

Keywords: *radiation, gamma rays, beta particles, nuclear power.*

Introduction

In recent years it became clear that the development of mankind is closely associated with more large-scale use of nuclear energy (Fig. 1). A striking example of this is the start of a program for building the world's first fusion power plant.

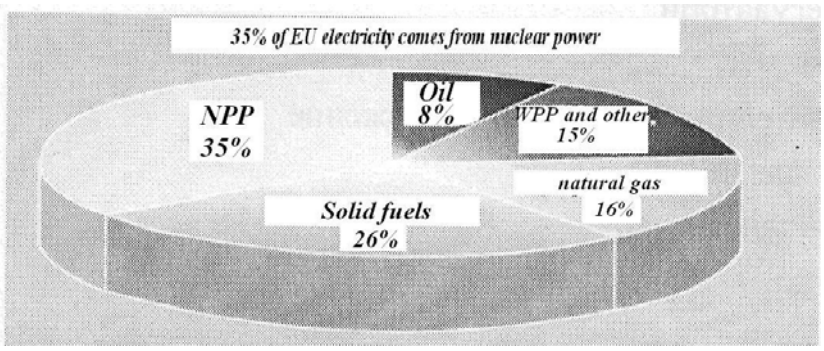

Fig. 1.

At the same time, however, accidents at nuclear power plants (NPP) in Fukushima and Chernobyl have led humanity to think seriously on the safe operation of existing and future NPPs. For many years also showed that the safe dose of radiation does not exist. Therefore, creating an opportunity for preventive control of the state of the natural radiation background (NRB) would contribute to warning of the danger of radioactive contamination with all ensuing consequences. In this regard, it was developed signaling apparatus - indicator of radioactivity, which allows control of the state of NRB.

Exhibition

The indicator of radioactivity is a device that reports the number of pulses per minute, generated by gamma or beta rays. Appearance of the device is shown in Fig. 2.
The number of pulses per minute is recorded in a file in the embedded memory card, and then the data can be viewed and displayed on a computer. If the computer is plugged into the Internet, it is possible to examine data from the entire network.
Simultaneously, the LED display shows the current radiation. Optionally it can include acoustic signal indication. The device can work with external power supply (from an adapter or USB) and battery (2xAA).

Fig. 2.

Block diagram of the device is shown in Fig. 3.

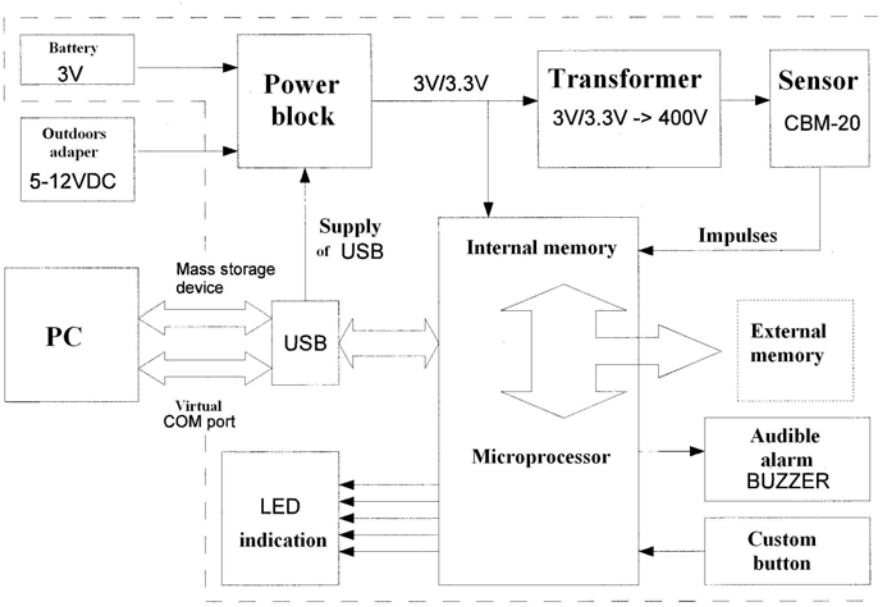

Fig. 3.

When the device is turned on it is desirable the user to set time: set the device in the USB and wait to install the drivers for the Mass Storage Device (this happens only when the board is included for the first time on a computer). If everything is successful will appear new Removable disk in My Computer, i.e. device behaves like a USB flash memory. This memory will find other drivers to be installed. If Windows asks for drivers, then it is identified those in the newly device. After installing all the drivers it will have to show a new virtual COM port on your computer. Trough this COM port can be made settings and to examine in real time when it enters each pulse. Access to the device through this port can be done with any terminal program. In our case we use the built in Windows “Hyper Terminal”. Start the Hyper Terminal and select the appropriate number of COM port - settings are 19200 8N1. The default password for entering the menu is "pass". When writing "pass" a menu will appear. First item of this menu is setup time. Select "1" and then press Enter to follow the prompts. When the time is properly entered it will be written "TIME is SET successfully".

At any time, the terminal can be observed when in the time arrives each pulse and how many pulses per minute. All information can be saved to a file on your computer if you choose Capture Text feature of Hyper Terminal from the menu Transfer.
Device always shows the number of pulses for the last minute by the LED, but does not record data, unless expressly asked by the user. Start recording data in memory after it is pressed and hold START / STOP button for more than 2 seconds. Short (0.5 seconds) beep will confirm that the application is accepted. In this situation becomes the following: it is created a new file name that corresponds to the time in which we pressed the button, i.e. the file name displayed when starting from the data entry. For example, if the button START / STOP is pressed in 21 hours and 34 minutes of 08 September, it will have a file name: 09082134.TXT. 09 is September, 08 is the date, 21 is the hours and 34 are minutes. From that time on will record the data on the number of pulses in each minute. New data in this file do not appear every minute and every hour. This is done to not write too often memory. However, the user at any time (but it should be past 1 minute from the creation of a file to be at least 1 outcome) may terminate and see the recorded results to date if press and hold START / STOP button for more than 2 seconds. Then, if there is data in the buffer, it is recorded and the current file is closed. The time of closing the file is the final time, which lasted until measurement. It is recorded in the file properties - visible if you right-click the file, select Properties - Modified field. So the file name will show the time in which the measurement started and Modified field from the file properties will show the final time of measurement. Once the current file is closed, the device continues to count pulses and to visualize the terminal program and through the LED, but not record them. If the user wants to record data once he has closed the file must again press and hold START / STOP button (at least for 2 seconds) to open a new file for writing.
Display results: the results in the file are arranged in columns, i.e. have the separator character for space and new line. There are many programs and ways to visualize data. The text file can be opened with Open Office Calc. Results will be arranged in the first column. Thus can exploit the potential of various programs for drawing diagrams and graphs in the desired form with the data from the menu (Fig. 4)

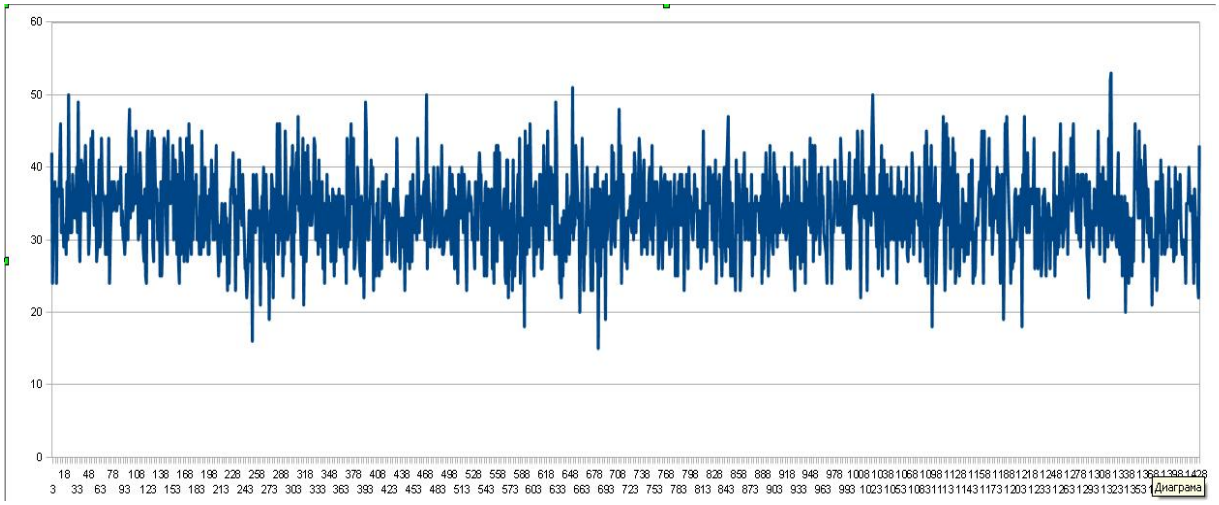

Fig. 4.

Conclusion

The developed indicator has a new principle, and allows anyone wishing to inquire about the state of its surroundings in terms of additional sources of radioactivity. When you turn the indicator to a computer it can draw information on the natural radiation background from another computer located at an arbitrary distance from the control site. For people with high

interest accumulated in the memory data can be processed with the help of appropriate software to obtain the necessary results for different periods of time.

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NONLINEAR DYNAMICS OF BUCK CONVERTER

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Abstract. *This paper is concerned with the problem of modeling and simulation of piecewise linear systems with the pulse width modulation control. Models of this kind of systems are widely used in engineering practice, in particular in power electronic converters. The research provides the study of chaos and bifurcations in one of the switching converters – step-down converter under voltage mode control, operating in discontinuous and continuous current modes, using Matlab and Simulink simulation environment. Various types of models, including discrete – time maps, switched state – space models are examined in order to detect their suitability and reliability in numerical investigation of nonlinear phenomena in DC–DC converters. Some analytical methods for the search of periodic regimes and their stability estimation were also used in order to validate numerically obtained results and evaluate the accuracy of models used. As direct simulation does not accurately pinpoint bifurcation points and computes only stable invariant sets, some aspects and advantages of numerical path-following are also discussed.*

Keywords: *bifurcation diagrams, buck converter, chaos, path – following, simulation tools.*

Introduction

High efficiency solid state power conversion has become possible through the continuing development of high power semiconductor devices. The operation of these devices as switches, which is necessary for high efficiency, means that power electronic circuits are essentially nonlinear, time varying dynamical systems. Thought this makes them difficult to study, the effort is well worthwhile as this systems are becoming increasingly important in the delivery of electrical energy.

In the case of switch mode power converters (SMPC) the most commonly used models are: averaged model (AM), switched state-space model (SSSM) and iterative mapping (IM). A considerable amount of work in analysis of nonlinear phenomena in DC-DC power converters has been reported during the latest three decades [1-4]. It has been proved that the use of AM, commonly accepted in engineering practice, does not allow determination of the existence of the majority of nonlinear phenomena in SMPC. Moreover, Tse in his study [5] showed that the conventional analysis using averaging is qualitatively wrong: it predicts stability in large parameter range, whereas in reality higher order orbits and chaos are present. Therefore, rather than recurring to AM, which are standard tools for the analysis of this kind of circuits, in our investigation we provide the analysis of the bifurcation phenomena in SMPS, highlighting regions where subharmonic and even aperiodic behavior is possible, using the most suitable nonlinear models (SSSM and IM).

Materials and methods

Step-down (buck) switching converter is one of the most popular circuits in modern electronics. It is especially widely used in the field of handheld devices that require many different voltage levels to be supplied by the same battery with minimal waste of energy. Among many possible implementations of this converter we focus on the pulse-width modulated (PWM) buck DC-DC converter with voltage mode control, whose circuit is schematized in Fig.1.

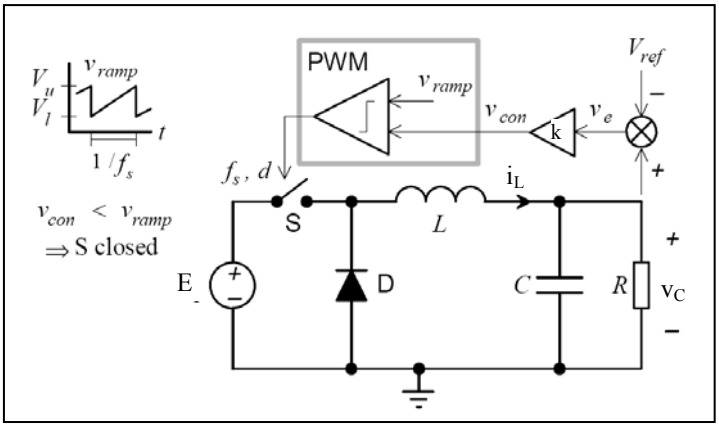

Fig.1. **PWM buck converter under voltage mode control**

The aim of buck converter is to preserve preferred output voltage lower than that provided by the input source. This can be achieved by appropriately turning on and off the switch, so that the circuit is repeatedly forced by the external voltage source. The SSSM consists of three linear susbsystems depending on the value of inductor current and switching condition – the value of the output voltage is compared with the ramp signal to generate the switching signal.

$$\begin{cases} \dfrac{dv_C}{dt} = \dfrac{1}{C}\left(i_L - \dfrac{v_C}{R}\right) \\ \dfrac{di_L}{dt} = \dfrac{1}{L}\left(-v_C\right) \end{cases} \text{ for } v_C \geq \frac{V_{ramp}}{k} + V_{ref}; \tag{1}$$

$$\begin{cases} \dfrac{dv_C}{dt} = \dfrac{1}{C}\left(i_L - \dfrac{v_C}{R}\right) \\ \dfrac{di_L}{dt} = \dfrac{1}{L}\left(E - v_C\right) \end{cases} \text{for } v_C < \frac{V_{ramp}}{k} + V_{ref} \text{ and } i_L>0; \tag{2}$$

$$\begin{cases} \dfrac{dv_C}{dt} = \dfrac{1}{C}\left(-\dfrac{v_C}{R}\right) \\ \dfrac{di_L}{dt} = 0 \end{cases} \text{ for } v_C < \frac{V_{ramp}}{k} + V_{ref} \text{ and } i_L=0; \tag{3}$$

$$V_{ramp} = V_L + (V_U - V_L)\left(\frac{t}{T} \bmod 1\right) \tag{4}$$

where v_C corresponds to output voltage; i_L – inductor current; k is the gain of the error amplifier; V_{ref} – reference voltage; V_{ramp} – is an external ramp signal with period T and upper and lower threshold voltages V_U and V_L, respectively, that is used to determine the switching instants; C,E,L and R are positive constants representing the capacitance, input source voltage, inductance and resistance, respectively.

Typically in high-power applications, where current ripple must be small to minimize losses, the components and threshold signal are chosen so that the inductor current is always strictly positive – the circuit is said to work in continuous conduction mode (CCM) and SSSM includes equations (1), (2), (4). On the other hand, for low–power applications, where opening and closing of switches causes a significant amount of overall losses, lower switching frequencies are used, letting the inductor current go to zero – the converter is operating in discontinuous conduction mode (DCM) and SSSM includes equations (1)-(4).

The best way to study the dynamics of the buck converter is to obtain a summary chart of the different types of behavior exhibited by circuit when some parameters are varied. For piecewise smooth systems there are two classes of numerical methods for investigating the possible dynamics for the range of parameters, namely: *brute force approach* and *numerical continuation* (also known as *path-following*) [6].

In order to determine stable behavior, direct numerical simulation methods can be used in an event-driven manner (brute-force approach). That is, for a given initial state, the equation (1) is solved exactly or via high – order time-stepping scheme such as Runge-Kutta method. The test function is monitored in order to determine the next switching point. After applying the switching law, this point is then used as the starting point for the next calculation (solving equation (2) or (3)). This process could be easily applied to calculate flows with many switching events or points of IM. To determine possible sets for particular parameter value a random set of initial data is chosen and the orbits from each such point are calculated over several hundreds periods (or iterations in case of IM) without storing, than the flow is continued for another hundred periods and stored. To see how the set changes, a small parameter adjustment is made and the process is repeated. The solution data obtained in such a manner can then be plotted in a bifurcation diagram where solutions are plotted against the parameter. Plots obtained in this way via direct numerical simulations are sometimes referred as Monte Carlo (or brute-force) bifurcation diagrams. This method has the advantage of capturing most (but not all) of the long time dynamics, but has the disadvantage of not being able to capture unstable behavior, which requires another algorithm, called *path-following*.

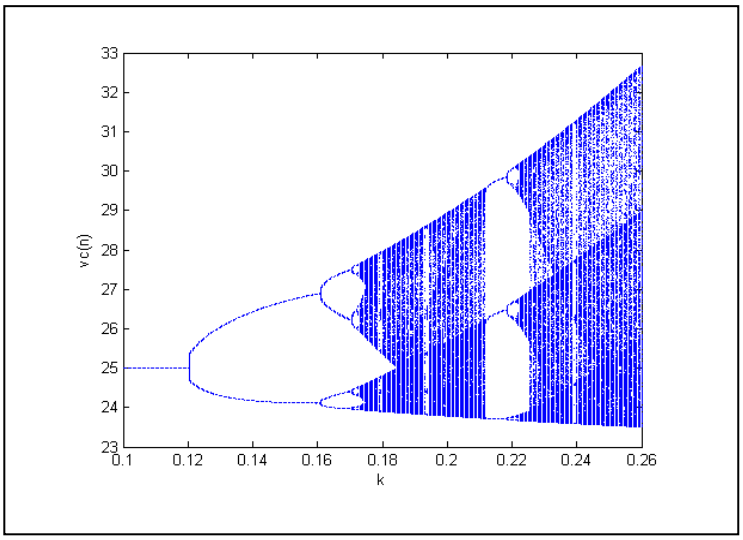

Fig.2. **Monte Carlo bifurcation diagram for buck in DCM mode**

In order to plot the brute-force bifurcation diagram it is necessary to calculate the Poincare section for the systems under investigation. In this case the most suitable would be the use of IM. It appears that it is not possible to obtain the closed form IM for the buck converter operating in CCM, as finding the switching instants in this case involves solving of transcendental equations. However, the operation of buck converter in DCM (when v_C is the only state variable) was studied by Tse [7], who obtained discrete time one dimensional map:

$$v_{C,n+1} = \frac{\alpha v^2_{C,n} + E(E - v_{C,n})\beta(H(D - k(v_{C,n} - V_{ref})))^2}{v_{C,n}}, \qquad (5)$$

$$D = \sqrt{\frac{(1-\alpha)V_C^2}{\beta E(E-V_C)}}; \alpha = 1 - \frac{T}{RC} + \frac{T^2}{2C^2R^2}; \beta = \frac{T^2}{2LC}; \quad H(x) = \begin{cases} 0, \_if\_x < 0 \\ 1, \_if\_x > 1 \\ x, otherwise. \end{cases}.$$

Where T is the switching period, V_C – steady–state output voltage and all other parameters are depicted on the Fig.1. The example of Monte Carlo bifurcation diagram obtained on the basis of this map is shown in the Fig.2. The parameters used are as follows: T=333.3(μs); R=12.5(Ω); L=208(μH); C=222(μF); V_{ref}=25(V); E=33(V). Small signal feedback gain was

chosen as the bifurcation parameter. This diagram clearly shows that the period-doubling route to chaos is initiated as k reaches 0.12.

While having the merits described above, direct simulation suffers from two main disadvantages – it does not accurately pinpoint bifurcation points and computes only stable periodic orbits. In order to accurately locate bifurcations it is sometimes necessary to compute unstable orbits. These typically comprise methods for numerical path-following of the solutions as parameter varies, for detecting codimension-one bifurcations, and possibly continuation of these bifurcation points in two or more parameters.

The key idea behind numerical continuation is to compute sequences of points at small intervals along the solutions curve [8, 9]. The most commonly used method to compute sequences of fixed points is Newton-Raphson method, but it is known that this requires a sufficiently good initial guess in order to converge. There exists a variety of modifications of this method, but the strength of approach is the ability to follow unstable periodic orbits and to detect regimes skipped in the process of construction of Monte Carlo bifurcation diagrams.

It is important to note, that when computing solutions to piecewise – smooth systems, it is usually not possible to use general purpose nonlinear software packages (such as AUTO [10], MATHCONT[11] etc.), as most numerical integration routines assume high degree of smoothness of the solution. Accurate computations must take special allowance for the non-smooth events that occur when switching boundary is crossed. Hence, using the conditions given above, special numerical continuation routines were written in MATLAB to trace the bifurcation curves in one parameter space.

Fig.3. shows the example bifurcation diagram of the buck converter operating in DCM, computed on the basis of IM (5) by means of path-following approach.

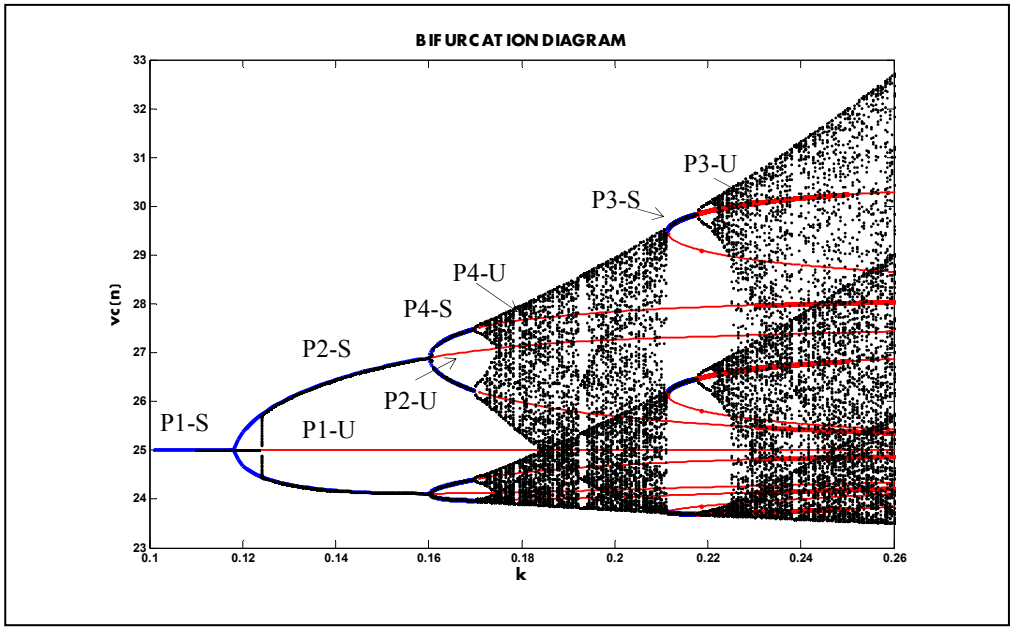

Fig.3. **Bifurcation diagram for buck in DCM mode**

For the sake of simplicity, this diagram depicts bifurcation branches of just few operating regimes. Blue lines represent stable orbits, thick red lines represent unstable periodic orbits (period-1 orbit is marked as P1, period-2 as P2 etc.), and black dots illustrate the brute-force diagram. It could be seen, that numerical continuation approach allows the detection of all possible periodic windows between chaotic bands as well it gives a possibility to explain some nonlinear phenomena. For example, the sudden birth of wide band chaos from several chaotic bands at k=0.223 could be explained by collision of chaotic attractor with unstable

period-3 orbit. This could be clearly seen on Fig.3., however, Monte Carlo bifurcation diagram does not show the explanation of this expansion of chaotic attractor.
As it was already mentioned, the path-following algorithm also uses the Poincare section of the flow, but authors established, that in the case of path-following approach, there exist some special requirements to the "quality" of this section.
The Fig.4.a. represents the phase portrait obtained for the period-1 operation of the buck converter, solving equations (1)-(4) by means of Runge – Kutta method. The solid blue line shows the exact solution of equations, and the black dashed lines – numerical solution. If this phase portrait is used to construct the Poincare section (Fig.4.b.), instead of one equilibrium point (big blue cross), corresponding to the period-1 operation, it will show a variety of points (small black crosses) around it.

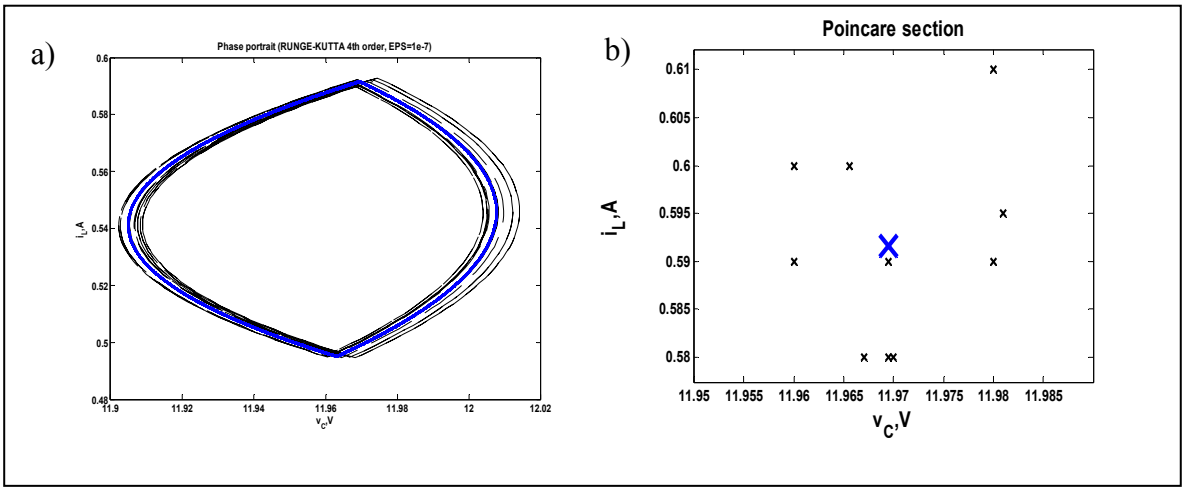

Fig.4. **Period-1 phase portrait and Poincare section**

Constructing the brute-force bifurcation diagram using this kind of data will lead to slightly "spread" but still sufficiently clear diagrams, similar to those, obtained in laboratory experiments in the presence of unavoidable noise. On the other hand, using the path-following algorithm, the Newton-Raphson or similar methods would not converge or will erroneously detect period-n (n>1) operation regime. So in the case of numerical continuation some special modifications of the model should be used.
The main cause of the "spread" phase portrait is that the use of numerical integration with fixed step does not allow precise detection of switching events, which leads to the fact, that even in the period-1 regime at the beginning of every cycle different starting points for the next calculations are used. We propose some useful methods, used by author in order to overcome this problem. The most straightforward approach is to decrease the overall integration step until the error becomes negligible. As the main drawback of the mentioned method is the unacceptable increase of simulation time and number of data points, the author would suggest using some numerical integration algorithms with variable step size in order to decrease the step only in the vicinity of switching event. Thus, appropriately choosing integration steps, it is possible to obtain clear Poincare sections and apply path following approach.

Results and discussion

Various types of models of the buck converter operating in CCM and DCM have been studied in order to detect their suitability and reliability in numerical investigation of nonlinear phenomena. The comparison of models is presented in the Table. As it was already

mentioned, all models could be used in order to detect subharmonics and chaos in DC-DC converters, however it is extremely important to acknowledge the possibilities and limitations of the use of these nonlinear models.

Table

The comparison of models

Model	Comments
SSSM (analytically solved)	+ Fast and precise models; -Could be applied in case of relatively simple systems of linear differential equations.
SSSM (numerical integration)	+No need to solve equations by hand; -The slowest models; - In order to use for numerical path following requires some special particularization measures.
Iterative mapping	+ Direct use in brute-force approach and path following; +Simple and fast models; - Impossible to use for buck converter operating in CCM; - Requires simplification procedures – some useful information could be lost.

It could be seen from the Table that the most attractive from the practical point of few is the IM, however, it has several noticeable drawbacks, that limit the applicability of this kind of models. In order to investigate the dynamics of buck converter, operating in CCM, we still have to use the SSSM. The example given in this paper and illustrated in the Fig.3. shows, that the use of numerical path following technique gives the most full understanding of nonlinear behavior of dynamical systems and allows explaining some complex phenomena. So the next step in this kind of research would be the development of systematic procedure, capable of merging the SSSM models of DC-DC converters and numerical path-following techniques in order to create the complete bifurcation diagrams, indicating all possible operating regimes.

Conclusions

This paper is concerned with the problem of modeling and simulation of piecewise linear systems with PWM control. The research provides the study of buck converter under voltage mode control, operating in DCM and CCM, using Matlab and Simulink simulation environment. Various types of models, including IM and SSSM, are examined in order to detect their suitability and reliability in numerical investigation of nonlinear phenomena in DC–DC converters. The main advantages and disadvantages of different models are pinpointed and some recommendations for the most appropriate use and implementations are provided. It has been shown that direct simulation does not accurately locate bifurcation points and computes only stable invariant set, so some aspects and advantages of numerical path-following are also discussed. The complete bifurcation diagrams, obtained by means of numerical continuation could be used not only to predict the operating regimes in given parameter range, but could also provide useful information for different nonlinear control schemes, when it is necessary to find and stabilize/destabilize certain periodic orbits (this technique is widely used in chaotic control [12] and spread spectrum applications[13,14]).

Acknowledgment

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MICRO-ELECTROMECHANICAL SYSTEMS IN THE ECOLOGY

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Abstract: *In the present paper a definition, a model for building of MEMS (micro-electromechanical systems), types, their advantages and disadvantages have been given. The elements and the components, from which they are built, the development and the prediction of market about them have been considered as well more important firms, that manufacture them. A classification of MEMS is made on the basis of their designation and the region, where they operate. A special place is separated on the application of MEMS in the ecology as well as concrete examples are indicated – developments of firms and own ones.*

Key words: *micro-electromechanical systems, ecology.*

Introduction

Each element, device or system, replaced by a definite number of micro-components, can be defined as ***micro-system*** or MEMS [1]. A generally accepted model of micro-system is the model of standard controlling system (Fig.1), but not all micro-systems follow this scheme of controlling system. The micro-sensors in the system detect alterations in the parameter, which has to be controlled. The electronic controlling logics (system) processes the information from sensors, after that it makes a signal for operating the actuating micro-mechanisms (micro-actuators) supporting the controlled parameter within desired limits.

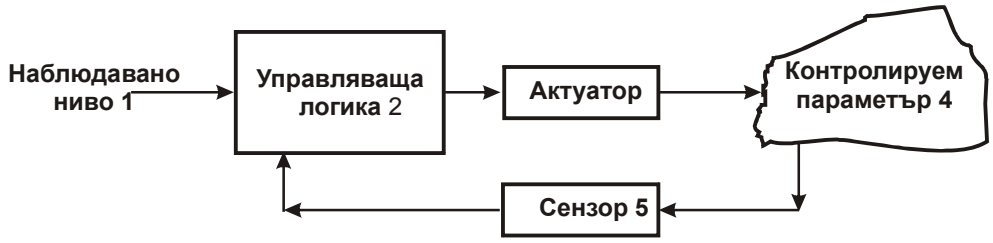

Fig.1. **Generally accepted model of micro-system**
Legende: 1-Observed level; 2-Controlling logics; 3-Actuator;
4-Controllable parameter; 5-Sensor

Depending on the used physical phenomena, the micro-systems can be classified in principle as it is shown on the diagram in Fig.2 [2]. The different combinations from optical, electronic and mechanical phenomena form the types of systems in the micro-systematic technique – optoelectronic, optomechanical MEMS and micro-optoelectromechanical systems (MOEMS). For systematizing the variety of micro-systems and their elements, the scheme shown in [3] can be used. A classification is imposed also according to the way of modeling nd the selected mathematical model for designing of micro-mechanical components, namely very often by means of the finite element method (FEM). According to this method, the model of the form of designed component is presented as one of the following basic types:
- elements from a type of beam – bar, beam, column;
- shell elements – slab, plate, shell;
- massive elements – elements with axially symmetric or arbitrary form.

The other kind of classification of micro-components as a base for selecting the technological process about their production is the type of material, from which they are produced and also the form of treated surfaces.

Legende: 1-Optics; 2-Optoelectronics; 3-Electronics; 4-Mechanics; 5-Optomechanics

Fig.2. **Classification of micro-systems**

The development at the production of micro-systems is in the direction of a decrease of the expenses about materials and equipment, the quantity of technological operations as well improvement of their functional properties (accuracy, operating range, sensitivity, etc.) during a simultaneous increase of the reliability. By increasing of the complexity of micro-systems, the stage of automated design engineering will hold all time a more-important role in the process of production. Figure 3 visualizes the growth of MEMS in the industry in 2006 and the values, which are predicted to be reached in 2011.

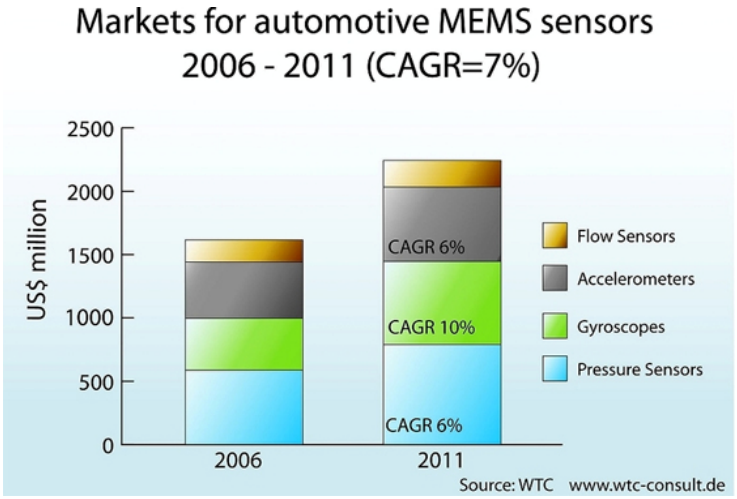

Fig.3. **Growth of MEMS in the industry in 2006 and 2011**

Statement

2.1. Classification of MEMS in the ecology

The classification of MEMS can be made on the basis of their designation and the field where they operate. According to fields of application MEMS about ecology are: of the water, the soil, the air, the atmosphere, the climate, etc. According to designation MEMS about monitoring and analysis in different branches of ecology are subdivided as follows:

- sensors for control of gases – detection of toxic and easily flammable, explosive gases as well for control of gas parameters as an expense, etc. Firms which work in this field are: Micro Chemical Systems, Alpha MOS, Neotronic Scientific Ltd, etc.
- satellite navigation and examination of the atmosphere and the Earth. The motion of water from the West to the East around the Equator taken down by Meteosat satellite is shown in Fig.4.

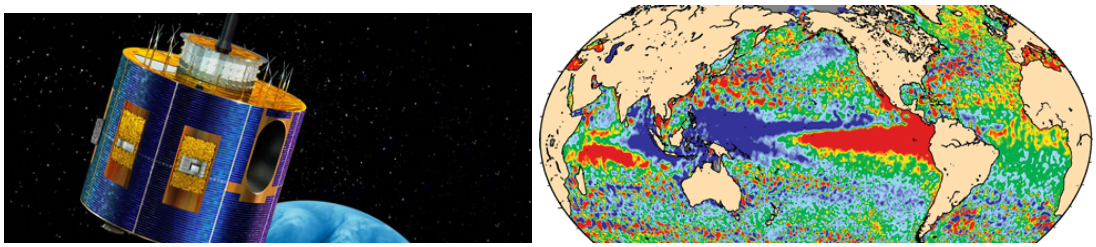

Fig.4. **Photo of the Earth and the motion of water by Meteosat satellite**

- sensors for humidity, acidity (pH-factor) of the soil, etc.;
- sensors for smell, electronic "noses" and detection of aromas;
- MEMS and sensors for change of the climate (Fig.5) and the comfort of living in the environment – rain, light, smoke, noise, etc.;

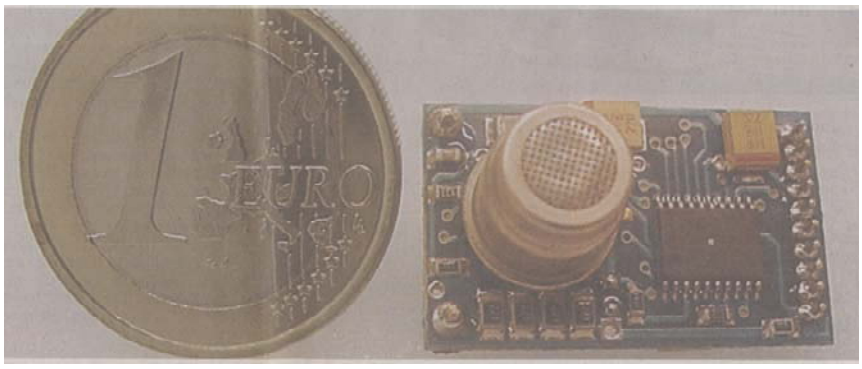

Fig.5. **Sensor module for control of the climate according to the necessity**

- sensors for industrial atmosphere and protection of the labour force and the articles from corrosion. The Multicomponential test of industrial gases is confirmed as a standard during tested IEC 60512-11-7(x), which is the nearest up to the application, especially at international norms. This is also referred to the next category of MEMS, at transboundary pollutions, interstate agreements, norms for pollutions in the telecommunications and the automobile technique, etc. In Fig.6 testers by HARTING firm are presented as for this purpose – testings of gases as nitrogen and sulphur oxides, hydrogen sulphide and chlorine.

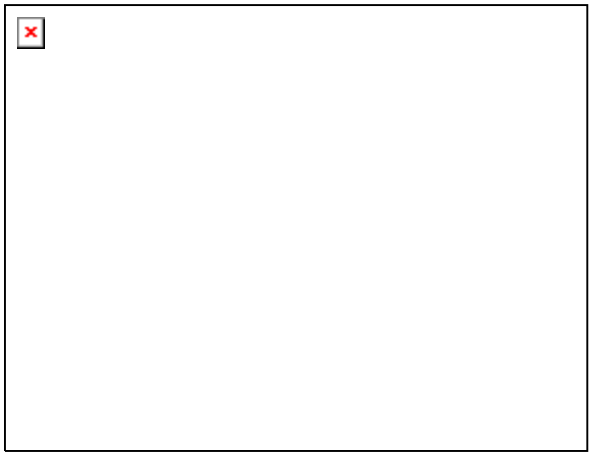

Fig.6. **Devices with MEMS for testing of multicomponential industrial gases by HARTING firm (Germany)**

Fig.7. **Map of Europe with indices for air quality–Indices for air pollution 0,5-2,5**

- sensors for air purity – dust loading, purity, content of CO, CO_2, nitrogen oxides NO_x, sulphur oxides SO_x, heavy metals Ca, Ni, Hg, aerosol Pb, polycyclic aromatic hydrocarbons, arsenium Ar, hard particles (dust, ash), etc.;
- sensors for ozone and ozone layer;

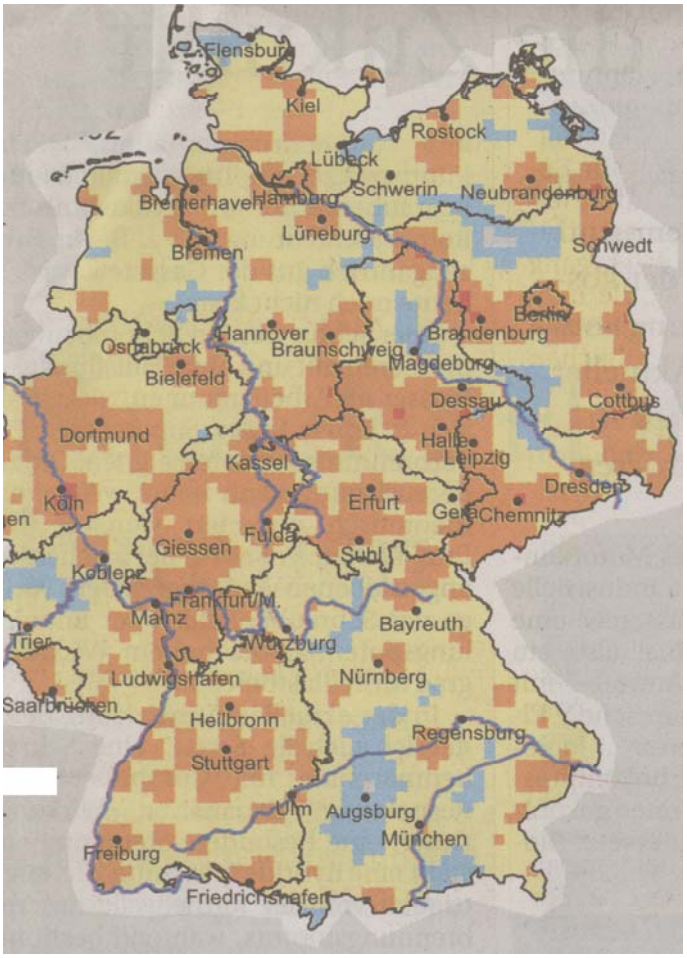

Fig.8. **Map of Germany with maximum values of ozone taken down by MEMS**
Note: Examplary values of ozone for the period in the beginning of September 2002 in a rising series are as follows: 1-40 μg/m^3, 41-100 μg/m^3, 101-160 μg/m^3 and >160 μg/m^3

In the European Union (EU) the limit values, which are dangerous to the health from 50 μg/m^3, are not excluded. The norm for content of ozone in EU is 125 μg/m^3. The values above 200 μg/m^3 in the smog-situation lead to damages of health [5,6].

- sensors for measurement of physical-mechanical magnitudes as compression, pressure, temperature, etc.

Strain Gauge (SG) sensors are widely distributed, since they are also used as a compound part of many other sensors for mechanical magnitudes. When a force F is applied on one solid body, its geometrical dimensions are changed – at compression the body is shortened (Compressive Strain) with Dl, but at tension it is elongated (Tensile Strain). Alterations of dimensions also occur at Torsion and Bending of the body. A group of sensors correspond to each of these four basic types of strains about their measurement. MEMS or SG-sensors for strains are with the largest application, which use the change of resistance of some materials at strains. For the first time this phenomenon was observed by Kelvin in 1856 about metal conductor, but its practical utilization began from 30th years of the last century. Specific parameters of each SG-sensor are the resistance without mechanical force R which is some hundreds W and the Gauge Factor GF=(DR/R)/e, where DR is the change of resistance because of the strain.

Depending on the used material, two types of SG-sensors exist. The metal sensors for strains are composed of thin spiral folded conductor as they measure strains along its length that is called Sensor Axis. At sensors for strains with metal foil or foil from constantan, chrome-nickel, platinum or iron-nickel alloy is laid on plastic band which is sticked on the measured object with epoxy resin ordinarily. The counted metals are used because of their large resistance, the considerable admissible values of Dl and the large standing of fatigue – precondition for long life of SG-sensors. The semiconductor sensors for strains possess an analogous structure, but they use the piezo-electric effect representing a change of the resistance of thin semiconductor layer at the strain.

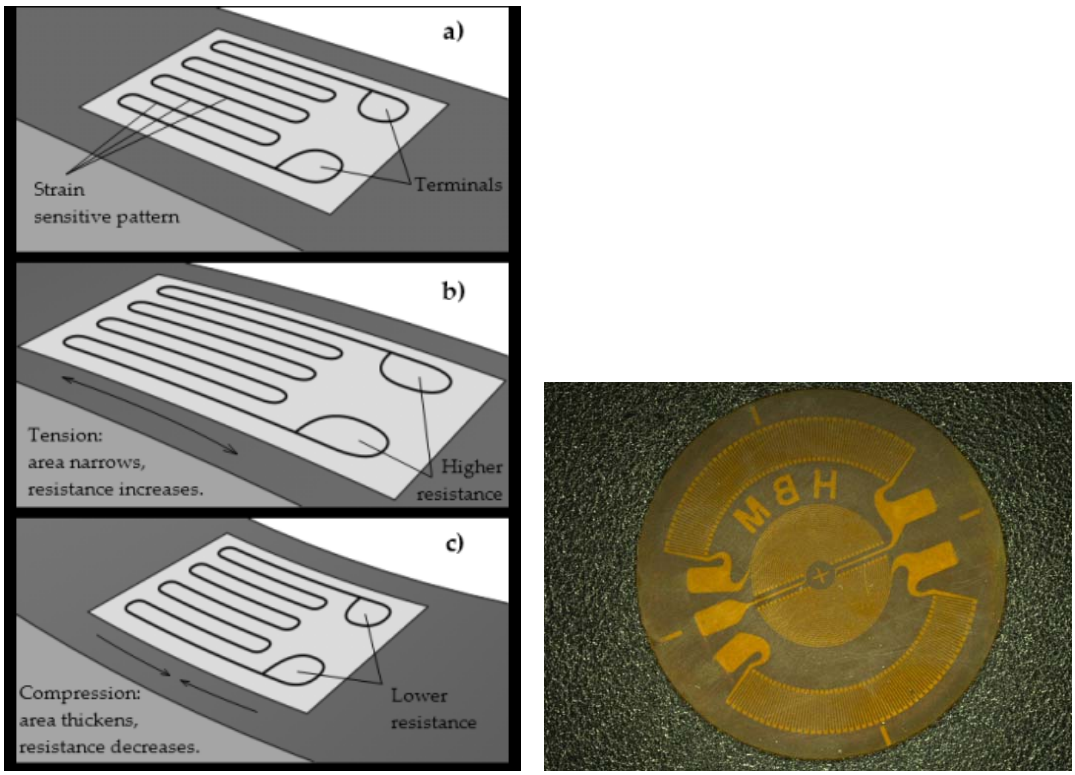

Fig.9. **Strain Gauge sensors of HBM firm, USA**

The Pressure Sensors (PS) operate on the following principle:
The magnitude pressure p=F/S, Pa expresses the force F, which acts perpendicularly per a unit of area. Two ways for evaluation of the pressure exist. The measurement of absolute pressure denotes determination of its value towards the full vacuum (zero pressure). Sometimes this is marked by means of adding the letter "V" towards the denotation of PS and the letter "a" towards the unit of measurement (psia) or adding of "absolute" (for example mmHg absolute). The used denomination is Absolute Pressure Sensors. The relative pressure is the difference between absolute and atmospheric pressure, that is taken as a supporting level. In the last case the term Gauge Pressure is used, towards the denotation of sensor "A" is added, but towards the unit of measurement – "g" (for example psig) or "gauge" (for example Pa gauge). The denomination is Gauge Pressure Sensors. A variety is Sealed Gauge Pressure Sensors, at which the comparison is made with exactly definite atmospheric pressure. It is usually at the moment of production of PS, that is "closed" in special sealed cavity. The measurement of difference between the two arbitrary pressures is used in a mass as well it is called Differential Pressure, at which the unit of measurement becomes psid. The denomination Differential Pressure Sensors is used. Given PS often possesses two or three operation modes for measurement of pressure. The output signal of PS is usually voltage that is several hundreds mV, but at a necessity of its transmission to a distance it is amplified up to several V or it is transformed in current (very often 4-20 mA). Here, specific parameter is also the maximum super pressure which is between 1,5FS and 3FS. A basic element in the construction of almost all PS-sensors is the diaphragm. It represents a round thin flexible plate, which is bent proportionally to the difference in pressures from its two sides (Fig.10). Namely, such sensor was developed together with the Technical University of Darmschtadt, Germany and published in [4, 7].

Fig.10. **Pressure sensors**

- sensors for "clean" premises;
- MEMS in the cleaning of surfaces, the restoration and the maintenance of works of art;
- sensors for the security, the reliability and the safety of work.

2.2. Study of MEMS with sensor for the ecology. Results

The study includes designing, making and encapsulation of one piezoresistant pressure sensor on silicic shim which is destined to needs of the ecology. Figure 11 shows the cross-section of sensor, which has to be made. It has to consist of one thin membrane, on which the semiconductor resistances are located and they will transform the mechanical magnitudes in electrical ones. Because of the selected projection they are not seen, but they have to be located on the upper side of sensor. The sensor has to be dimensioned about maximum pressure from 1.10^5Pa. The membrane has to possess an area from 2x2 mm.

At very large voltages in the membrane, linear errors arise in the transfer function of transducer. Because of this the maximum stress T, which appears in the membrane, has not be larger than 1/10 from the failure stress. That is why, the thickness of membrane h and the maximum deflection x have to be calculated. The formulae and constants, which are used, are as follows:

Mobility of the electrons in the silicon at room temperature: $\mu = 1250 cm^2/Vs$; (1)

Charge of the electron: $e = 1{,}6.10^{-19}.As$; (2)

Failure stress of the silicon: $T_B \approx 500$ MPa; (3)

Modulus of elastic deformation of the silicon: E = 170 GPa; (4)

Poisson's coefficient: $\nu \approx 0{,}26$; (5)

Stresses in the rectangular membrane: $T = 1{,}18.\left(\frac{b}{2h}\right)^2.p$ (6)

Mean deflection of the rectangular membrane: $x = \frac{b^4(1-\nu)^2.p}{32.h^3.E}$ (7)

Specific resistance for n-doted silicon: $\rho = \rho = 1/e.n.\mu_n$ (8)

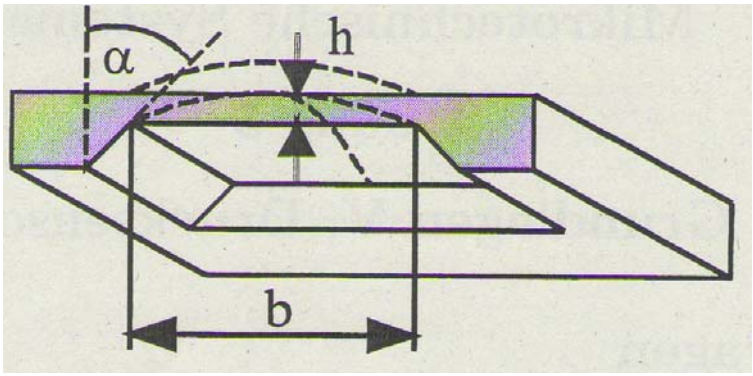

Fig.11. **Section-view through the sensor from below**

$T = T_B / 10$; $T_B \approx 500$ [MPa] ;$p = 10^5$ [Pa] ;b = 2 [mm] ; h =? x = ?

$$T = T_B / 10 = 500 / 10 = 50.10^6 \text{ [Pa]} \quad (9)$$

The maximum stress and the deflection of membrane are:

$$T = \frac{1{,}18.b^2.p}{4h^2} \quad h = \frac{\sqrt{1{,}18.b^2.p}}{4T} = \frac{\sqrt{1{,}18.2^2.10^5}}{4.50.10^6} = 0{,}236[mm] = 236[\mu m] \quad (10)$$

$$x = \frac{b^4.(1-\nu)^2.p}{32h^3.E} = \frac{2^4.(1-0{,}26)^2.10^5}{32.0{,}236^3.170.10^{-9}} = 12{,}25[\mu m] \quad (11)$$

It also follows to study: How are the planes of crystal orientated and with what kind of method of laying-on the surface layer can the membrane in shown form be made? The planes of crystal have to be indicated (Fig.12), how large is the angle α and how is the thickness of membrane adjusted exactly?

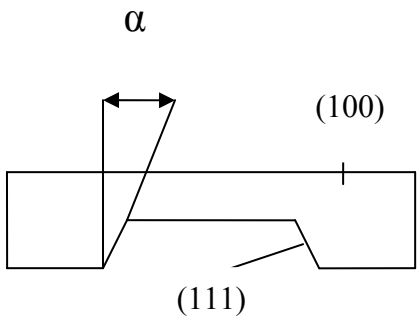

Fig.12. **Planes of crystal**

The membrane, which possesses the shown form in Fig.12, is received by means of anisotropic etching. The angle between directions (100) and (111) is equal to 54,74°. The angle α is the difference from this angle to right angle.

$$\alpha = 90 - 54{,}74 = 35{,}26° \quad (12)$$

The thickness of membrane is inversely proportional to the time of etching h=1/t, but the speed reaches to 3 μm/h. The necessary thickness is achieved by means of the exact determination of the time of etching.

The resistances have to be realized in material doted with n-type of conduction. In the making of sensor, the density of electrons has to be adjusted on $n=10^{16}/cm^3$. The resistance without the action of piezo-electric effect from 1000Ω has to be accounted for along 200 μm length. It is necessary the resistances to be arranged in the form of a bridge circuit of switching-on for maximum sensitivity. Three possible arrangements exist, which are shown in Fig.13. The indicated formulae are with approximations and they can be used without assuming of a serious error.

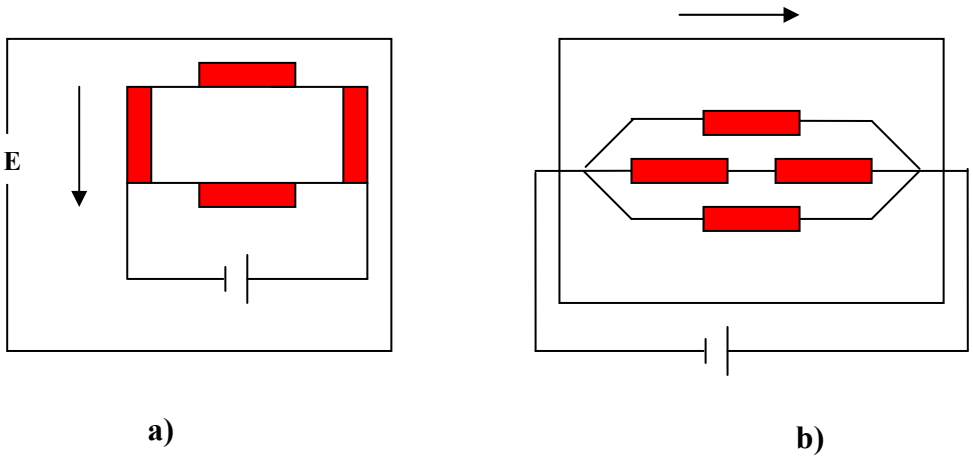

Fig.13. **Bridge ciruits of switching-on the resistances**

Legende: a) mixed arrangement – small linear error, R1/R2 – resistance in longitudinal direction towards the current network, R3/R4 – resistance that is crosswise of the current network, b) longitudinal arrangement – large linear error, c) cross arrangement – small linear error, large voltage in the zero point (no gezeigt)

The data are as follows:

$$E = 1{,}6.10^{-19}\ [As];\ \mu n = 1250\ [cm3 / Vs];\ n = 10^{16}\ [cm^3]; \quad (13)$$

$$l = 200\ \mu m = 0{,}2\ [mm]; \quad (14)$$

$$R = 1000\ [\Omega] \quad (15)$$

$$\rho = \frac{1}{e.n.\mu_n} = \frac{1}{1{,}6.10^{-19}.10^{16}.1250} \approx 0{,}5$$
$$R = \frac{\rho.l}{A} \Rightarrow A = \frac{\rho.l}{R} = \frac{0{,}5.200}{1000} = 0{,}1\left[\mu m^2\right] \quad (16)$$

In order to study the production of pressure sensor with membrane and transducers, it is necessary to analyze the technological process of production as well as to describe the technological scheme of basing – how and with what technology the separate working operation have to be performed.

In Fig.14 piezoresistant pressure sensor with membrane from silicon, that is made by means of anisotropic etching on the opposite side of silicic shim, is presented. In the place of maximum deformation of the membrane, the strongest piezoresistant effect is appeared. For forming the active structure of sensor, stoppers are used which are made by means of diffusion or ion implantation. The silicic p-layer, alloyed with high content of boron (concentration of boron admixtures $5.10^{19}cm^3$), is etched very more slowly in potassium hydroxide (KOH) than it is weakly alloyed. This possibility is applied during production of the membrane. However, in order to be able to create a notion about one similar product which is suggested in trade type by Novansensor firm – in Fig.15 two photos can be seen that are proposed to use in the ecology and it is produced according to the variant from Fig.14.

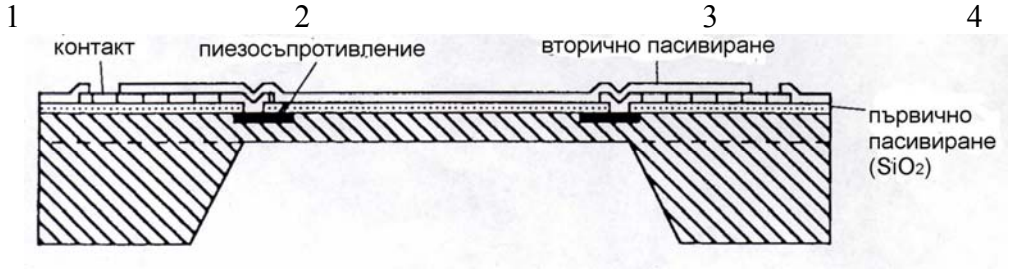

Fig.14. **Piezoresistant silicic pressure sensor**
Legende: 1-contact; 2-piezoresistance; 3-secondary passivation; 4-primary passivation (SiO_2)

Fig.15. **Principal scheme and photo of pressure sensor by Novasensor firm with application in the ecology**
Legende: Dielectric coating; Output valve; Filling from polycarbonate gel; Contact plate; Input pressure; Height of coating

2.3. Application

The present development of MEMS leads to a multilateral introduction of miniature systems for analysis in the ecology. In this field the microsystems are developed predominantly for analysis of water and gases. As an example sensor for cigarette smoke will be pointed, which can recognize selected and determinate types of smokes during combustion. The conditions of introduction, especially in industrial mediums as for example thermo-electric power stations of coal, require protection against dust (ash) and corrosion, external moisture and changes in the temperature, shocks and vibrations, electromagnetic fields as well gases disturbing its operation (for instance from solvents, welding works, natural smokings with materials). The research group with Prof. H. Baltes from the Physical Electronics Laboratory of ETN-Zurich has developed sensor microsystem representing a three-dimensional silicic chip for detection of harmful gases in the air. In it three types of sensor elements for measurement and analysis of three different physical magnitudes are integrated, at that with accuracy up to 1 milliardth part of the gramme. Masssensitive, capacity and calorimetric sensors are realized within the framework of common chip, together with the processing and controlling electronics. The introduced membranes with sensitive layers in many chemical sensors serve simultaneously as a protective layer between the measured medium and electronics. For example, the sensor developed by Siemens firm for residual emissions from hydrogen during control of the ignition of cylinders in the automobiles.

Summary

A classification of MEMS is made on the basis of their designation and the region, where they operate. A special place is separated on the application of MEMS in the ecology as well as concrete examples are indicated – developments of firms and own ones.

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INTEGRATION OF FLEXIBLE KEYPAD INTO CLOTHING

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Abstract. *The aim of this paper is to consider data input methods and technologies related to information input into electronic systems that would be suitable for smart garments. An overview of recent developments in the area of flexible switches is provided, describing processes used to fabricate these connections and highlighting issues and problems associated with it. Available soft button / keypad products are considered and keypad construction methods are analyzed. This study resulted in the creation of a flexible textile keypad prototype with row-and-column addressable structure and with breaking point technology underneath button design.*

Keywords: *flexible keypad, smart garment, electro-textile interface*

Introduction

Smart clothing is linked to the information and communication infrastructures and provides quiet service to humans by perceiving the environment and at the same time by providing the information generated in personal areas such as health, emotions, and locations of person to the environment. To carry out these functions, all the information systems are equipped with input and output functions [1].

Sensors or switches are used for input in smart clothing; they determine conditions of the surrounding environment (for example, temperature or humidity sensor) or operate and control the system (for example, system ON/OFF switch, volume control buttons). To keep wearing feeling as satisfactory as possible, it is preferable to replace data input mechanical buttons with flexible switches and connections. The aim of this paper is to consider data input methods and technologies related to information input into system that would be suitable for smart garments. As a result of this study, a prototype of input interface is developed.

Materials and methods

During the last ten years micro-system technology has not only focused on the size of the components but also on their flexibility. Electrotextiles represent enormous potential in creating a new generation of flexible, conformable and multifunctional textile structures for many electrical and electronic systems. Achieving flexible electrical switching is an important part of developing integrated circuits [2]. This chapter provides an overview of recent developments in the area of flexible switching, describing processes used to fabricate these connections and highlighting issues and problems associated with it.

Flexible switches

Switch is a mechanism that is used to open or close circuit in mechanical or electrical way. Flexible switches can be made using different materials and technologies. Soft circuits can be created using operating principles of conventional switches, replacing hard materials with textile materials to provide flexibility, besides that traditional clothing fasteners can be used for electrical connections. Several unconventional examples of flexible switching and connections designed with textile materials or clothing accessories are shown in *Table 1*.

Table 1.

Examples of flexible switches

Title	Material	Description
Soft press button / keypad	Textile, conductive material, insulating material	Press buttons introduce a breaking point somewhere in the circuit. A braking point is area where it is possible to reconnect the circuit, in result we can determine if the soft pushbutton is active (pushed) or not [3]. For keypad the same principle is used but with more complicated configuration. Usually two layers of conductive material are separated with a perforated insulator in this design.
Flexible capacitive keypad	Textile, conductive material	In a capacitive keyboard, electricity is flowing through the key matrix at all times. When a key is pressed, it changes the flow of electricity at that point, which the keyboard's controller interprets as input. Though these keyboards are more expensive than traditional ones, they tend to be more durable [4].
Knitted pressure sensitive button	Acrylic fibers, stainless steel	Knitted pressure sensitive fabric made of three layers. Two layers of stainless steel are separated by one layer of acrylic fibers. When pressed, the two external layers touch, an electrical circuit is closed allowing current flow [5].
Conductive hook and loop connection	Nylon tape with silver coating	Nylon hook and loop tape, both sides are coated with silver. Good for making switches or connections that might need to be opened and closed [6].
Zipper switch	Plastic or metal zipper	To turn a zipper into a switch, the two upper and lower teeth opposite each other can be sewn with conductive thread. A conductive path from each zipper tooth can be continued to the rest of the circuit. When the zipper is closed or opened with the slides, two opposing teeth connect, closing the circuit. Each set of teeth on opposing rows of the zipper can also individually addressed to create a switch [7].
Connection of traditional metal fastener for clothing	Metal	Large part of clothing accessories are made from metal, hence they are conductive and suitable for creating electronic connections. These parts can be used for connections: hook and eye, buttons, snaps, poppers, magnets, grommets etc. Good for making switches or connections that might need to be opened and closed.

Commonly it is provided that in smart garments wearer may input information to the devices, for example, to control which sensor to use. The most common input interface for this purpose involves buttons or keyboards because simple button interfaces are easy to learn, implement and use with few errors. As the complexity of wearable electronic devices increases, however, the need for more complex interfaces arises [8]. Further in the paper available soft button / keypad products are considered, other methods and types of keypads are analyzed, in the conclusion to this study a flexible keypad prototype is constructed.

Available soft button / keypad products

Introduction of soft buttons at the end of the previous century was one step further for smart clothing development – hard plastic material contacts were replaced with rubber and foam material combination, which later led to further development of electronic industry, for example, to the design of soft electric boards. Currently there are several companies in the market producing flexible switch panels for smart garment, some of them are shown in Table 2.

Table 2.

Available soft button / keypad products

Company	Technology	Application
Peratech	The company produces flexible switch panels using Quantum Tunnelling Composite (QTC) technology. QTC is composite material made from conductive filler particles combined with an elastomeric binder. QTC can change from an electrical insulator to a metal-like conductor. While in an unstressed state the QTC material is a near-perfect insulator; with any form of deformation the material starts to conduct [9].	QTC can be used to produce low profile, low cost, pressure activated switches or sensors that display variable resistance with applied force and return to a quiescent state when the force is removed [11]. Switching panels provided for integration into clothing, soft furniture, walls, toys and other soft surfaces. Flexible switches were used in MP3 and iPod jackets.
Eleksen	Switches are made using ElekTex technology, which is based on QTC electro-conductive fabric. ElekTex is a laminate of multiple fabric layers, which are arranged to form a resistive touchpad. The sensor is contact activated - positional X and Y values are generated together with a low resolution pressure measurement (Z) [13].	Widely used in different fields from entertainment to military field. Touchpad can be provided in different interfaces: keypad, MP3 player interface, volume regulation slider etc [8]. Examples: iPod jacket grooveRider, Zegna iJacket, Message bag, rolled up keyboards.
Fibretronic	The company produces textile and polymer based switches and keypads. Each of the buttons has a click response to ensure that the user can feel that the button has been activated when pressed. This keypad cannot be false triggered by body movement and so does not require a keypad locking function [14].	The company supplies textile switches, flexible keypads, iPod, iPhone controls, mobile phone interfaces, garment heating systems, fabric sensors and wearable lighting systems. Products designed specifically for integration in clothing and soft goods [15]. Example: RedWire DLX jeans.

Flexible fabric interface

Electro-textile interface is indispensable in producing smart clothing, but it is very difficult to integrate the electronic products and fabric products because their manufacturing processes and their physical properties differ greatly. In addition to these differences specialists of the textile industry and electronics industry must break out of stereotypical way of thinking and connect these two vastly isolated fields [1]. In order to replace bulky wires and solid breadboards it is necessary to search for such solutions as flexible textile interfaces.

Flexible circuit substrates

Conventional printed circuit boards (PCB), which consist of multi-layered structured organic material and conductive elements made using photolithography or electron beam lithography method, are solid and bulky. In order to form flexible circuit board, printing of circuit patterns is carried out on polymeric substrates such as film. Fabric based circuits potentially offer additional benefits of higher flexibility in bending and shear, higher tear resistance, as well as better fatigue resistance in case of repeated deformation [2]. An ideal textile sensor would be fabric that can generate electricity or change the flow of electric current in its reaction to external stimulation. Unfortunately, with the currently available technology it is almost impossible to obtain woven fabrics or compounds possessing such functions. Hence it is necessary to consider combining electronic components with fabric materials to the extent that would not hinder the user's activities [1]. Used methods for textile platform construction are described below.

Embroidery. Conductive threads are often sewed or embroidered along the circuit paths [1]. One of the advantages of this process of fabric circuit formation is that the conductive threads can be embroidered in any shape on the fabric irrespective of the constituent yarn path in fabric [2]. Embroidery can be used for example in textile keypad creating – it could be made on a single layer of fabric. This process enables one to specify precisely the circuit layout and stitch pattern in a computer-aided design (CAD) environment, from which any number of items can be sewn under machine control [16]. In Fig.1.A a keypad is shown that was embroidered with conductive threads on denim and was used in MIT Media Lab project 'Musical Jacket'. During sewing conductive threads encounter various levels of stresses and friction – this requires an embroidery thread to have relatively high strength and flexibility because stress can lead to yarn breaks. Discontinuities are not desirable in fabric circuits – joints or splices to fix the discontinuities in sewn conductor lines may lead to undesirable additional impedance [2]. In the case of the narrow band, short circuits in between wires are another weakness of the embroidery method [1].

Printing. Conductive ink printing produces a circuit, using a method similar to the PCB manufacturing process, which theoretically can be the simplest and easiest way to make a circuit. It is also easy to make the mass production system. The circuit can be made by silk-screening or by using digital textile printer. The biggest problem is the procurement of highly conductive ink [1]. Conductive ink can be used for low-powered control and secondary elements that don't conduct high current. It is unadvisable to use it in connections where high safety and reliability is necessary. It is not recommended to apply printed circuits technology on elastic fabric – stretching can result in breaking of printed conductive tracks. Printed circuit pattern is shown in Fig.1.B.

Weaving and knitting. Much attention has been paid to the conductive textiles with woven in metal yarns. However, once a conductive fabric is woven, the electrical tracks and tailoring are restricted in weft or wrap direction [1]. Narrow woven technology was shown to be one of the most promising textile manufacturing methods because the fabric structure allows for easy integration of conductive and optical materials [17]. The narrow band is similar to the flat electric cable; it is woven with several threads of conductive fiber placed in parallel. In general metal yarn or thread coated with metallic particles is used as a conductor. To prevent possible short circuits in between wires, threads are generally coated with insulating material. Narrow knitted band is shown in Fig.1.C.

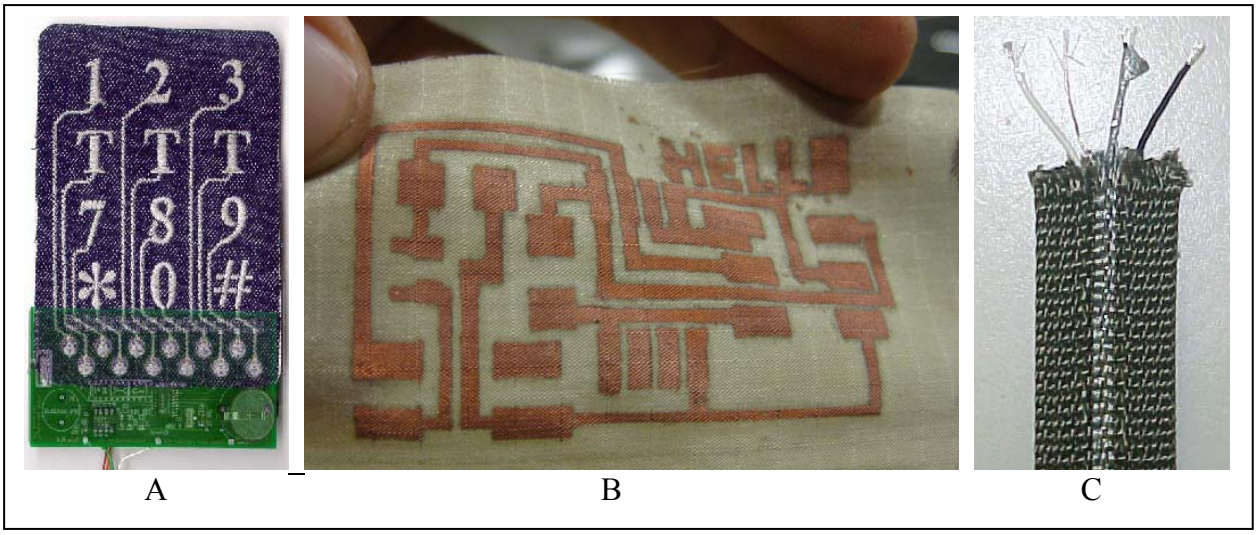

Fig.1. **A - Musical Jacket keypad; B – printed circuit pattern; C – narrow knitted band**

Coating. Textile substrates with conductive polymer or metal coatings are potential candidates of electronic textile, having good characteristics such as good conductivity, flexibility, free tailoring and easy sewing. One of the drawbacks of this method is the loss of electric conductivity when washed. Tin/copper coated fabric is shown in Fig.2.A and B.
Sew on / stick on. Textile transmission lines can be suggested as one of the applications of surface-conductive fabrics. The surface of the coated fabric is conductive in all directions so that it can be cut into any shape and in any direction. The fabric pieces can be directly sewn onto clothing, thus dangling wires or cables often seen inside today's smart wear might disappear [18]. Flexible circuit made of conductive fabric stuck on elastic non-conductive surface is shown in Fig. 2.C.

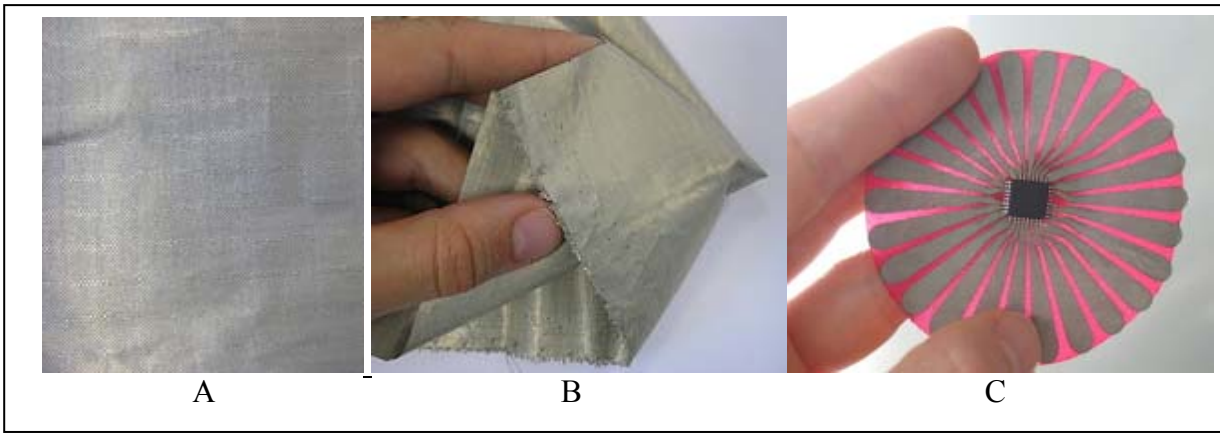

Fig. 2. **A, B – Tin/copper coated fabric; C – Conductive fabric stuck to soft citcuit**

Insulation
In most applications it is important to insulate the conductive traces. For stretchy traces this requires a stretchy insulator. Suitable insulators are: stretchy fabric glue, puffy fabric paint, extra layers of fabric, silicone layer. It is important to take into consideration that coating of insulating layer adds thickness and rigidity, therefore it is necessary to choose insulators that would make coating layer as thin as possible, would be safe enough and at the same time would reduce system flexibility as little as possible.

Arrangement and applications of flexible keypad

Flexible keypads can be integrated in the majority of smart clothing and accessories where data input and/or control is necessary from wearer's side. Examples are MP3 clothing, iPod jackets, GPS jacket, Message bag etc. Control interfaces should be close to the parts of body concerned, for example in MP3 jacket earphones are located in a collar or a bonnet, a microphone is in a collar and a keyboard is applied to the sleeve of a jacket. Some variants of keypad arrangements are shown in Fig.3.

The ergonomic adaptation of all these control interfaces to clothing is also very important. In contrast to certain miniaturized communication devices, clothing has a greater surface area, which enables it to offer more functionality. For example, the small keyboard of a mobile phone becomes much more readable when transposed to the surface of a piece of clothing that is three times larger [19].

Fig. 3. **Variants of keypad arrangements**

Flexible keypad prototype

Flexible fabric keypad prototype was created with row-and-column addressable structure and with breaking point technology underneath button design.

Interfaces. First step in button/keypad design is choosing flexible conductive material for buttons contact surfaces. Copper is a good conductor, thus thin copper film was chosen for the first prototype. Soft keypad interface is a mobile phone's keyboard with buttons embroidered on cotton fabric.

Operation principle. Conductive elements of keypad construction are thin 1 cm wide copper strips that are placed vertically and horizontally. Each intersection of strips corresponds to a button. Insulating intermediate layer is located between the vertical and the horizontal strips – foam plastic material is chosen for this purpose and it is perforated at strip intersections. By pressing a button, strips of vertical and horizontal layers are connected through isolating layer holes and the circuit is closed. When button is not active, strips disjoin and circuit opens.

Insulation layer fixing. Foam plastic material is chosen as insulation layer for the first prototype. To align all layers precisely without displacement it is necessary to fix them. For layer fixing fusing method was used. Adhesive netting was applied as fusing material, which traditionally is used in clothing production process. Adhesive netting was placed between two layers and fixed with iron (temperature of iron was about 150 °C). To one side of insulating layer vertically positioned copper strips were fixed and to the other side of insulating layer horizontally positioned copper strips were fixed.

Results and discussion

This paper summarizes literature about different approaches towards design of flexible switches, besides that processes and materials used in soft switches and connections were described and advantages and drawbacks were highlighted. The acquired information was used to analyze the available materials and technologies and a flexible keypad prototype was made. Keypad is shown in Fig.4. It proves that the chosen method can be applied practically: all keys are functioning correctly and are located at a convenient distance. However several ways of improving this design are possible. For example, it is preferable to put in use different materials to reduce rigidity of multilayered keypad construction, it applies both to conductive materials and to the insulator.

A B

Fig.4. **Flexible keypad prototype. A – construction of keypad; B - embroidered interface**

During further research in flexible keypad design we plan to replace copper foil with more flexible material – conductive fabric or copper net. On the other hand, foam plastic insulator can be replaced with softer foam latex; this will reduce keypad thickness and will increase its flexibility.

Another prospective direction of research are capacitive touch-sensitive panels, which do not require any physical deformation, they are especially suitable for using in textile materials and smart garments.

Textile-based input devices constitute one of the most important challenges in electronic textiles area, since soft buttons integrated into clothing must be flexible and easy to operate. In this paper data input methods and technologies are considered, which are suitable for smart garments. An overview of recent developments in the area of flexible buttons is provided, describing steps needed to make these buttons and highlighting issues and problems associated with it. Several unconventional examples of flexible switching and connections designed from textile materials or clothing furniture are described. Available soft button / keypad products are considered and other methods and types of keypads are analyzed. Some flexible circuit substrates for textile platform construction are described – embroidery, printing, weaving, knitting, coating, sewing, gluing. Suitable insulators are provided and arrangement and applications of flexible keypad are discussed. As a result of this study a flexible fabric keypad prototype was created with row-and-column addressable structure and with breaking point technology underneath button design.

Acknowledgment

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FUEL CONSUMPTION REDUCTION BY USE OF HYBRID DRIVE SYSTEMS

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Abstract. *Vehicles with hybrid drive systems are characterized by their driving dynamics, their energy efficiency and their environment-friendliness especially. Dependent on the electrical power and the drive train structure these hybrid drives are grouped into different classes. Designations such as micro-hybrid, mild-hybrid, full-hybrid, serial-hybrid, serial/parallel-hybrid or power-split-hybrid reflect the large variance of these different drive train possibilities.*
In hybrid drive systems electronically controlled converters take an important role. With such a converter also the energy exchange between electrical power system and electrical machine is regulated. The reduction of the vehicle fuel consumption here is of special interest. Today's hybrid vehicles use for the control mainly information from the present driving conditions, taking into account the actual electrical power system-charge as well as the power demand of the driver. With such a control already considerable fuel reductions are reached. But additionally superimposed control and information systems promise substantial potential for more fuel reduction. With these systems an outstanding energy-saving and anticipatory way of driving could be realized. The aim is to find the best operating point in each case for the combustion engine and to adapt the charge state of the electrical power system to the respective driving situation.

Keywords: *Hybrid electric vehicle (HEV), Automotive power train topologies, Automotive electrical system architectures, Battery energy management, Automotive electronic.*

Introduction

Developers in the automotive industry are testing again and again options to improve the driving dynamics and the fun factor of motor vehicles. Directly associated to these demands is the installed power and its direct use. Despite these requirements the fuel consumption and the emission of automobiles must be reduced further in the future. These apparently contrary demands can be very well achieved with a hybrid drive system - the combination of a combustion engine with an electrical machine. This new drive concept for automobiles makes many new functions possible, which can reduce the fuel consumption and the exhaust emission and in addition increase the travelling comfort and the driving dynamics substantially.
In the last years in the technical literature different hybrid drive systems have been presented. The electrical power of these systems varied between that of a micro-hybrid, used for combustion engine start and for starting support, and that of a full-hybrid, used for electrical driving with a power of up to 100kW. For efficient use of the electrical power often two electrical machines in the automobile are to be integrated. In this way many different hybrid drive concepts for motor vehicles can be realized.
This report first shows different drive train structures and electrical on board structures for hybrid vehicles. Afterwards for the different system concepts the fuel savings achieved are described and compared with each another. Further possibilities for an efficiency increase are also discussed.

System Functions for Hybrid Electric Vehicles

Even though the electrical machine of a hybrid drive system in principle can be driven only in the generator or motor mode, a lot of more interesting modes of operation can be realized with a hybrid vehicle. These do not only reduce the fuel consumption and the technical wear, but

also increase the travelling comfort and improve the driving dynamics. Following list shows the most important modes of operation and functions of a hybrid drive system.
These functions effect a reduction of fuel consumption and of exhaust emission. But substantial electrical power is necessary for a noticeable support in the motor operation. For example in vehicles of the compact class an additional "boost-torque" is only discernible starting from 20Nm. This corresponds to a mechanical power of approximately 3kW at rotor speed of 1500rps [1, 4].

- **Cold start**
  Reduction of fuel consumption and emission during the start process
- **Generator mode**
  High efficiency during electric energy generation (e.g. 10kW with $\eta > 80\%$)
- **Stalling prevention**
  Starting support of the combustion engine at low speed
- **Boost mode**
  Support of the combustion engine at higher speed (e.g. during overtaking)
- **Regenerative braking**
  Energy recovery in delay and brake phases
- **Start-Stop mode**
  Combustion engine switch-off at idle speed with fast restart
  (E.g. within approx. 290ms)

A pre-condition for the combined operation of the combustion engine and the electrical machine is a high-capacity energy storage. This storage system must be designed for sufficient numbers of cycles because of the enormous start and boost modes over the life. With such a dynamic drive the energy storage system is subjected to a short-term load of direct currents of up to 400A.

Power Train Structures for Hybrid Electric Vehicles

The mechanical coupling of a hybrid drive system in the vehicle can be realized in different ways. On the one hand the electrical machine can be connected as a conventional generator. Here, the electric machine and the combustion engine are coupled by a belt (micro-hybrid). But if large torque and engine power has to be transferred a better mechanical coupling to the automobile's power train is necessary. Fig. 1 shows different drive train structures of hybrid systems. In all these examples the electrical machine is integrated in the power train directly. In this way a good mechanical contact to the combustion engine is realized [2, 3, 4, 5].
The typical power train structure of a mild-hybrid is represented in figure 1a. The electrical machine is tightly coupled to the combustion engine. In this way, the required torque for starting the combustion engine can be transferred easily. During acceleration phases the engine can be supported electrically. Also, during deceleration and brake phases an energy recovery to the battery is possible. With an additional clutch, the typical structure of a full-hybrid concept can be realized (Fig. 1b). This configuration allows pure electric drive in addition to the functions of the mild-hybrid.
Figure 1c shows the drive train structure of a series/parallel hybrid. This system provides many functions. For example with an open clutch, the combustion engine can be started by the electrical machine 1. With a closed clutch (parallel operation) accelerating, decelerating and braking can be supported electrically. Pure electric drive (without combustion engine) is possible by machine 2 with opened clutch. If there is not enough energy stored in the battery, the series operation can be realized together with the help of the combustion engine and electrical machine 1. In this operation mode machine 2 is supplied by machine 1 electrically.

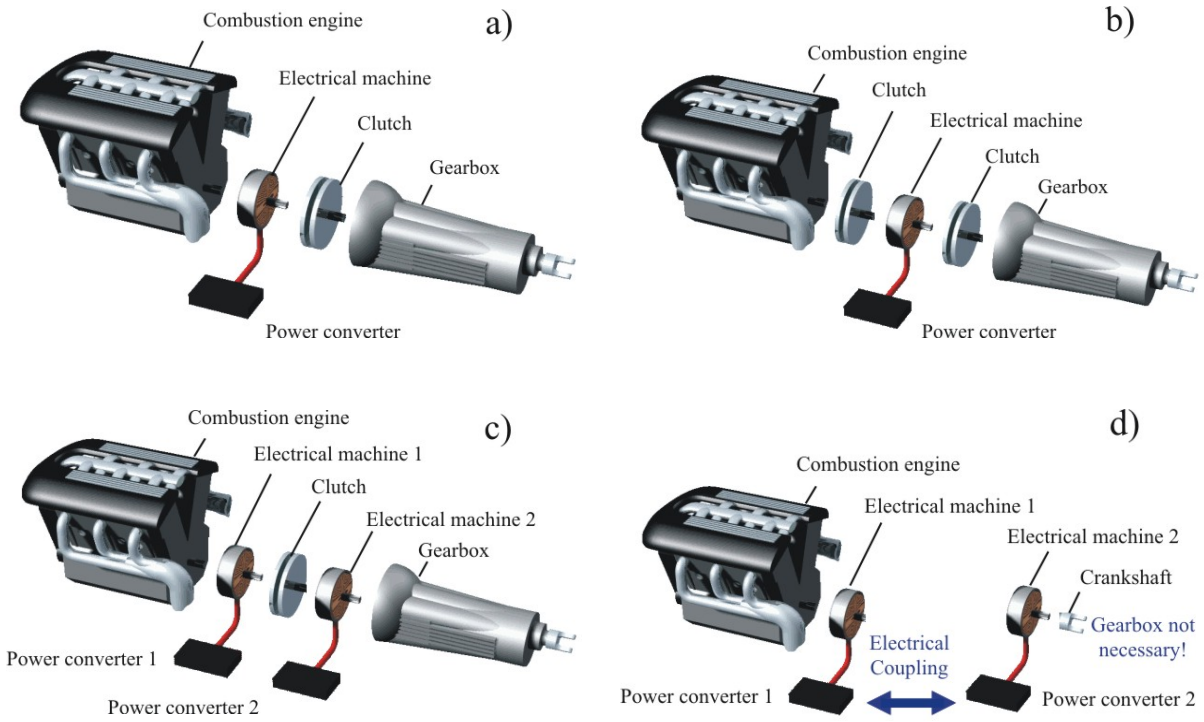

Fig. 1. **Power train topologies for hybrid electric vehicles**

A series-hybrid concept without transmission unit is presented in the figure 1d. In this concept, the combustion engine is connected only by two electrical machines to the crankshaft output side. The electrical dimension of machine 2 must be designed to drive the whole vehicle. This machine also allows energy recovery in deceleration and brake phases. A special example of a series-hybrid is the electric four-wheel drive. Instead of machine 2, four electrical machines, one for each wheel, are used. The machines are supplied electrically by machine 1. In this hybrid concept the mechanical components of the drive train can be reduced to a minimum.

Electrical Power System Architectures for Hybrid Electric Vehicles

Generally, hybrid drive systems are also used for the energy supply of the electric on-board power system inside the vehicle. For that reason the hybrid concepts have a substantial influence on the electrical system architectures. Fig. 2 shows typical electrical power system architectures for hybrid electric vehicles [3, 4].

A very simple power system architecture with only one dc-voltage level is represented in figure 2a. A DC/AC converter connects the electrical machine and the on-board power system. The electrical system voltage of 14V is just high enough to operate a micro-hybrid. To operate the more powerful mild-hybrids these vehicle electrical power system voltage must rise to 28V or 42V at least.

The typical on board system of a mild-hybrid is shown in figure 2b. Here the electrical machine is coupled by a DC/AC converter with a separate on board battery system. The voltage level of this power system can be increased up to 60V. For power supply of the 14V electrical system a DC/DC converter is used, which normally consists of a simple chopper. This electrical structure is equivalent to the typical on board power system architecture of a full-hybrid (figure 1c). But for full-hybrid electrical power systems the voltage of the storage is substantially higher. Also here the on board power system is coupled by DC/AC converter to the electrical machine and has to handle the high energy transfer. Today for full-hybrid

electrical power systems voltages up to 650V are used. Consequently, the voltage isolation effort is larger. Furthermore a DC/DC converter with galvanic isolation must be used.

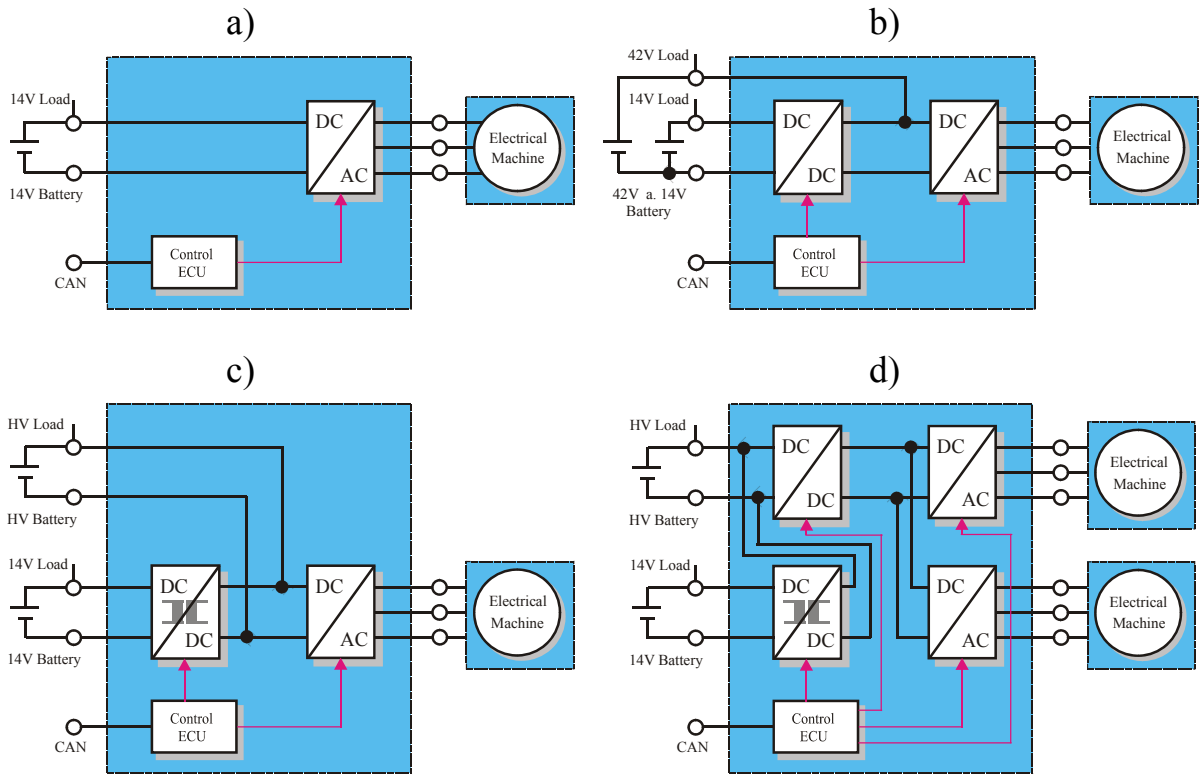

Fig. 2. **Electrical system architectures for hybrid electric vehicles**

A typical electric on board system of a series or series/parallel-hybrid is shown in figure 2d. Here two electrical machines are coupled electrically via powerful DC/AC converters to each other. This way the energy between the electrical machines can be exchanged in series operation on high voltage level. On the dc-voltage side these two converters are connected by a DC/DC converter to a high voltage energy-storage board-net. In this case a simple chopper can be use as DC/DC converter. In general the chopper is not designed for the complete power of a DC/AC converter. Theoretically the two DC/AC converters could also be connected to the energy storage directly. In this case the DC/DC converter would not be necessary. But due to the high electric power a high voltage level is preferred to reduce the losses. To generate this high voltage a series connection of many energy-storage cells is required. For supply of the 14V electrical power system another DC/DC converter with galvanic separation is necessary. Thus all high voltage hybrid components can be isolated correctly from the usual automobile on board power supply [5, 6].

Energy Management Strategies

With the first series hybrid vehicle introduction on the market the characteristics of vehicles with hybrid drive are increasingly discussed in public. In this discussion, the potential for the reduction of vehicle consumption is of special interest. Car manufacturers often emphasize the considerable reductions of consumption that can be achieved. This consumption minimization is reached by the combined operation of the different drive technologies in the vehicle. To achieve this, the present hybrid vehicles are using above all the information from the driving conditions. This procedure considers the actual battery charge as well as the power request of

the driver. With these provisions the energy consumption can already be reduced substantially with the hybrid systems presented in Table 1 [1, 6].

Table 1.

System functions and fuel reduction of different hybrid concepts

Hybrid System	System Functions	Fuel Reduction
Micro - Hybrid 	- Start-Stop Mode - Regenerative Braking - Stalling Prevention	6 – 12%
Mild – Hybrid 	- Start-Stop Mode - Regenerative Braking - Stalling Prevention - Boost Mode	10 – 18%
Full – Hybrid 	- Start-Stop Mode - Regenerative Braking - Stalling Prevention - Boost Mode - Electrical Drive	16 – 25%

A further reduction of the fuel consumption and of the emission can be achieved by integration of information and communication systems. With the data collected in such a way the optimal operation for each moment can be realized with the help of an online energy management system. The following list shows some systems and criteria, which allow a more optimized energy-saving driving [7].

- Distance- and relativity speed in relation to the ahead-driving vehicle
- Traffic holdup identification by means of radio data information
- Information about the driving route: highs and lows, curve radiuses and sign-posting
- Information about the traffic light phase as well as the time of change over
- Local traffic holdup identification by means of vehicle to vehicle communication

Today the necessary information is partly already available. So the distances to the ahead-driving vehicle can be determined by means of distance sensors. Traffic holdup identification could be realized today by a simple evaluation of the radio traffic data information. Route information can be taken from a digital road map of the navigation system. While the maps today are still inexact and do not contain actual information about the road infrastructure, this will be different with the next generation of digital maps. These maps contain also street upgrade data, curve radiuses and sign-posting. In the medium-term it is also to be expected that information about the traffic light phase and the time until the next change of lights is made available. By automatic evaluation of all this information the saving potential of hybrid vehicles can be increased even further [6, 7].

Conclusion

In this article at first different drive train and electrical system architectures for hybrid systems were presented. To be able to realize many different hybrid systems, most manufacturers have opted for a modular concept with electronic devices. These devices consist in general of a battery, an electrical machine and electronic converters that are controlled by means of microprocessors. Thus during the operation not only the energy flow between storage and the electrical machine can be steered but also control-technical functions for example during the vehicle starting process can be taken over.

The present hybrid vehicles use mainly the information from the actual driving situation for the energy flow control, taking into account the battery charge and the power request of the driver. With this control concept today already considerable fuel consumption and emission reductions are reached. Further advancements could be achieved by integration of information and communication systems. So the efficiency of the hybrid vehicles could be increased by evaluation of further route information.

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MOBILE PHONE BASED REMOTE CONTROL SYSTEM FOR FURNACE AUTOMATION

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Abstract. *Nowadays, an increasing role in various technologies holds electronic devices that automate the various systems to facilitate people's daily life. This publication describes one of those types of automation capabilities, as a control system using mobile phones and mobile communications. Innovative approaches for the modification can be used for various purposes, such as a room or vehicle security alarm systems, remote management for various processes, the heating system furnace firing, the combustion process control, as well as many other remote management and control purposes.*

Keywords: *Remote Control Systems, GSM communications, Microcontroller.*

Introduction

The research prototype device described in this publication was designed for the control of solid fuel (firewood, charcoal, briquettes, etc.) furnace firing process through the strictly defined content of a mobile phone short message service (SMS). Remote control is realized by exchange with text messages between the mobile phone and the embedded SIM card of furnace unit. The implemented approach provides execution of received SMS commands, as well as notification of a sender about the furnace operational status or response to the received commands. The research prototype of the remote control system is implemented as a segregated unit and useable for improvement of already existing solid-fuel furnace heating systems, or for design of new models of furnaces and heating equipment.

Control methods and system design

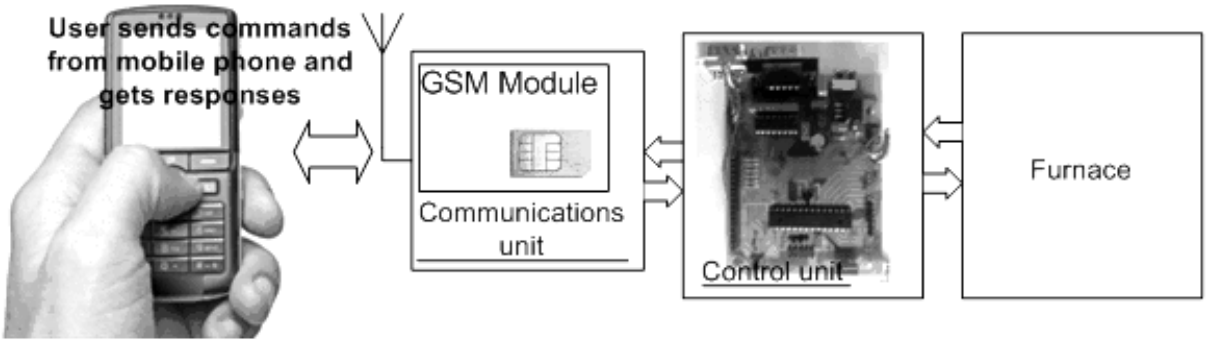

Fig. 1. **Experimental device assembly blocks (modules)**

The research prototype device is divided into several blocks (modules) in order to more clearly be able to view an assembly operation, and to easy carry out a separate block for configuration and maintenance work if needed. The blocks are: user, communication module, the control module and the device that will be operated, in our case – furnace. Assembly of the individual blocks is shown in Figure 1.
Each of these blocks is an indispensable and vital element in equipment, required for device to work properly. Even one malfunctioning module affects device's overall operation.

Let's take a brief look at all device modules:

- User. This part consists of a human and a mobile phone. Correct human action is required for successful functioning of the device. The human has to make decisions about device's performance and control and, by using corresponding commands in the form of an SMS, send the commands to the device, which device will try to execute and then notify the user back about command execution status.
- Communications module. This part consists of GSM module, SIM card, antenna and battery. This module is responsible for receiving commands from the user and sending reports back to the user.
- Control module. In this part of pilot study as a key component in this block was used microcontroller ATMEGA8. Control module is responsible for managing communications module, instruction receiving and processing as well as status checks and reporting back to the user. The main task of this block in our experimental case is the furnace firing and management.
- The device, which will be managed. Innovative remote firing and room heating system uses a specially designed solid-fuel furnace, which ensures 100% fire safety without human presence. Firing burner is placed in specially designed place inside the furnace. User fills furnace with the proper fuel to ensure that firing will be accomplished. When it's time to remotely kindle the furnace, user sends appropriate command to the control module from mobile phone. Control module then will read the fuel combustion process status and if no problems are detected, furnace firing is executed by a specified sequence algorithm:
    1. Open flue damper and turns on smoke pump (if it's built into the system);
    2. After a certain time kindle the fuel;
    3. After a certain time read the temperature on the heating element surface and temperature in the heated room.

If the algorithm by any conditions is not fulfilled in a specific order, fuel ignition process is stopped. Information about the ignition, fuel combustion and room warming processes is then sent to the user.

User

In this part user is the most important device operator and coordinator. In this particular example, the experimental device action directly depends from the user – whether or not furnace will be kindled.

At beginning to use the remote furnace firing, fuel combustion and room heating information reading device, each user must prepare device for work. The first thing to do is acquire the SIM card from the mobile communications operator and activate it. SIM card activation process differs for various mobile communication operators, but its activation process always is explained in the user manual, which comes together with the selected mobile communications operator SIM card.

During the activation process, the SIM card is inserted into a functional mobile phone. When SIM card is successfully activated, user must create a new contact named ADMIN and save it into devices SIM card phonebook and allocate it the telephone number from which device will be controlled. User must do it because by default the device does not respond to commands, which are sent from any other telephone number, except the one that is assigned to ADMIN contact. In the pilot studies there was also studied possibility if several users would be able to control the devices, from which the user ADMIN is the main user with greatest privileges for device management, and other users named USER with fewer device use privileges. It is very important to verify that the contact number named ADMIN is saved directly into devices SIM card phonebook, not the one that is in cell phone's memory.

When activation is completed and the necessary contact phone numbers have been assigned, the SIM card may be inserted into communication module. User is responsible for checking if the control module is attached to the sensors and the furnace control unit is operational, that all the equipment units are connected to their appropriate power supplies, as well as to check whether kindling is properly composited and fuel for the furnaces firing process will be successful.

Communication Module

As a key component for this experimental communications module in this experimental study is used branded SIMCOM GSM module SIM300CZ. The GSM module in its basics is a full-fledged mobile phone, which includes all the most essential functions of mobile communication - making and receiving voice calls, as well as receiving and sending short text messages (SMS).

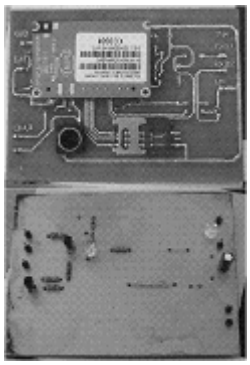

Fig. 2. **Communication module research prototype**

These functions are implemented in accordance with internationally accepted standards, so the module is able to work without any changes anywhere in the world with any mobile communications operator SIM card. By creating a wholesome control module, the communication module can also be used as a base for mobile phone development, but because this module is relatively large in size, it will not be suitable for this task.

Experimentally manufactured communication module can be viewed in Figure 2. During the experiment, communication module was fed with a NOKIA cell phone company BL-5C accumulator, which can provide the necessary voltage and current supply for the GSM module. Although the experimental accumulator was providing 3.7 volts and the module worked correctly, GSM module manufacturer recommends the use of higher-voltage accumulators - with the recommended voltage 4.2 volts. [1.]

Communications module can be fully functional only with the active SIM card, that's why SIM card must be activated (it must be able to register on network, receive calls and receive short text messages). SIM cards activation procedures are slightly different for various mobile network communication operators, but activation is one of the few activities that user must do before starting to use each device. SIM card activation procedure is always explained in the user's manual, which comes together with the selected mobile communication operator SIM card.

Without the control module, communication module is able to just register on a network, receive calls and short text messages, but it can't in any way react to these events, or make any response action (e.g. send short text message reply to the caller). To successfully use a communications module it is also required for some external devices - an active SIM card, antenna, power source (accumulator) and the control module.

Control Module

As a key component for this experimental control module, is used a microcontroller ATMEGA8 produced by ATMEL. This chip is able to process the signals that enter on the input pins, and output signals according to the input state. This behavior can be programmed into microcontroller. Experimentally manufactured control module is shown in Figure 3.

In this pilot studies part, the microcontroller's main task is to maintain connections with the communications module, to execute command received by SMS and to reply command responses received back to user. Communication with the communications module is like

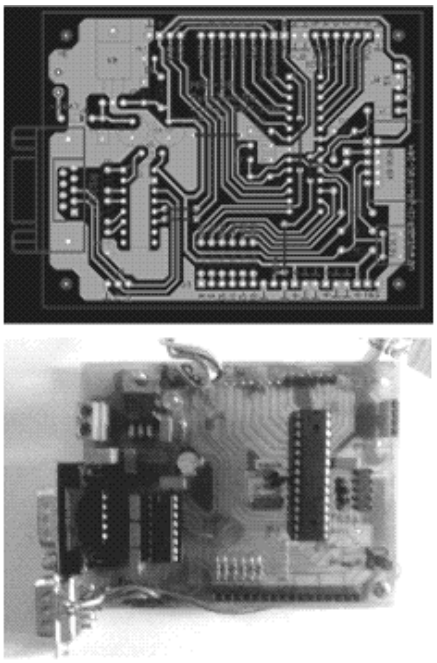

Fig. 3. **Control module research prototype**

using an ordinary modem. Communication is established by using only two microcontroller pins (one of which sends the data, while the other receives). As a communication protocol used in the pilot studies was AT-command set [2.], which is an international standard protocol for communication with modems, and is used to communicate with the modem. This includes a set of standardized commands for specific tasks, and also each modem manufacturer-specific commands that are directly linked with modem configuration. [3.]

The microcontroller used in pilot studies has 28 input / output pins, of which 23 are available for end-user needs. Two input / output pins are used for communication with communication module, and one output pin is required for switching on the communication module. User can use remaining available 20 input / output pins, which can be added various types of sensors, or expand module functionality by using various accessories that after receiving commands from the communications module can be turned on or off, as well as the communications module is able to notify the user information about the status of devices.

During the experiment, the control module was fed with 5 volts received from the computer's USB port power supply. Due to the fact that the microcontroller requires a stable current, the easiest solution is to take already stabilized current from the computer's USB port, so avoiding need for specific power supply.

Remote control device work algorithm

Switching on the device and register on the available network. Once the user has pressed the devices power on switch, current is passed to the control module. The control module controls the voltages and connected devices status (if any) and if determined that the processes are running in the corresponding mode, the control module switches on the communication module. Communications module after receiving switching on impulse, in addition controls the used voltages, working temperature and SIM card status. If the system works correctly, communication module starts to register on to the available network. Registering on to the GSM network is done by GSM module, which has already built-in network registration protocol and methods, which operate on the internationally accepted standards. If registration process to the network has been completed successfully, the control module receives the command "CALL READY", which means that the communications module is in working order and is ready to receive and send text messages.

The control module operation. When the control module has received the command "CALL READY", a microcontroller moves to the idle state. In this pilot studies part, the control module was not intended to carry out any activities with controlled device until the moment when the furnace firing command was received. In idle state, microcontroller runs endless loop, which in each cycle, checks all the equipment status and the availability of new commands from the communications module. If there is any new command to execute, command execution or processing of received information begins and if necessary - user is notified about executions results, but if there are not any new commands - the idle state continues.

The responses to the events and commands. In the experimental example, voice calls were not used, so the control module automatically rejected incoming calls, as soon as they are received.

Communications module from time to time notifies the control module about the status changes, such as low battery level, incoming call or SMS. Part of these events is insignificant and they don't affect overall functioning of the device modules, but some events are very important. For example, if the control module receives the status "UNDER-VOLTAGE WARNNING" from communication module, it means that the communications modules accumulator voltage is too low and the communications module will soon be automatically turned off if not connected to external power supply - accumulator charger. Communication module will still able to operate for a while, but before the automatic shutdown control module receives the last status report from the communications module - "UNDER-VOLTAGE POWER DOWN". Following this announcement, communication module is no longer able to perform as a result the device is not able to receive commands and transfer status reports anymore.

The responses to the errors. Unfortunately, the device is unable to anticipate and prevent errors, so all errors must be prevented while programming the control module. By default, in case of the error, the control module to notify the user about the error and device management will be stopped. However, through prudent control module programming, it is possible to develop solutions that allow to predict these errors and, where possible, prevent them and continue normal operation of the device.

Unit Testing

In this work there has been carried out communication and control modules design and experimental prototypes development, based on the available manufacturer's recommendations and Internet resources.

The first thing was to develop the control module. As the base for it, was used solution found on robot forum [4.] that allows full use of all possible microcontroller ATMEGA8 features. When the experimental control module prototype board was designed and the parts were soldered, control module testing and programming part was launched.

As first task was set to provide the communication module communication with the computer. To achieve this, the computer must be prepared at first. Also we needed to program a library that will provide data input and output to / from the microcontroller.

As part of this experiment was a hypothesis that the developed scheme will be operating successfully with maximum data exchange rate, based on a microcontroller technical documentation. [5.]

To realize Experimental data exchange it was used on a computer that is running Ubuntu 9.10. Different standard RS232 port speeds were used [5., 6], using different amount of data. As a successful outcome of the experiment, in the terminal Putty was observed correctly received text (data) with no errors, proving that, each sent text bit is successfully received. As fastest possible data transfer speed was used 115200 bits per second, which is both a communication module and control module maximum data exchange rate.

Communications module design was based on the GSM module manufacturer - SIMCOM offered education board. After examining available technical documentation from manufacturer for hardware design [1.], keeping recommendations in mind we developed suitable scheme for the experiment. Based on scheme we made the board drawing and communications module. (See Figure 2.)

The factory default settings for GSM module was that it will operate with not fixed data transfer speed (autobouding), which means that the GSM module will automatically "agree" with the computer for maximum data transfer speed, both of which are acceptable to computer and GSM module. The control module is unable to work in this mode, so the AT commands [3.] were used to set a fixed data transfer rate to 115200 bits per second, which is acceptable as a PC, so the control module.

When all modules were able to communicate with each other, was launched the control module functionality programming. Programming took place through an integrated development environment Eclipse. [7.] This environment was chosen because it is easily adaptable to the needs; it has a lot of free publicly available plug-ins that allow expanding functionality of the environment. To write a program code into microcontroller, AVR Eclipse Plug-in was used. [8.] It is a simple and easily customizable plug-in, it supports various programmers, including USBASP programmer used in this experiment. [9.] All documentation and software needed to build the programmer is available free of charge in developer's website, which makes this programmer a cheap and easily produced device even at home. Also, the data recording speed to the microcontroller surpasses many other programmers.

Recording microcontroller code is done by pressing the button in Eclipse development environment, which appears by installing AVR Eclipse plug-in. Microcontroller's logic was programmed using C programming language. Due to microcontroller architecture differences, a lot of problems were faced, as conventional solutions that work on computer, do not work on microcontroller, so we had to look for other solutions.

Beginning control and communications module development one needs to understand the manufacturers given information. Also, knowledge in electronics, programming and computer architecture were used. As a result of the experiment, are communications and control modules that are able to work and is already practically tested in real applications. The control module logic still has some gaps and deficiencies, but they are being corrected. Work is mostly based on error prediction and prevention in order to make the device more stable and automatic without requiring the user to interaction.

Potential applications

Device can be relatively easily adapted to different purposes, where the SMS communication with the device is necessary, respectively, by reprogramming the control module logic for each specific task. In this scientific study, a prototype device will be used for solid fuel furnace firing after receiving the appropriate SMS command. The control module is connected to the device that will accomplish the ignition process. It consists of relays and some optional equipment that provides furnace firing process. Successful furnaces firing also depends on whether it will be properly prepared for fuel ignition, material (in this case, the correctly composited kindling) or fuel (firewood) will be properly composited into furnace, dry enough, etc.

If the device will be used for sensors reading and periodic reporting of results (such as furnace temperature and temperature in heated room), it is necessary to develop a specific mechanisms to manage the sensors and receive the data from them. The other measurement specific changes need to be made only to the control module by reprogramming microcontroller.

As the control module main part can be used any microcontroller, not the one used in the experiment. Depending on the application and the controlled device complexity, it is possible to use other microcontrollers, which differ mainly with the microcontroller's processor speed and data transfer rate, as well as available to the user input/output pins. For example, ATMEGA64 microcontroller enables the user to use more than 40 input/output pins, which should be in fact enough for any remote-control device.

Conclusions

1. In this scientific research developed innovative communication and control unit was used for solid fuel furnace firing, the combustion process and the heated room heating dynamics monitoring.
2. Innovative communication and control device can be successfully used for various process controls, for example, alarms, security and many other purposes.
3. The maximum experimentally determined speed at which the device is able to work without any data loss during transmission is 115200 bits per second.
4. In the future there is a need to realize control algorithm improvement. At the moment there is no chance to work with control SMS queue (for example in multi-users mode when users send commands to the device separately).
5. At the moment algorithm is working linear and each control command will be treated as separate command. But in multi-user mode, there is a need to be able to share resources between all users and to prevent commands collisions (for example USER sends command to fire the furnace, but the ADMIN has already fired the furnace).

Acknowledgments

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AN INVESTIGATION ON HIGH FREQUENCY PERMEABILITY OF POLYCRYSTALLINE FERRITES

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Abstract. *The problem under examination is the magnetic loss of polycrystalline ferrites. Their total loss include: hysteresis, eddy current and anomalous (AN) or excess ones. The mentioned first two losses more or less adequately are covered by modified Steinmetz equation whereas AN loss is less well understood. Conceptually this loss is defined by the components of complex permeability spectra of ferrites which as a rule are experimentally obtained. Large body of these experimental spectra shows a great variety of forms and specific features. This variety is the main reason why there still is not adequate analytic presentation of AN loss. It is shown in the research that important progress is possible to achieve in analytic presentation of AN loss on the basis of realistic account of microstructure of polycrystalline ferrites and dividing the variety of all samples into subgroups according to their actual structure.*

Keywords: *polycrystalline ferrite, complex initial permeability, magnetic spectra, microstructure.*

Introduction

Polycrystalline soft ferrites (PF) as the most significant magnetic materials for electronics find use in numerous of its high frequency application fields: in electromagnetic compatibility (EMC) domain as energy absorbing materials and filtering magnetic elements; in switch-mode power supply systems as energy storing and filtering components; within broad range of different inductive elements as magnetic flux concentrators, in the new class of composite materials – metamaterials as an active constituent, a.o. No matter what is actual application of PF, the user essentially needs to know, along with the set of other appropriate their characteristics, the magnetic loss parameters as well (the desired level of the losses may be quite different in different applications: usually as high as possible for the above mentioned EMC; typically as low as possible for energy storage and inductive elements). Total magnetic loss of magnetic materials conventionally (nevertheless with certain degree of scepticism because lack of theoretical justification [2]) is presented by three components [1]: hysteresis, classical eddy current and anomalous (excess, residual) loss. Such a decomposition attempts to underline the main reasons of magnetic loss but research activities on this ground does not bring to proper analytic presentation of the components still (especially anomalous one); as a consequence there appear new and new pertinent publications and improved and modified loss models. At this situation in practice the presentation of total loss both of metallic and ferrite magnetics rather often is based on well known Steinmetz empirical equation:

$$P_{core} = k\, f^{a} B_m^{b}, \tag{1}$$

where P_{core} is the magnetic core average power dissipation per unit volume; k, a, b are the material dependent empirical coefficients determined by best-fitting of measured data, f is the sinusoidal operation frequency and B_m is the peak value of magnetic flux density (the induction); for ferrites a is between *1.1…1.9* and b is in the range *1.6…3* [3]. Manufactures of magnetic materials typically make known these empirical coefficients or display the experimental curves of P_{core} over limited ranges of frequency and flux density [4]. In the case of nonsinusoidal magnetization there is offered, e.g., modified Steinmetz equation [2].

Even so, such empirical presentation is a highly limited way of looking at the loss since Eq.1 accounts only for influence of two parameters – f and B therein limited ranges of their values, but ignores several other important factors, e.g., type of magnetization process (domain wall displacement or spin rotation), influence of microstructure characteristics, a.o. This is why magnetic loss problems still are challenging; the solutions of problems are being searched by a closer look into generalization [6] as well as more adequate separation of total loss in components [7] both within the frequency and the time domains [5].
This study deals with the anomalous loss problems of PF, which there are studied on the basis of the concept of relative complex permeability:

$$\mu_r^*(f) = \mu'(f) - j\mu''(f), \tag{2}$$

where $\mu'(f)$ is the real and $\mu''(f)$ is the imaginary parts of a complex permeability $\mu^*(f)$ at the frequency f (it is common also to name $\mu'(f)$ and $\mu''(f)$ as the dispersion (DCp) and the absorption (ACp) components of magnetic spectrum (MS) respectively). This concept is the most appropriate for practically nonconducting materials such as PF [8]: there is possible to ignore macroscopic eddy currents and in the case of weak excitation fields the hysteresis loss as well. This in fact means that there really is investigated anomalous loss (at times named as resonance/relaxation loss [9]), corresponding to complex *initial* permeability (CIP), $\mu_{ri}^*(f)$; from here on Eq.2 is used in this sense omitting as a rule the subscript *i*. Use of CIP approach to anomalous loss allows more directly to account for influence of microstructure parameters of PF on its loss characteristics.

Losses versus magnetic spectra

The presentation of magnetic loss by CIP in fact implies that DCp and ACp of spectrum are known over proper frequency range. The loss most directly is proportional to ACp $\mu''(f)$ but the real practice calls for DCp $\mu'(f)$ as well since important loss characteristic – loss tangent $\tan\delta(f)$ is defined as

$$\tan\delta(f) = \mu''(f)/\mu'(f) \tag{3}$$

which in its turn is possible immediately to relate with the specific loss [10]:

$$p(f) = \left(\tan\delta(f)/\mu_a\right)\pi f B^2, \tag{4}$$

where p is the loss per unit volume; μ_a is the absolute permeability, $\mu_a = \mu'(f)\cdot\mu_0$, $\mu_0 = 4\pi\cdot 10^{-7}\ H/m$; B is the effective value of induction (flux density). From Eqs.(3) and (4) it gets clear that the deeper insight into magnetic loss of PF calls for investigation of CIP components behaviour in frequency range (typically within radiofrequencies) and for their proper analytic presentation.
The problem of analytic presentation of CIP spectra appears concurrently with the publication of the first research on absorption and dispersion in PF [11]. Then there comes a time with active investigations on MS and soon the achievements were summarized in the reviews [12, 13] showing the manner in which various researchers first of all were trying to find out the dominating magnetization process of PF using often the graphical forms of experimental MS as an argument as well. A clear understanding of magnetization process is crucial for CIP spectra modeling. The problem seems to be solved at previous seventies and eighties (mainly by investigations inspired by basic works of A.Globus, e.g. [14]) when it was stated that CIP definitely depend on microstructure characteristics (more pronouncedly on average grain size D_a) and that dominating magnetization mechanism is domain wall (DW) displacement.
At times however there appear claims that the dominating magnetization process is the spin rotation [15]. We presume that MS data taken over really broad frequency range strongly suggest that the highest losses (related with the most pronounced absorption and dispersion) is

connected with DW processes. In more details it is substantiated by details in Fig.1 (experimental data are taken from [16]) which shows that if one moves across MS in general there can be found three dispersion regions [16]: a) in *kHz* range – relaxation type diffusion after effect (DIF), not always presented; b) in the decades placed directly near *1MHz* – the large amplitude dispersion attributed to DW processes; c) in the decade of several *100MHz* – the small amplitude dispersion related to the natural spin resonance (NSR).

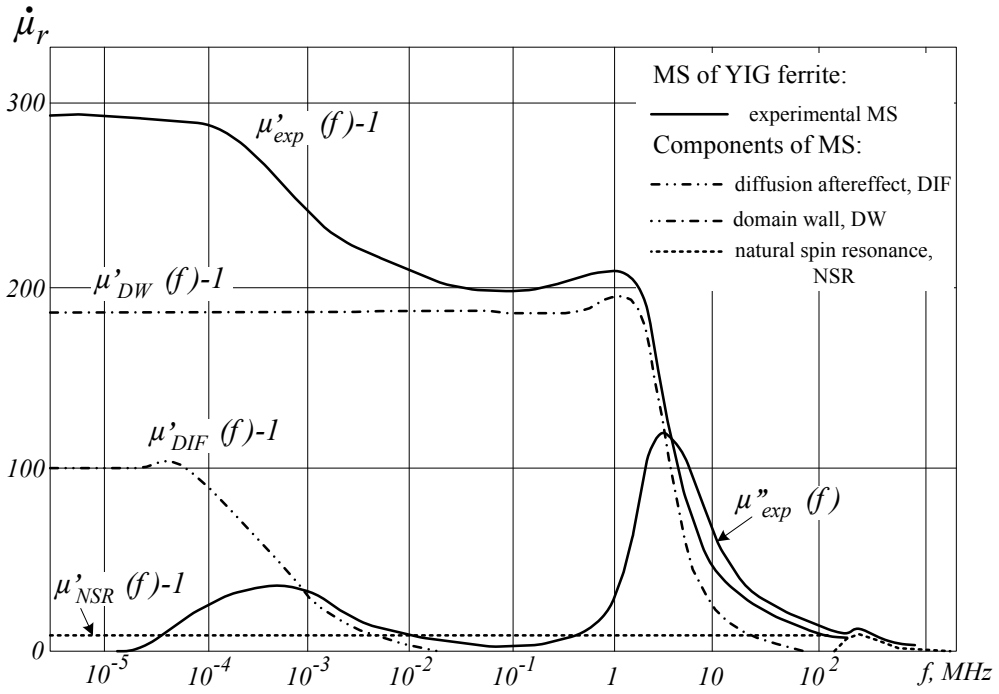

Fig.1. **Results of MS decomposition: the experimental ACp $\mu''_{\exp}(f)$ firstly is graphically broken in three clearly seen absorption components, which consecutively are used for calculation of corresponding components of DCp $\mu''_{DW}(f)$, $\mu''_{DIF}(f)$, $\mu''_{NSR}(f)$ by KK relations**

This becomes clearer after decomposition of ACp $\mu''_{\exp}(f)$ into three mentioned components [17] and calculation of DCp $\mu'(f)$ by the use of Kramers-Kronig (KK) relations:

$$\mu'(f)-1=\frac{2}{\pi}\int_0^\infty \frac{x\mu''(x)}{x^2-f^2}dx;\ \mu''(f)=-\frac{2}{\pi}f\int_0^\infty \frac{\mu'(x)-1}{x^2-f^2}dx\ . \qquad (5)$$

Within the radiofrequency range (at room temperatures) for spinel and garnet type PF (most often used in practice) typically more or less clear are observed DW and NSR dispersion regions. Similarly as in Fig.1 contribution from NSR process in the total permeability $\mu^*(f)$ of a sample often is small and frequency independent up to very high frequencies; this is why the modeling of CIP is restricted over the region of large amplitude dispersion as DW processes.

Approach to MS based on account of their characteristic features

When displayed as graphical curves the experimental MS disclose great variety of forms thus sending one first of all in search of most important typical characteristics of the spectra (it is

apt at this point to mention that it is meaningless to analyze doubtful experimental spectra – e.g., the ones not obeying KK relations, Eq.5, at least).

The typical experimental ACp of MS (Fig.2) is asymmetrical along $\log f$ scale axis and broadband (often extending over several decades of f [13]) thus far in excess broader than it is obtainable by the approximation with the simple relaxation (with one relaxation time) dependence:

$$\mu'(f) = \mu_{stat} / [1 + (\tau f)^2] \; ; \quad \mu''(f) = \mu_{stat} \tau f / [1 + (\tau f)^2], \tag{6}$$

where μ_{stat} is the static value of CIP. But even with this fact that dispersion within MS is pronouncedly broad, a closer look at DCp reveals the clear evidence of resonance attributes as well (positive ups on DCp and negative downs on ACp): in Fig.1 near *1MHz* and in Fig.2 near *2MHz* and *1GHz*. If the approximation of MS is done by the use of simple harmonic oscillator relations:

$$\begin{aligned} \mu'(f) &= \mu_{stat} f_0^2 (f_0^2 - f^2) / [(f_0^2 - f^2)^2 + 4\xi^2 f_0^2 f^2], \\ \mu''(f) &= 2\mu_{stat} \xi f f_0^3 / [(f_0^2 - f^2)^2 + 4\xi^2 f_0^2 f^2], \end{aligned} \tag{7}$$

with ξ as the normalized damping *const*, then in the case of $\xi < 0.5$ the resonance features is possible to reproduce, but in the substantially closer frequency limits corresponding to much narrower width of ACp (between the ascending and the descending parts of absorption).

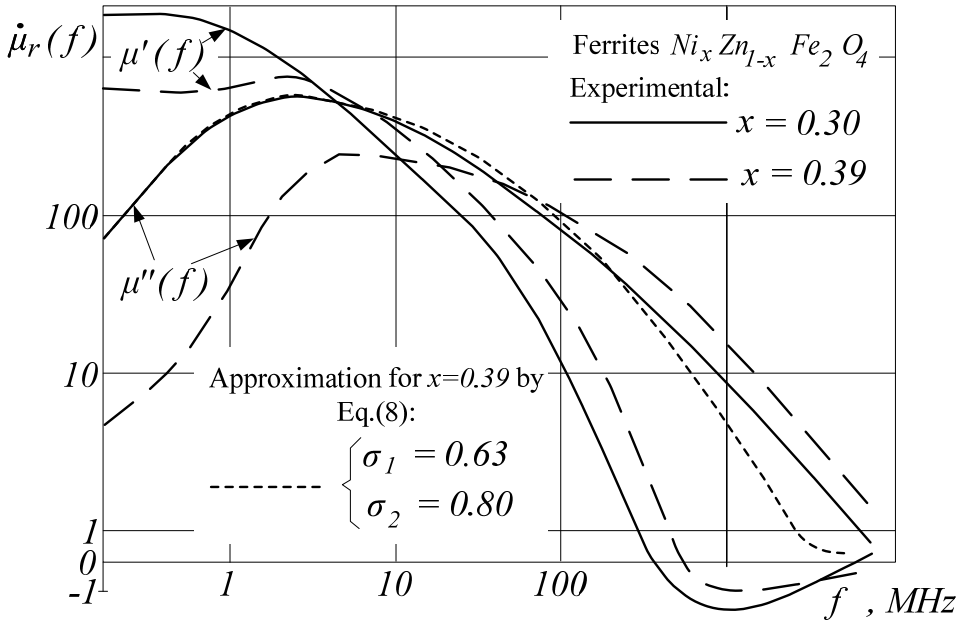

Fig.2. E**xperimental MS of NiZn polycrystalline ferrites showing as it usually is an available compromise of both relaxation and resonance features**

Inadequate presentation of MS separately by the relaxation and the resonance dependences (but at the same time with several features of reality) naturally calls for their superposition, i.e., joint use of Eqs. (6) and (7) (in fact proposed by Y.Naito [18]). In this case it is assumed that for frequency $f \to 0$ static permeability

$$\mu_{stat} = \mu_{stat/relax} + \mu_{stat/reson}$$

i.e., is divided into relaxation, $\mu_{stat/relax}$ and resonance, $\mu_{stat/reson}$ components which are used with their frequency dependences according to Eq.6 and Eq.7 correspondingly. Even though

there is no physical background for this decomposition of μ_{stat} as well as of parameter τ, ξ, f_0 estimation except the best fit to experimental data, such a formal approach nevertheless is used in a series of publications because of more or less degree of certainty in the presentation of MS. The main limitations of this approach are its formality and clear ignorance of effects of microstructure of PF on its CIP [16].

Modeling of MS based on account of microstructure

The microstructure (MST) of PF, which there is considered as the one manifesting itself by the grain size distribution law and the value of average grain size D_a of PF, is dependent on specific details of their processing ceramic technology [19]. This indicates that there are a rich variety of different ferrites supplied from various manufacturers which technologies used nevertheless differ and so MST, and since the modeling of MS for whole class of PF with the account of their MST is rather challenging task. In order to solve the problem in [21] it has been suggested that whole body of PF samples is possible to separate into two groups: the one for samples with a rather perfect, defectless MST (named as intrinsic quality group, IQG, assumed as reference one) and the another one for all the others (typical technical quality group, TQG). This division allows for PF of IQG to relate the magnetization process directly with material MST and to apply quantitatively the concept that experimentally observed characteristics of the sample in fact are integral ones appearing as such in the process of natural averaging their inner parameters over the ranges set up by the grain size distribution.

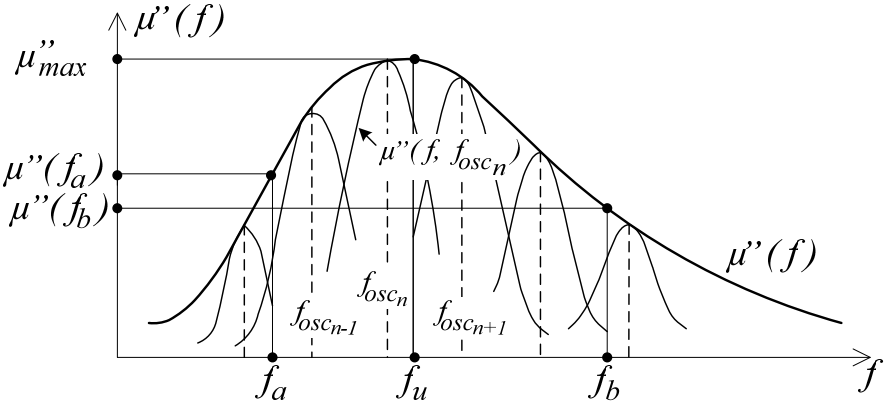

Fig.3. **Parameters of ACp ($\mu''_{\max}$, f_u , $\mu''(f_a)$, f_a , $\mu''(f_b)$, f_b) as well as the demonstration of concept for ACp composition by absorptions of elementary oscillators**

This concept translated to MS allows assuming for ferrites from IQG that every polycrystal grain of the sample can be considered as the low loss oscillator (the grain with DW having $\mu_{stat} \propto D$ and resonating at $f_{osc} \propto 1/D^2$ with D standing for the current gain size). As a consequence, e.g., the whole curve of ACp $\mu''(f)$ can be formed up from absorption curves of these tiny oscillators (having the absorption line $\mu''_{osc}(f)$ of Eq.7 form) with continuously distributed f_{osc} (for clarity in Fig.3 the principle is shown as if ACp $\mu''(f)$ would be compassed up only by the group of several oscillators). Accepting further (in accord with the experiments [20]) that the grain size distribution probability density function is log-normal:

$$\varphi(D) = (\log e / \sigma_D D\sqrt{2\pi}) \exp[-(\log D - \log D_m)^2 / 2\sigma_D]^2$$

where σ_D and $\log D_m$ are the distribution parameters of $\log D$, and relating the parameters of current absorption line of oscillator with current value of grain size, after integration over full

range of the oscillator resonant frequencies, it is possible to obtain the mathematical form of ACp [21]:

$$\mu''(f) = \mu''_{\max} \exp[-(\log f - \log f_u)^2 / 2\sigma^2] \ , \qquad (8)$$

where $\mu''_{\max}$ and f_u, Fig.3, are characterizing the absorption maximum of $\mu''(f)$; $\sigma = 2\sigma_D$.
The potentialities of Eq.8 in presentation of MS (for different values of σ) as normalized curves are shown in Fig.4, *a*: it can be seen that the change of σ (which in the reality means the change of grain distribution) allows to go from deeply relaxation type of spectra ($\sigma = 0.6$) to clearly resonant one ($\sigma = 0.2$), having the distinguishing boundary value near *0.5* (in the process the dispersion components DCp were calculated by the use of KK relations, Eq.5).
For definite experimental spectrum $\mu''_{\exp}(f)$, under the assumption that it and that of Eq.8 coincide, the specific value of σ for the presentation of given MS is possible to evaluate from a complimentary point on the curve $\mu''_{\exp}(f)$ at frequency f_a:

$$\sigma = (1/\sqrt{2\ln \mu''_{\max} / \mu''(f_a)}\ )\left|\log f_u / f_a\right| \ , \qquad (9)$$

(particularly for $\mu''(f_a) = 0.5\mu''_{\max}$ and corresponding frequency denoted as $f_a = f_{0.5}$, i.e. for half-level absorption $\sigma = 0.85\log(f_u / f_{0.5})$).

Applications of the modeling to experimental MS

In the case of practical use of Eq.8 for definite MS it should be recalled that the modeling was developed for samples from IQG and frequencies corresponding to large amplitude dispersion region. As such the results of modeling has been applied to MS of high quality YIG (Fig.5, data from [22]) showing a close agreement with this symmetrical MS ($\sigma = 0.7$). The value of standard deviation obtained just for grain size distribution $\sigma_D = \sigma / 2 = 0.35$ in this case correlates well with the typical values $(\sigma_{\ln D} \approx 0.5) / \ln 10 \approx 0.22$ for normal grain growth structure of PF [23]. Thus the results gained show that principles of modeling are realistic.

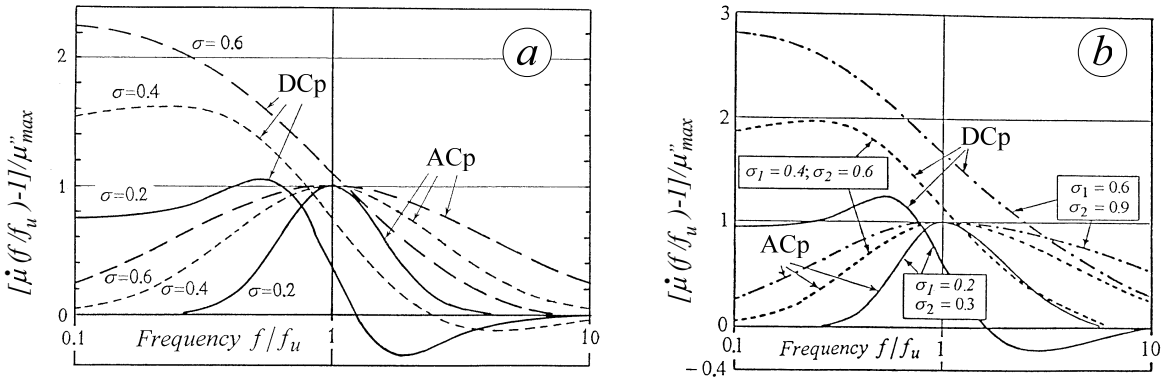

Fig.4. **Normalized theoretical MS: *a* – with the symmetrical (for IQG samples) and *b* – with the asymmetrical absorptions (for TQG samples)**

Even so, the majority of experimental MS show asymmetrical absorption curves $\mu''(f)$. In [17] it was shown that for presentation of these MS it is possible to use Eq.8 as well but by applying two values of σ: one, σ_1 for $f < f_u$ and another, σ_2 for $f > f_u$. Corresponding frequency dependences by thus modified Eq.8 in normalized form for several combinations of σ_1 and σ_2 (naturally $\sigma_2 > \sigma_1$) are shown in Fig.4, *b* – they really are depicting the most typical features of experimental MS. The physical background for this modification comes from the fact that majority of real samples (of industry technology) belongs to TQG of PF.

This implies that in coarser grains having higher dimensions there are intragrain defects pinning DW and thus fragmenting their displacement. This rises the shift in the frequency response in relation to that of IQG because instead of one, low frequency $f_{osc}^{(LF)}$ (corresponding to oscillating DW of full size within larger size grains) there appear several higher frequencies $f_{osc}^{(HF)}$ corresponding to vibrations of the fragments of pinned DW; this is lowering the value of σ_1 and increasing that of σ_2; the values thus gained only indirectly are

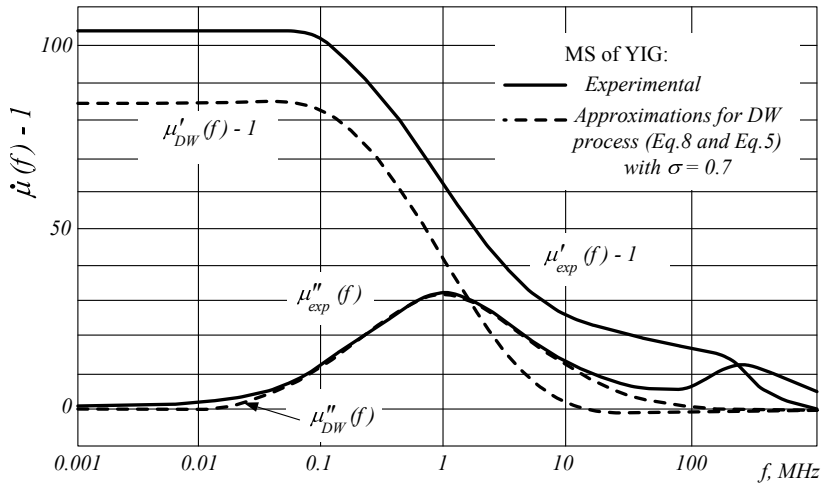

Fig.5. **Wide frequency range experimental MS of YIG and its approximations for large-amplitude dispersion range DW process**

related to actual grain size distribution. For approximation of the definite MS specific values of σ_1 and σ_2 is evaluated similarly as for σ but by the use of Eq.9 with two frequencies: f_a for σ_1 and f_b for σ_2 (Fig.3). Approximation of experimental $\mu''(f)$ in Fig.2 ($x = 0.39$) based on modified Eq.8 ($\sigma_1 = 0.63$; $\sigma_2 = 0.80$) show a close agreement between both thus demonstrating usefulness of such modification.

Conclusions

In relation to anomalous loss of PF it is shown that considerable contribution to it may come from DW processes which manifest themselves at radiofrequencies as the large amplitude dispersion of CIP. At present more rigorous analytic modeling based on realities – account of microstructure effects of PF is possible for absorption component of CIP for samples from high, intrinsic quality group (as a rule of laboratory production). In this case the modeling reveals that type of CIP spectrum – resonance or relaxation is determined by actual grain size distribution function which directly governs the distribution of resonance frequencies of oscillators – vibrating DW.

For samples from the group of usual technical quality (the majority of industrial technology magnetics) adequate analytic presentation of absorption component is possible as well but it is less strictly related to the grain size distribution since the coarser grains within sample are with intragrain defects effectively pinning DW. This creates misshape of symmetrical absorption – there appears more pronounced absorption at higher frequency. Reflection of this reality needs one additional parameter in the presentation.

In both cases the frequency dependence of dispersion component of CIP is obtained by the use of effective computer program for Kramers-Kronig relations.

This modeling, based on the concept that magnetic characteristics of the sample directly relates from that of log-normally distributed grains, as a whole is clearly productive since it allows not only to model the spectra of CIP (i.e. low field object) but permits to anticipate what happens with those spectra in increasing fields – both alternating and polarizing ones. In the first case the increase of amplitude is unpinning DW in coarser grains of the sample and thus is increasing the value of low frequency permeability and lowering its f_u. In the second case it is necessary to notice that coercitivity of grains $H_C \propto 1/D$; it means that increasing polarizing field first of all is saturating these coarser grains thus lowering low frequency permeability and increasing f_u. Both statements are in line with the experiments.

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MAKING DECISIONS ON ARRANGEMENT OF ELECTRONICS IN SMART GARMENT

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Abstract. *This paper describes the prototype of a smart jacket and offers several alternative ways of designing and arranging of electronic elements, which are based on ergonomic design guidelines, using principles of external and internal stress zoning in garments. Seven variants of arrangement are proposed, which are compared using decision making methods AHP and ELECTRE. One of the goals of this research is to carefully aggregate the available information and to rank different variants of arrangement using a set of criteria as objectively as possible. Comparing several variants of arrangement of electronic elements in clothing enables one to determine the most suitable variants according to the selected criteria.*

Keywords: *smart garment, electronic system integration, clothing ergonomics, decision making.*

Introduction

With wearable electronics usually denote a functioning device that always is attached to the wearer, as well as is comfortable, easy-care and easy-use. In other words – it is clothing with integrated electronics that does not disturb the wearer of the apparel. Therefore, during the development of the smart clothing it is important to consider design and arrangement of electronic elements in order to get functional, comfortable and ergonomic layout of electronic components in smart garment.

In this research we analyze construction of electronic part of a smart jacket prototype, searching ways of improvement and designing alternative variants of electronic element arrangement.

The aim of the research is to rank different variants of electronic element arrangement, to aggregate carefully the available information and to rank different variants of arrangement using a set of criteria as objectively as possible, using decision making method ELECTRE. AHP is used for criteria weighting. These methods are deemed necessary because the problem at hand is not a trivial one, since there are several possible alternatives, which are compared using a set of criteria of different importance. On the other hand, this approach is more feasible than the construction and testing of physical prototypes, which is too costly in terms of time and resources.

Materials and methods

This chapter provides description of the prototype, of different ways to improve its construction and offers several alternative construction variants. Used decision making methods are described and the decision problem is analysed.

Description of prototype

The developed prototype is an innovative solution in the field of child care and safety; it is a garment, which reacts to microclimate changes with the help of integrated electronics and signals temperature and relative humidity.

Output interface is represented in two ways:
1) with the help of optical fibre fabric integrated into clothing: when microclimate conditions change, fabric starts to emit light with a different frequency;
2) with the help of a LCD screen integrated into mother's purse and displaying information about the child's body temperature and relative humidity. Maximum operational range between the purse and the jacket is about 30 m, ZigBee is used for wireless communication.
In addition to its decorative and functional properties, this light-emitting children's garment will protect children on dark roads and will help parents to take better care of their children.

Arrangement of electronic elements in the prototype
Electronic elements are integrated in a way that makes it possible to remove them before washing. For this purpose, a removable layer for electronic components was developed. Light emitting diode and mode button are permanently integrated into clothing and are not removable, all the other electronic elements are placed on a removable layer, which is placed in the back of the jacket and is attached to the jacket with the help of 6 press studs. Jacket construction and electronics layout is shown in *Fig.1*. Information on prototype functionality and a broader description was published in one of the previous papers [1].

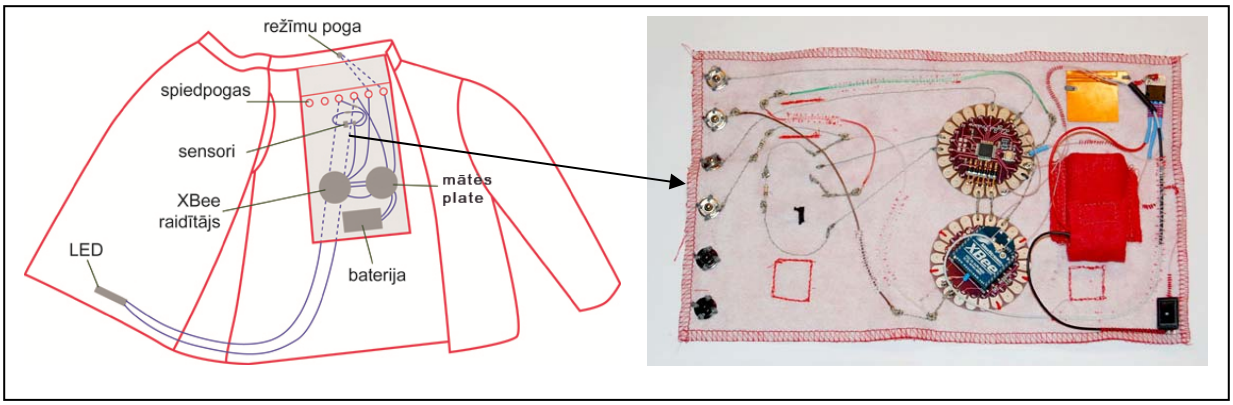

Fig.1. **Jacket construction and electronics layout**

One of the disadvantages of this system is a possible risk of injury if a child falls on its back, since battery and RF-transmitter are located there – these modules are larger than other elements and they are located in the backbone area. In order to solve this problem, it is possible to attach additional isolation layer to the area in question. Another solution would be to provide an alternative arrangement of electronic elements in the jacket.

Improving the layout of electronic elements
One of goals during the optimization of jacket construction was to ensure that the garment follows ergonomic design guidelines. For the integration of electronic modules into wearable garments it is important to take into consideration arrangement, weight distribution and selection of suitable clothing area. Principles of external and internal stress zoning in garments (Standard EN 13595-1: 2002 Protective clothing for professional motorcycle riders: zoning of risk categories; and Ashdown and Watkins research about identification of stresses on seams during wear) were analyzed and the results can be found in one of the previous papers [2]. According to external and internal zoning principles it can be derived that the most suitable zones for electronic elements are jacket front side and back side till waist level, as well as small zone on sleeve between shoulder and elbow. Of course we have to take into account that clothing is tailored to child and there can be certain deviation from fixed zones in clothing.

Besides principles of zoning other ergonomic requirements have been proposed:
− It is necessary to ensure equal weight and size distribution of electronic elements in clothing.
− Electronic elements must be placed in such a way that children cannot reach and damage them.
− Electronic elements must be chosen as small as possible both in weight and size.
Analysis of the requirements mentioned above and optimization of jacket design resulted in several alternative proposals of electronic elements distribution in child jacket. These variants are described in Table 1.

Table 1.

Alternative variants for arrangement of electronic elements in child jacket

Var	Title	Description	Advantages and drawbacks
1	2	3	4
A	Removable layer in back part and inner pockets for electronic elements	The same electronic as in the original prototype are used. LED and mode button are permanently integrated into the jacket. Part of electronic elements are located on the removable layer in the back, other elements are positioned laterally above waist level in pockets under lining. Bulky elements are placed in pockets, so that they don't cause discomfort to the wearer with stress in backside. Balanced weight distribution is obtained.	Circuit advantages: Balanced weight distribution, easy battery change. Circuit drawbacks: High costs, large dimensions of electronic elements, complicated removal of electronic block before washing.
B	Removable layer in back part and outer pocket for electronic elements	Alternative electronic elements are used - smaller in size and weight. The most problematic element still is a bulky battery (9V PP3). Electronic elements are located on removable layer in the back, which is more compact due to the dimensions of the elements – the layer is more compact. Battery and switch are located in the outer pocket on the jacket's sleeve.	Circuit advantages: Lower costs, minimized dimensions of elements, easy battery change. Circuit drawbacks: Quite complicated removal of electronics before washing.
C	Lateral removable layer and outer pockets for electronic elements	This variant is similar to the one mentioned above - electronic elements are located on the lateral removable layer, battery and switch are located in outer pocket on the jacket's sleeve. Lateral arrangement of the layer ensures better microclimate data readout and gives additional protection by wearer's hand.	Circuit advantages: Better microclimate data readout; extra scheme protection. Circuit drawbacks: Longer contact paths, lateral attrition.

1	2	3	4
D	Removable layer in front part for arrangement of electronic elements	According to external and internal zoning principles, safer placement zone for electronic elements is front of the jacket, thus electronic elements arrangement in the front part of the jacket below optical fiber fabric is provided. LED and mode button are permanently integrated into the clothing, all other electronic elements are located on the removable layer in the front part of jacket.	Circuit advantages: Lower costs, compact disposition, easy removal of electronic block. Circuit drawbacks: Worse microclimate data readout due to position of sensors, battery change is not very handy.
E	Removable layer in front part and inner pockets for power supply	Similar to the variant mentioned above, but in this case there is a better weight distribution, because the batteries are moved from the removable layer to inner pockets positioned laterally above waist level under lining and they are placed symmetrically – one at each side. Two AA batteries are used in this variant.	Circuit advantages: Lower costs, zoning principle, balanced weight distribution. Circuit drawbacks: Quite complicated removal of electronic block before washing.
F	Removable layer in back part and inner pockets for power supply	Such symmetrical battery arrangement is preferable to use if electronic elements are located on removable layer on the back. Two AA batteries are used in this variant.	Circuit advantages: Lower costs, zoning principle, balanced weight distribution. Circuit drawbacks: Quite complicated removal of electronic block before washing.

Schemes of alternative variants of electronic elements arrangement and design in child jacket are shown in *Fig.2*.

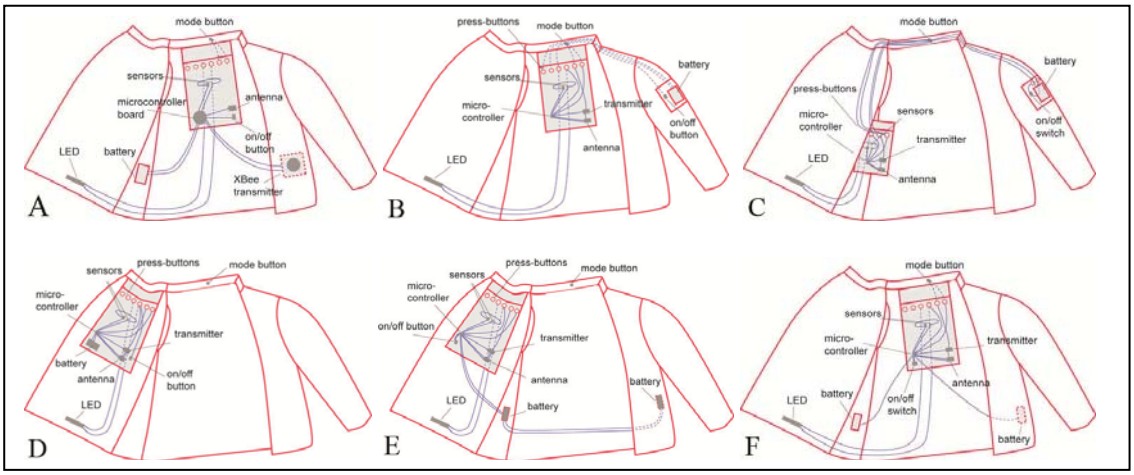

Fig.2. **Schemes of alternative variants of electronic elements arrangement and design in child jacket**

Decision making methods for objective analysis of subjective data

Decision making is the study of identifying and choosing alternatives based on the values and preferences of the decision maker. Making a decision implies that there are alternative choices to be considered, and in such a case we want not only to identify as many of these alternatives as possible but to choose the one that best fits with our goals, objectives, desires, values, and so on. To perform the multi-criteria analysis, we consider two proven techniques. The first one is ELECTRE, which aims at establishing an outranking relationship among alternatives. The second method is AHP, which is based on pairwise comparisons of criteria. The rationale behind choosing these methods was the fact that they are human-centered and enable one to model and formalize decision maker's subjective preference in a seamless and intuitive way.

● ***ELECTRE method description***

The ELECTRE methodology is based on the concordance and discordance indices defined as follows. We start from the data of the decision matrix, and assume that the sum of the weights of all criteria equals to 1. For an ordered pair of alternatives ($\mathbf{A}_j$,$\mathbf{A}_k$), the concordance index c_{jk} is the sum of all the weights for those criteria where the performance score of $\mathbf{A}_j$ is least as high as that of $\mathbf{A}_k$, i.e.

$$c_{jk} \sum_{i:a_{ij} \geq a_{ik}} w_i, \quad j,k = 1,...,n, \quad j \neq k. \tag{1}$$

Clearly, the concordance index lies between 0 and 1.

The computation of the discordance index d_{jk} is a bit more complicated: d_{jk}=0 if a_{ij}>a_{ik}, i=1,...,m, i.e. the discordance index is zero if $\mathbf{A}_j$ performs better than $\mathbf{A}_k$ on all criteria,. Otherwise,

$$d_{jk} = \max_{i=1,...,m} \frac{a_{ik} - a_{ij}}{\max_{j=1,...,n} a_{ik} - \min_{j=1,...,n} a_{ij}}, \quad j,k = 1,...,n, \quad j \neq k. \tag{2}$$

i.e. for each criterion where $\mathbf{A}_k$ outperforms $\mathbf{A}_j$, the ratio is calculated between the difference in performance level between $\mathbf{A}_k$ and $\mathbf{A}_j$ and the maximum difference in score on the criterion concerned between any pair of alternatives. The maximum of these ratios (which must lie between 0 and 1) is the discordance index.

A concordance threshold c* and discordance threshold d* are then defined such that 0<d*<c*<1.

Then, $\mathbf{A}_j$ outranks $\mathbf{A}_k$ if the c_{jk}>c* and d_{jk}<d*, i.e. the concordance index is above and the discordance index is below its threshold, respectively.

This outranking defines a partial ranking on the set of alternatives. Consider the set of all alternatives that outrank at least one other alternative and are themselves not outranked. This set contains the promising alternatives for this decision problem. Interactively changing the level thresholds, we also can change the size of this set.

The ELECTRE I method is used to construct a partial ranking and choose a set of promising alternatives.

● ***Analytic Hierarchy Process (AHP) method description***

The basic idea of the AHP approach is to convert subjective assessments of relative importance to a set of overall scores or weights [3]. AHP is a quantitative comparison method used to select a preferred alternative by using pair-wise comparisons of the alternatives based on their relative performance against the criteria [4]. For each pair of criteria, the decision maker is required to respond to a pairwise comparison question asking the relative importance

of the two. The responses can use the following nine-point scale expressing the intensity of the preference for one criterion versus another:
1= Equal importance or preference.
3= Moderate importance or preference of one over another.
5= Strong or essential importance or preference.
7= Very strong or demonstrated importance or preference.
9= Extreme importance or preference.
If the judgement is that criterion **C***j* is more important than criterion **C***i*, then the reciprocal of the relevant index value is assigned [3].

Description and analysis of criteria for electronic elements arrangement
One of the goals of this research is to carefully define a set of criteria that would make it possible to compare variants of arrangement as objectively as possible.
Criteria should be [3]:
− able to discriminate among the alternatives and to support the comparison of the performance of the alternatives,
− complete to include all goals,
− operational and meaningful,
− non-redundant,
− few in number.
Eight criteria were used for analysis and they are described below.
1. Dimension of electronics. It is preferable to use electronic elements, which are as small as possible in weight and size to ensure that the smart garment is comfortable to wear.
2. Electronic block removal. Since integration of electronic was provided in a way that makes it possible to remove it before garment washing, it is important to ensure easy electronic block removal. Attachment technology, number of disjoining cycles at one time etc. are considered.
3. Battery change. The power for this item is supplied from battery, so it is necessary to provide easy battery replacement – battery must be easy to find, to disconnect and to connect.
4. Cost. Costs of electronic elements were taken into consideration.
5. Microclimate data readout. It is preferable to place sensors in area where sweating is intensive, so that the sensors are able to react to the microclimate changes as fast and as precise as possible.
6. Weight distribution. Relatively proportional weight distribution is important – it is relevant from ergonomic aspect, as well as it prevents clothing from being skewed to one side.
7. Inaccessibility of electronic components by child. Since jacket is intended for a child, it is important that the child cannot access electronic block – to damage it or to injure himself by choking small elements.
8. Zoning. According to the analyzed principles of external and internal zoning it follows that the most suitable zones for electronic elements are front and back side of jacket till waist level, as well as small area on sleeve between shoulder and elbow.
Weight coefficients of criteria were estimated using AHP method, by indicating how important criterion **C***i* is relative to criterion **C***j*. Pairwise comparison matrix is shown in Table 2.

Table 2.

Pairwise Comparison Matrix

Crit.N.	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1	1	1.5	1.5	3	1.5	2.5	3	2.5
2	0.67	1	0.67	2.5	1	2.5	3	2.5
3	0.67	1.5	1	2	1	2.5	3	2.5
4	0.33	0.4	0.5	1	0.5	0.5	0.5	1
5	0.67	1	1	2	1	2	2	2
6	0.4	0.4	0.4	2	0.5	1	1	2
7	0.33	0.33	0.33	2	0.5	1	1	1
8	0.4	0.4	0.4	1	0.5	0.5	1	1

Comparison of electronic elements arrangement variants

The original prototype (P) and alternative improved designs (A, B, C, D, E, F) were considered in the analysis. Each variant was evaluated according to each criterion, evaluating it using a ten-point scale, where 1 was the lowest estimation and 10 was the highest estimation. Performance of alternatives on criteria was evaluated in relation to other analyzed alternatives, thus these evaluations are not universal and apply only to the problem considered. Estimations for alternatives and calculated weight coefficients are shown in Table 3.

Table 3.

Comparison of electronic elements arrangement variants

No.	**Criteria**	**Estimations for alternatives**							**Weight**
		P	**A**	**B**	**C**	**D**	**E**	**F**	
1	Dimension of electronics	4	4	10	10	10	10	10	0.21
2	Electronic block removal	10	7	9	9	10	7	7	0.16
3	Battery change	8	9	10	10	8	7	7	0.18
4	Cost	5	5	10	10	10	10	10	0.06
5	Microclimate data readout	9	9	9	10	7	7	9	0.15
6	Inaccessibility for child	10	10	10	7	7	7	10	0.09
7	Weight distribution	8	10	9	9	8	10	10	0.08
8	Zoning	4	8	8	9	10	10	8	0.07

Results

Concordance indices matrix of object dominance and discordance indices matrix of object dominance is calculated and the results are shown in Table 4. These indices are in interval 0...1 and define concordance and discordance with hypothesis that alternative A dominates alternative B.

Table 4.

Concordance and discordance indices matrix

Concordance matrix								Discordance matrix							
	P	**A**	**B**	**C**	**D**	**E**	**F**		**P**	**A**	**B**	**C**	**D**	**E**	**F**
P	-	0.12	0.12	0.25	0.25	0.5	0.25	**P**	-	0.11	0.6	0.6	0.6	0.6	0.6
A	0.38	-	0.12	0.25	0.5	0.38	0.12	**A**	0	-	0.6	0.6	0.6	0.6	0.6
B	0.62	0.5	-	0.12	0.5	0.5	0.25	**B**	0	0	-	0	0.1	0	0
C	0.75	0.75	0.25	-	0.38	0.38	0.5	**C**	0	0	0	-	0.1	0	0.3
D	0.38	0.5	0.25	0.25	-	0.25	0.38	**D**	0	0	0	0	-	0	0.3
E	0.5	0.38	0.25	0.25	0.12	-	0.12	**E**	0	0	0	0	0	-	0
F	0.5	0.25	0.12	0.25	0.38	0.25	-	**F**	0	0	0	0	0	0	-

The limiting values used in outranking relation are chosen to be c* = 0.45 and d* = 0.4. Partial ranking on the set of alternatives is shown in Fig.3.

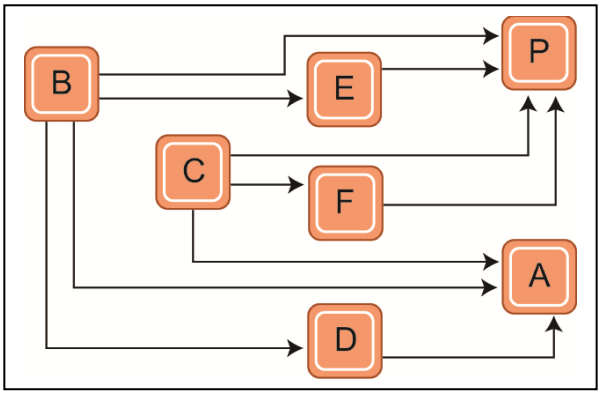

Fig.3. **Partial ranking on the set of alternatives**

In the diagram of partial ranking on the set of alternatives we can see that the most suitable variants for electronic elements arrangement in clothing are alternatives B and C, which are not dominated.

Concluding discussion

Comparison of several variants of arrangement of electronic elements in clothing based on decision making methods AHP and ELECTRE shows that the most suitable variants according to the selected criteria and evaluation of alternatives are variant B with removable layer in the back part and outer pocket for electronic elements and variant C with removable layer in the lateral part and outer pockets for electronic elements.

One of the goals of this research was to carefully choose a set of criteria what would make it possible to compare different variants of arrangement as objectively as possible. Such set is presented and description for each criterion is provided. The decision methods used, which are based on criteria selection and evaluation of alternatives, help to choose the most suitable arrangement of electronic components in smart clothing. This method is especially useful when large number of alternatives and criteria have to be analyzed.

This paper describes a study on designing of electronic part in a smart child jacket, which reacts to microclimate changes with the help of integrated electronics and signals about temperature and relative humidity inside the jacket. The paper describes arrangement of electronic components in jacket, as well as different ways of improving this arrangement by providing several alternative variants. Seven variants of arrangement are described, which are compared using decision making methods. To perform the multi-criteria analysis, two proven techniques were considered – AHP and ELECTRE. Comparison of several variants of arrangement of electronic elements in clothing shows the most suitable variants corresponding to the selected criteria.

Acknowledgment

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SYNTHESIS OF RECONFIGURABLE SLOTTED WAVEGUIDE ARRAY ANTENNA

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Introduction

Double mirror spherical antennas (DSA) are highly accurate and effective systems and are of great importance in antenna techniques. They are used in radio-astrology, remote space network and in other network spheres. The intensive development of the mentioned spheres entails the optimization of the antenna parameters. Accordingly the deliberate selection of the radiation system of those antennas is very important when solving a specific problem. For the optimatization of parameters of existing DSA and particularly the parameters of ROT-54/2.6 (radio optical telescope) [1] of Radio-physics Research Institute (RRI) Aragats Scientific Centre founded by RA academician Paris Herouni and for providing the multi-functionality the following conditions can be set on their radiation systems:

- During radio-astrological measurements it is essential to define the radiation field polarization of any cosmic object. For this it is necessary to provide the elliptic polarization of the radiation field.
- A multi-beam mode is required for increase in the effectivity of the distance scanning and for simultaneous observation of several objects
- The transformation of the RP is necessary when there are sources of interference in the observation area as well as for solving some target problems.
- A simultaneous maintenance of conducting and receiving operation mode.

Designing of the antennas with reconfigurable and electrical scanning radiation pattern that provide a multi-beam elliptic polarization, the optimization of the structure and parameters are of the most actual problems that require new solutions.

Materials and methods

There has been worked out a package (in Java and MatLab programming languages) for DSA modeling and quantitative evaluation of basic parameters as well as for defining the optimal view of the RP [2]. For providing different cases of amplitude distribution in DSA operating aperture the corresponding view of the radiator RP has been defined with the use of the program package. According to the implemented analysis, the ROT 54/2.6 secondary mirror optimal radiation condition, when we get the highest equal amplitude distribution in the antenna aperture, is provided if the index of radiator RP level under 119.7^0 angle is lower by 20.4 dB from the RP highest index, and the width of RP main lobe is 9^0. There have been defined the conditions for the change of the radiator RP view for providing the equability of amplitude distribution in the antenna's operating aperture caused by deformations conditioned by DSA movement in case of a radiator deviation from the focal location (table 1).

The data analysis makes it clear that within acceptable phase errors in case of the index increase of the radiator deviation from the focal location for maintaining the equability of amplitude distribution in the DSA aperture it is necessary to provide radiator RP main lobe width reduction as well as to provide the index reduction of the RP side lobe level in case of corresponding angle in the secondary mirror edges. It is to say that for the compensation of the equability break of the amplitude distribution in DSA aperture it is necessary to provide a dynamic reconfiguration of the radiator RP.

Table 1.

Focal distance	The width of the radiator RP main lobe $2\vartheta_{0,5}$ (deg)	The radiation angle in secondary mirror edges (deg)	The index of the radiator RP level in case of the radiation angle in the secondary mirror edges (dB)
0,5581	12	120,7	-19,4
0,5593	10	120,2	-20
0, 56	9	119,7	-20,4
0,5604	8,4	119,5	-20,9
0,5607	7,2	119,3	-21,9
0,5611	6	119	-22,5
0,5615	5,7	118,8	-23,1
0,562	5	118,5	-24,4

There has been developed a sketch project for designing a reconfigurable, multi-beam slotted waveguide antenna array (SWA) radiator with an elliptic polarization of the field that meets the above given requirements. For providing the condition of the elliptic polarization of the SWA radiation field the method of vibratory antennas with elliptic polarization has been used. According to it the intervertical antennas with linear polarization in the surface will provide an elliptic polarization of the radiation field in case there is a 90 degree phase difference between their current phases [3]. We can provide a 90 degree difference between intervertical waveguides with linear polarization with the use of angular bypass method well-known in ultra high frequency (UHF) techniques [4]. We shall provide an elliptic polarization of the radiation field with a tri-step angular bypass (frame-like) of SWAs with linear polarization. For developing the antenna RP formula we use the RP multiplication method [5].

We observe the antenna array, which is composed of N (the number) primary radiators that are extended on a certain V distance. We use Deckard's coordinate system in a way that the SWA centre coincides with the origin of the coordinate system. We define the array radiation field in the observation point (point R). The complex amplitude of the electrical field vector of the radiation of the n-th array element can be presented by through the following formula:

$$\dot{E}_n = iCA_n \exp i\psi_n \frac{\exp(-ikr_n)}{r_n} F_n(\theta_n, \varphi_n) e_n^0 \quad , \tag{1}$$

here A_n and ψ_n respectively are the amplitude and phase of the field created by the n-th aperture. $F_n(\theta_n, \varphi_n)$ is the RP of the n-th aperture. The aperture is a kind of magnetic vibrator. The RP can be calculated like the RP of an electrical vibrator:

$$F_{¾Ê}(\theta) = \frac{\cos[(\pi/2)\cdot\sin\theta]}{\cos\theta}, \tag{2}$$

r_n, θ_n and φ_n are the spherical coordinates of point R, e_n^0 is the orth, which describes the polarization of the radiation field of the n-th aperture, C is constant, which depends on the radiator type : $C = 30k \cdot l$, $k = \frac{2\pi}{\lambda}$ is the wave number, l is the length of the aperture.

The radiation field of the antenna array constitutes the vectoral sum of radiation fields of all the elements:

$$\dot{E} = \frac{CA_1}{r} ie^0 F_n(\theta, \varphi) \sum_{n=1}^{N} a_n e^{i\psi_n} e^{ikr_n \cos\alpha_n}, \tag{3}$$

If the elements of the array have different polarization, the radiation field of each element can be presented through the sum of E_θ meridian and E_φ azimuthal constituents.

$a_n e^{i\psi_n} = I_n$ is the current n-th aperture. Suppose H_{10} basic wave is spread through the waveguide. In case of non-resonance system it is supposed that SWA apertures are stimulated with $\Delta\psi = 2\pi d/\lambda_{\text{w}}$ (d is the distance between the apertures) phase deviations (for adjacent co-phase apertures) and $\Delta\psi = 2\pi d/\lambda_{\text{э}} \pm \pi$ (for adjacent interconnected apertures). I we take into consideration that in each case of SWA angular bypass the aperture stimulation phase changes by $\pi/2$ then the power calculation algorithm should be developed in a way that after $n = \frac{N}{4}$ aperture (a single angular bypass) the aperture phase changes: $\psi_n = \frac{\pi}{2} m$ ($m = 1, 2, 3$).

$r_n \cos\alpha_n = x_n \sin\theta\cos\varphi + y_n \sin\theta\sin\varphi + z_n \cos\theta\cos\varphi$,

where r_n is the n aperture distance from the antenna central axis. It is limitary and is defined according to the evaluation of the DSA focal location parameters.

α_n is the angle formed between r_n and the radius vector of the observation point,

x_n, y_n and z_n are the coordinates of the n-$^{\text{th}}$ aperture.

In formula (3) the sum presents the directedness multiplier of the system:

$$f_{\Sigma}(\theta,\varphi) = \sum_{n=1}^{N} a_n e^{i\psi_n} e^{ikr_n \cos\alpha_n}, \qquad (4)$$

The SWA radiation field dimension will be defined by the following formula:

$$E = \frac{CA_1}{r} F_n(\theta,\varphi) f_{\Sigma}(\theta,\varphi) \qquad (5)$$

The SWA amplitude RP will be defined by the following formula:

$$f(\theta,\varphi) = F_n(\theta,\varphi) \sum_{n=1}^{N} a_n e^{i\psi_n} e^{ikr_n \cos\alpha_n} \qquad (6)$$

Results and analysis

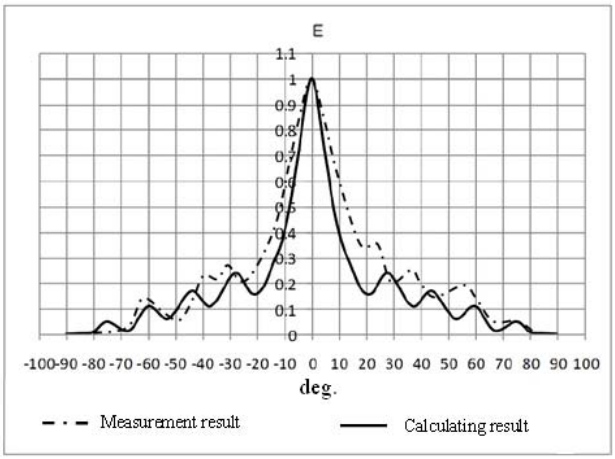
There has been developed a model for calculating the frame SWA with the use of LabVIEW program package. At first calculation were done for static SWA in 6 sm length operation wave diapason to make sure that we provide mentioned requirements with this approach. According to calculation data there has been designed and made frame SWA in RRI base laboratory (fig. 1).

Fig. 1. **Static SWA**

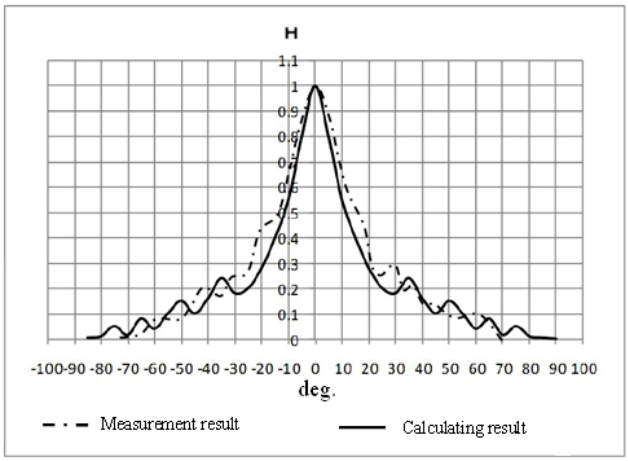
According to the measurements the polarization ellipticality coefficient of the frame SWA is $k_e = 0{,}81$, polarization ellipticality angle - $\beta = 18^0$, gain=11 dB.

In combination with "National Instruments" tools there has been developed a laboratory stand for the measurement of the antenna RP and a measurement model with the use of LabVIEW program package has been designed [6].

The results of measurements and calculations of frame SWA RP respectively on horizontal and vertical surfaces are presented in fig. 2.



a) horizontal surface



b) vertical surface

Fig. 2. **Radiation pattern of frame SWA**

Afterwards there has been sketched and made with elliptic polarization, reconfigurable, multi-beam SWA radiator with 3cm-length operation wave for ROT 54/2.6 antenna in RRI base laboratory in 2009. The radiator consists of three frame SWA parts (fig. 3).

For the combined operation of the frame SWA parts there has been designed a supporting construction. Each part has its own power system. Such a selection of the power system enables to provide comutational, simultaneous conducting and receiving as well as multi-beam operation mode.

Fig. 3. **Reconfigurable multi-beam SWA**

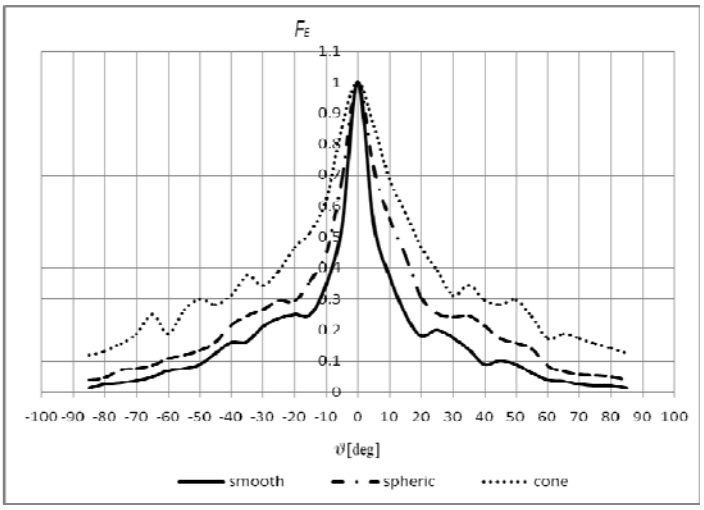


Fig. 4. **Radiation pattern of Reconfigurable multi-beam SWA**

Frame SWA parts can simultaneously work with similar as well as different frequencies this way providing the receiving of co-independent beams in the antenna aperture. The analysis of the measurement results makes it clear that the RP of each SWA part provides the required RP view of the radiator for DSA. The supporting construction provides for the simultaneous operation of the SWA parts along the central axis. Due to this peculiarity we provide the receiving of smooth, regimental and cone surfaces of the radiation. As a result of this we get different radiation parameters. The results of the measurements of the reconfigurable frame SWA RP in case of respectively smooth, spherical and cone surfaces are presented in fig. 4.
The distance between the antenna parts is changed with 5mm-length steps and basic electrical parameters are measured. The results of the measurements are presented in table 2.

Table 2.

SWA reconfiguration step (mm)	0	5	10	15	20	25	30	35	40	45	50
The width of the reconfigurable SWA RP main lobe $2\vartheta_{0,5}$ (deg)	4,8	5,1	6,3	7	8,5	10	11,8	13	15,3	17	18,4
The level index of the reconfigurable SWA RP in case of $119,7^0$ angle (dB)	-28	-24,2	-22	-21,7	-21,1	-20,8	-19	-18,7	-17.2	-16,4	-15
Gain (dB)	24	23,7	23,4	22,8	22,3	21,6	21.2	20,8	20,4	20	19,6
Polarization ellipticality coefficient	0.88	0.84	0.87	0.86	0.88	0.89	0.87	0.86	0.82	0.85	0.78
Polarization ellipticality angle (deg)	14	16	15	15.5	14	13.5	15	15.5	18	15,7	19

In case of increase in the dimension of the distance between the SWA parts the width of the RP main lobe increases. Simultaneously the level of the SWA RP side lobe increases in case of $119,7^0$ angle (a radiation angle in the secondary mirror edges). According to the received data the maintenance of the radiation optimal condition of ROT 54/2.6 antenna radiator is received when the distance between SWA parts constitutes 25mm.

According to the data brought in the table 2 through the mechanical reconfiguration of this antenna we shall provide the changing conditions of radiator RP view for the maintenance of equal amplitude distribution in DSA aperture in case of radiator deviation from the focal location. The change in the reconfigurable SWA RP view can be achieved also through RP electrical oscillation typical to SWA's.

According to the measurements the overall mirror surface using factor is reduced by 6% in case of the highest possible radiator deviation from the DSA focal location (within acceptable indexes of phase deviation). It becomes possible to restore the surface using factor by 5.2% with reconfiguration of the SWA radiator.

Conclusion and inference

1. The calculation data received from the developed formula of the RP of multi-beam reconfigurable frame SWA with elliptic polarization of radiation field correspond to the results of experimental measurements.
2. The laboratory stand designed for the measurement of basic parameters of the antenna distant zone, in combination with National Instruments tools and the use of LabVIEW program package provides the efficiency and rapidity of the measurement.
3. With the use of the suggested multi-beam, reconfigurable frame SWA with an elliptic polarization of radiation field the deformation deviations conditioned by the motion can be minimized hereby providing equal amplitude distribution in DSA aperture. It is an optimal radiator for ROT- 54/2.6 antenna.
4. The antenna surface using factor can be corrected by 87% with the use of SWA-radiator in case of the radiator deviation from the focus location caused by different deviation deformations which in their turn are conditioned by ROT-54/2.6 antenna movement.

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PATH PLANNING USAGE FOR MOBILE ROBOTS

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Abstract. *The paper deals with path planning programme for mobile robots. The aim of the paper is to develop a path planning programme for mobile robots that is based on simulation software development. The results of the careful analysis were considered for optimal path planning algorithms. The experimental evidence was proposed to demonstrate the effectiveness of the algorithm for steady covered space. The results described in this work can be extended in a number of directions, and applied to other algorithms.*

Keywords: *robotic, robot, RRT, RRT*, path planning.*

Introduction

In order to achieve the wide range of the robotic application it is necessary to provide iterative motions among points of the goals. For instance, in the industry mobile robots can replace any components between a storehouse and an assembly department. Ammunition replacement is widely used in military services. Working place is possible in ports, airports, waste site and etc. Mobile robots can be used for monitoring if it is necessary to observe control points in the secret place. There are a lot of scenarios where the iterative motion is applied [1].

The environment for such mobile robots used is complicated, various, non – structural and dynamic by nature. Robots must get rid of the obstacles which are different in size, form, location and can appear or disappear at any time. At that time avoiding the obstacles the possible of collision risk, sensor information and movement planning imprecision, error location and uneven surface are always foreseen. Robot can be damaged, trapped or embed in any construction etc. Environmental imprecision is always very hazardous for mobile robots [2].

At the same time the effective utilization is required from robots. Robots should work as much as possible and fast and safely [1, 3, 4]. Although the safety of people and the place of their living is primary and the same can be said about the safety of robots as well.

Algorithms for motion planning have proved themselves as optimal methods in this planning. The best conditions are normally measured with a distance. But it is possible to measure the conditions mentioned differently. For instance, in order to find safe ways space robots take into consideration surface, roughness and slope. However, the effectiveness of complex, dynamic and partly unknown spaces was not investigated for a long time. Nowadays, it is little research in the choice of motion planning in the dynamic conditions. Approaches [5, 6, 7] admit that environmental structure is known as *a priori*. In source [8] it is admittable that unknown environment is static and unchangeable during some period of time. Source [9] reflects uncertainty except the two previous statements.

Commonly, in order to work out any motion planning system which is used mobile robotic platform and it is necessary to do the following tasks:

- to familiarize with the essence of motion planning task i.e. to observe the algorithm of classical and modern planning;
- to identify the advantages and disadvantages of the algorithm;
- to select the most relevant algorithm;
- to work out system design.

The representation of working area for the robot can vary from continuous geometrical behavior to approved decomposition of topological maps. The first step for any motion planning system is permanent environmental model transformation in the map relevant to the

motion planning algorithm chosen if it is possible. The motion planning distinguishes due to the influence on the discrete decomposition. The three basic decomposition strategies can be mentioned [1]:

- Motion maps: to show the package of motion in free space;
- Unit decomposition: to distinguish empty from occupied units;
- Potential field: robot reaches the target unit if it follows the least resistance direction. That function is sometimes called as navigation function if additional conditions are added.

Then some motion planning algorithms can be briefly envisaged i.e. RRT and RRT*.

Goals

According to the mentioned above statement to compare RRT and RRT* algorithms by means of simulation is becoming rather interesting.

The aim of the research paper is to analyse motion planning algorithms that contain the design of modelling programme. The programme is needed as environment modelling to obtain the simulation data. The programme product is based on RRT algorithm. The simulation data give the possibility to conduct the wide analyses for selected algorithm. Analysis means the simulation data interpretation and comparison with other data obtained using the RRT* algorithms for motion planning.

Methods

RRT – in the last decade the motion planning algorithms on the basis of step sample have been proved as efficient ones and worked out theoretically as probable definiteness. The theoretical limits of these algorithms have not solved so far. It is proved that RRT algorithms always converge but do not insure the optimal magnitude.

RRT* - the algorithm always converges and insures the optimal motion planning. RRT* saves asymptotical optimality and holds the tree structure as RRT. Both algorithms are different in means of construction of motion planning maps [1, 10].

The use in practice and the necessity of it is very connected to autonomous robots that move in the space and are able to plan route on their own. One of such robots exiting in our everyday life is autonomous vacuum cleaner. Autonomous vacuum cleaners do not usually use the motion planning algorithm. They are based on different simple algorithms, for example cleaning in a spiral, crossing the premises avoiding the walls and their moving is casual after touching the walls. The philosophy of this design was proposed by the scientists of Massachusetts Institute of Technology. Robots must be like insects having primitive controlling devices aimed at the environment. As a result, an autonomous vacuum cleaner is very effective in cleaning premises, but much more time is required for them as compared with work made by a person. There is a drawback, the autonomous vacuum cleaner tidies one and the same places many times but other places are cleaned only once. The use of motion planning algorithms can raise the effectiveness of an autonomous vacuum cleaner.

Assumptions

In order to fulfill the aim of the research paper the following conditions are introduced for:

- premises where an object moves;
- robot (or object) moves around the premises;
- path the robot moves on in the premises.

The premises are presented as two – dimensional plane. The plane of premises is equally divided into the checks. The check dimensions are equal to robot dimension that moves in the premises. The robot moves only one check forward and back. During one motion the object can move to the one check from empty eight ones (eight checks around one check) paying attention to that check is not occupied by the obstacle.

RRT algorithm is introduced to the programme product as the only one which calculates the motion planning task (fully covers all empty space).

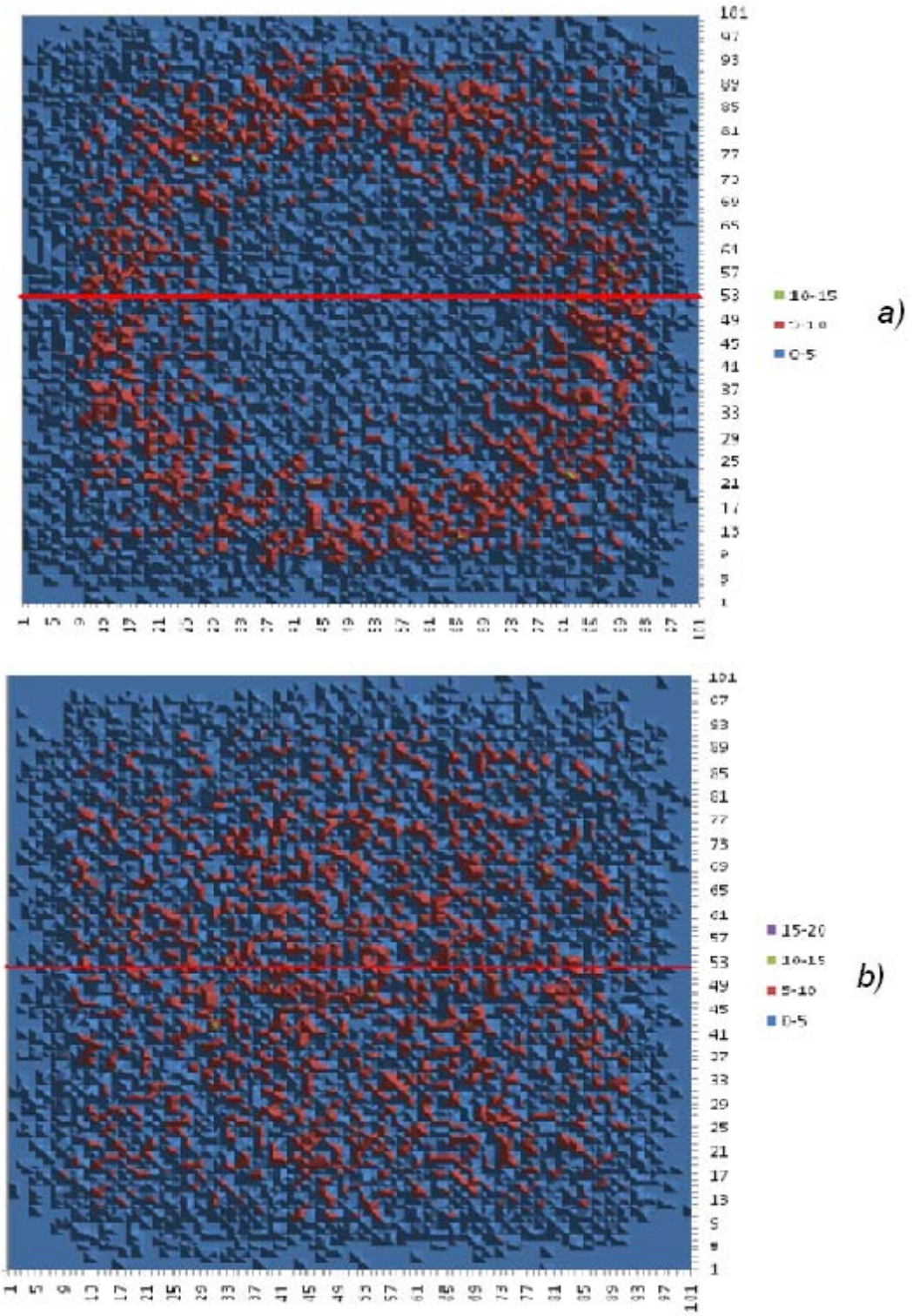

Fig.1. **Density of the covering (a – for RRT; b – for RRT*; and where a red line is longitudinal section)**

The results were compared with RRT* algorithm data. In order to receive the data based on RRT* algorithm, the new programme product was not developed from the very beginning but an open source programme was extended and coded in *C* programming language. The changes had to be made because the programme calculated the path of motion planning

between two points. After the first section which is the only the programme did not continue the motion planning i.e. to choose the next point freely from empty points (with the way covered or obstacle). A drawback of the programme (taking into account the requirements claimed before) was successfully kept away extending the programme code.

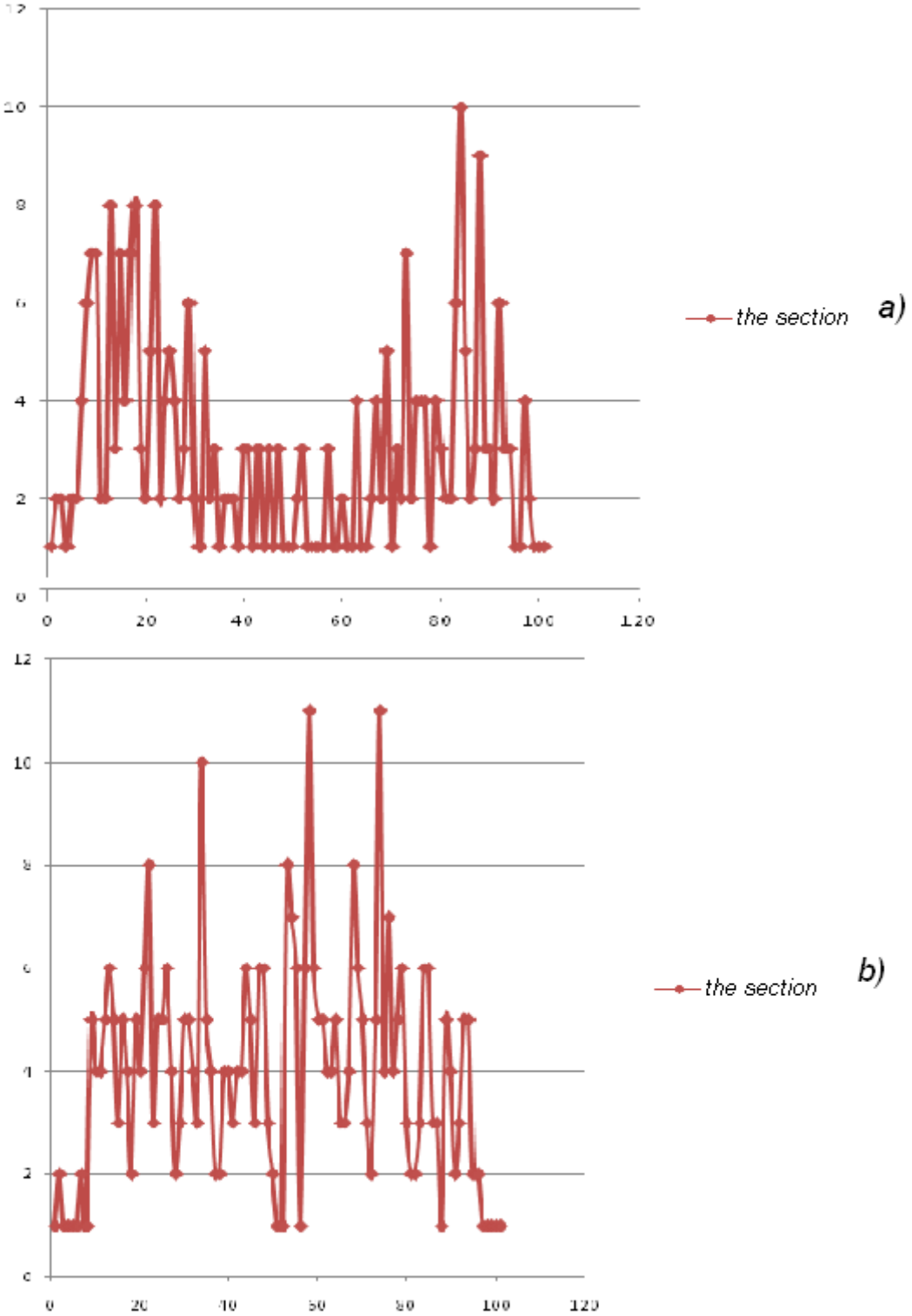

Fig.2. **Density of the covering in longitudinal sections**
(see Fig.1; a – for RRT; b – for RRT*)

In this research paper both algorithms were compared practically using and combining different placement of obstacles in the unchangeable two-dimensional space. All the results

were obtained on one and the same computer (2.66 GHz processor and 2GB RAM), operating systems (Microsoft Windows XP or Ubuntu 10.10 Linux were used). The following information was collected about:

- the number of covering for each check;
- the time which was necessary for both algorithms to plan the route.

The given illustrations show the density of the covering (how often a robot covers each check), but the cutting is demonstrated with a red line on a definite axis (Fig.1 and 2).

Results

Different coverings of the premises using RRT and RRT* algorithms in the identical conditions are shown in the research paper. The measure of the premises during simulation was not changed (100 x 100 checks) but the dimensions, placement and the number of obstacles in the premises were changed. The simplest case is when the premises do not contain any obstacles i.e. completely empty. So, for example the simulation was done in the empty premises using the both algorithms. This process was repeated several times. It is very important to stress that the principle of previously mentioned process was used for the placement of any obstacles in the premises i.e. not only in the case of utterly empty premises. The simulation data were calculated as average ratio to the number of simulation repetition. During each simulation the following characteristics were calculated:

- the number of initial empty checks;
- the time which was necessary to plan the route to cover the whole premises;
- the total number of steps taking into account the facts that a robot can move one and the same check several times.

Table 1.

Some typical comparison values between RRT and RRT*

Number of free checks	t_{mp_RRT} (where t_{mp} - period of time of motion planning)	N_{RRT} (where N - number of steps)	t_{mp_RRT*} (where t_{mp} - period of time of motion planning)	N_{RRT*} (where N - number of steps)	t_{mp_RRT*}/t_{mp_RRT}	N_p (%) (where N_p - least number of steps for RRT*)
10201	185	32303	1020	31782	5.51	1.62
7800	170	26064	600	4283	3.53	6.83
4582	172	14147	960	12761	5.58	9.90
5191	180	12596	1000	10829	5.56	14.03
5510	180	11441	840	9681	4.67	15.38

Periods of time of motion planning for RRT and RRT* algorithms were compared (i.e. RRT* period of time were divided with RRT interval of time). The results of division were between 3.53 and 5.58 times for different placements of obstacles. It means that motion planning for RRT algorithm is 6.14 times faster at least. It is very important to stress that periods of time of motion planning were between 3 and 15 minutes (15 minutes applies to RRT*). Route was planned better with RRT* in comparison with RRT and premises were covered more regularly that was observed from Surface diagram. RRT* showed the better results than RRT did in case the number of occupied checks were increased. The least number of steps was needed in the case of RRT*, i.e. between 1.62% and 15.38% least number of steps. It is very important to stress that the number of steps was oscillated between 9681 and 32303. The total period of time for route can be between 9681 and 32303 s (2.69 and 8.97 hours) if considering that real robot performs 1 step a second (Table 1).

Conclusion

The period of time for route is bigger than period of time for motion planning and it restricts all the process. The period of time for route planning can be decreased if computational power is increased. That is why the effectiveness of robot depends on effectiveness of rout planning, i.e. from the number of steps. The using of RRT* can improve real robot effectiveness from 1.67% to 15.38%. It is very important to stress that effectiveness of process is strongly connected to energy saving and it is possible to prove that 15.38% of electric power can be saved.

Both algorithms can be successfully used in the requirements of autonomous tasks for robots, military technology and dynamic games.

Therefore, it is possible to use motion planning algorithms in other fields of studies which are out of rout planning.

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VII

SUSTAINABLE AGRICULTURE

COMPARATIVE TECHNOLOGICAL AND COMMERCIAL EVALUATION OF FLAX VARIETIES FOR THE REVIVAL OF FLAX GROWING IN LATVIA

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Abstract. *As renewable raw material flax increasingly gain more importance as the range of its use is spreading more and more. Besides the conventional uses in home textiles, clothing and sails products, demand of flax raw materials for technical uses increases rapidly as flax fibers have high specific properties, become components of biodegradable composites, environmental friendly isolation materials, besides flax shives pay attention as well as components of environment friendly building materials. Unfortunately in Latvia during last decades flax crop production had decreased rapidly and nowadays reintroduction of flax growing traditions and conditions are become more and more actual. In spite of depression in sector, in Agriculture Science Centre of Latgale are not interrupted experiments on development of local flax lines. Field trials were sown at the Centre in 2010 and 98 flax lines investigated. In this article reflected analysis results of one perspective local fibers flax line from different aspects and its properties comparison with the standard fibers flax variety Vega 2.*

Keywords: *flax, fibers, variety, bast crop production, biodegradable, renewable recourses.*

Introduction

In conformity with the world trend a more intensive use of renewable raw materials gets more and more attention from police makers and scientists. Bast crop production is one of opportunity to supply renewable raw materials for a wide range of applications. In the same time it is an important key to the creation of employment in crop growing and processing areas and the development of a sustainable economy of the region and country.

As renewable raw material flax increasingly gain more importance as the range of its use is spreading rapidly. Besides the conventional uses in home textiles, clothing and sails products, demand of flax raw materials increases for technical uses as flax fibers have high specific properties: a low density, water absorption, they are soft and flexible, stronger than cotton or wool. Moreover, all flax components are recyclable and fully combustible without the production of noxious gases, can be obtained at a comparatively low cost. Strength and biodegradability attract attention as reinforcement of partly or fully biodegradable fiber plastic composites and breathing isolation materials. Even the woody core shives, which are removed during scutching, are used for particleboards and animal bedding (9)

As flax is a crop for temperate regions and requires abundant moisture and cool weather during the growing season (Berger, 1969) it meets proper Latvian climate conditions. Although climate conditions is favourable for flax cultivation, during last decades flax crop production in country was decreased fast (Developm., 2006). At the same time flax is one of the oldest sources of textile fibers used all around in the world as well in Latvia too. At the first part of twenty century Latvia was successful in flax fibers export to European countries.

Nowadays flax fibers is a scarce resource in Latvia, our linen producers are almost fully dependent from imports (Fig. 1).

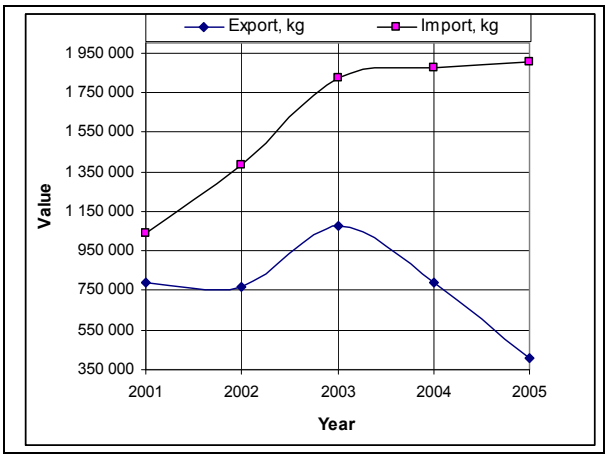

Fig. 1. **Latvian flax fibers export-import balance**[2]

Materials, methods

The reintroduction of a crop involves the question of quality and predictability, as well as the environmental conditions under which profitable production may be undertaken. Varieties enter into the quality and predictability of the crop. The object of our work has been to determine which variety is most desirable from the standpoint of fiber production and determine predictability of agronomical, commercial and technological properties. In order to solve this problem, a comparative study of properties of available local 98 flax varieties/lines cultivated in field experiments in Agriculture Science Centre of Latgale at 2010 was made, following the routine methods (Stramk., 2009) and compared with the corresponding properties of Lithuanian variety Vega 2 as a standard. Summer of year 2010 with high temperatures and unsufficient rains was quite unfavorable for flax growing. Varieties were evaluated and compared for 8 commercial and fibers production variables (Stramk, 2010), a description of variations in the performance of fiber flax varieties is also necessary as current guidance and the differences between the varieties were analysed. As for varieties and lines under inspection variability of properties are high, analysis is carried out by using methods of mathematic statistics such as descriptive statistics, correlation, distribution curves and regression analysis.

To investigate interdependence between variables with influence on fibres productivity correlation coefficients R are calculated for variables average values of all 98 varieties (Table 1). Largest values of correlation coefficient take place between unretted stem yield and bast and shives yield, respectively R = 0,78 and 0,73, corresponding determination coefficients 61 % and 53 %; more impact on retted stem yield has shives yield (R = 0,83), less fibres yield – R = 0,7. Coefficients with values in range from 0,7 till 0,5 witness on medium strong correlation between unretted and retted stem yield (0,61), bast and fibres content (0,66), retted shives and fibres densities (0,65); values close to 0,2 or less present evidence that no correlation between corresponding variables at all. It means that after retting correlation absent between fibres yield and fibres content, stem yield and fibres content.

As it is not easy in flax growing practice to make decisions with a line of variables, all range of varieties/lines were sorted by fibers content and by fibers yield, as a result first 12 varieties with the best values of main parameter are separated (fig.2 and 3).

Table 1.

Correlation matrix

	Unreted				Dew reted			
	Stem yield, g/m^2	**Bast content, %**	**Bast yield, g/m^2**	**Shives yield, g/m2**	**Stem yield, g/m^2**	**Fibers content, %**	**Fibers yield, g/m^2**	**Shives yield, g/m^2**
Stem yield, g/m^2	1,00							
Bast content, %	0,29	1,00						
Bast yield, g/m^2	0,78	0,38	1,00					
Shives yield, g/m2	0,73	0,23	0,72	1,00				
Stem yield, g/m^2	0,61	0,31	0,70	0,58	1,00			
Fibers content, %	0,21	0,66	0,28	0,10	0,16	1,00		
Fibers yield, g/m^2	0,56	0,33	0,61	0,41	0,70	0,29	1,00	
Shives yield, g/m^2	0,58	0,18	0,57	0,52	0,83	0,09	0,65	1,00

As seen from Fig. 2 graph for all 12 selected varieties/lines fibres contents are higher then for standard variety Vega 2 (for line S37-11/15-93 diference 22 %). The graph testify that inside this short range correlation between bast content and fibers content after dew retting absent too.

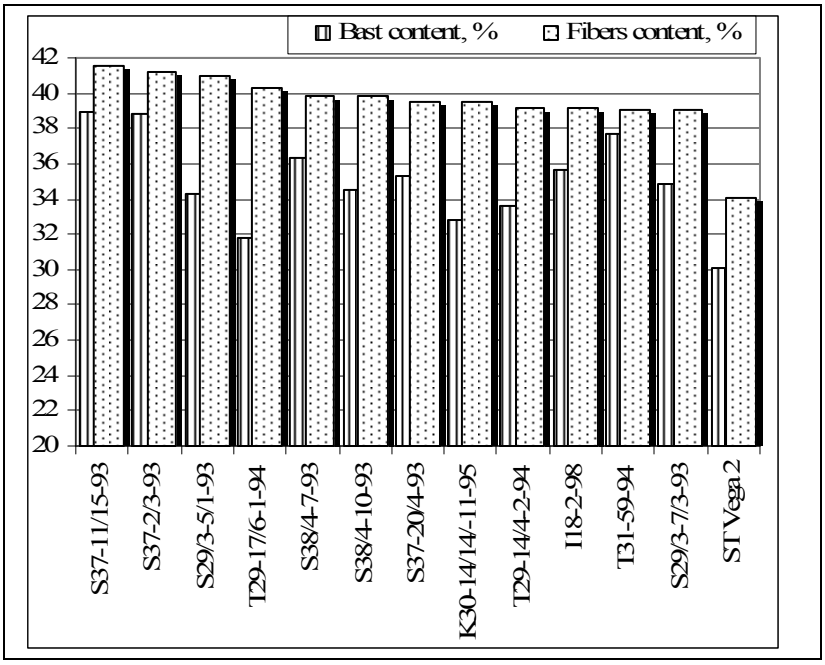

Fig. 2. **Alteration of fiber contents after dew retting**

Sorting results by fiber yield values shown in Fig.3 represent first twelve favourable by this property flax lines. Diference between line with higher rank and standard variety is quite impressive - 43,6 %. It is not hard to see from Table 2 that varieties/lines in both columns

are different. As a cosequence question arise which of these two properties are more important? More commercial is second one – customers pay for fibers yield.

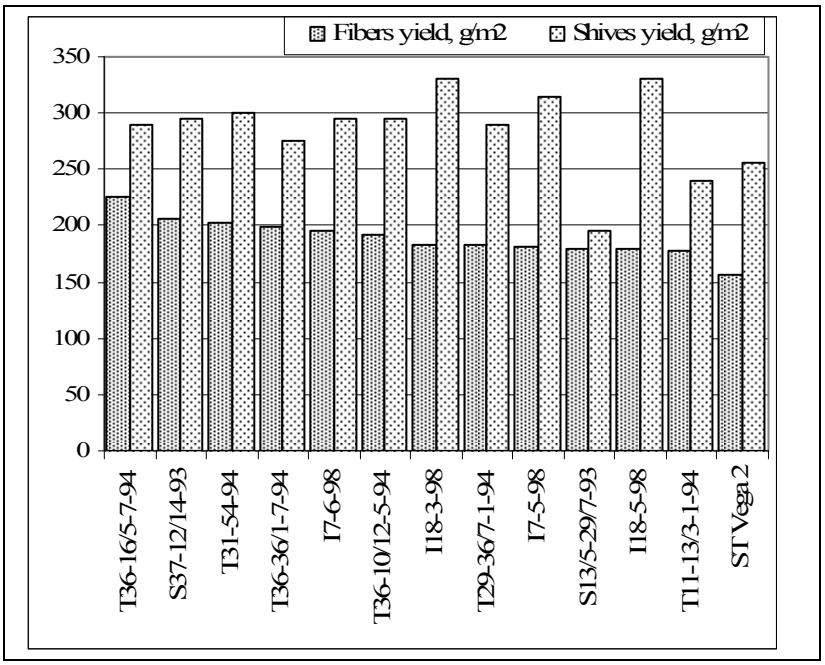

Fig. 3. **Alteration of flax fiber yield after dew retting**

Table 2.

Comparative range of flax lines sorted by fibers content and fibers density after dew retting

	Flax variety/line	
	Sorted by fibers content	**Sorted by fibers yield**
1	S37-11/15-93	T36-16/5-7-94
2	S37-2/3-93	S37-12/14-93
3	S29/3-5/1-93	T31-54-94
4	T29-17/6-1-94	T36-36/1-7-94
5	S38/4-7-93	I7-6-98
6	S38/4-10-93	T36-10/12-5-94
7	S37-20/4-93	I18-3-98
8	K30-14/14/-11-95	T29-36/7-1-94
9	T29-14/4-2-94	I7-5-98
10	I18-2-98	S13/5-29/7-93
11	T31-59-94	I18-5-98
12	S29/3-7/3-93	T11-13/3-1-94

From a technological viewpoint fiber yield is more important too, but not less important are technological properties which are differ dependent on technology applied for processing and end usage of fibres. Important for most applications are fibres tensile properties. In this article is compared tensile strength of a small fiber bundles prepared for testing with 3 mm distance between clamps, testing clamp velocity 150 mm/min. of local variety T36-16/5-7-94 and standard Vega 2. In the result of tensile tests of one hundred samples from line T36-16/5-

7-94 and standard variety Vega 2 is found out that average tensile strenght of T36-16/5-7-94 is almost 2 times higher than for Vega 2 fibers (Table 3).

Table 3.

Comparative tensile strength parameters of flax line T36-16/5-7-94 and variety Vega 2

	Average, N	Mode, N	Median, N	Range, N	Absolute deviation, N
Vega 2	10,35	10,30	10,30	16,7	0,37
T36-16/5-7-94	20,40	18,00	19,25	17,2	0,42
Diference, %	97%	75%	87%	3%	15%

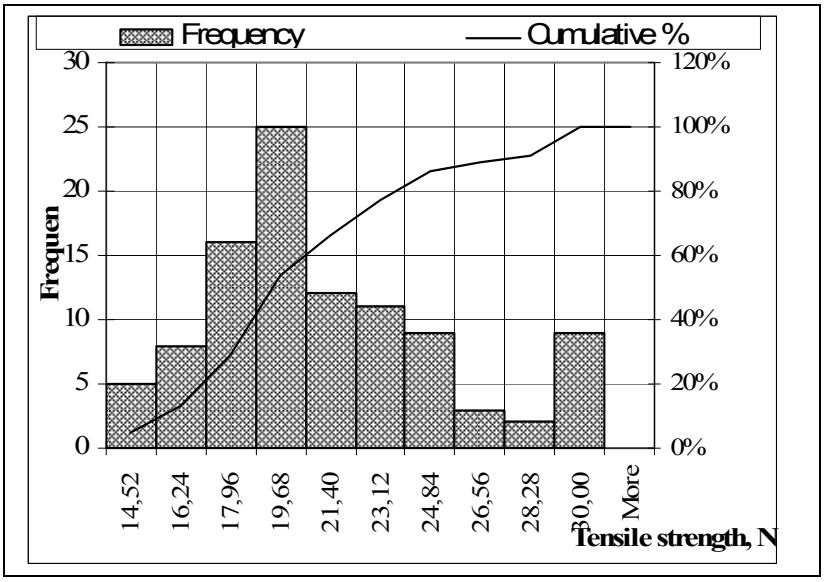

Fig. 4. **Tensile strength histogram of flax line T36-16/5-7-94**

Results and discussion

As seen from tables 2 and 3 identified flax line T36-16/5-7-94 developed in Agriculture Science Centre of Latgale shows higher fiber yield in 2010 as standard variety Vega 2 (43,6 %) and quite high fibres content - 37,7 %. From commercial viewpoint line T36-16/5-7-94 is quite promising breeding line for further developments to create flax variety resistant to dry and warm weather conditions during vegetation period.

Agriculturally important traits, such as flax total plant height 90 cm, technical plant height 78,2 cm (higher then for the selected best lines in period 2007-2008, Grauda, 2009 and TOND., 2003), logging resistance 9, vegetation period 75 days, yield of straws 6130 kg/ha and yield of seeds 670 kg/ha (Stramk., 2010) are reasonable. Comparison of properties of the line T36-16/5-7-94 with properties of the line S37-11/15-93 shows that flax average total plant height 84,4 cm and technical plant height 73,8 cm are lower, logging resistance 10 higher, vegetation period 81 days longer, yield of straws 5430 kg/ha lower, and yield of seeds 1160 kg/ha (Stramk, 2010) higher then corresponding agricultural properties of the line T36-16/5-7-94. Retted fibres yield is 1,38 times higher for the flax line T36-16/5-7-94 to compare with S37-11/15-93.

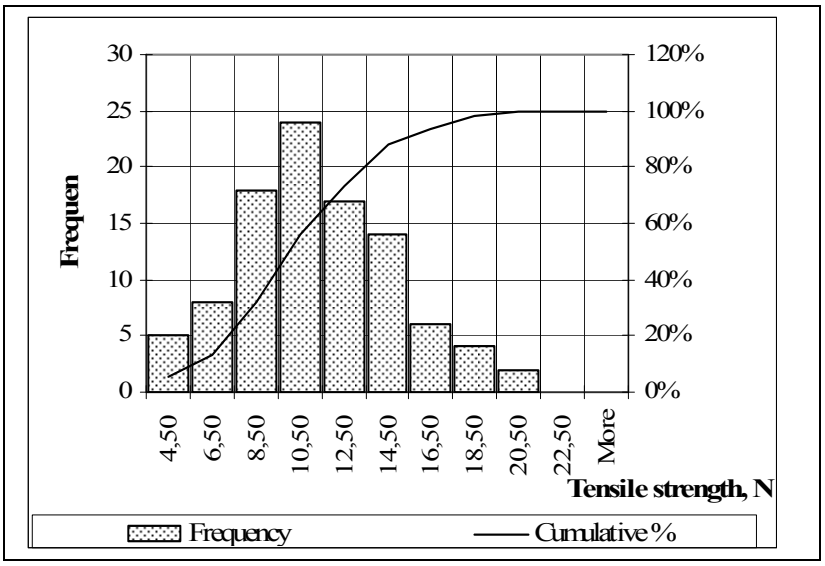

Fig. 5. **Tensile strength histogram of flax standard variety Vega 2**

To evaluate this variety from technological and usage viewpoints from Table 3 and compare graphs of Fig. 4 and Fig. 5 we can see that flax line's T36-16/5-7-94 all main parameters of tensile strength distribution are higher then for Vega 2 (Table 3). Distribution in entirety of T36-16/5-7-94 is shifted to higher tensile strength values compare with histogram of Vega 2 (Fig. 3 and Fig. 4) and is missing quite voluminous (~ 30 %) segment of fibres with tensile strength 6,5 N and less. Inspected characteristics are important for flax fibres processed into consumer or technical textiles or composite materials.

Conclusions

Flax breeding line T36-16/5-7-94 shows higher agricultural, commercial and technological properties resisting to unfavourable for the flax cultivation climate conditions at summer of year 2010 and in that way is treated as a serious candidate for the development of local fibres flax variety with medium long vegetation period, resistant to extreme weather conditions and with good commercial and technical performance.

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BREEDING FOR ORGANIC FARMING: OBTAINING AND EVALUATION OF FLAX SOMACLONAL FAMILIES

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Abstract. *Plant calli culture could be used as a source of genetic changes (somaclonal variation). There are known several flax varieties, bred on the basis of somaclonal variation, with improved resistance to biotic and abiotic stresses, plant height, seed yield and other traits. This method is useful for obtaining the new initial material for flax breeding, including for intensification of breeding for organic farming. Goal of the study was to obtain plants-regenerants from the calli culture of the fibre flax variety 'Vega 2' and to evaluate their agronomical traits and resistance to powdery mildew. For obtaining plants-regenerants was used early elaborated protocol of somatic calli cultivation. Agronomically important traits, such as total and technical plant height, number of seed vessels, number of seeds in a seed vessel, and resistance to diseases were evaluated. Most of somaclonal families had higher total and technical plant height in comparison with the initial variety 'Vega 2'. In the opposite, number of seed vessels and number of seeds in a seed vessel had a tendency to decrease. It was concluded that even changes in not desirable direction may be recognised as an indirect indicator of the rather high level of induced somaclonal variation, which can occurred also in traits, which were not evaluated during this experiment, therefore there is a potential to exploit flax somaclonal variation in applied breeding programs as an additional source of variability.*

Keywords: *fibre flax, calli culture, somaclonal variation, agronomical traits.*

Introduction

Processing and use of different types of renewable resources is an actual task for future development of industry. Among them are different crops, adapted for growing in appropriate territories. Flax, from this point of view, is very promising cultivated plant because it can be used for producing of wide choice goods and products. From the one hand, flax seeds contain up to 40% of oil, and are very riche source of polyunsaturated fatty acids, vitamins, proteins, muciloginous substances and antioxidants. Thanks this fact flax oil is used broadly in medicine and modern pharmacology. Flax seeds are used as well as a source of industrial oil in the production of paints, varnishes, inks, linoleum *etc*. From the other hand, flax fibre and shove can be used in textile industry, as engineering and building material, and as well as the energy resource [1]. Exclusive new flax niche products with high added value could be produced by organic farming.

For obtaining of high-quality yield the choice of appropriate varieties is crucial. Unfortunately, presently there are not officially registered and recommended for growing any local flax varieties suitable for the Latvian weather conditions. Therefore an important task for the Latvian flax breeding is obtaining high yielding, middle early varieties with the good resistance to logging and to flax diseases, which could be suitable both for conventional and organic farming. For obtaining a good yield in conditions of organic farming especially important is variety resistance to biotic and abiotic stresses. Breeding of flax even nowadays is a long and complicated process, based on hybridization and selection of the best plants. Taking in account the facultative cross-pollination, the development of genetically stabile lines could take more than 15 years [2, 3].

For intensification of the breeding process we are looking for a possibility to use methods of biotechnology, for example, somatic calli culture, to obtain additional flax breeding initial material without necessity of crossing of different parent genotypes. It is well known that plants- regenerants from calli culture often perform higher variation, so called somaclonal variation. Somaclonal variation has been described for many crops, including flax. Three types of the variation are described: heritable stable, heritable unstable and non-heritable (epigenetic) [4-6].

From practical point of view it is important that many changes occur in agronomic traits, for example in disease resistance, dates of heading and maturation, plant height, seed yield and quality *etc*. [7-10]. However, the possibility to select and use somaclonal variants in breeding is different for specific traits and is considerably depended from the genotype of particular variety. By explore of somaclonal variation, new flax lines have been derived with increasing resistance to biotic and abiotic stress, plant height, number of seeds in a vessel, and number of seeds [11-13]. The goal of the study was to obtain plants-regenerants from the calli culture of the commercially registered in Latvia fibre flax variety 'Vega 2', bred in Lithuania, and to evaluate their agronomical traits and resistance to powdery mildew.

Materials and methods

Obtaining of somaclonal families

For calli induction explants (stem segments) of the variety 'Vega 2' were placed on the Murashige and Skoog (MS) medium with 2,4-dichlorophenoxyacetic acid (2,4-D, 1.0 mg/l). As a calli regeneration medium was used MS medium with 6-benzylamiopurine (BAP, 1.0 mg/l), for induction of shoot formation MS medium with addition of indolil acetic acid (IAA, 0.1 mg/l) was used. Shoots of regenerants with the length 3-6 cm have been cut 2-4 times and rooted. Plantlets with roots about 0.5 cm were planted in the autoclaved sand fertilized by 0.5 MS medium salts. Well rooted plants were transferred from the sand into soil and covered by a glass [14]. 30 plants-regenerants from the one calli were chosen for evolution of somaclonal variation. Progenies of the each 30 plants-regenerants comprise a separate somaclonal family.

Field experiments

Somaclonal families were evaluated in field trial in the Agricultural Science Centre of Latgale in 2010. Somaclonal families were grown in 2-3 rows (depending of the number of available seeds) plots, between the plots a long straw oat variety was sown. Agriculturally important traits, such as flax total plant height, technical plant height, number of seed vessels and number of seeds in a seed vessel were evaluated. Somaclonal families were compared with the source variety 'Vega 2'.

Detection of resistance to powdery mildew

Resistance of 20 seedlings of the each somaclonal family to powdery mildew was detected in greenhouse in September 2010 when highest level of fungi spores was occurred. Resistance were recorded on the age started from 5 till 9 weeks in the scale 0 (fully resistant) – 4 (completely susceptible).

Data analysis

Microsoft Excel program was used for data statistical processing. Phenotypical correlation coefficients were calculated among individual data of all plants of the experiment, genotypical correlation coefficients were calculated as correlations among mean values of corresponding traits of somaclonal families, environmental correlation coefficients were calculated separately among individual plant characteristics within each somaclonal family.

Results and discussion

The total plant height and technical plant height of flax somaclonal families and the source fibre flax variety 'Vega 2' are presented on Fig. 1. Somaclonal families shown considerable variation in this trait, most of them were higher than 'Vega 2'. The similar situation was observed in the plant technical height which was demonstrated previously [3] as the most important trait for the fibre flax breeding. Obtained somaclonal families could be used in breeding as an additional initial material for the fibre flax breeding.

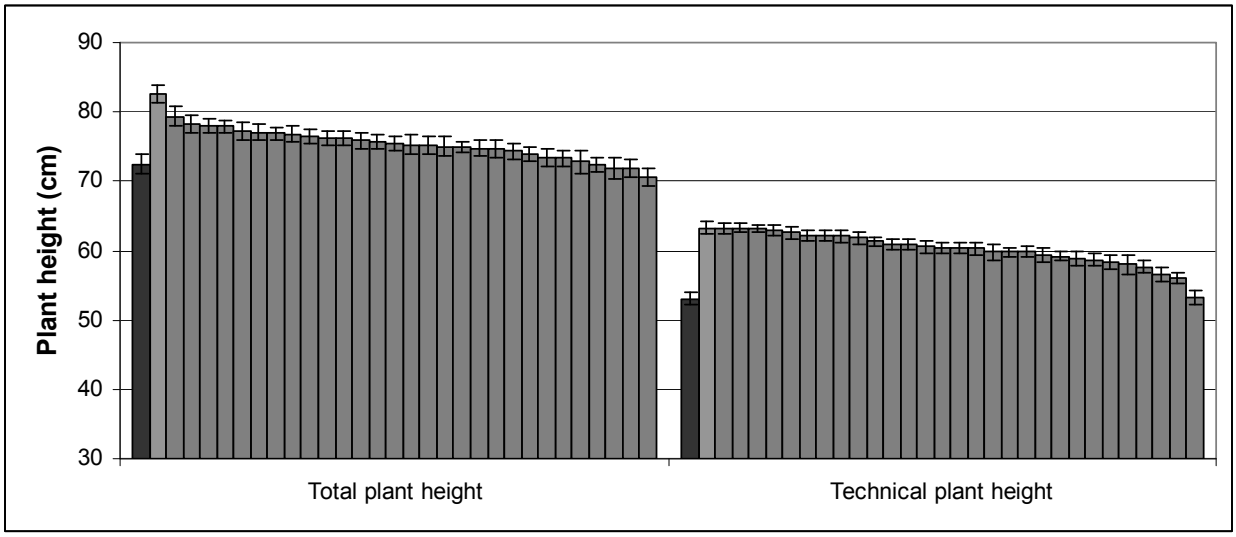

Fig.1. **Total plant height and technical plant height of flax somaclonal families and source variety 'Vega 2'** (black column)

Number of seed vessels (Fig. 2) showed a tendency to decrease in comparison with the source variety 'Vega 2', several somaclonal families had substantially reduced number of seed vessels. All somaclonal families have less seeds in a seed vessel than source variety 'Vega 2'. These changes are not desirable to breeding.

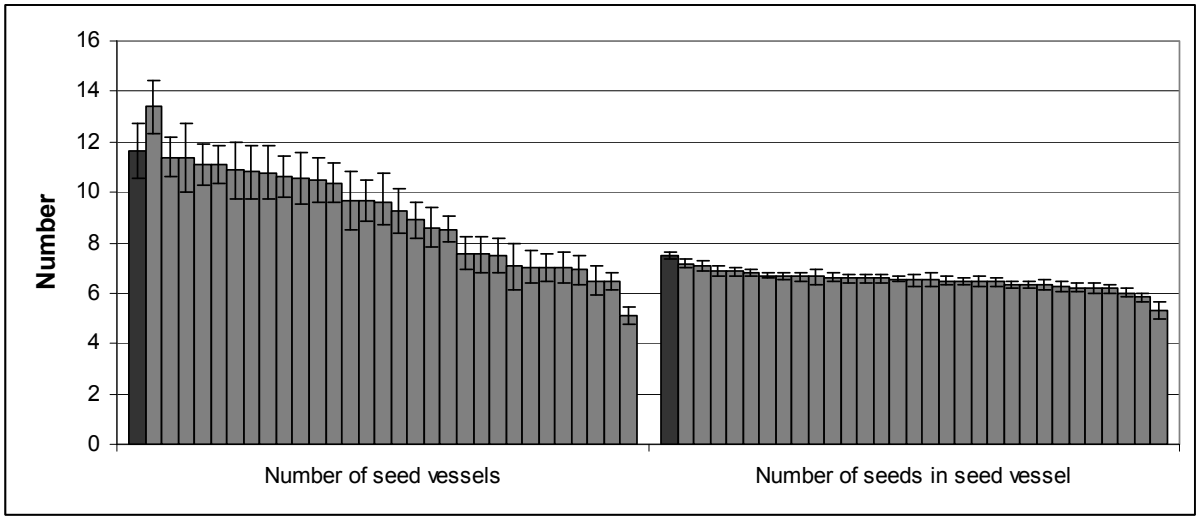

Fig.2. **Number of seed vessels and number of seeds in a seed vessel of flax somaclonal families and source variety 'Vega 2'** (black column)

In the Table 1 are presented phenotypical and genotypical correlation coefficients between evaluated flax traits. As expected, there are high both phenotypical and genotypical

correlations among close related total plant height and technical plant height, what showing, that preliminary selection for technical plant height could be done on the base of evaluation of total plant height. In opposite, there was observed not favourable for breeding significant negative correlation among technical plant height and number of seed vessels while the correlation between those traits on phenotypic level was absent. Most of other correlations were not significant.

Table 1.

Phenotypical (above diagonal) and genotypical (below diagonal) correlation coefficients among traits of flax somaclonal families

	Total plant height	**Technical plant height**	**Number of seed vessels**	**Number of seeds in a seed vessel**
Total plant height	–	0,6123**	0,5840**	0,1035
Technical plant height	0,5851**	–	-0,0122	-0,0455
Number of seed vessels	0,2985	-0,5046**	–	0,1283
Number of seeds in a seed vessel	0,0691	-0,2334	0,4764**	–

** – correlation significant at $p \leq 0.01$

Coefficients of environmental correlation are presented in the Table 2. Those correlations could not be used directly for breeding purpose because based on not heritable trait variation but differences between environmental correlations among families pointed out on they different reaction norm (in other term, genotype and environment interaction) as a consequence of somaclonal variation. For example, plants of several families had not correlation between total and technical plant height, there was big variation among families in correlation between total and technical plant height and seed vessels characteristics.

Variety 'Vega-2' was fully resistant to powdery mildew. Nevertheless, that not any somaclonal family was completely susceptible, only 50% of somaclonal families retained highest level of resistance of the initial variety (Table 3).

Somaclonal variation occurred in this experiment was positive, and, as well, negative from breeding point of view. As it is known, somaclonal variation is usually asymmetric and changes in most cases are occurred in direction not desirable for breeding. Nevertheless, the big number of families with decreased seed production and lower level of resistance may be recognised as an indirect indicator of the rather high level of induced somaclonal variation. which could influence also other traits which were not evaluated in this investigation.

Conclusions

Considerable somaclonal variation in agronomic important traits include technical plant height has been demonstrated among plants regenerated from stem calli culture of fibre flax variety 'Vega 2'. Because increased variation, lines with favourable combinations of agronomically important traits for fibre flax growing in the Latvian conditions, including organic farming, could be selected from obtained somaclonal families in further breeding process. In general, there is a potential to exploit flax somaclonal variation in applied breeding programs as an additional source of variability.

Table 2.

Coefficients of environmental correlations among traits within flax somaclonal families

Somaclonal family	Total plant height / technical plant height	Total plant height / number of seed vessels	Technical plant height / number of seed vessels	Total plant height / number of seeds in a seed vessel	Technical plant height / number of seeds in a seed vessel	Number of seed vessels / number of seeds in a seed vessel
'Vega 2'	0,719**	0,863**	0,408*	0,345	0,439*	0,340
7LSm1	0,693**	0,290	0,055	-0,265	-0,188	-0,114
7LSm2	0,710**	0,627**	0,039	0,406*	0,207	0,359
7LSm3	0,559**	0,737**	-0,006	0,092	0,190	-0,082
7LSm4	0,257	0,790**	-0,163	-0,047	-0,223	0,090
7LSm5	0,287	0,741**	-0,330	0,471**	0,108	0,350
7LSm6	0,674**	0,648**	-0,075	0,310	0,239	0,083
7LSm7	0,610**	0,802**	0,295	0,042	-0,179	0,155
7LSm8	0,626**	0,608**	-0,092	0,308	0,200	0,333
7LSm9	0,652**	0,614**	0,067	0,354	0,183	0,199
7LSm10	0,456**	0,619**	-0,192	0,151	-0,465**	0,406*
7LSm11	0,625**	0,758**	0,132	0,169	-0,239	0,386*
7LSm12	0,862**	0,714**	0,406*	-0,381*	-0,330	-0,401*
7LSm13	0,699**	0,546**	0,053	0,400	0,328	0,349
7LSm14	0,725**	0,605**	0,010	0,023	0,066	-0,229
7LSm15	0,651**	0,881**	0,527**	-0,003	-0,082	-0,090
7LSm16	0,669**	0,805**	0,285	-0,365*	-0,307	-0,337
7LSm17	0,738**	0,785**	0,336	0,341	0,105	0,402*
7LSm18	0,805**	0,719**	0,256	0,040	0,122	-0,214
7LSm19	0,910**	0,872**	0,658**	0,173	0,188	0,303
7LSm20	0,795**	0,791**	0,308	0,177	0,026	0,269
7LSm21	0,122	0,795**	-0,234	0,088	-0,313	0,153
7LSm22	0,713**	0,802**	0,513**	-0,510**	-0,386*	-0,436*
7LSm23	0,724**	0,508**	0,290	-0,092	-0,401*	-0,249
7LSm24	0,828**	0,774**	0,368*	0,099	-0,080	0,215
7LSm25	0,712**	0,640**	0,106	-0,108	0,013	-0,240
7LSm26	0,868**	0,834**	0,544**	0,135	0,211	0,017
7LSm27	0,648**	0,780**	0,233	-0,052	0,221	-0,283
7LSm28	0,087	0,713**	-0,370*	0,287	-0,015	0,034
7LSm29	0,640**	0,552**	-0,129	-0,227	-0,340	-0,010
7LSm30	0,745**	0,716**	0,345	0,318	0,136	0,101

* − correlation significant at $p \leq 0.05$

** − correlation significant at $p \leq 0.01$

Table 3.

Number of somaclonal families with different level of resistance to powdery mildew

Infection rate	Plant age (weeks)				
	5	**6**	**7**	**8**	**9**
0	30	29	20	15	15
1	0	1	9	10	10
2	0	0	1	5	5
3	0	0	0	0	0
4	0	0	0	0	0

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PHYSICAL PROPERTIES OF LATVIAN HEMP FIBRES

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Abstract. *Each year more and more people focus on healthy, ecological and environmental-friendly living. Environmentally friendly lifestyle doesn't mean that we are using only natural products, but attention is pointed to the manufacturing and production process also. The rapid development of recycled and biodegradable products causes expanding usage of hemp fibers both in household and technical textiles. The analysis of hemp cultivation and usage trends in the world and Europe shows that hemp cultivation and processing in Latvia has good perspectives.*
Product quality is influenced by raw materials. In this case it is hemp fiber descriptive characteristics. Hemp fibers are natural fibers and their properties varies according to plant growing regional climatic conditions, amount of manure, plant density, harvesting time and pre-treatment technological processes. There are studied the influence of above mentioned factors on chemical composition, geometrical and physical properties of the Latvian hemp fiber both local and foreign cultivars.
The work was carried out in cooperation between Riga Technical University, Textile Technology and Design Institute and the Agriculture Science Centre of Latgale.

Keywords: *Cannabis Sativa, hemp fibers, fibre content, fibre flexibility, fibre tenacity, fibre extension.*

Introduction

With the development of recycled and biodegradable raw materials increases the use of hemp fiber both in household and technical textiles. Mainly hemp in Latvia is grown for seed production. In 2008 and 2009 some individual farms sown hemp for fibre production. As in Latvia there was no experience, knowledge and skills of hemp cultivation and fiber production the Riga Technical University together with the Agriculture Science Centre of Latgale started scientific research work on hemp fibre analysis The main tasks of the present work is to evaluate the various foreign varieties and domestic variety Purini to identify the most appropriate harvesting time for the best quality of hemp fiber. The fiber quality is determined by the chemical and physical properties.

British scientists [1] studied five different varieties of hemp (Chamaeleon, Futura, Fedora, Beniko and Bialobrzeskie) to determine cultivation facilities in their country. The highest percentage of fibers derived from Beniko variety of plants. From this variety also the longest fibers are produced.

Fiber quality greatly is affected by its chemical composition. The chemical components of hemp fibre are: cellulose, hemicellulose, lignin, water and solvent soluble substances, wax, ash, pectin, protein and water. Lignin is a complex three-dimensional polymer whose function is to connect elementary fibers in bundles, therefore the more is lignin content the stiffer is fibre structure [2].

According to the literature [2-7] cellulose percentage is 73.98 - 77.89%, hemicellulose - 3.7 to 19.76, lignin content can be very variable - 1.75 - 10.6%.

According to the datas of different authors hemp fiber strength can be from 10.9 cN / tex up to 52.40 cN / tex [2,3]. Hemp fiber properties affects the plant growth climate. It can be concluded [7] that fiber strength can be influenced by the amount of moisture and the windy

weather during plant growing. Hemp plant growing conditions influence not only fiber mechanical properties, but also their geometrical dimensions - stem length, fiber fineness. Fiber chemical composition, fineness and mechanical strength are influenced by straw cutting time. The smallest lignin content in fibers are at the beginning of flowering [9]. During flowering and seed maturation lignin content increases. In this time increases also fiber thickness. It can be concluded that the best hemp fiber harvesting time is early blooming.

Materials and methods

Hemp fibers are obtained from Cannabis Sativa plants grown in the experimental fields of Agriculture Science Centre of Latgale in 2010. There were used nine varieties of foreign hemp: Bialobrzeskie, Beniko, Epsilon 68, Fedora 17, Felina 32, Santhica 27, Futura 75, USO 31, Finola, and the local variety Purini. Basically plants of all varieties, other than Purini, grown in test plots 1 x 1m in three replications. Amount of seeds sown is so to provide 400 germinating plants to $1m^2$. Hemp plants Purini grown in the wider area.

Seeds sowed in 11th May. 17th May marked hemp sprouting. The second decade of the May was warm and the average air temperature for 5.5°C was higher than normal, but rainfall was below the norm, and amounted to 82.3%. The mean air temperature in the third decade of May decreased and for 0.4°C was lower than normal, but rainfall was 70% of the norm. Average air temperature of June for 0.6° C was higher than normal and precipitation was normal. July and the first and second decade of August was hot and sunny. In July the average temperature exceeded the norm by 4.8° C, and rainfall accounted for 31% of the norm. Third decade of August temperature was normal, but precipitation was 38% of the norm. Hot and dry weather negatively affected the growth of hemp. Plants drooping were a result of the great heat and lack of moisture. The daily air temperature of the first decade of September was by 3.7° C lower than normal, but precipitation 105% of the norm.

Hemp completely was harvested from the first to 15th September. Hemp straw samples for fibre quality assessment were taken on the fourth of August and after harvesting in September. Because of the different growing time, the most part of the varieties in the August 4 didn't flower yet, Finola and USO31hemp varieties had already faded, but Purini hemp was still blooming.

Experimentally there was tested:

- Straw length;
- Straw productivity;
- Percentage of obtained fibres from the straws;
- Fiber linear density;
- Fiber bending;
- Fiber tenacity;
- Fiber extension.

From the selected fibres there were made bundles with weight 100 - 300g. Fibers were straightened and held for several days under load. Fiber bundles at least 24 hours were aged under normal climatic conditions before the experiments.

Ten bundles were used to determine the fiber linear density. From the bundles there were cut out middle parts with the length approximately 50mm and mass 0.7 to 0.8 g. 10mm long middle parts of each fiber bundle were cut out. After that fibres were counted. As one fibre there were counted undivided fibers or those fibres which are split less than half of the length. If the fiber was split into two or more parts and each of them is longer than half of the sample, then each branch treated as a separate fiber.

The fiber linear density can be calculated as follows:

$$T = \frac{m}{n \cdot l}, \qquad (1)$$

where

T –linear density, Tex;
m –mass of the sample, mg;
n –count of the fibres;
l –sample length, m.

For the measurements of fibre flexibility there was used tester F - 2. The flexibility of fiber bundles was characterized by the bending of bundle ends from the horizontal position.
There was used universal tester from Instron to determine fibre bundle tenacity and extension at break. Sample length - 10mm, selected speed - 15mm/min. Pretension was not applied, because the fibers are rigid and elongation abilities are limited.
For fiber flexibility, tensile strength and elongation testing bundles at first were prepared as described above. After that 270mm long the middle parts were cut out. From the middle parts there were formed 30 new fiber bundles with the mass 420 ± 20 mg.

Results and discussion

Straw length measured before hemp harvesting (see Fig.1.). The longest ones are Futura75, Santhica27, Fedora17 and Felina32 varieties of hemp, but the shortest Finola straws.

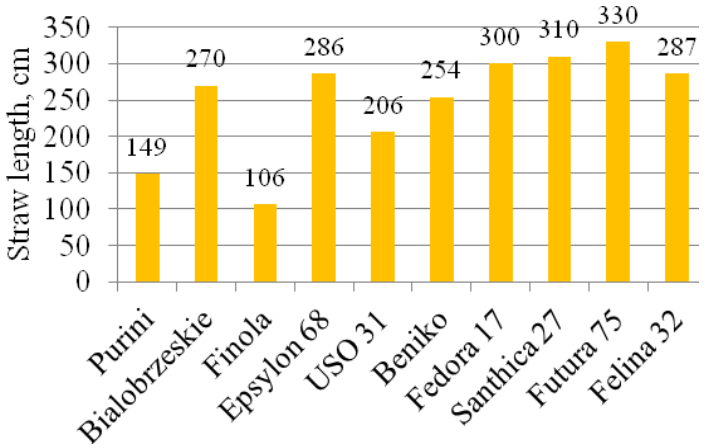

Fig.1. **Straw length of different varieties**

Taking into account that foreign varieties have been cropped in small areas, but Purini grown in wider area, the productivity of this variety can't be compared with other ones. In the fig.2 there is given straw productivity of foreign varieties.
The highest straw productivity obtained from Futura, Santhica and Epsylon, but the lowest from Finola hemp variety.
Fig. 3 reflected the fiber content in the straws. The largest content is for the variety Beniko, but the smallest one in the varieties Purini and Finola. Taking into account the straw productivity and fiber percentage in them, there was calculated the amount of obtained fibre from one square meter.
As it is shown in Fig.4 the largest amount of fiber can be obtained from Santhica 27, Futura 75 and Felina 32 hemp varieties.
Futher there is determined certain fiber properties and their variations according to plant maturity.

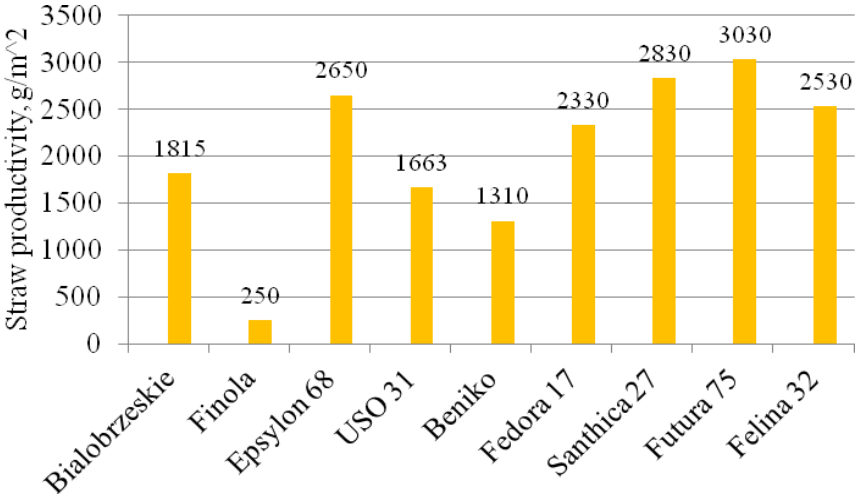

Fig.2. **Straw productivity of diferent cultivars**

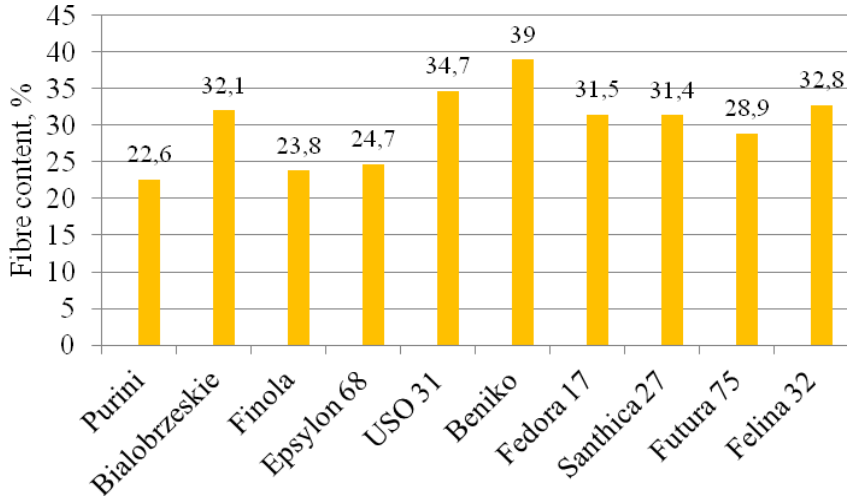

Fig.3. **Fiber content in the straws**

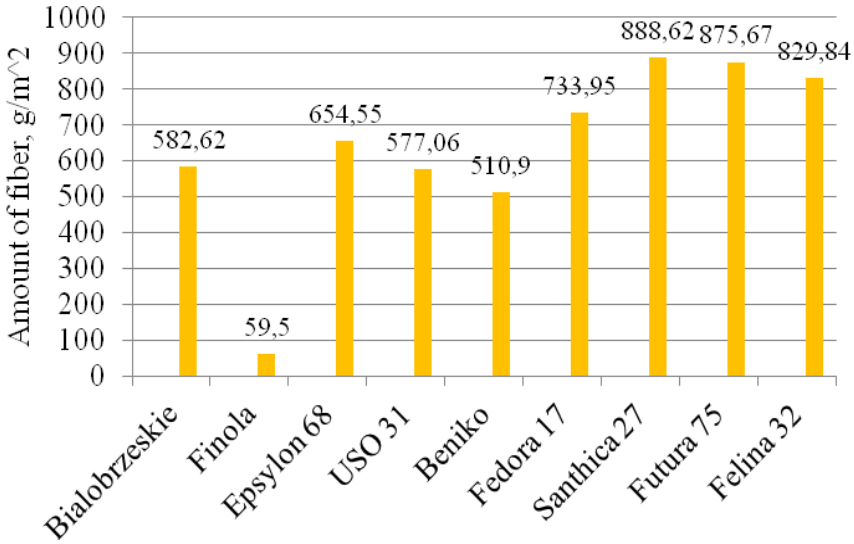

Fig.4. **Obtained amount of fiber from one square meter**

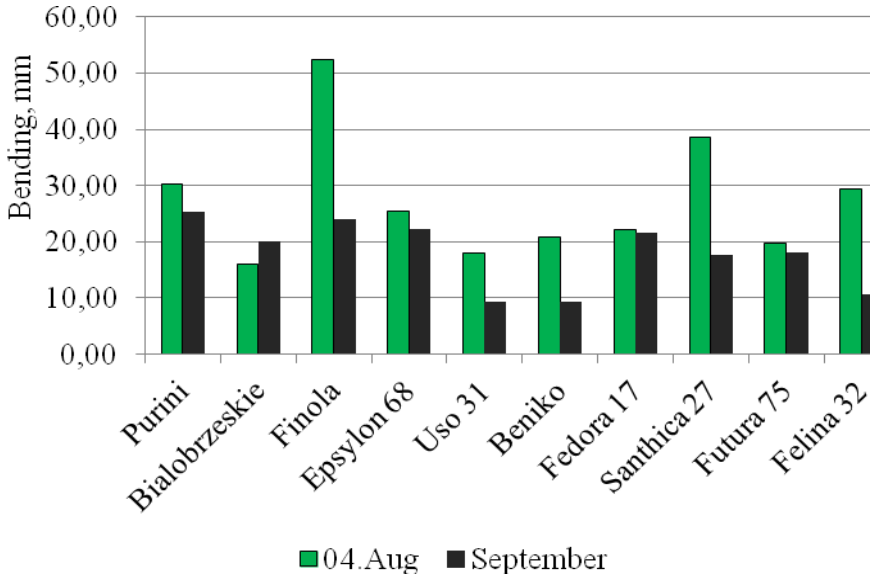

Fig. 5. **Bending of fibre bundle ends from horizontal possition**

The largest fiber flexibility (see Fig.5) has hemp fibres of varieties Purini, Finola, Epsilon 68 and Fedora 17. Besides for most of the fibers flexibility decreases with the maturity of plants. Only if we compare flexibility of Bialobrzeskie hemp fibres , then it is higher for fibres which are harvested in September compared with August fibres. Fig. 6 shows the changes of fibre linear density. There is no correlation between plant maturity and fibre linear density. Mainly it depends on the hemp fibre obtaining and pretreatment technological processes. The finest fibers in this case are derived from the Purini and Finola varieties, but the largest linear density is for Felina 32 variety.

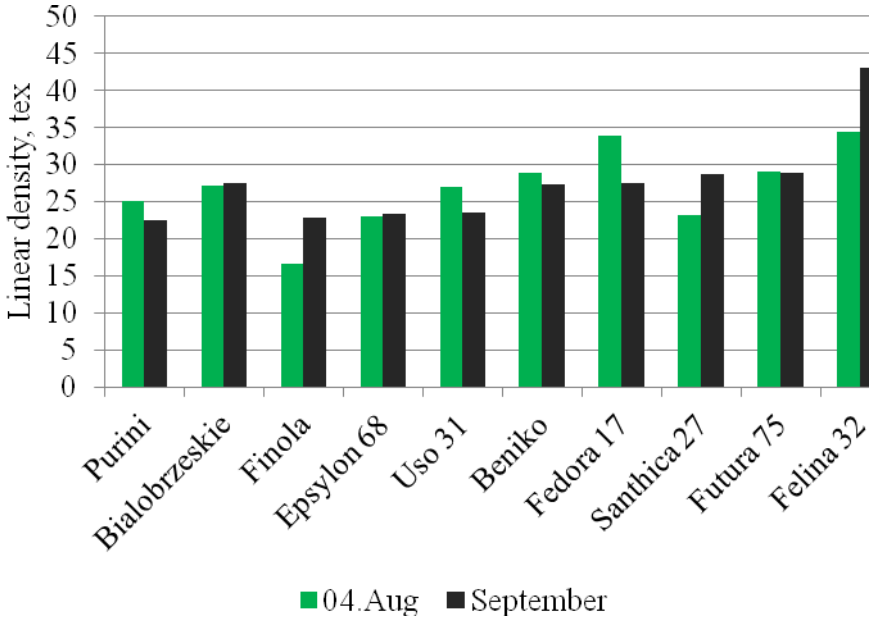

Fig. 6. **Fiber linear density**

Values of hemp fiber breaking tenacity and extension at break are given in Table 1 and force extension curves in the Fig. 7. and 8. The highest strength has fibres from varieties Bialobrzeskie, USO 31un Futura 75, the lowest from Fedora 17 and Santhica 27. Basically the

strength is higher for all hemp fibres which were harvested in August than in September. The exception is the only variety Epsylon 68, the experimentally determined average strength of which is slightly higher in September than in August. Although it should be noted that this difference is very small.

Table 1.

Strength characteristics of hemp fibre

Hemp variety	Breaking tenacity (cN/tex)		Extension (%)	
	August	September	August	September
Beniko	10,37	7,34	2,33	0,87
Bialobrzeskie	13,81	11,49	2,03	1,59
Epsylon 68	9,68	9,76	2,85	1,33
Fedora 17	8,06	7,86	2,14	1,24
Felina 32	9,23	9,70	2,05	1,33
Fenola	8,10	12,26	2,04	2,42
Futura 75	11,20	10,87	1,75	1,22
Pūriņi	9,78	11,85	1,84	1,84
Santhica 27	8,51	8,11	2,55	1,07
Uso 31	11,72	10,59	2,26	1,20

Hemp fiber breaking elongation ability is very small. For September harvested hemp fibres it is between 0.87 - 2:42%, but for August fibres it is from 1.75 - 2.85%. Consequently we can conclude that August fibers elongate better than hemp fibres harvested already in September.

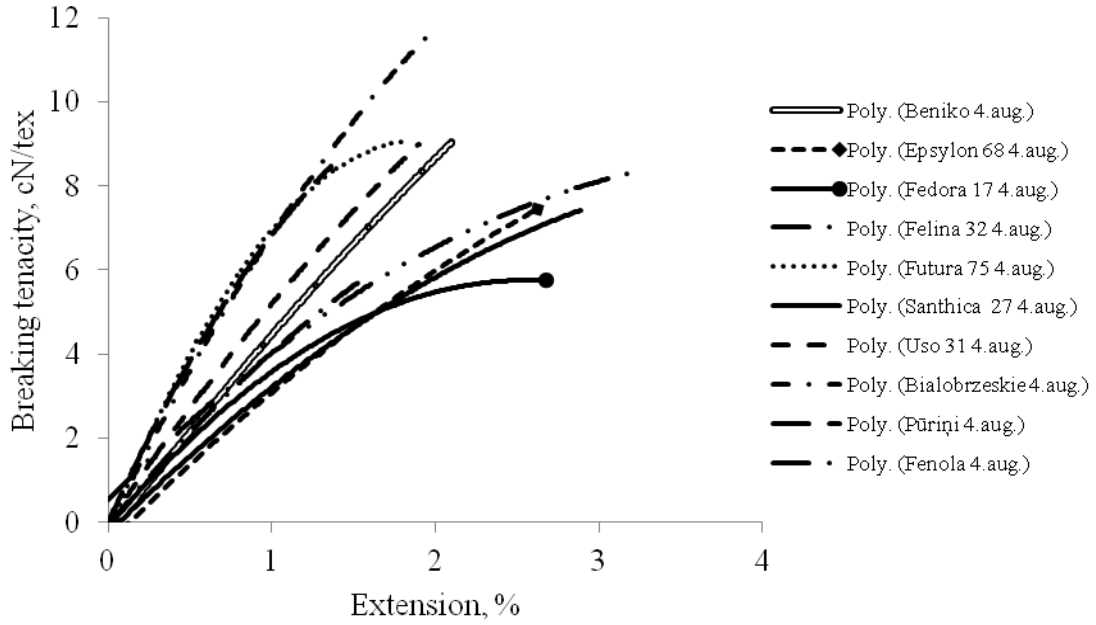

Fig. 7. **Force extension curves for fibers of different varieties harvested in August 4**

The higher strength and elongation ability of hemp fibres harvested in August can be explained with the increase of lignin content during and after plant flowering.

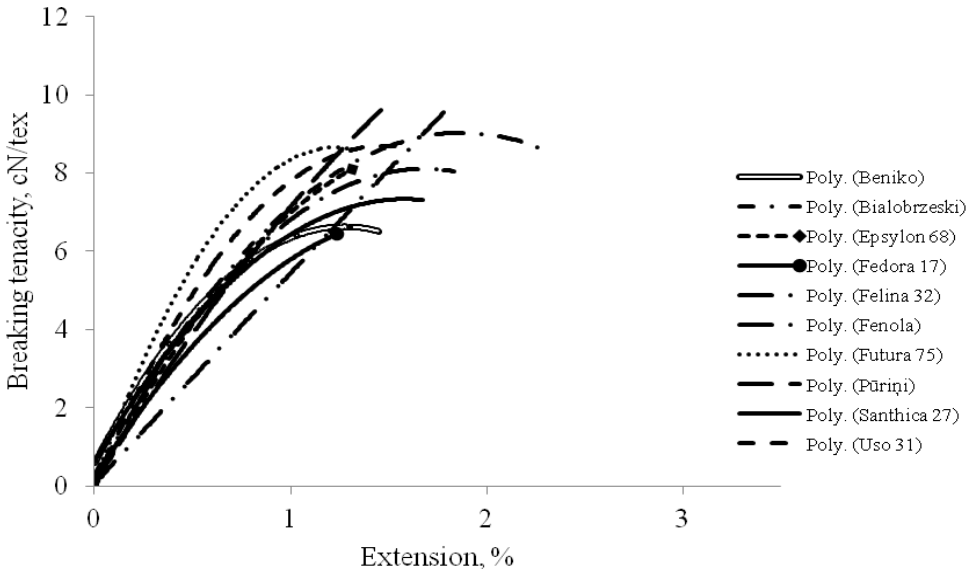

Fig. 8. **Force extension curves for fibers of different varieties harvested in September**

Conclusions

It can be concluded:

- The largest mass of fibers can be obtained from varieties Santhica 27, Futura 75 and Felina 32.
- The strongest fibres can be obtained from varieties Bialobrzeskie, USO 31un Futura 75.
- The most flexible fibres are from varieties Purini, Finola, Epsilon 68 and Fedora 17.
- Hemp fibres form local variety Purini have high flexibility and good tensile charecteristics.
- It is recommended to harvest hemp straws when they are still immature to get better fibre quality.
- Additional research should be done to find out better harvesting time for hemp fibres - before flowering, at flowering or immediately after flowering.

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THE PRODUCTIVE LONGEVITY OF PERENNIAL GRASSES SWARDS DEPENDING ON THE NPK FERTILIZER RATES

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Abstract. *The longevity and producing capacity of perennial grasses swards was studied on mineral soils at the LUA Research Institute of Agriculture in long-term experiment during 1974-2010. There were applied lime and mineral fertilizers with different NPK doses (0-400 kg ha^{-1}) protractedly many years. In such way there formed soils with various content of P, K, organic matter content and pH_{KCl} level as well. Research results showed that liming of soils and using of mineral fertilizer changed not only productivity of grass mixtures but also botanical composition. Mineral fertilizer $N_{200}P_{100}K_{300}$ provided the highest yield of dry matter – 7.32 - 12.0 t ha^{-1} and optimal botanical composition of a sward during many years. On unlimed soils (pH_{KCL} <4.0 in 1997) dry matter yields of grass sward was substantially lower and there was observed disappearance of seeded valuable grasses out of the sward and increase of herbs and non-seeded grasses –Festuca rubra L., Agrostis tenuis Sibth., Taraxacum officinale Wigg. and others. Liming of soils increased dry matter yield in treatments with high doses of N (300-400) fertilizer.*

Keywords: *botanical composition, dry matter, fertilizer, liming, perennial grasses, swards.*

Introduction

One of the high-quality, wholesome and cheap feed sources is a perennial grasses. Grasslands are important elements of agricultural production under many management systems. Perennial grasses in Latvian meadows and pastures occupy nearly half of agricultural land. They are the most economical consumers of applied fertilizer. Therefore this is the most important plant group in our country and the main source of energy and nutrients for dairy cattle, meat animals, horses and other domestic animals [1].

Usually, within grassland sward there are several components with the aim to improve the use of nutrients, received from the soil as well as to get a better chemical composition of the green mass, and to obtain longevity. Sustainability is a measure of our ability to produce food with the maximum efficiency combined with the minimum damage to the environment [2]. Due to a big proportion of perennial grasses areas it is important to establish way of grasslands cultivation for more long and effective use of swards with the aim to save resources, environment and biodiversity.

To find out the yield ability and longevity of perennial grasses swards according to the fertilizer, in 1974 was established an appropriate test. Originally it was intended to clarify the role of irrigation too, therefore, chosen a relatively high mineral fertilizer rates, but over time, failed to successfully solve the technical problems related to irrigation, so a trial was added with the liming variants. Part of the research results published in the references in those works [3, 4, 5, 6, 7, 8, 9]. The research shows that grassland perennity, its botanical composition and productivity are influenced by the fertilizers and the way how they are used [6, 7, 9].

In this article is continued to summarize the results of research in recent years.

Materials and methods

The trial was established in 1974, on the sod-faintly podzolic sandy-loam soil within two grassland swards:

1. cocksfoot *(Dactylis glomerata* L.*)* 20 kg ha^{-1} + white clover (*Trifolium repens* L.*)* 4 kg ha^{-1};
2. grass mixture: meadow fescue (*Festuca pratensis* Huds*)* 10 kg ha^{-1}+ timothy (*Phleum pratense* L.*)* 4 kg ha^{-1} + perennial ryegrass (*Lolium perenne* L.*)* 4 kg ha^{-1} + meadow grass

(*Poa pratensis* L.*)* 3 kg ha^{-1} + red clover (*Trifolium pratense* L.*)* 4 kg ha^{-1} + white clover *(Trifolium repens* L.*)* 2 kg ha^{-1}.

There was choosed cultivars: cocksfoot 'Priekulu 30', meadow fescue 'Priekulu 519', timothy 'Priekulu', perennial ryegrass 'Priekulu 59', meadow grass 'Priekulu 129', red clover 'Stendes velais', white clover 'Priekulu 60'.

The fertilizer doses were the following:

N – 0, 100, 200, 300, 400 kg ha^{-1};

P_2O_5 – 0, 50, 100, 150, 200 kg ha^{-1};

K_2O – 0, 75, 150, 225, 300 kg ha^{-1}.

Phosphorus and potassium fertilizers were applied in autumn or in early spring. Nitrogen mineral fertilizer in the form of ammonium nitrate was applied in spring, by resurgence of vegetation, and after the 1st and 2nd harvests as well.

Before establishing the grassland swards, the soil was limed ($CaCO_3$ 3 t ha^{-1}).

Grassland productivity (the green mass and the dry matter harvest) was defined during the 3rd mowing periods, but from 2005 during the 2nd mowing periods.

Botanical composition of the swards was determined at the beginning of June before 1st cut in 20 x 25 cm accounting areas by visual evaluation of cropped area of each species. In depends of species quantity and its distribution regularity there were estimated 10- 30 accounting places in each trial plot. The trial data were statistically processed using analysis of variance.

Results and discussion

The swards of grasses produced during the trial were of various qualities, depending on the particular fertilizer application that caused disappearance of seeded grasses away and spreading of other species of herbs. The differences among the swards in the variants without liming were determined both by the soil pH_{KCl} level and the changes in amount of nutritive substance, but in the variants with liming occurred that the main effect on these differences had changes in plant nutrients.

The proportion of seeded grasses in the composition of sward during the 36-year trial period was gradually reduced and as a result in some places seeded grasses completely disappeared away and were replaced by non-seeded perennial and legume grasses, and broadleaf species plants as well. Considerable effect on the number of species counted up in 2010 had the fertilizer application, especially nitrogenous fertilizer. There was observed an interconnection: higher fertilizer rates produce smaller number of species in a sward. The evaluation of the species showed that the most diversity in species, on average 11, were present in the variants with fertilizer inputs of 100 kg N ha^{-1}, the least, on average 3, were present in the high-yielding variants with liming and high inputs of nitrogenous fertilizer.

Changes in a sward were easier to establish in the variants with cocksfoot. Though in the assessment of changes in a poly-component sward there must be taken into account that smooth meadow grass (*Poa pratensis*), sown with grass mixture, is not distinguishable from its wild subspecies. In order to characterize botanical composition in a sward, Antonijs and Rumpans [9] used the tiller counting method; however, there must be taken into account the fact that tillers of various species are of different shape. In particular, it concerns culm grasses and broad-leaved species; besides, the obtained results do not disclose if there are any areas not covered with plants.

Legume grasses were not present in the sward already after 5-6 years growing, but in some variants without nitrogenous fertilizer applied or with small rates of nitrogenous fertilizer and high rates of phosphorous and potassium fertilizer applied there were present white clover (*Trifolium repens* L.*).* White clover persists and spreads well in limed (pH_{KCl} 5.6-7.0) legume grass mixtures [10]. During the experiments, white clover content in the sward ranged from 18 %, in 1997, to very little 8 %, in 2010, for the variant 022 without using of nitrogen

fertilizer. It is common that the white clover content in a sward is higher in autumn; white clover was more spread in the variants with little nitrogen and high phosphorus and potassium rates applied, if the weather was wet.

After 22 years, acidity of topsoil (0-20 cm) in the variants without liming was increased from pH_{KCl} 5.7-6.2 to pH_{KCl} 4.4-5.3; after 10 years more, it was pH_{KCl} 3.5. In the topsoil (0-10 cm) such a pH level was recorded already after 22 years of cultivation when interconnection between the composition of sward and the soil pH level in upper soil was evaluated. Acidification of the soil resulted from calcium remove by yields, as well as due to application of mineral fertilizers. Over the last years of the trial the fertilization with 100 kg N ha^{-1} produced average soil pH_{KCl} 4,2, in the variant with 300 kg N ha^{-1} the average soil pH_{KCl} was 3,8. Further decline in the soil pH was prevented by liming; liming repeated after 10 years, in 1997, ensured that the soil pH was even higher than before it. The proportion of seeded perennial grasses in a sward after 22 years had changed significantly. It must be noted that the term "seeded perennial grasses" in this case is a quite relative term, because along with the seeded smooth meadow grass (*P. pratensis* L.) in the sward there appeared also its wild forms. Similarly in the sward of cocksfoot (*Dactylis glomerata* L.) there also were present meadow grasses (*P. pratensis* L., *P. trivialis* L.), meadow fescue (*F. pratensis* Huds.), and timothy (*Phleum pratense* L.). Cocksfoot present in a poly-component sward was regarded as seeded culm grass. Each of these perennial grasses is of high productivity and quality and the proportion of them in a sward determines the total value of a sward.

Higher amount of seeded perennial grasses (65 % - 77 %) after 22 years was present in the swards of the variants with liming, whereas the amount of seeded grasses for the variants without liming varied, depending on fertilization. The highest proportion of seeded perennial grasses, on average 42 %, was present in the variants with fertilizer dose N_{100}. Increasing of fertilizer N input up to 200 kg ha^{-1} had a negative effect - only 26 % of seeded grasses were left in the sward; in the variants with N input 300 kg ha^{-1} - on average only 9 % of seeded grasses remained. Because of the high level of potassium and phosphorous fertilizer applied, in the sward of the variant 444 the proportion of seeded grasses was still at comparatively high level - 65 %, while in the variants without nitrogenous fertilizer applied the seeded grasses had almost disappeared away (Table 1). A few seeded stem grasses were present also in the variants without phosphorous or potassium fertilizer applied (202, 220), and in the variants with small doses of fertilizers applied (422, 311, 331) what caused shortage of the easy accessible nutrients in soil, i.e. potassium content in the soil was reduced and ranged from 43 to 59 mg kg^{-1}; phosphorus, from 99 to 133 mg kg^{-1}.

The proportion of the seeded stem grasses in the sward continued to decline during a continued usage of the sward for over 10 years, and in 2010, in the 36th year after the establishment of the trial, even in the best variants the seeded grasses formed only 50 % of the sward. The liming and the relatively high soil pH could not ensure that seeded grasses remained in the sward, especially in the variant with N_{300} application. The withering of seeded grasses may be determined by potassium deficiency, because even at the variants with high rates of potassium fertilizer applied (225 kg K_2O ha^{-1}) the concentration of the easy absorbable potassium in soil was poor and ranged from 32 to 117 mg kg^{-1}. In the variants without liming and lower doses of nitrogenous fertilizer applied the soil pH_{KCl} level remained at 4.0 or was higher, and the average proportion of the seeded grasses remained 42 % of the sward. Such a negative factors as the rise of soil acidity and the deficiency in potassium may have disadvantageous effect if higher doses of nitrogen are applied.

As the seeded grasses fell out from the swards, other grasses gradually invaded the place. After 22 years, the couch grass (*Elytrigia repens* L.) began to invade more intensively in the variants with medium or high nitrogenous fertilizer doses (N_{200} – N_{400}) applied; it was recorded that couch grass was more spread in the variants without liming. Over the time, the

spreading became more intense, and the variants with liming and high nitrogen fertilizer doses (N_{300}) applied also were invaded, moreover, after 35 years couch grass had formed several pure swards or the swards with high proportion of couch grass.

Table 1.

The proportion of seeded perennial grasses species and changes of soil pH_{KCl} level

Code of variant	Variant	pH_{KCL} of soil		Listed number of species 2010	Seeded perennial grasses in the sward, %			
		1997	2006		1997	2010		
						In total	Int.al. *Poa pratensis*	*Dactylis glomerata*
Unlimed								
22	$N_0P_{100}K_{150}$	4.89	4.44	6	35	4		2
202	$N_{200}P_0K_{150}$	4.69	4.10	5	10	8	5	
220	$N_{200}P_{100}K_0$	4.69	3.90	5	25	8	8	
222	$N_{200}P_{100}K_{150}$	4.92	4.41	9	65	30	8	40
224	$N_{200}P_{100}K_{300}$	4.83	4.48	4	79	54	23	48
242	$N_{200}P_{200}K_{150}$	4.84	4.21	7	75	33	7	45
422	$N_{400}P_{100}K_{150}$	4.42	3.52	6	3	6	6	
444	$N_{400}P_{200}K_{300}$	4.27	3.92	3	63	35	15	35
111	$N_{100}P_{50}K_{75}$	4.83	3.90	6	88	47	25	28
113	$N_{100}P_{50}K_{225}$	5.04	4.36	11	59	42	6	27
131	$N_{100}P_{150}K_{75}$	5.30	4.64	8	79	43	3	20
133	$N_{100}P_{150}K_{225}$	4.83	3.90	10	65	37	1	20
311	$N_{300}P_{50}K_{75}$	4.39	3.73	6	28			
313	$N_{300}P_{50}K_{225}$	4.88	3.85	6	58	5	3	5
331	$N_{300}P_{150}K_{75}$	4.53	3.76	3	35	10	10	
333	$N_{300}P_{150}K_{225}$	4.42	3.89	5	52	20		30
N1	Average N_{100}	5.00	4.20	8	73	42	9	24
N2	Average N_{200}	4.79	4.22	6	51	26	10	27
N3	Average N_{300}	4.55	3.81	5	43	9	3	9
Average $N_{100,300}$		4.78	4.00	7	58	25	6	16
Limed								
111k	$N_{100}P_{50}K_{75}$	5.48	6.02	9	73	43	3	27
113k	$N_{100}P_{50}K_{225}$	5.43	5.93	7	65	45	1	35
131k	$N_{100}P_{150}K_{75}$	5.51	5.94	7	79	49	18	15
133k	$N_{100}P_{150}K_{225}$	5.51	5.89	6	77	50	15	25
311k	$N_{300}P_{50}K_{75}$	5.45	5.09	3	77	11	8	7
313k	$N_{300}P_{50}K_{225}$	5.02	5.42	3	68	9		15
331k	$N_{300}P_{150}K_{75}$	5.16	5.00	3	70	7	4	5
333k	$N_{300}P_{150}K_{225}$	5.11	5.43	3	69	8		10
LSD $_{0.05}$		*0.66*	*0.61*		*15*	*17*		*11*
N1	Average N_{100}	5.48	5.94	7	73	47	9	26
N3	Average N_{300}	5.18	5.23	3	71	9	3	9
Average for limed		5.33	5.59	5	72	28	6	17

The proportion of cocksfoot in the swards of sown mixture of cocksfoot with white clover was the highest in the variants with moderate nitrogen rates applied and high phosphorus and potassium rates applied (222, 224, 242), the proportion of cocksfoot in 2010 ranged from 40 % to 48 %.

Smooth meadow grass was present not only in the poly-component mixture variants, but it was present also in the sward of pure cocksfoot; still on the plots where it was sown the proportion of smooth meadow grass was higher by 5-15 %. Along with smooth meadow grass also small amount of rough-stalked meadow grass (*P. trivialis*), which was not registered, was present on these plots. Rough-stalked meadow grass was more distributed on plots that where fertilized with little or medium doses of nitrogen fertilizer, or sufficiently fertilized with phosphorus and potassium fertilizer.

In the course of time, light spreading of couch grass was observed also in the variants without liming and little doses of nitrogenous fertilizer applied, more significant spreading was observed at the variants with moderate and high doses of nitrogenous fertilizer applied. In the variants with liming compared to ones without liming amount of couch grass was noticeably lower. After 22-year long period of trial, in the variants with N_{300} applied couch grass formed 23 % of the sward, and in the variants with liming, only 14 %. After another 13 years the situation was opposite: in the variants with liming and fertilizer N_{300} applied the couch grass formed 85 % of the sward, whereas in the variants without liming, 42 % (Table 2).

All the other stem grasses present in the sward were united in the one group. The mostly represented species were red fescue (*F. rubra* L.) and common bent grass (*Agrostis tenius* Sibth.), as well as tufted hair grass (*Deschampsia caespitose* L.) in small amounts. There were registered also a few sedges (*Carex* L.) and rushes (Juncus L.).

Even though red fescue traditionally is regarded as forage perennial grass of high value or at least of moderate value, according to the regulations on environmental protection it was more convenient to include it in the group with common bent grass. The major difference between these species was that red fescue faster and to greater extent replaced timothy and meadow fescue on the plots where poly-mixture of grasses were sown on.

After 22-year long period, red fescue (*F. rubra* L.) and bent grass(*Agrostis tenius)* mainly were present on the plots of the variants without liming; at the greatest extent these species were on the plots (variants 202, 220, 422, 311) with significant deficiency in phosphorus or potassium, or both of them. After 22 years these grasses were light spread, on average 7 % of total amount, in the variants with fertilization rate N100, on average 26 % - 27 %, in the variants with higher nitrogenous fertilizer dose applied; 13 years later the proportion of red fescue and bent grass increased also in the variants with fertilizer rate N100, as well as in the variants with liming and the same nitrogenous fertilizer rate applied. At several variants where the first counting recorded high proportion of smooth meadow grass and red fescue, the amount was reduced due to the disappearance, leaving large areas not covered with plants (variants 202, 422).

Broadleaf species were represented mostly by dandelion (*Taraxacum officinale* Wigg.), less frequently present was meadow buttercup (*Rununkulus acris* L.) and yarrow (*Achillea millefolium* L.).

Rare found was also creeping thistle (*Cirsium arvense* L.), sorrel (*Rumex acetosa* L.), field chickweet (*Cerastium arvense* L.), hedge bedstraw (*Galium mollugo* L.), lady's mantle (*Alchemilla vulgaris* L.), etc., among them also one lesser butterfly orchid (*Platanthera bifolia* L.) plant.

Broadleaf weeds, mostly dandelion, were replacing seeded grasses at the variants without nitrogenous fertilizer applied or with small nitrogenous fertilizer rates (N100) applied. The more intense spreading of dandelions in the variants without liming may have occurred due to the application of potassium.

Table 2.

The DM yields and proportion (%) of non-seeded grasses in the swards (1997 and 2010)

Code of variant	Variant	*Elytrigia repens*,		*Agrostis tenius*, *F. rubra* a.o.,		Broad-leaved grasses		Clear area		DM t ha^{-1}		
		1997	2010	1997	2010	1997	2010	1997	2010	1974-1976	1997-1999	2007-1999
Unlimed												
22	$N_0P_{100}K_{150}$	3	5	8	39	38	45			4.29	6.35	4.13
202	$N_{200}P_0K_{150}$	5	8	69	54	6	9	10	23	6.82	6.41	3.26
220	$N_{200}P_{100}K_0$	10	5	50	73			15	15	6.63	4.59	3.54
222	$N_{200}P_{100}K_{150}$	20	40	8	20	8	10			7.31	9.69	7.15
224	$N_{200}P_{100}K_{300}$	3	43	3		16			4	7.86	12.0	7.32
242	$N_{200}P_{200}K_{150}$	13	50	5	15	5	3	3	0	7.66	10.32	6.92
422	$N_{400}P_{100}K_{150}$	15	9	55	39		9	28	38	8.65	8.03	4.28
444	$N_{400}P_{200}K_{300}$	20	55	13	10			5			10.97	6.33
111	$N_{100}P_{50}K_{75}$			5	35	8	19			5.53	6.75	5.36
113	$N_{100}P_{50}K_{225}$	1	13	10	33	30	14			5.65	8.58	5.63
131	$N_{100}P_{150}K_{75}$	1	3	8	23	13	33			5.38	6.66	5.60
133	$N_{100}P_{150}K_{225}$	3	15	4	29	29	19			5.88	9.06	6.47
311	$N_{300}P_{50}K_{75}$	18	10	40	43		8	15	40	7.04	6.05	3.61
313	$N_{300}P_{50}K_{225}$	20	33	20	34		7	3	23	7.58	9.02	5.82
331	$N_{300}P_{150}K_{75}$	28	60	28	23		0	10	8	7.46	7.92	6.17
333	$N_{300}P_{150}K_{225}$	26	64	15	9	5	8	3		8.20	11.87	6.97
N1	AverageN_{100}	1	8	7	30	20	21	0	0	5.51	7.76	5.76
N2	AverageN_{200}	10	29	27	32	7	4	6	8	6.74	8.60	5.64
N3	AverageN_{300}	23	42	26	27	1	5	8	18	7.58	8.71	5.65
Average $N_{100,300}$		12	25	16	28	10	13	4	9	6.55	8.24	5.71
Limed												
111k	$N_{100}P_{50}K_{75}$		5	1	15	26	38				7.79	5.50
113k	$N_{100}P_{50}K_{225}$	3	5		8	33	43				10.44	6.27
131k	$N_{100}P_{150}K_{75}$			1	27	20	25				7.74	5.45
133k	$N_{100}P_{150}K_{225}$		3		5	24	43				9.50	6.30
311k	$N_{300}P_{50}K_{75}$	9	82	5		10	8				8.55	6.75
313k	$N_{300}P_{50}K_{225}$	8	79	5		20	13				12.06	7.55
331k	$N_{300}P_{150}K_{75}$	23	91	3		5	3				8.52	6.79
333k	$N_{300}P_{150}K_{225}$	18	89			14	4				13.79	8.45
LSD $_{0.05}$		*11*	*15*	*13*	*15*	*12*	*16*	*13*	*15*	*0.65*	*0.92*	*0.87*
N1	Average N_{100}	1	3	1	14	26	37	0	0		8.87	5.88
N3	Average N_{300}	14	85	3	0	12	7	0	0		10.73	7.39
Average for limed		7	44	2	7	19	22	0	0		9.80	6.63

In the time course, the proportion of broadleaf species increased in the variants with small nitrogenous fertilizer rates (N100) applied, and it decreased in the variants with high doses of nitrogenous fertilizer applied, as well as they were invaded by couch grass. The broadleaf species were represented as follows: dandelion 49 %; meadow buttercup 15 %; sorrel 9 %; creeping thistle 7 %; yarrow 4 % of total area covered with broadleaf plants. The other broadleaf species were represented only by some few plants or their amount did not exceed a few percents of the total area.

As the seeded grasses disappeared away, in the variants without liming, with topsoil pH_{KCl} level below 5, and pronounced deficiency in plant nutrient (202, 220, 311, 313, 331, 422)

occurred areas not covered with plants. Such areas with phosphor concentration in the soil at the level 100 mg per 1 kg, and content of potassium in the soil below the level 100 mg per 1 kg were found already in 1997, after 23 years. The analogous variants with liming were invaded by couch grass and broadleaf plants. In the variants with high nitrogen rates applied, as time went along, areas not covered with plants expanded due to removal of nutrients by high yields leaving the soil in deficiency in nutrients. In summer time, the areas not covered with plants usually wane, as they are invaded mostly by bent grass and shoots of broadleaf plants, but usually these plants do not over-winter and in spring again there are areas not covered with plants.

Also over the time changed the obtained dry matter yields, depending on the particular fertilization. Diversity in dry matter, using multifactor regression method, has been analyzed previously [5], as well as has been explained the long-lasting stability in productivity [6]. The present article reveals an attempt to associate changes in yield to the changes in sward. During the first years after the establishment of trial, the swards were similar to the introduced swards, and productivity was mostly determined by fertilization, not modification it had made to the soil nutrient status, and modifications caused by the sward botanical changes.

At first time the main effect on the differences in yields had the nitrogenous fertilizer applied, however, there was observed also small influence from phosphorous and potassium fertilizer application. As the soil nutrient level and the composition of sward changed due to particular fertilizer application, increased diversity among yields of particular variants, and the standard deviation from the average rate changed from 1.22 t ha^{-1} to 2.12 t ha^{-1}, correspondingly, the ratio of variation, from 17.42 to 25.31 %; still along with a further degradation of the swards decreased total productivity, as well as the distribution of yields, correspondingly, 1.33 t ha^{-1}, from the standard deviation, and 24% from the ratio of variation. If initially in the variants without liming the highest yields were produced by the variants with high doses of nitrogenous and potassium fertilizer applied, and sufficient doses of phosphorous fertilizer applied (422, 333), then after 22 years only the variant 333 with high doses of phosphorous and potassium fertilizer applied remained productive, but the highest yields were obtained in the variants with medium nitrogenous fertilizer usage (224), and these variants remained high productive also in the further period (Table 2).

Although direct correspondence between changes in a sward and changes in a yield is not significant, still in the variants without liming there is a medium-close correlation between proportion of seeded grasses in sward and dry matter yield, and it is as follows: after 22 years – 0.47, after 13 years – 0.65. A higher productivity had swards with higher proportion of couch grass: if indicated correlation between yields and proportion of couch grass in the sward after 22 years was 0.25, then after 13 years more it was 0.71. A very negative correlation, as -0.50 and 0.90, was established between the yields of dry matter and the proportion of red fescue and bent grass in a sward.

Conclusions

The applying of balanced fertilizer, which cover runoff of nutrients and prevent the worsening of soil agrochemical qualities provide ensure the longevity and high productivity of perennial grass swards. The highest yields of DM – 7.32 - 12.0 t ha^{-1} and optimal botanical composition of a swards during many years were provided with medium (224) nitrogenous fertilizer $N_{200}P_{100}K_{300}$ application.

The task of liming is to prevent of soil acidification under pH_{KCl} 4.0.

Unbalanced fertilizer of grass mixtures and nutrient deficiency leads to the emergence of areas not covered with plants.

High nitrogen fertilizer in soils close to neutral increasingly introduced in couch grass (*Elytrigia repens* L.), which is more productive than the other not-seeded grasses, but does not compensate productivity of sown perennial grasses.
Broad-leaved, mostly dandelion (*Taraxacum officinale* Wigg.), increasingly introduced in fertilizer use by small, up to 100 kg ha^{-1} fertilizer rates of nitrogen as in acid (pH_{KCl} around 4.0), as in soil close to neutral (around 5.0 pH_{KCl}).

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Anotācija. *Daudzgadīgie zālaugi ir nozīmīgākā kultūraugu grupa Latvijā, tie ir galvenais enerģijas un barības vielu avots slaucamām govīm, gaļas lopiem, zirgiem un citiem dzīvniekiem. Daudzgadīgie zālaugi Latvijā aizņem gandrīz pusi no lauksaimniecībā izmantojamās zemes platības. Lai noskaidrotu daudzgadīgo zālaugu ražību atkarībā no mēslojuma un izpētītu vērtīgo sēto stiebrzāļu iespējami ilgākas saglabāšanās zelmenī nosacījumus, 1974.gadā ierīkots attiecīgs izmēģinājums. Zelmeņu mēslošanai ilgstoši- 36 gadu garumā tika izmantotas nemainīgas minerālmēslojuma NPK devas (0-400 kg* ha^{-1}*) dažādās proporcijās. Sākotnēji bija paredzēts noskaidrot arī laistīšanas nozīmi, tādēļ izvēlētas salīdzinoši lielas minerālmēslojuma normas, tomēr laika gaitā neizdevās sekmīgi atrisināt ar laistīšanu saistītās tehniskās problēmas, un izmēģinājums tika papildināts ar kaļķošanas variantiem.*
36 gadu laikā izmēģinājuma variantos izveidojušies atšķirīgi augsnes apstākļi ar dažādu P, K, organiskās vielas saturu un pH_{KCl} *līmeni, kas būtiski ietekmējis ne tikai zelmeņu ražību, bet arī botānisko sastāvu. Daudzu gadu garumā labākos rezultātus- augstāko sausnas ražu un vērtīgo stiebrzāļu saglabāšanos zelmenī nodrošinājis minerālmēslojums* $N_{200}P_{100}K_{300}$*. Nelīdzsvarots mēslojums un kādas uzturvielas iztrūkums noved pie tukšo vietu rašanās zelmenī. Augsta slāpekļa mēslojuma fonā augsnēs tuvās neitrālām pastiprināti ieviešas vārpata. Platlapji, galvenokārt cūkpiene pastiprināti ieviešas, mēslojot ar nelielām, līdz 100 kg* ha^{-1} *slāpekļa (N) mēslojuma normām kā skābās, tā arī augsnēs tuvas neitrālām.*
Nekaļķotās augsnēs vērojams būtisks zelmeņu sausnas ražas samazinājums un vērtīgo sēto stiebrzāļu izkrišana no zelmeņa, kā arī nesēto zālaugu un platlapju (F.rubra, Agrostis tenuis, Taraxacum officinale) īpatsvara pieaugums.

RESPONSE OF YOUNG SOUR CHERRY TREES TO WOODCHIP MULCH AND DRIP IRRIGATION

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Abstract. *The productivity of sour cherries grown in Latvia is insufficient. Yielding of sour cherries can be advanced providing appropriate soil moisture and control of diseases. Cherry leaf spot as well as spur and twig blight are the most important sour cherry diseases which cause economical losses of the yield. The influence of woodchip mulch and drip irrigation on sour cherry yielding and resistance to the diseases is investigated. The drip irrigation and woodchip mulch increased the yield of cherries. The cultivar 'Bulatnikovskaya' was the most productive. Drip irrigation slightly improved resistance to cherry leaf spot for the cultivars 'Zentenes', 'Orlica' and 'Tamaris'.*

Keywords: *sour cherries, woodchip mulch, drip irrigation, spur and twig blight, cherry leaf spot.*

Introduction

Sour cherries are distributed fruit plants in Latvia. Productivity of the sour cherries is about 5 – 7 t/ha in the countries where they are grown intensively [16]**.** Sour cherries often are less productive in Latvia conditions. The diseases of sour cherries are one of the factors decreasing productivity. Cherry leaf spot as well as spur and twig blight cause significant losses of the yield [1, 11].

Spur and twig blight can be caused by fungus *Monilinia* spp. as well as by bacteria *Pseudumonas* spp.

The fungus *Monilinia* spp. infects blossom parts, and through the floral tube and pedicel moves into the spur or twig [3]. *Monilinia* species over-winter on spurs, twigs, cancers and mummies of fruits where the conidia form in the early spring at the temperatures of 5°C or higher. Conidia are disseminated by wind and rain and germinate rapidly under favourable conditions. The incidence of blossom blight caused by *M. fruticola* Honey is related to the temperature and the duration of wetness; as little as 3 – 5 hours of wetting at 20° C may lead to significant infection. Optimum temperature for blossom infection is 25° C. In general, within the range of 5 – 30° C, temperatures above or below the optimum delay the infection but do not prevent it. The infection and development of fungus *M. laxa* Honey occur during periods of wetness at temperatures above 13° C (optimum 24° C). The disease incidence increased with longer wetness duration [17].

The bacteria *Pseudumonas* spp. overwinter in cankers and buds and systemically inside other symptomless host tissue [3]. Periods of frequent rainfall, high humidity, cool temperatures, and wind favour dispersal and infection of the pathogens Infected dormant buds often died, but some invaded buds open normally in spring. The leaves, blossoms and the fruits from these buds wilt. Cankers can develop on twigs at the base of infected spurs. The bacteria colonize new leaves in the spring and grow also epiphytically on weeds and leaves of crop plants. After entering through stomata, the pathogens colonize intercellular spaces of the spongy parenchyma and moves through the parenchyma to axillary buds and to the twigs. Optimal temperature range for visible symptom development on plants is 15 – 25° C [15]. In vitro estimated temperature optimum was 28° C, but no significant differences of growing rate were observed in temperature range from 23 to 33° C [19]. It was noted that Pseudomonas syringae grew well at low temperatures too.

Cherry leaf spot is caused by the fungus *Blumeriella jaapii* Rehm. [3]. Visible symptoms appear as small reddish spots on the upper surface of the leaves. Infected leaves turn yellow,

and defoliation may result. The infection of fruit pedicels is possible when weather conditions are optimum for the disease. The fruits on severely defoliated trees fail to mature normally. The fungus *Blumeriella jaapii* Rehm. over-winters in the infected leaves where the apothecia are produced in the spring. The optimum temperature for apothecial development is 13 - 16.5°C. The ascospores may be discharged during and shortly after the rainfall from late bloom to about six weeks after petal fall. Ascospore discharge is the highest at 16 – 30° C, less at 12° C and lowest at 4 – 8°C. The fungus infects the leaves of the cherries through stomata. A wet period only a few hours is required for spore germination and infection when temperatures are 15 – 20° C. The fungus *Blumeriella jaapii* Rehm. produce the acervuli, which contain the conidia on lower surface of the leaves. The conidia are developed in 5 – 15 days, and the lesions became visible. The conidia are discharged during rainy weather conditions. Repeated secondary infection by the conidia continues until leaf fall in the autumn.

The control of the diseases by spraying of the pesticides is limited for the sour cherries. Cherry fruits ripen for a short time and it is difficult to protect cherry fruits from pesticide residues. Several researches were done to deal this problem. In Bulgaria the control of cherry leaf spot by decreased number of pesticide sprayings was investigated [1]. Such control of cherry leaf spot was successful if both preventive and curative treatments were done, and long periods of wetness were absent. In Germany, susceptibility for *Monilia* sp. and *Blumeriella jaapii* Rehm. was tested for 24 sour cherry cultivars under organic cultivation methods [11]. Similarly, the susceptibility of sour cherries was significantly influenced by weather conditions in vegetation season. The cultivars 'Rubellit' and 'Hortei' had low susceptibility to diseases and high productivity even if the conditions were favourable for the infection.

Pathogens *M. laxa* and *M. fruticola* have antagonist fungi Trichoderma spp., it makes biological control possible [6]. The effect of microbial plant growth promoter based on fungus *Trichoderma asperellum* on the development of fungus *Monilia* was investigated [9]. About 50 % reduction of symptoms of blossom and spur blight was observed on treated trees (the cultivar 'Lutovka'). It was additionally noted that the aphids avoided to colonize the treated branches contrary to untreated. The obtained yield was threefold increased comparing to the control.

The susceptibility of cherries to the diseases is significantly varied by the cultivar [1, 11], consequently the cherries have genetically stated preventive responses to diseases. The water is related in plant responses to the environmental stress factors [2]. Positive response of soil moisture regulation to sour cherry productivity is observed in several reserches. Straw and moved grass mulch significantly increased the yield of sour cherry cultivar 'Montmorency' in Mitchigan [13]. Additionally, the amount of leached nitrogen was decreased in the mulch variant. Drip irrigation increased yield of sour cherry cultivar 'Łutovka' in Poland [8, 12]. Water is involved in all essential living processes of the plant as transport of nutrients, photosynthesis etc. It is supposed that practices reducing the stress through good nutrition or proper soil moisture can increase tolerance to diseases [3]. Contrary, the advanced growing due to favourable soil moisture can lead also to dense canopy which is appropriate for disease development [6]. There is no information about water supply relation to susceptibility of sour cherries to diseases. The aim of the research is to evaluate the influence of woodchip mulch and drip irrigation to the sour cherry productivity and susceptibility to cherry leaf spot as well as to spur and twig blight in Latvia.

Materials and methods

The trial was established at the Latvia State Institute of Fruit Growing in Dobele in 2007. The treatments were arranged in a split plot design: the method of soil moisture treatment – on the main plots, the cultivars – on the split plots. The factor – method of soil moisture treatment had three variants:

- using of woodchip mulch in the tree strips, thickness of woodchip layer was 10 cm,
- drip irrigation which moistens soil in 1 m wide tree strips,
- the control – neither mulch nor irrigation in the tree strips.

There were three replications both per mulch and control variants, and four replications per the irrigation variant. Seven sour cherry plants (one of each cultivar) were planted in every replication. The factor – cultivar of sour cherries had the following variants: 'Latvijas Zemais', 'Zentenes', 'Tamaris', 'Bulatnikovskaya', 'Desertnaja Morozovoi', 'Orlica', and 'Shokoladnica'.

The trial was established on clay Podzoluvisol soil which was slightly acid – pH 6.4. The content of P was 53 mg kg^{-1}, content of K was 124 mg kg^{-1}. Sour cherries were planted in spring of 2007 at distances of 4 × 4 m. The fertilizers were given yearly as 12 g m^{-2} of N, 5 g m^{-2} of P, and 10 g m^{-2} of K in the tree strips. Nitrogen fertilizer was given in the spring (in April), phosphorus and potassium ferilizers were given in the autumn. Weeds were controlled both by removing them and spraying with herbicide Basta (active ingredient glufosinate-ammonium) in 1 m wide strips along the trees. Perennial grasses were sown in the space between strips. The diseases were controlled by spraying:

1) fungicide Champion (active ingredient cooper hydroxide) at beginning of second decade of April,
2) fungicide Efector (active ingredient dithianon) at first decade of May and at beginning of first decade of August,
3) fungicide Topas (active ingredient propiconasole) at beginning of third decade of May.

Soil moisture was measured with device Theta Probe type ML2x once during 7–11 days. In the variant with drip irrigation, soil moisture was provided at about 70 per cent of the field water capacity. In Dobele, the total amount of precipitation during the period of active vegetation was 275 mm in 2009, and the sum of active temperatures was 2454°C (based on data of Latvian Agency of Enviroment, Geology and Meteorology). The weather conditions were dry in May. In 2009, irrigation was done 12 times and the total amount of water was 876 L per a 4 m long tree strip. In 2010, the total amount of precipitation during the period of active vegetation was 556 mm and the sum of active temperatures was 2604°C. Drip irrigation was not done in this year because soil was moist during all season.

The susceptibility for diseases was evaluated in 2009 and 2010. The infected twigs and blossom clusters were counted at the end of May in order to evaluate twig and blossom blight. Afterwards the infected parts were removed from trees. The susceptibility to cherry leaf spot was evaluated at the middle of September. The scala of 5 degrees was used:

0 – cherry leaf spot did not cause defolation or decoloration of leaves,
1 – less than 25 % of leaves had fallen
2 – about 25 % of leaves had fallen,
3 – about 50 % of leaves had fallen,
4 – about 75 % of leaves had fallen,
5 – all leaves had fallen.

The yield was characterized as total amount of fruits (kg) per tree in 2010. The data were statistically processed using analysis of variance and Duncan's test for *post hoc* analysis. The relationships between disease susceptibility and cherry yield were calculated using Spearman's correlation. This calculation was done for each cultivar separately because yield differences among cultivars were significant.

Results

In general, drip irrigation and woodchip mulch advanced the yielding of sour cherries. The intensity of this influence differed depending on yielding habit of the cultivar. Most of sour cherry cultivars are yielding on twigs and on spurs.

The cultivars ‘Latvijas Zemais’, ‘Shokoladnica’ and ‘Desertnaya Morozovoi’ mainly yielded on the twigs – on the shoots grown up in the previous season of the vegetation [4]. The woodchip mulch did not influence the vegetative growth of sour cherries in second growing year (in 2008) significantly. Decreased yielding but essential increase of growth caused by woodchip mulch was observed in third growing year (in 2009). Accordingly, advanced vegetative growth in 2009 provided significantly higher yield in next year (in 2010) for the cultivars Latvijas Zemais’, ‘Shokoladnica’ and ‘Desertnaya Morozovoi’ in the woodchip mulch variant (on average, 1.5 kg per tree) comparing with control variant (on average 0.5 kg per tree) (Table1). The yield of these cherry cultivars grown with drip irrigation (on average 0.9 kg per tree) did not differ significantly with other variants.

Table 1.

Influence of woodcip mulch and drip irrigation on sour cherries yielding on the twigs

Factors	Yield, kg per tree		
	Woodchip mulch	Drip irrigation	Control
‘Shokoladnica’	2.23	1.47	0.61
‘Desertnaya Morozovoi’	1.01	0.53	0.55
‘Latvijas Zemais’	1.11	0.59	0.20
On average	1.45[a]	0.86[ab]	0.45[b]

[ab] - the means in the rows marked with the same letter did not differ significantly at P≤0.05

The cultivars ‘Orļica’, ’Zentenes’ and ‘Tamaris’ have high proportion of the spurs in their canopy [4]. The spurs are short fruiting branches which develop on two years old shoots. In 2010 yielding spurs developed in 2009 on the shoots which grew up in 2008. Drip irrigation increased vegetative growth of sour cherries in first growing years - both in 2008 and 2009. So the development of the spurs and following yielding was advanced (Table 2). The cultivars ‘Orlica’, ’Zentenes’, ‘Tamaris’ and ‘Bulatnikovskaya’ had tendency to increase yield (p=0.1) in the variant with drip irrigation (on average, 1.7 kg per tree) comparing to control and woodchip mulch variants (on average, 1.0 and 1.1 kg per tree, respectively).

Table 2.

Influence of woodcip mulch and drip irrigation on sour cherries yielding on the spurs

Cultivars	Yield, kg per tree		
	Drip irrigation	Woodchip mulch	control
‘Bulatnikovskaya’	3.65	2.87	2.40
‘Zentenes’	1.40	0.72	0.91
‘Orlica’	1.13	0.73	0.48
‘Tamaris’	0.67	0.20	0.14
On average	1.71 [a]	1.13 [a]	0.99 [a]

[ab] - the means in the rows marked with the same letter did not differ significantly at P≤0.05

The yielding was essentially influenced also by cultivar. The most productive was the cultivar ‘Bulatnikovskaya’ – the average yield was 3.0 kg per tree. The yield of the other cultivars (with exception of cultivar ‘Tamaris’) ranged from 0.6 to 1.5 kg per tree and did not differ significantly each with other in 2010.

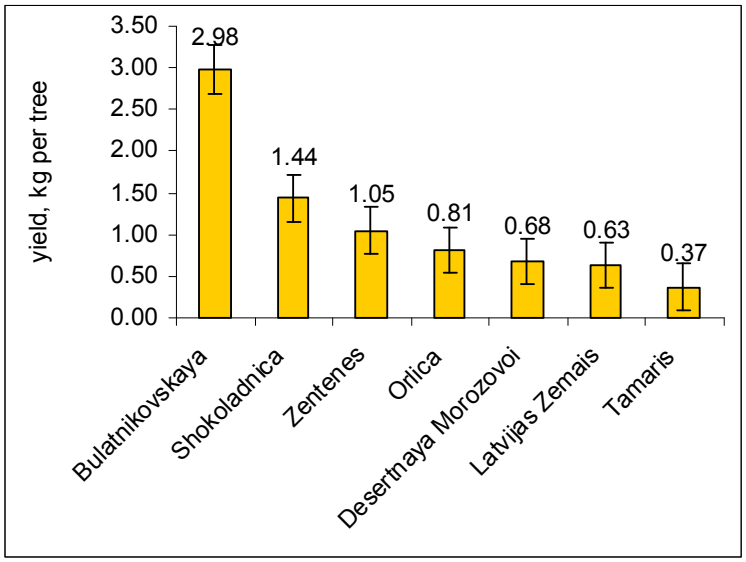

Fig. 1. **Yield of sour cherry cultivars in 2010**

In generally, yield of sour cherries was not high in 2010. One of the reason was insufficient fruit set, but low productivity of the cultivar 'Tamaris' was caused by low vigour of the tree and by damaged flower buds in the winter.

Dry weather conditions in May of 2009 were unfavourable for *Monilinia* spp. and *Pseudomonas* spp. development. The incidence of spur and twig blight was very low – only few infected blossoms in the orchard.

Warm and wet weather conditions in May of 2010 advanced the development of diseases. Nevertheless, the level of the spur and twig blight was low for the cultivars 'Latvijas Zemais' and 'Orlica' (Table 3). The cultivar 'Zentenes' was the most susceptible to the spur and twig blight.

Table 3.

The susceptibility of sour cherry cultivars to the spur and twig blight

Cultivars	The susceptibility to the blossom and twig blight
'Latvijas Zemais'	1.0[a]
'Orlica'	1.2[a]
'Tamaris'	1.5[ab]
'Shokoladnica'	1.7[ab]
'Bulatnikovskaya'	2.8[ab]
'Desertnaya Morozovoi'	3.3[b]
'Zentenes'	7.1[b]

[ab] - the means in the column marked with the same letter did not differ significantly at P≤0.05.

The soil moisture treatments did not influence the susceptibility of cherries to the spur and twig blight in 2010 (P≤0.05).

The yield of sour cherries was not influenced significantly by incidence of spur and twig blight in 2010. Consequently, the integrated pest management, cultivation technologies and resistance of cherry cultivars was appropriate for controlling of spur and twig blight without losses of the yield.

Symptoms of cherry leaf spot were observed on most of the sour cherry cultivars at the end of active vegetation period in 2009. The average air temperature was in range of the optimum for cherry leaf spot until second decade of the September in 2009. Defoliation of susceptible

cultivars began in the middle of August and continued during the September. The cultivar 'Tamaris' was the most resistant in this year (Table 4).

Table 4.

The susceptibility of sour cherry cultivars to the cherry leaf spot

Cultivars	The susceptibility to the cherry leaf spot		
	in 2009	in 2010	on average
'Latvijas Zemais'	2.9^{a}	3.3^{ab}	3.1^{a}
'Shokoladnica'	1.9^{b}	4.2^{a}	3.1^{a}
'Orlica'	2.2^{ab}	2.3^{bcd}	2.3^{b}
'Zentenes'	1.5^{b}	2.9^{bc}	2.2^{b}
'Desertnaya Morozovoi'	1.4^{b}	1.4^{d}	1.4^{c}
'Bulatnikovskaya'	1.4^{b}	1.3^{d}	1.4^{c}
'Tamaris'	0.2^{c}	1.9^{cd}	1.1^{c}

^{ab} - the means in the column marked with the same letter did not differ significantly at $P \leq 0.05$.

The infection by fungus *Blumeriella jaapii* Rehm. in 2009 did not affected the yield of sour cherry cultivars in 2010 – the correlation was insignificant. The soil moisture treatments did not influence the susceptibility of cherries to the cherry leaf spot in 2009.
In 2010, the first symptoms of cherry leaf spot appeared already in June due to favourable, wet weather conditions. The average air temperature was in range of the optimum for cherry leaf spot until first decade of the September. The defoliation caused by *Blumeriella jaapii* Rehm. in 2010 was more pronounced than in 2009. The cultivars 'Bulatnikovskaya' and 'Desertnaya Morozovoi' showed better resistance than the other cultivars in 2010. The cherry leaf spot was not influenced significantly by soil moisture treatments for cultivars 'Bulatnikovskaya', 'Latvijas Zemais', 'Shokoladnica' and 'Desertnaya Morozovoi'. The tendency ($p=0.06$) of increased resistance to cherry leaf spot in drip irrigation variant was observed for the cultivars 'Orlica', 'Zentenes' and 'Tamaris' (Figure 2). These cultivars responded to drip irrigation with increased productivity too.

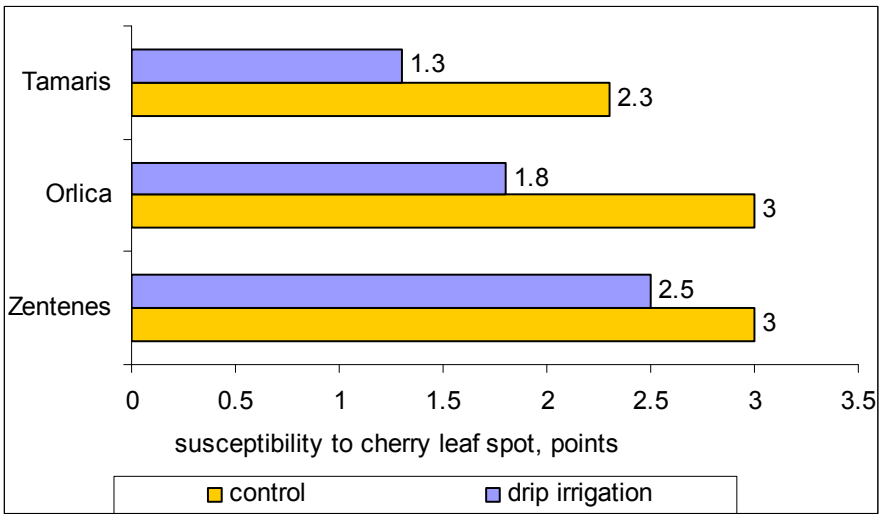

Fig. 2. **Influence of drip irrigation to sour cherry suspectibility to cherry leaf spot in 2010**

The average evaluation of the susceptibility to the cherry leaf spot was the highest for the cultivar 'Tamaris' and the lowest for the cultivars 'Latvijas Zemais' and 'Shokoladnica'.

Discussion

Positive effect of drip irrigation and mulch determined in our research confirms with the results obtained in Poland and in USA [13, 18]. The amount of precipitation was high in our investigation in 2010. Nevertheless, the effect of the mulch was positive. It can be caused by advanced activity of microorganisms and nitrogen mineralization [10], less fluctuations of soil temperature [18] as well as by high water necessity of the cherries.

Drip irrigation caused sour cherry yield increase of 25% in research carried out in Poland; drip irrigation was applied on 15 years old productive cherry orchard [12]. On average, drip irrigation caused yield increase more than 55 % in our research. Such effect can be explained by the young age of our cherry trees. The vegetative growing was more active then of mature trees, and positive effect of irrigation was more pronounced. The observed tendency of better resistance to cherry leaf spot in drip irrigation variant confirms the water supply necessity in the responses to stress. The differences of resistance among the cultivars were more essential than among soil moisture treatment variants. The disease resistance of cherries is one of main goals in breeding programs in Germany and USA [7, 14].

It must be appointed that positive effect was caused by irrigation managed in previous year. Similarly, positive post-influence of irrigation was observed in research of cherry rootstock 'Colt' [5]. Cuttings of 'Colt' were grown with drip irrigation and compared with non-irrigated rootstocks. The irrigation advanced growth in first growing year. Afterwards rootstocks were replanted and grown without irrigation. However, the previously irrigated plants produced significantly longer total shoot length then previously unirrigated plants.

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Summary

In generally, woodchip mulch and drip irrigation positively influenced yielding of young sour cherries. The cultivars 'Desertnaya Morozovoi', 'Latvijas Zemais' and 'Shokoladnica' was significantly more productive in woodchip mulch variant than in other variants due to rash vegetative growth in previous year. Drip irrigation provided even growth and development of spurs, so it advanced yielding of the cultivars 'Bulatnikovskaya', 'Zentenes', 'Orlica' and 'Tamaris'. The cultivars 'Latvijas Zemais' and 'Orlica' were more resistant to spur and twig blight than other cultivars. 'Bulatnikovskaya' and 'Tamaris' showed better resistance to cherry leaf spot comparing to others. Drip irrigation slightly improved resistance to cherry leaf spot for the cultivars 'Zentenes', 'Orlica' and 'Tamaris'.

Kopsavilkums

Šķeldu mulča un pilienveida apūdeņošana kopumā labvēlīgi ietekmēja skābo ķiršu jaunkoku ražību. Škeldu mulča būtiski paaugstināja ražību kailzaru ķiršu šķirnēm 'Desertnaja Morozovoi', 'Latvijas Zemais' un 'Šokoladņica' pateicoties spēcīgajam veģetatīvajam pieaugumam iepriekšējā gadā. Pilienveida apūdeņošana nodrošināja vienmērīgu augšanu un pušķzaru attīstību iepriekšējos gados, tādejādi veicinot šķirņu 'Bulatņikovskaja', 'Zentenes', 'Orļica' un 'Tamaris' ražību. Šķirnes 'Latvijas Zemais' un 'Orļica' bija izturīgākas pret ķiršu mēri nekā citas šķirnes. Skābajiem ķiršiem 'Bulatņikovskaja' un 'Tamaris' novērota labāka izturība pret lapbiri salīdzinājumā ar pārējām šķirnēm. Pilienveida apūdeņošanas ietekmē novērota tendence paaugstinātai izturībai pret lapbiri šķirnēm 'Zentenes', 'Orļica' un 'Tamaris'.

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AGRONOMIC TRAIT AND GENETIC ANALYSIS OF LATVIAN FLAX GERMPLASM

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Abstract. *There is a long history of flax cultivation in Latvia, and breeding programs were active until 1970's, when flax breeding in Latvia was halted. Since 1992, the Agriculture Science Centre of Latgale (ASCL) has repatriated Latvian flax germplasm from various genebanks, as well as renewed limited breeding activities in flax. Currently, the ASCL holds a collection of 497 flax accessions, as well as 9865 accessions of various lines and hybrids developed at the LLZC since 1993. To assist in the characterization of this Latvian flax germplasm, we have utilised DNA markers to assess genetic diversity and relatedness, as well as surveying functional polymorphism. We have utilised Simple sequence repeat (SSR) markers developed from both genomic libraries as well as expressed sequences. The results of the DNA marker survey were utilised to determine the genetic polymorphism and relatedness within Latvian flax germplasm, and these results were compared with the analysis of agronomic traits carried out in field trials at the ASCL. The development of DNA markers linked to traits of agronomic importance will assist in the development of a Latvian flax breeding program. The use of DNA marker technology will allow more efficient assessment and rational utilization of Latvian flax germplasm*.

Keywords: *flax breeding, DNA markers, characterisation and evaluation.*

Introduction

During the 1920's and 1930's, flax (*Linum usitatissinum* L.) was grown throughout the territory of the Republic of Latvia. Flax breeding was undertaken at Priekuļu, Stende and Ošupe breeding stations, and many flax varieties were developed, including 'Balva', 'Rota', 'Rota 2', 'Priekuļu 665', 'Priekuļu uzlabotie', 'Ošupe 30', 'Ošupe 31', etc. In the 1970's, flax breeding activities were discontinued in Latvia [1].

Currently, the flax varieties grown in Latvia are foreign varieties, which are not suited to Latvian soil and climatic conditions, and do not ensure stable flax fibre and seed yield. Successful development of the Latvian flax industry requires the creation of new, locally adapted varieties of flax.

Since 1992, the ASCL has actively engaged in research on flax fibre, oil and genetic resources, as well as repatriation, propagation, research, preservation and maintenance of a Latvian flax collection. A large part of the collection comprises of varieties and lines of Latvian origin repatriated from the N. Vavilov All-Russian Plant Institute, the Russian Flax Research Institute, and German gene banks. The ASCL flax collection also contains 497 flax accessions from other countries, including 427 fibre accessions and 70 oil accessions. Flax breeding activities were started at the ASCL in 1993, and accessions with valuable qualitative and quantitative characteristics are used for breeding and hybridisation. The flax collection also contains 9865 lines and hybrids of Latvian origin developed at the ASCL in recent years. Only a small proportion of the resulting hybrids and lines have been evaluated, the other varieties and lines are maintained in the ASCL gene bank.

The use of DNA markers has become widespread in the study of a wide range of crop species. In contrast to phenotypic traits and markers, they have the advantage of not being influenced by environmental conditions; they reveal a higher level of polymorphism; and markers linked to specific genes or quantitative trait loci (QTLs) can be characterized. DNA markers are utilised in characterization of genetic resource collections and have been integrated into breeding programs for various crop species. While not as widely studied as other crop species, DNA markers have been extensively studied in flax, and a range of molecular tools have been

developed and utilised, including SSR markers, genetic linkage maps, QTL studies, microarray and proteomics studies [2; 3, 4, 5].
This study utilised DNA markers to characterize a subset of the best established Latvian oil and fibre flax varieties and lines, and these genotyping results were compared to agronomically important traits measured in field trials of these varieties.

Materials and Methods

The flax material analysed included older Latvian cultivars, which were developed before the 1950's, as well as newly developed breeding lines, derived from crosses between these old Latvian varieties and more modern, foreign cultivars, as well as crosses exclusively between modern, foreign cultivars.
The flax material was planted in the field at the ASCL, and the following agronomic properties assessed for: plant height (total and technical), yield (straw and seed), boll number, seed count, 1000 seed weight, bast content, oil content, unretted bast and shive yield. Agronomic trait values reported in this study were measured in 2010.
Seed material was obtained from the ASCL collection. Seeds were germinated and genomic DNA was extracted from 1-2 week old seedlings using a modified CTAB protocol [6]. Samples were ground in a mortar with 500-800µl 2x CTAB buffer (heated to 65° C), and transfered to 1.5ml centrifuge tubes. After incubation at 65° C for 15-20 min., chloroform (1:1) was added and mixed for 3-5 min. The tubes were centrifuged for 10 min at 13000 rpm., the supernatant tranfered to new tubes and 0.2 volumes 5x CTAB buffer (65° C) added. Samples were gently mixed for 3-5 min and then incubated for 10 min at 65° C. Chloroform (1:1) was added and mixed for 3-5 min., then samples were centrifuged for 10 min at 13000 rpm. Supernatant was transfered to a new tube, 0.7 volumes of isopropanol added, gently mixed and incubated for 20-30 min at room temperature. Tubes were centrifuged for 10 min, the supernatant removed, and the remaning pellet washed twice with 70% ethanol (-20° C), centrifuging for 2-3 min between washes. The pellet was air-dried, and resuspended in 75µl TE buffer. DNA from 6 individuals of each cultivar was extracted and analysed separately.
Nine SSR markers were used to genotype these cultivars (Lu 002, Lu 013, Lu 021, Lu 023, Lu 031, Lu 032, Lu44E4, Lu178, Lu765B) [2, 5, 7]. The forward primer was synthesised with a 6-FAM, HEX or NED fluorescent label to allow visualisation of amplification products on a fluorescent sequencer (Table 1).
SSR locus amplification was carried out using the following PCR conditions: 95ºC for 3 min, 38 cycles of 95 ºC for 30 sec, 55ºC – 30 sec, 72ºC – 30 sec; 72ºC - 10 min; in a total volume of reaction 20µl containing 50 ng template DNA, 1x PCR buffer, 2 mM $MgCl_2$, 0.2 mM dNTP mix, 0.5 U *Taq* polymerase (*Fermentas*), 0.5 mM of forward (labelled) and reverse primers. Amplification fragments were separated on an ABI Prism 3130xl Avant Genetic Analyzer (*Applied Biosystems*) and analyzed with GeneMapper 3.5. Population analyses were performed with GenAlEx version 6.4 [8], and dendrograms constructed using MEGA version 4 [9].

Table 1.

SSR markers utilised in this study

Locus	Primer name	Primer sequence	Repeat motif
LU002[a]	LU002F	AACCGGAACTTTCGGCTGAG	$(TC)_{18}$
	LU002R	GGTTGGAGTAATCGCCGGAG	
LU013[a]	LU013F	TGTGCCAATAGCCATGTGAG	$(AC)_4(AG)_{18}$
	LU013R	GTATGGCTTCCTATGGGCTAAC	
LU021[a]	LU021F	CCGAGTCCGAAAGAATCTGG	$(GA)_{15}(A)_4$
	LU021R	CAGCTCCCATTGTTGTTCCC	
LU023[a]	LU023F	CATGACCATGTGATTAGCATCG	$(CA)_8(GA)_{22}$
	LU023R	CATAGGAGGTGGGTTGCTGC	
LU031[a]	LU031F	CACGAATCTCTCCCAGACA	$(TC)_8$
	LU031R	GAGAGTTTAGGGTATGCACTGA	
LU032[a]	LU032F	GAAAAGGAAGGCTTAGAAGAAGAAG	$(AG)_{10}$
	LU032R	AGTTTCTCAATACACAGATCGAAGG	
Lu44E4[b]	Lu44E4F	TCCTCAACCCACCACCTAAA	Not reported
	Lu44E4R	ATCGTGCAGTCTTGCAACC	
Lu765B[c]	Lu765BF	CCTCATTCCGCTCAGCAA	$(TTC)_8$
	Lu765BR	CGAAAATGGGGAAGATGATG	
Lu178[c]	Lu178F	CAAGGGAGTGCTGCTCTGAT	$(TC)_9$
	Lu178R	ATTGCGAGCAACAACAACAG	

Cited in: a – [2], b – [7], c – [5].

Results and discussion

SSR marker analysis

The number of alleles detected by the 9 analysed markers ranged from 4-16 (average 8.56); however, the distribution of these alleles was uneven, as seen by the low figures for the effective number of alleles, which ranged from 1.13-4.58 (average 2.68). The observed heterozygosity ranged from 0.00-0.95 (average 0.42), while the expected heterozygosity ranged from 0.12-0.78 (average 0.55). The inbreeding coefficient *F*, ranged from -0.58-1.00 (average 0.23), indicating an overall excess of homozygotes, which is to be expected from a mainly inbreeding species, that has been homogenised by line selection over multiple generations. One interesting observation was that the SSR markers developed from expressed portions of the genome (Lu178 and Lu765B) were the most highly polymorphic markers (allele numbers were 10 and 16, respectively). However, most of these alleles were of low frequency, as reflected in the number of effective alleles (1.93 and 3.44, respectively) (Table 2).

The level of genetic polymorphism was compared between the old cultivars and the new lines. The mean number of alleles in the cultivars was 4.56, while in the lines then mean number of alleles was 7.44. This difference was a function of the number of individuals analysed, with 121 individuals from the lines analysed, and only 33 from the cultivars. When 33 individuals were randomly chosen from the lines, the mean number of alleles was similar (4.67 in the lines, 4.56 in the cultivars). Analysing the full set of data, the other measures of genetic diversity were similar between the cultivars and lines. The number of alleles with a frequency over 5% was 2.67 and 3.00 respectively, the number of effective alleles was 2.44 and 2.46, and the expected heterozygosity was 0.52 in both groups. The Nei genetic distance between

all analysed individuals was calculated, and a principal co-ordinates analysis plot calculated (Fig. 1). It can be seen that there is no clear differentiation between the cultivars and lines, and that the genetic diversity of the old cultivars has been retained in the newly developed lines. This low differentiation between the two groups was confirmed by analysis of molecular variance (AMOVA), where 95% of the genetic variance was within the groups, and only 5% between ($p \leq 0.001$).

Table 2.

Genetic parameters of analysed SSR markers

Locus	LU002	LU013	LU032	Lu21	Lu23	Lu31	Lu44E4	Lu178	Lu765B	Average over loci
Number of alleles	5	9	7	5	7	4	14	10	16	8.556
Effective number of alleles	1.539	4.581	2.360	1.130	4.426	2.247	2.502	1.929	3.441	2.684
Observed heterozygosity	0.333	0.632	0.730	0.103	0.769	0.000	0.946	0.149	0.113	0.419
Expected heterozygosity	0.350	0.782	0.576	0.115	0.774	0.555	0.600	0.481	0.709	0.549
Inbreeding coefficient	0.049	0.191	-0.266	0.107	0.006	1.000	-0.576	0.691	0.840	0.227

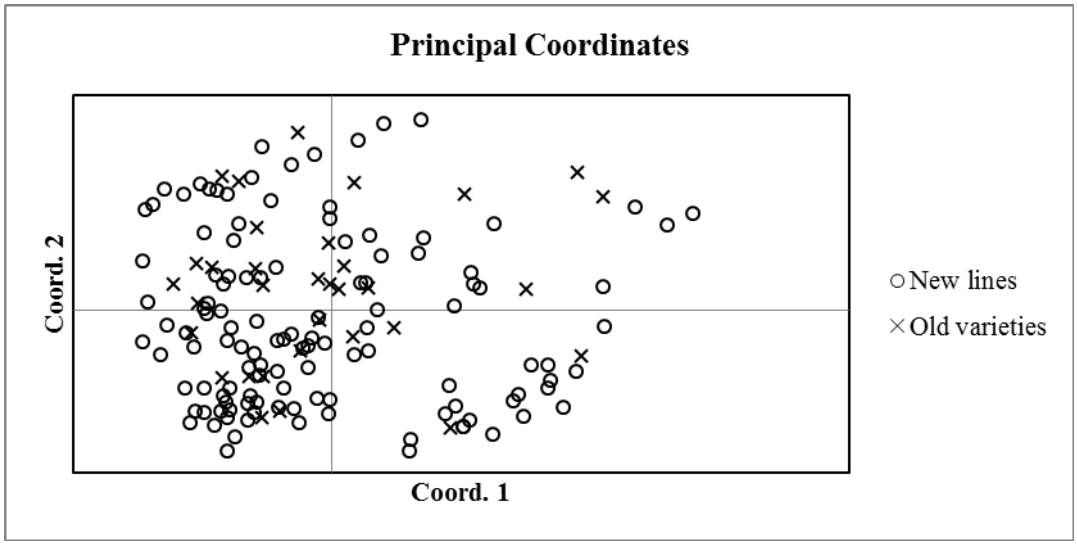

Fig. 1. **Principal coordinate analysis of analysed flax accessions**

The pairwise Nei genetic distance between the cultivars and lines was calculated, and a dendrogram constructed using the Neighbour-Joining algorithm (Fig. 2). No distinct clusters were identified within the dendrogram, however, lines derived from the same cross tended to cluster closely to each other (but not always), and the old varieties were found to cluster together. This lack of defined clusters within the dendrogram is probably a reflection of the fairly low level of genetic polymorphism, and the low differentiation between the lines and cultivars

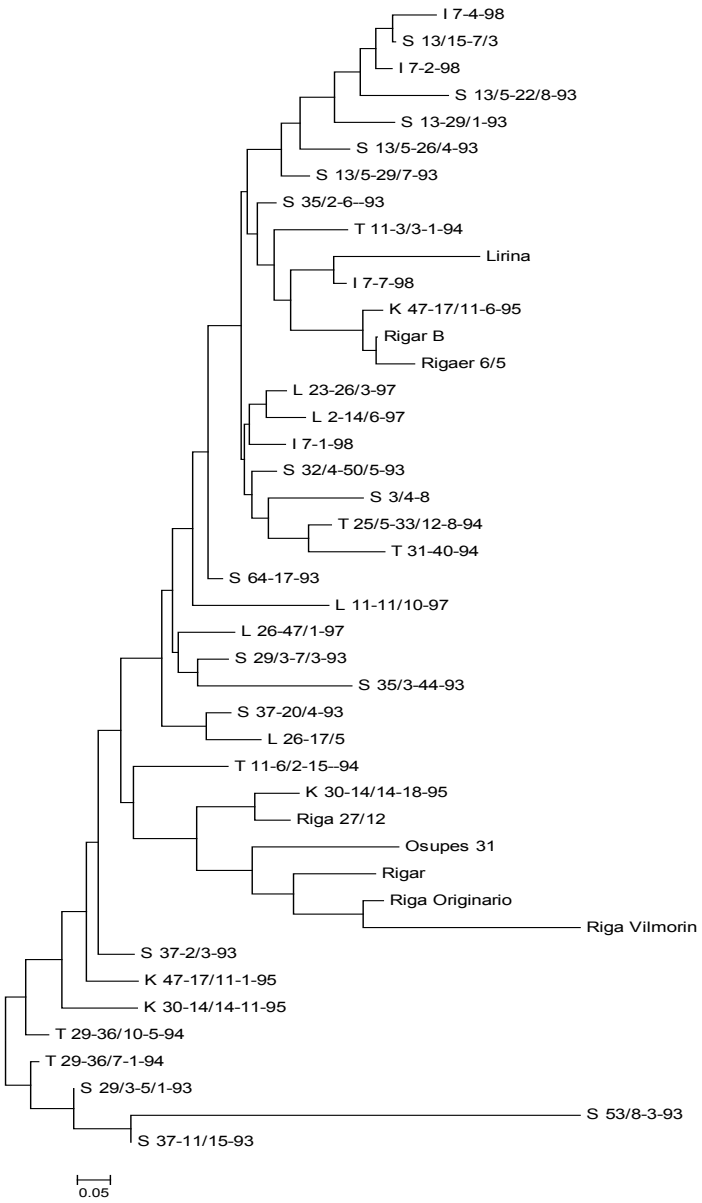

Fig. 2. **Neighbour-joining dendrogram of analysed flax accessions**

Correlation of genetic analysis with agronomic traits

The lines included in this study were selected for having agronomic properties that are desirable, and that could be potentially utilised in the development of new, locally adapted varieties. Therefore, the agronomic trait values in the lines usually exceeded those of the control varieties (Vega2 and Lirina), particularly for fibre-related traits. Examination and ordering of the agronomic trait data showed that in some cases, lines derived from the same cross yielded the best agronomic trait scores. In particular, lines derived from the cross Blakitnij x Ošupes 31 (K 30) and M-12 x Eva (S 37), were consistently ranked in the top five best lines, especially with regard to fibre traits. The agronomically best performing lines do not show any particular clustering within the dendrogram, and they are not distinct when considering the measures of genetic diversity such as the number of alleles, the number of effective alleles and heterozygosity. The old varieties tended to show better results for such parameters as seed yield, boll number and 1000 seed weight (Table 3).

Table 3.

Agronomic trait data from 2010 field trials

Variety or line	Plant height, cm		Yield, g/m²		Boll number	Seed count	1000 seed weight	Bast content	Oil content	Unretted bast	Unretted shives
	total	technical	straw	seed	per plant	per boll	g	%	% dry weight	g/m²	g/m²
I7-1-98	84.2	71.9	597	128.7	5.9	8.8	4.4	27.7	43.2	260	260
I7-2-98	85.1	74	617	142.1	7.1	8.8	4.41	32.3	42	260	270
I7-4-98	89.2	78.3	540	126.1	6.9	8.5	4.28	32.7	42.2	210	250
I7-7-98	83.9	72.2	623	117.6	5.8	9	4.15	31.5	40.2	220	240
K30-14/14/-11-95	88.9	78.2	637	96.8	6.1	8.9	3.95	35.3	46.9	290	270
K30-14/14-18-95	91.6	81.7	630	72.4	6.4	8.8	3.95	32.6	47.1	260	300
K47-17/11-1-95	80.6	68.8	553	115.9	7.2	8.6	4.08	34.8	46.6	210	200
K47-17/11-6-95	80.9	68.7	537	112.1	8.6	8.3	4.1	32.7	44.7	200	200
L11-11/10-97	74.7	64.3	510	126.9	8	9.1	4.72	30.9	45.6	159.8	190
L2-14/6-97	72.7	61.6	377	99.3	6.5	8.2	3.95	30.6	42.9	170	170
L23-26/3-97	78.6	65.4	410	82	7.9	8.3	3.73	32.5	41.6	116.3	160
L26-47/1-97	79.1	68.4	407	80	6.7	8.2	3.33	31.8	45.6	190	180
S 13/15-7/3-93	79.4	69.7	5.67	81.2	6.6	9.3	4.06	29.5	43.3	26.0	32.0
S13/5-22/8-93	79.2	67.8	497	62.1	8	9	3.72	25.3	42.3	127.8	190
S13/5-26/4-93	78.3	68.4	480	97.3	6.3	8.9	3.75	32.6	42.8	173.1	190
S13/5-29/7-93	79.3	70.1	453	98.7	5.5	8.9	3.8	28.7	42.5	163.4	170
S13-29/1-93	79.2	70.3	483	77.1	5.6	8.3	3.85	29.1	42.5	190	230
S29/3-5/1-93	72.4	62.4	507	82.9	6.1	8.2	3.9	36.8	43.8	172.8	210
S29/3-7/3-93	80.5	69.8	607	79.7	6.7	8.9	3.86	35.6	43.7	220	250
S32/4-8-93	76.6	63.9	420	75.7	8.2	8.6	3.96	32.5	42.6	210	200
S32/4-50-93	72.1	60.2	400	71.8	8.1	8.7	3.97	35.8	43.3	127.9	130
S35/2-6-93	72.5	61.4	417	102.9	5.9	8.5	3.41	34.1	44.6	210	160
S35/3-44-93	76.8	65.7	410	76.8	7.6	8.9	2.63	29.5	43.7	136.1	200
S37-11/15-93	86.2	73.8	543	116.6	7.1	9	4.56	38.7	44.8	175.1	190
S37-2/3-93	78.3	66.2	507	77.9	7	8.8	4.18	38.4	43	190	220
S37-20/4-93	82.7	71.4	557	72.9	6	8.5	4.56	36.1	44.6	210	220
S53/8-3-93	80.7	71.2	507	91	7.1	8.3	3.92	33.4	44.8	200	150
S64-17-93	81.5	70.7	587	135.2	7.4	8.9	4.56	30.2	44.5	250	290
T11-13/3-1-94	77.9	68	520	98.9	5.5	8.5	4.23	32.1	43.2	210	190
T11-6/2-15-94	77.5	66.4	417	110.6	7.5	8.6	3.84	35.3	41.2	190	170
T25/5-33/12-8-94	85.4	73.1	430	65.5	5.8	8.6	3.61	31.1	44.9	240	140
T29-36/10-5-94	79.2	69.6	573	83.4	4.8	8.8	4.17	34	42.9	230	170
T29-36/7-1-94	82.4	70.7	577	97.1	6.7	9.1	4.47	33.1	44.1	250	150
T31-40-94	83	69.8	480	102.7	8	9.1	3.71	33.1	45.2	210	150
Vega 2 (standard)	71.8	61.6	500	108.6	5.6	8.1	4.59	30.1	45.4	151.4	170
Ošupes 31	70.9	59.5	537	113.4	8.5	8.2	3.77	28.6	42	190	210
Riga 27/12	57.7	45.6	373	114.3	7.7	7.9	4.1	32.3	42.3	137.7	170
Riga Originario	59.9	47.5	460	161.3	5.7	8.2	5.25	31.1	44.1	165.9	200
Riga Vilmorin	62	51.4	397	84.8	6.9	8.6	4.73	31.2	42.7	159.9	200
Rigaer 6/5	65.6	51.3	390	139.5	5.7	8.2	4.94	31.9	44.4	161.9	190
Rigar	61.2	48.9	360	122.4	6.8	7.7	5.86	29.2	45	110.3	130
Rigar B	66	53.5	410	93.7	7.1	8.2	4.49	31.5	44.3	148.2	130

Trait values in shaded cells exceed that of standard varieties (Vega 2 and Lirina).
Lines with identical initial letter/number combinations are derived from a single cross

The level of genetic polymorphism identified with the utilised SSR markers was modest. While the number of alleles detected with the analysed SSR markers is not extremely low, the distribution of the alleles is very uneven, with only 2 or 3 alleles with a frequency above 5% found at most loci. A fairly low level of polymorphism is found in many crop species, which have been subjected to intensive selection pressures in breeding programs. There was very little genetic differentiation found between the old cultivars and the newly developed lines. This is a reflection of the fact that some of the lines are derived from crosses between these old Latvian cultivars, and more modern foreign cultivars. However, some of the new lines are derived entirely from crosses between foreign cultivars, and these lines are also not genetically differentiated from the old Latvian cultivars. This indicates the narrow genetic base of cultivated flax in general, which has been reported previously [2, 5].

An interesting observation was that the two SSR markers derived from expressed gene sequences (EST-SSRs) (Lu178 and Lu765B) were the most highly polymorphic markers in term of the number of alleles detected. This is surprising, as SSR markers derived from expressed sequences have often been reported to detect a lower level of genetic polymorphism in comparison to SSR markers derived from genomic sequences [10]. This is presumed to be a result of evolutionary constraints upon these repeat sequences due to their proximity to coding sequences. It would be interesting to survey larger amount of flax SSRs derived from expressed sequence to determine if this tendency is maintained.

There was genetic polymorphism detected within all lines and cultivars surveyed. This may be a consequence of the type of flax material included in this study – old cultivars dating from the first half of the 20th century, and breeding lines. It is interesting that most of the alleles detected were of a low frequency, however, they were often found in multiple individuals from a particular line or cultivar, indicating that these rare alleles are probably due to remaining heterozygosity within these lines and cultivars, and not to pollen contamination from other flax lines and cultivars. It is not surprising to find such intra-varietal variation within older cultivars, which were not bred to such strict uniformity as required by modern cultivar registration regulations. Furthermore, this genetic heterogeneity is to be expected in breeding lines, which have not been fully homogenised through many generations of self-pollination.

That fact that the agronomically best performing lines did not show an increased degree of genetic similarity (except for those lines derived from a single cross), can be explained by the fact that the agronomic traits measured are complex, and are probably influenced by a large number of genes. In addition, the dendrogram was not particularly well-resolved, probably due to the low level of genetic polymorphism. Lines derived from the same cross did not always cluster together (e.g. lines derived from the cross I7, S37 and K47). The SSR markers utilised in this study will be useful for monitoring the overall genetic diversity within Latvian flax germplasm and breeding programs. In order to find markers that are linked to traits of agronomic interest, it will be necessary to develop markers based on functional regions of the genome, such as polymorphisms within expressed genes and gene copy number variations. Further work in this area will be the assessment of polymorphism in candidate genes that have been identified from previously published microarray and proteomic studies of fibre development in flax.

Conclusions

This study was an initial survey of the genetic polymorphism found within the Latvian flax collection using SSR markers. The data obtained will provide a baseline for further characterization and assessment of Latvian flax germplasm. Use of these SSR markers to further investigate the accessions in the flax collection held at the ASCL which have yet to be

characterised will enable genetically unique and differentiated germplasm to be identified, thus making process of screening for agronomically important traits more efficient.

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Anotācija. *Latvijā jau izsenis ir kultivēti lini, un linu selekcija Latvijā tika veikta līdz 20. gadsimta septiņdesmitajiem gadiem, līdz tā tika apturēta. Kopš 1992. gada linu selekciju Latvijā ir atjaunojis Latgales lauksaimniecības zinātnes centrs (LLZC) un veicis Latvijas linu šķirņu sēklu repatriāciju no vairākām pasaules gēnu bankām. LLZC šobrīd atrodas kolekcija, kurā ir 497 šķirnes un 9865 līnijas un hibrīdi, kas izveidoti kopš 1993. gada. Latvijas linu raksturošanai mēs izmantojām DNS marķierus, ģenētiskās daudzveidības un līniju savstarpējās radniecības izvērtēšanai, kā arī funkcionālā polimorfisma izpētei. Mēs esam izmantojuši mikrosatelītu (SSR) marķierus, kuri izveidoti no genomiskām un ekspresētām DNS sekvencēm. Ar DNS marķieriem iegūtie rezultāti tika izmantoti, lai noteiktu Latvijas linu ģenētisko polimorfismu un ģenētisko radniecību. Iegūtie dati tika salīdzināti ar LLZC veiktajiem lauka izmēģinājumu rezultātiem. Ar agronomiski nozīmīgām īpašībām saistītu DNS marķieru lietošana palīdzēs linu selekcijai Latvijā. DNS marķieru izmantošana palīdzēs racionālāk un efektīvāk izvērtēt linu selekcijas materiālu, un varēs atbalstīt un attīstīt linu selekciju Latvijā.*

Atslēgas vārdi: *linu selekcija, DNS marķieri, aprakstīšana un izvērtēšana*.

IMPROVING WINTER WHEAT YIELDS IN ORGANIC FARMING SYSTEMS THROUGH INNOVATIONS IN GREEN MANURE MANAGEMENT

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Abstract. *The paper presents effect of perennial grasses (Trifolium pratense L., Medicago sativa L., xFestulolium) and their aboveground mass management methods (removed from the field, mixed, mulching) as preceding crops on N_{inorg} in the soil as well as on yield of winter wheat under conditions of ecological farming. Field experiments were carried out at the Joniškėlis Research Station of the Lithuanian Institute of Agriculture (LIA) on an Gleyic Cambisol. Experimental evidence indicated that content of symbiotically fixed nitrogen in the biomass of legumes accounted for the largest share (61–84 %) of the total nitrogen content (208.0–298.0 kg ha^{-1}), accumulated in the biomass. Winter wheat grain yield significantly ($r = 0.783$; $P < 0.05$) correlated with soil inorganic nitrogen content in spring. Grain yield productivity increased by 0.01 t ha^{-1} after incorporation of 1 kg ha^{-1} nitrogen of legume crops biomass.*

Key words: *ecological agriculture, green manure, legume, $N_{inorg.}$, winter wheat yield.*

Introduction

The emphasis of agricultural development programs is on economical, effective and sustainable farming systems to reduce energy consumption, protect environment and providing consumers with safe quality food. The rapid spread of organic farming. Many organic farms do not conform to basic requirements, provide the whole system of self-regulation and wellness. One of the problems of organic farming system is plants supply of nutrients, inadequate utilisation of biologically nitrogen fixed (BNF) of legume. There is a lack of an innovative multi-technology.

Some researchers suggest that legumes that can support biological N_2 fixation, offer a more environmentally sound and sustainable source of N to cropping systems [1, 2]. Researchers have indicated that one tone of biomass of dry legumes (aboveground and underground) can approximately bind 30–40 kg of nitrogen from the air [3]. This is one of the main nitrogen sources in organic farms. Perennial legume grasses overtake grain legumes by nitrogen fixation from the atmosphere, increase productivity of crop rotation plants, and improve soil properties [4, 5]. Hence, the application of biomass of perennial legumes in arable organic farming, whose area is growing, has been limited.

This article deals with application of the green mass of perennial legumes for manure by applying the mulch technology. The aboveground mass of perennial legumes is mulched in the soil surface 2–4 times during the period of vegetation: it is cut, chopped and spread in order to use the biologic nitrogen, bound by legumes more efficiently, and to save the environment from pollution [6, 7]. Chopped mass of legumes is rich in nitrogen and has a property of rapid mineralization; therefore the free nitrogen is bound by intensively growing perennial grasses or is incorporated to the content of organic matters of soil [8]. The mentioned above describes how organic compounds, rich in nitrogen, are formed in soil; they have feature of slow mineralization and provide wheat with nutrients for several years or may be incorporated to a more stable content of soil organic compounds.

Aim is to analyze effect of perennial legumes and their aboveground mass, used for the yield and green manure, on change of soil $N_{inorg.}$ as well as effect on the grain yield of winter wheat under conditions of organic farming.

Materials and methods

Site and soil. Experiments were carried out during 2007–2009 at the LIA's Joniškėlis Research Station on an *Endocalcari-Endohypogleyic Cambisol* (*CMg-n-w-can*), with a texture of clay loam (clay particles < 0.002 mm in Ap horizon 0–30 cm make up 27.0 %), on silty clay with deeper lying sandy loam. Parental rock is limnoglacial clay on morenic clay loam at the depth of 70–80 cm. Bulk density of the ploughlayer is 1.5 Mg m^{-3}, total porosity 41–43 %, air-filled porosity 15–17 %. Agrochemical characteristics of the ploughlayer: pH_{KCl} – 6.4, mobile P_2O_5 and K_2O – 154 and 224 mg kg^{-1} of soil respectively, N_{total} – 0.135 %, C_{org} – 1.68 %. Soil and plant analyses were done at the Laboratory of Chemical Research at LIA.

Experimental design and field management. Research was conducted in the following sequence of the crop rotation: 1) barley + undersown perennial grasses, 2) perennial grasses, 3) winter wheat. Factor A: perennial grasses: 1) red clover (*Trifolium pratense* L.) (control, aboveground biomass removed from the field), 2) mixture of red clover and festulolium (x *Festulolium*), 3) lucerne (*Medicago sativa* L.), 4) mixture of lucerne and festulolium, 5) festulolium. Factor B: management methods of aboveground biomass of perennial grasses: 1) removed from the field, 2) mixed, 3) mulching.

In the first experimental year (2007), spring barley (*Hordeum vulgare* L., cv. 'Ula') was undersown with perennial grasses in compliance with the experimental design: red clover (cv. 'Vyliai', at a seed rate of 7.5 million ha^{-1}), lucerne (cv. 'Birutė', at a seed rate of 7.5 million ha^{-1}), intergeneric hybrid festulolium (cv. 'Punia', at a seed rate of 6.2 million ha^{-1}) and mixtures of both legume grasses with festulolium (seed rate ratio of legume to grass 2:1). In the first treatment (B1) of application of the aboveground biomass of perennial grasses, the grass was cut twice at the beginning of flowering: on 10 06 2008 and 25 08 2008 and removed from field. In the second treatment (B2), the aboveground biomass was used under mixed management: the first grass was cut at the beginning of flowering (10 06 2008) and removed from the field, the second and third cuts were taken during perennial grass inflorescence growth stage (17 07 2008, 12 08 2008) and mulched on the soil surface. In the third treatment (B3), the grass was cut every 30–40 days four times (12 05 2008, 13 06 2008, 11 07 2008, 12 08 2008) and mulched on the soil surface. Aboveground biomass for green manure was cut by a self-propelled mower, equipped with a mulching device, then chopped and evenly spread on the plot. In the second half of August, the plots of all treatments were disked and 2 weeks later were ploughed at the 25 cm depth. Before sowing, the field was cultivated and harrowed at the same time. Winter wheat (*Triticum aestivum* L., cv. 'Tauras') was sown at a seed rate of 220 kg ha^{-1}. Organic wheat cultivation technology was applied.

Soil analyses. Soil samples for the determination of N_{inorg} ($N\text{-}NH_4$ + $N\text{-}NO_3$) content were collected from the 0–30 and 30–60 cm soil layer after resumption of wheat growth (08 04 2009). N_{inorg} was determined: $N\text{-}NH_4$ by spectrophotometric method, $N\text{-}NO_3$ by ionometric method.

Plant analyses. After each cut, the aboveground biomass of perennial grasses was weighed. To determine the root macro-fraction biomass of plants, monoliths 0.25 x 0.25 x 0.24 m in size were dug out in the plots of each treatment replicated three times [9]. The roots were washed, dried, and air-dry weight was determined. Samples of the aboveground and underground biomass were taken for the determination of dry matter (dried to a constant weight at 105ºC), nitrogen. Elementar analyzer "Vario EL" and "Carry 50" were used for the determination of nitrogen in plant biomass. Having determined nitrogen concentration in the biomass, we calculated the amount of nitrogen, incorporated into the soil (kg ha^{-1}). Nitrogen

content (N_{2fix} kg ha^{-1}) fixed from the atmosphere in legume biomass was calculated using the method of difference according to the following formula [2]:

$$N_{2fix} = N_{legumes} - N_{festulolium} \quad (1)$$

The experimental data were processed by the analysis of variance and correlation-regression analysis methods using a software package "Selekcija".

Results and discussion

Nitrogen content. The content of nitrogen incorporated into the soil was significantly dependent on the species of perennial grasses and aboveground biomass management method. The soil received the highest nitrogen content with the ploughed in biomass of pure legumes (Table 1).

Table 1.

Nitrogen content, incorporated to soil together with mass (underground and aboveground) of perennial grasses

(Joniškėlis, 2008)

Perennial grasses (A)	***Management methods of perennial grasses (B)***		
	removal from field	***mixed***	***mulching***
	N kg ha^{-1}		
RC	25.4	215.8	298.0
RC + F	35.5	156.6	258.3
L	99.5	208.0	266.6
L + F	79.6	171.8	281.5
F	22.5	63.8	81.4

Note: RC – Red clover; RC+F – Red clover + festulolium; L – Lucerne; L+F – Lucerne + festulolium; F – Festulolium

Cultivation of legumes in mixtures with festulolium tended to reduce the nitrogen content, incorporated into the soil. Significantly (3.2 and 3.4 times) less nitrogen was incorporated into the soil with the biomass of pure festulolium compared to red clover and lucerne, respectively.

When the aboveground biomass of red clover had been used under mixed management, the total amount of nitrogen incorporated was 215.8 kg ha^{-1}, while during the process of mulching – 298.0 kg ha^{-1} N, respectively 8.5 and 11.7 times more, compared to the plot with removed herbage. With the aboveground biomass of red clover and festulolium mixture used under mixed management and mulching, the soil received less nitrogen compared to pure red clover sward with the same management of the aboveground biomass. Lucerne, during the first year of cultivation, formed a greater root biomass, though the aboveground biomass increased more rapidly only during the second half of summer. As a result, after lucerne cultivation, the incorporated nitrogen content was lower compared to that after red clover. Moreover, the effect of the biomass management methods on the incorporated nitrogen content was different. When the aboveground biomass of lucerne had been used under mixed management, the total incorporated N content was 208.0 kg ha^{-1}, while in mulching treatment 266.6 kg ha^{-1} N, or respectively 2.1 and 2.7 times more than in the treatments with all herbage yield of lucerne removed from the field. Cultivation of lucerne/festulolium mixtures and use of their aboveground biomass under mixed management influenced the fact, that the soil received by 36.2 kg ha^{-1} less nitrogen, while after mulching by 14.9 kg ha^{-1} more compared to pure lucerne sward with the same management of the aboveground biomass. When the aboveground biomass of festulolium had been used under mixed management and mulched, the soil received 63.8 kg ha^{-1} and 81.4 kg ha^{-1}, or 2.8 and 3.6 times more nitrogen,

respectively, compared with the treatment with all festulolium herbage removed from the field. However, the total nitrogen, accumulated in festulolium biomass, was removed from the soil. According to summarized data, lucernes annually fix from 300 to 600, red clover – from 150 to 300 kg ha^{-1} of symbiotic nitrogen in their total biomass [10]. According to our research data, symbiotic nitrogen content, fixed from the air by red clover was: if the aboveground mass was removed from field – 137.9 kg ha^{-1}, if mixed method was applied – 182.4 kg ha^{-1}, if mulching was applied – 191.4 kg ha^{-1}; meanwhile lucernes – respectively 206.5, 204.4 and 251.9 kg ha^{-1}. According to methods of the aboveground mass management, symbiotic nitrogen (N_2) fixation efficiency in red clover biomass was 61–83 %, in lucernes – 68–84 %. According to Hatch D.J., mulching of the aboveground mass of clover-grass led to reduction of relative part of fixed nitrogen in biomass [11].

Inorganic nitrogen. In spring, the amount of N_{inorg} in soil reduced in most cases, compared to its status in the autumn. The greatest reduction in N_{inorg} content was noted in the treatments with the highest NO_3 to NH_4 ratio and the highest nitrate nitrogen content in the autumn (except for the plot with incorporated mulch of lucerne and festulolium mixture. Similar research conducted in Denmark showed that mulch, incorporated into a light-textured soil increased the risk of nitrogen leaching during the autumn-winter period [12]. Tripolskaja and Šidlauskas [13] have indicated, that incorporation of red clover biomass as green manure in a sandy loam *Luvisol* significantly increased nitrogen leaching in spring and summer (52 %) compared to the plot without organic manure. Literature sources indicate that leached nitrogen content during autumn period depends on precipitation and on the soil type and fertility management, ranging from 4–12 kg ha^{-1} in soil with a high clay content [14] to 30–70 kg ha^{-1} in sandy soils [15].

In spring in the 0–30 cm soil layer, the highest N_{inorg} content was after red clover, lucerne, and their mixture with festulolium. (Table 2). The use of green manure increased the amount of $N_{inorg.}$ With increasing N_{inorg} content in the topsoil layer it also increased in the deeper layer ($r = 0.80$; $P < 0.01$). In this layer (30–60 cm), N_{inorg} content varied in a similar pattern to that in the topsoil layer, but the differences were higher. In this soil layer significantly lower amount of N_{inorg} was observed after festulolium. In cases when legumes were cultivated in mixtures with festulolium, $N_{inorg.}$ had a tendency to decrease. Comparing separate perennial grasses' management methods, it was defined that if the whole aboveground mass is mulched in the soil surface, $N_{inorg.}$ content significantly increase, if compared to treatment when herbage was removed from field.

Winter wheat yield. The productivity of winter wheat was significantly influenced by the pre-crops – perennial grasses as well as their aboveground biomass management method. Comparison of various perennial grasses, used as pre-crops, revealed that winter wheat grain yield was the lowest after festulolium, significantly by on average 55 % or 2.92 t ha^{-1} lower compared to that after red clover (Table 3). Application of their aboveground biomass as green manure did not increase grain yield appreciably. The highest grain yield was produced when winter wheat had been cultivated after legumes. Legume/festulolium swards reduced winter wheat yield: red clover/festulolium by on average 27 % or 1.45 t ha^{-1} and lucerne/festulolium by on average 27% or 1.11 t ha^{-1}, compared to respective pure legume sward.

Averaged data indicated that application of all herbage of perennial grasses as green manure (mulching) significantly increased the grain yield by 16 % or 0.62 t ha^{-1}. When part of the aboveground biomass had been used as green manure (mixed management), the grain yield tended to increase, the increase amounted to on average 8 % or 0.30 t ha^{-1}, compared to the treatment where all herbage had been removed from the field. Norwegian researches suggest that with the application of green manure for mulch (legume/non-legume) no significant increase in spring barley grain yield was obtained [16], meanwhile German researchers point

out that red clover/grass mulch significantly increased wheat grain yield by 6%, compared to the treatments where all herbage had been removed from the field [7]. The efficiency of nitrogen application from legume/festulolium mulch varied from 14 % to 39 % with the lowest value on the coarse sandy soil [12].

Table 2.

The amount of N_{inorg} in 0–30 and 30–60 cm soil layer in spring depending to perennial grasses' species and their aboveground mass management methods

(Joniškėlis, 2009)

Perennial grasses (A)	*Soil depth cm*	*Management methods of perennial grasses (B)*			*Mean for factor A*
		removal from field	*mixed*	*mulching*	
RC	*N_{inorg} kg ha^{-1}*				
	0–30	22.27	28.18	24.06	24.84
	30–60	27.00	32.15	33.20	30.78
RC + F	0–30	20.38	22.26	25.64	22.76
	30–60	22.76	24.45	24.82	24.01
L	0–30	20.91	24.11	28.36	24.46
	30–60	25.53	29.67	35.82	30.34
L + F	0–30	23.55	25.08	29.53	26.05
	30–60	19.82	27.64	40.72*	29.39
F	0–30	20.13	19.28	26.22	21.88
	30–60	16.96	17.77	17.89	17.54**
Mean for factor B	0–30	21.45	23.78	26.76**	24.00
	30–60	22.41	26.34	30.49**	26.41

Note. N_{inorg} (0-30 cm) – LSD_{05} A = 4.218, B = 3.267, AB = 7.306; (30-60 cm) – LSD_{05} A = 7.393, B = 5.727, AB = 12.805; difference (0-30 cm) – LSD_{05} A = 16.318, B = 12.640, AB = 28.264; (30-60 cm) – LSD_{05} A = 12.089, B = 9.364, AB = 20.939; * - significant at $p<0.05$, ** – significant at $p<0.01$.

The highest winter wheat grain yield was produced when the crop had been cultivated after red clover with aboveground biomass used under mixed management or mulched. The grain yield increase was by 0.72 and 0.71 t ha^{-1} respectively, higher compared to that in the control plot. After lucerne pre-crop, the wheat grain yield was lower (0.37 t ha^{-1}) than that after red clover. It might have been influenced by higher root biomass and its C : N ratio. This fact influenced slower mineralization of organic matter and reduced N_{inorg} accumulation in the soil (except for aboveground biomass mulching), compared to red clover. After lucerne sward, the greatest wheat grain yield increase was obtained when the aboveground biomass was used for mulch.

When the aboveground biomass of red clover/festulolium was used under mixed management or mulched, the grain yield increased, but not as much as in the treatments where it was cultivated after red clover with all herbage removed from the field. When the aboveground biomass of lucerne/festulolium had been used as green manure, especially when all of it was used as mulch, the grain yield increased and was similar to that after lucerne with herbage yield removed from the field. According to statistical analysis, winter wheat productivity increased by 0.01 t ha^{-1} after incorporation of 1 kg ha^{-1} nitrogen of legume crops biomass.

Table 3.

The winter wheat yield (grain and straw) depending to perennial grasses' species and their aboveground mass management methods

(Joniškėlis, 2009)

Perennial grasses (A)	*Management methods of perennial grasses (B)*						*Mean for factor A*	
	removal from field		*mixed*		*mulching*			
	grain yield t ha^{-1}	*straw yield t ha^{-1} DM*	*grain yield t ha^{-1}*	*straw yield t ha^{-1} DM*	*grain yield t ha^{-1}*	*straw yield t ha^{-1} DM*	*grain yield t ha^{-1}*	*straw yield t ha^{-1} DM*
RC	4.83	3.54	5.55	4.24	5.54	4.44	5.31	4.07
RC + F	3.65**	2.80	4.10	3.13	3.82	2.97	3.86**	2.97**
L	4.64	4.13	4.80	3.99	5.58	4.20	5.01	4.10
L + F	3.44**	3.01	3.74*	2.59	4.51	3.87	3.90**	3.16**
F	2.37**	1.86**	2.23**	2.20**	2.58**	2.30	2.39**	2.14**
Mean for factor B	3.79	3.07	4.08	3.23	4.41**	3.56*	4.09	3.29

Note: RC – Red clover; RC+F – Red clover + festulolium; L – Lucerne; L+F – Lucerne + festulolium; F – Festulolium; Grain yield – LSD_{05} A = 0.500, B = 0.387, AB = 0.865; Straw yield – LSD_{05} A = 0.531, B = 0.643, AB = 1.439; * - significant at $p<0.05$, ** – significant at $p<0.01$.

Winter wheat straw yield was significantly influenced by perennial grasses species and their aboveground mass management methods. Straw yield was 1.86–4.44 t ha^{-1} and varied between variants. Festulolium and legume/festulolium swards reduced winter wheat straw yield (22–47 %), if compared to red clover. Comparing management methods of perennial grasses, it was defined that in cases all aboveground mass was used for the green manure, wheat straw yield increased, if compared to data from plots, where all yield of perennial grasses was removed.

Within sequence of crops from legumes to non-legumes, it is important to assess synchronic features of nitrogen release from remains of incorporated crops or green manure and need for nitrogen of cultivated crops [8]. Together with increase of $N_{inorg.}$ content in soil, the yield of crops increases [8, 17]. According to our research data, winter wheat grain yield significantly ($P < 0.05$) correlated with soil inorganic nitrogen content. (Fig. 1). Summarized data from many research indicated that crops can assimilate 4–33 % of nitrogen from remains of legumes during the first year [3].

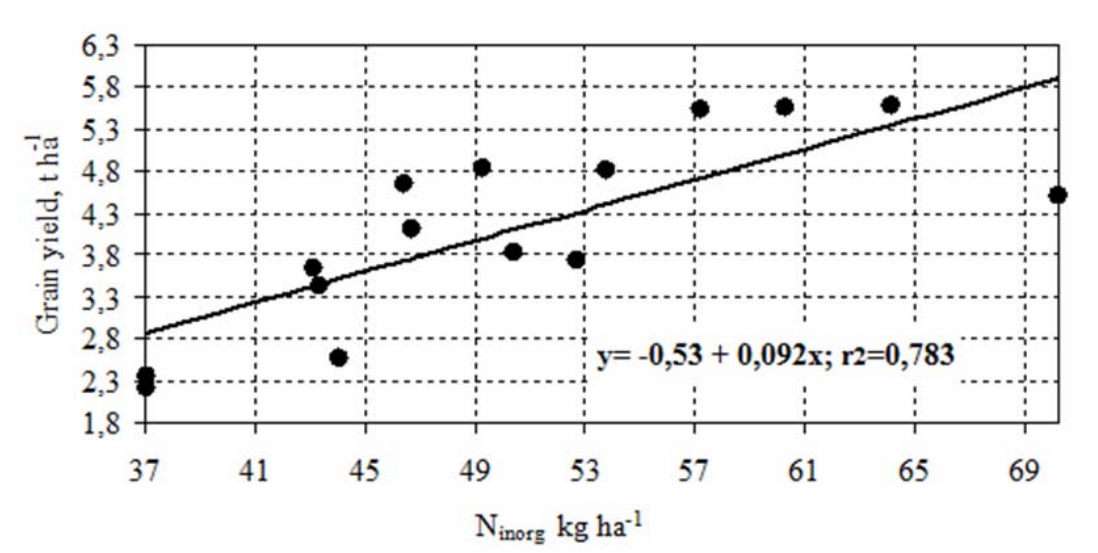

Fig. 1. **Grain yield relation with N_{inorg} content (soil layer 0–60 cm) in spring after renewal of winter wheat vegetation** (Joniškėlis, 2009)

Conclusions

1. With the aboveground biomass of red clover and lucerne used under mixed management, the soil received 215.8 kg ha^{-1} and 208.0 kg ha^{-1} of nitrogen, respectively, while in the mulching treatments – 298.0 kg ha^{-1} and 266.6 kg ha^{-1}, respectively. Symbiotically fixed nitrogen content in the biomass of legumes accounted for the largest share (61–84 %) of the total nitrogen content, accumulated in the biomass.
2. In spring the highest N_{inorg} content was identified having used mixed management of the aboveground biomass of legumes or having mulched all biomass of legumes and that of legume/festulolium mixture. Winter wheat grain yield significantly ($P < 0.05$) correlated with soil inorganic nitrogen content.
3. Winter wheat grain productivity increased by 0.01 t ha^{-1} after incorporation of 1 kg ha^{-1} nitrogen of legume crops biomass. Festulolium and its mixtures with legumes as pre-crop reduced winter wheat grain yield, compared with red clover. Application of all aboveground biomass of perennial grasses as green manure (mulching) increased grain yield by on average 0.62 t ha^{-1}; when part of the aboveground biomass had been used as green manure (mixed management) – by 0.30 t ha^{-1}, compared with the treatments with herbage removed from the field.

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THE DIVERSITY OF WEEDS IN ORGANIC LINSEED AND FLAX CROP

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Abstract. *The flax is grown in the world for many years. The area of linseed in the world is much more than that of fibre flax. The seeds of ecologically grown linseed have high value as the row material for food, medicine, fodder, oil production. The cold pressed oil and seeds of ecologically grown linseed are especially popular in EU, Canada and USA. The quality of the finished linen product is often dependent upon growing conditions and harvesting techniques. The organic textile trend is starting to develop worldwide, while in Lithuania it is still almost non-existent. Therefore, the chance for Lithuanian farmers appears to export the ecological seed and fiber, not only use them in local market.*

Lithuanian farmers are in luck for the advices how to grow flax in ecological way. Therefore, in 2007-2009 some investigations were carried out at the Upytė Experimental Station of the Lithuanian Research Centre for Agriculture and Forestry (Panevėžys district, Lithuania). The results of our investigation showed that it is possible to grow and harvest fibre flax and linseed in organic farms without any pesticides. The incidence of weeds is one of the biggest problems in organic growing of flax and linseed.

Keywords: *Linum usitatissimum L., flax, linseed, organic farming, conventional farming, weeds.*

Introduction

The flax is grown in the world for many years. The area of linseed in the world is much more than that of fibre flax. The seeds of ecologically grown linseed have high value as the row material for food, medicine, fodder, oil production. The cold pressed oil and seeds of ecologically grown linseed are especially popular in EU, Canada and USA. The quality of the finished linen product is often dependent upon growing conditions and harvesting techniques. The facts of the International Federation of Organic Agriculture Movements (IFOAM) suggest that certified organic flax seed for oil is grown in about a half of the USA and certified organic fiber flax is grown in Europe and China [1].

In all agricultural crops the competition between crops and weeds is going on. The incidence of weeds is one of the biggest problems in flax and linseed growing. Their growing intension, compared with the weeds, is small, so weeds can dwarf the germinating flax. The losses of fibre flax yield can reach from 12 % to 36 % depending of weed incidence [2].

Many authors suggest that herbicides are one of the reliable means to solve weed problem in flax crop [2, 3, 4, 5, 6, 7]. Some herbicides had phytotoxic effect on flax plants and may to reduce scutched fiber yield [8], plant height [9]. The results of experiments on the sensitivity of *Linum usitatissimum* to the herbicides showed stronger phytotoxic effect on flax grown on poor and light soils [8, 10].

Organic farming attempt to control crop weeds, without herbicides in agroecosystem. The agroecosystem includes the farm's crops, weeds insect and other pests, and their natural enemies; soils and their tremendous diversity of micro- and macroorganisms; ground and surface waters etc. Understanding these interactions and how they can impact on the crop and its pests can point the way to nontoxic and non-disruptive practices that limit pest species' ability to proliferate and become a problem that requires a pesticide treatment [11]. Harrowing is a traditional form of mechanical weed control for dealing with annual weeds, but is ineffective against perennial and established deep-rooted weeds. In spring of the weed harrow control weeds by uprooting and/or covering small weed plants with soil. Post-emergence harrowing may also cause crop injury, but selectivity depends on many factors

including the soil covering mechanism [12]. J. Duval suggest, that for small-seeded crops (like flax), mechanical weed control is risky and seldom needed due to the good competitive ability of these crops when the seeding rate is high enough. For flax J. Duval recommend underseeding with clover instead pre-emergence and post-emergence harrowing [13].
Common weeds in flax crop in Lithuania are *Chenopodium album* L, *Polygonum convolvulus* L, *Galeopsis tetrahit* L., *Matricaria inodora* L., *Agropyron repens* L., *Cirsium arvense* Scop. and *Sonchus arvensis* L. [14]. *Chenopodium album* L. was one of numerous weeds in the Upyte Experimental Station's flax crop, moreover on the less number the *Lamium purpureum* L., *Matricaria inodora*, L., *Melandryum album* Garckie and *Polygonum* sp. were found in the flax crop. The weed incidence in trial plots was from 77 to 276 plants per sq. meter, and annual dicotyledonous weeds predominated [2].
Flax is less competitive with weeds and should be grown on relatively weed-free fields [15]. Tishkov N.M. and Dryakhlov A.A. suggest that competitiveness of oil flax (linseed) to weeds is depending on crop's contamination and species composition [16].
The diversity of weeds in organic linseed and flax crop was investigated in Jurbarkas and Panevėžys districts by the scientists of the Upytė Experimental Station of the Lithuanian Research Centre for Agriculture and Forestry in 2007-2009.

Materials and methods

Weed diversity investigations in the fiber flax crop were carried out in Jurbarkas and Panevėžys districts in 2007. Investigations in Jurbarkas district was carried out on the Venslauskienė V. farm (situated in the Mantviliai village). The data were collected from 3 hectares of fibre flax in organic farm and from 5 hectares from flax grown by conventional technology. Investigations in Panevėžys district were carried out on the A. Vaičiūnas organic farm (situated in the Puškoniai village). Weed diversity in conventional technology flax fields were carried out on the Joint Stock Company Upytės eksperimentinis ūkis fields (situated in the Upytė village). Fiber flax variety 'Hermes' was cultivated in all tested fields.
Weed diversity investigations in the linseed crop were carried out on the Upytės eksperimentinis ūkis fields (situated in the Upyte village, Panevėžys distr.) in 2008-2009. Data were collected from 1.5 hectares of organic farming and from 1.5 hectares of conventional technology fields of linseed cultivar 'Biltstar'.
Soil tillage, the protection against pests and weeds was performed in accordance with a linseed-growing advice for flax grown by conventional technology [17].
Number of weeds was determined when flax reached "fir tree" stage by counting weeds on 0.25 square meter plots in 10 random locations. Weeds were categorized by particular species. Later on the average amount of weed in 1 square meter was calculated. Weed data representing in this article conventional technology were collected before herbicide application.

Results and discussion

The flax preceding crop in Jurbarkas was black fallow, so weed species composition in flax was not various. The *Sonchus arvensis* L. dominated (59% of the total amount of weeds), and less quantity of *Poa annua* L. (10%), *Convolvulus arvensis* L. (9%) and *Fallopia convolvulus* L. (sin. *Polygonum convolvulus* L.) (7%) was found. On the edge of the flax field there were several flashpoints, where the *Artemisia vulgaris* L. grew tighter. Weed density in some places reached 130 to 150 units in square meter. It should be noted that just a few plants of *Agropyron repens* L. has been found in organically growing flax field. Less number of *Galeopsis tetrahit* L., *Equisetum arvense* L. and *Cirsium arvense* L. was found in small isolated flashpoints. In flax crop grown by the conventional technology weed number was very low, only 5-7 units in square meter. The *Poa annua* L. dominated in conventional

technology flax fields and several plants of *Polygonum persicaria* L., (sin. *Persicaria maculosa* L.) and *Viola arvensis* L. were found. Perennial weeds were not found in these crops.

Many authors suggest, that weed problem in organic crop may be solved by crop rotation [18, 19, 20]. Weed problem in fiber flax crop rotation in Jurbarkas distr. was tackled by applying the black fallow like a flax preceding crop. Black fallow was harrowed twice in the spring before flax sowing. Due to favourable weather conditions – warm weather and adequate moisture content before flax sowing, weeds germinated and were destroyed in a satisfactory manner. After flax sowing, favorable weather conditions, good flax seed quality and emergency benefited to good flax sprout and its ability to compete with the rest shoots of annual weeds.

Different weather conditions were in Panevėžys district in 2007. In the spring before flax sowing soil was cool and a lack of moisture was noted, therefore before harrowing weeds not sprouted. Flax was sown, and germinated process lasted for a long time and weeds emerged previously. Further followed prolonged rainy period, weeds have raised together with flax, and even faster than they, and crop harrowing was impossible. At flax green maturity stage the crop was abundant and widespread with various species of annual and perennial weeds. A plenty of perennial weed species: *Sonchus arvensis* L., *Cirsium arvense* L., *Centaurea cyanus* L., *Artemisia vulgaris* L., *Matricaria inodora* L. and *Agropyron repens* L. were identified the flax crop. The most widespread annual weeds were *Chenopodium album* L., *Viola arvensis* Murray *Poa annua* L., and biennial (overwintering) *Myosotis arvensis* (L.) Hill, *Papaver rhoeas* L., and *Tragopogon pratensis* L. The abundance of weeds in the flax crop was conditioned by preceding crop – organically grown peas.

The preceding crop of fiber flax grown by conventional technology in Upytės eksperimentinis ūkis field was winter wheat. In this field weed number was low, only 3-8 units in square meter. Perennial weeds were not found in the crop. Only few species were identified in conventional technology grown flax: a *Viola arvensis* L., *Fumaria officinalis* L., *Galium aparine* L.

For linseed growing the years 2008 and 2009 were moderate favourable. Linseed preceding crop in 2008 was winter wheat for both growing technologies and for conventional technology in 2009. For linseed grown by organic technology preceding crop in 2009 was old grassland (perennial grasses).

The incidence of weeds was different in both years and depended upon meteorological conditions: there were 13-33 units of weeds in square meter in 2008 and in 2009 we found from 119 to 534 units of weeds in square meter.

Overall the number of weed species (growing linseed by both technologies) was 17 species in 2008. In 2009, in organic farming system, the total number of weed species was 30, and in conventional farming system – 24 (Table 1).

K. Heller states that earlier some weed species as *Lolium remotum* Schrank, *Spergula arvensis* L. subsp. maxima (Weiche) O. Schwarz, *Camelina alyssum* (Mill.) Thell. and *Cuscuta epilinum* Weihe Ex Boenn. were found only in flax crop. The results of research on segetal weed communities in fibre flax crop in Poland show that now weed communities in fibre flax crop consist of several species typical for cereals and root crops: *Chenopodium album* L., *Polygonum convolvulus* L., *Viola arvensis* Murr., *Stellaria media* Vill., *Lamium amplexicaule* L., *Thlaspi arvense* L., *Elymus repens* (L.) Gould, and *Polygonum nodosum* Pers. and weed species typical for flax are not found [21].

Table 1.

The detected weed species in linseed crop (%). Upytė, 2008-2009.

Weed species	Detection in crop %			
	Organic farming		Conventional farming	
	2008	2009	2008	2009
Anagallis arvensis	0	1	0	0
Artemisia vulgaris	0	1	0	0
Barbarea vulgaris	0	1	0	7
Chenopodium album	20	15	16	19
Chenopodium polyspermum	11	1	16	0
Centaurea cyanus	0	7	0	0
Cerastium arvense	0	1	0	2
Cirsium arvense	0	1	0	0
Convolvulus arvensis	5	2	4	0
Descurainia sophia	0	1	0	2
Erysimum cheiranthoides	0	2	0	1
Erodium cicutarium	2	1	4	4
Euphorbia helioscopia	0	0	0	1
Fumaria officinalis	1	0	1	1
Galeopsis tetrahit	0	0	1	1
Galium aparine	3	1	0	2
Mentha arvensis	2	1	0	0
Myosotis arvensis	1	1	1	7
Papaver rhoeas	1	1	2	1
Persicaria maculosa	4	4	6	4
Polygonum aviculare	5	4	2	5
Raphanus raphanistrum	12	15	5	11
Rumex acetosella	2	3	0	1
Silene pratense	6	6	5	7
Spergula arvensis	0	2	0	0
Solanum nigrum	0	0	0	1
Sonchus arvensis	0	2	0	0
Stelaria media	17	1	13	1
Tripleurospermum perforatum	0	3	0	0
Tussilago farfara	0	1	0	0
Veronica arvensis	0	3	1	6
Viola arvensis	6	5	3	4
Apera spica-venti	0	0	15	1
Elytrigia repens	2	5	5	4
Poa annua	0	8	0	7
Total:	100	100	100	100

Summarizing our research results of weed diversity in linseed, we can conclude that annual weeds, typical for cereals and root crops – *Chenopodium album* L., *Chenopodium polyspermum* L., *Raphanus raphanistrum* L., *Stellaria media* L. (2008) and *Chenopodium album* L., *Raphanus raphanistrum* L., *Poa annua* L. (2009) prevailed in linseed crop in both:

in organic and in conventional farming systems. Perennial weeds had recessive position in linseed crop.

The results of investigation showed that in linseed crop grown on the organic farming weed number ranged from 215 to 534 units in square meter. In linseed crop grown in conventional farming weed number was 119-312 units in square meter.

Conclusions

1. The diversity of weed species in fiber flax fields was not various. The *Sonchus arvensis* L. dominated in the organic flax field. Weed density in some places reached 130 to 150 units in square meter. In flax crop grown by a conventional technology weed number was very low, only 5-7 units in square meter, *Poa annua* was dominating weed specie. Perennial weeds were not found in flax grown in conventional cropping system. Weed problem in fiber flax crop rotation in Jurbarkas distr. was solved applying the black fallow like a flax preceding crop.
2. Unfavourable weather conditions for flax emergency and preceding crop – organically grown peas – determined abundance of weeds in the flax crop grown in organic farming in Panevėžys distr. Only few species of weeds were identified in flax crop, grown by conventional technology, probably due to preceding crop – winter wheat.
3. Research results of weed diversity in linseed crop allowed concluding that annual weeds prevailed in both: in organic and in conventional farming systems.
4. The preceding crop and weather conditions (not depending on growing technology) can determine diversity and the composition of the weed species in fiber flax and linseed crop.

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Summary

The incidence of weeds is one of the biggest problems in organic growing of flax and linseed. Presented in the article research results showed the possibilities of flax and linseed growing in organic farm and weed diversity in these crop.

Weed diversity investigations in the fiber flax crop were carried out in Jurbarkas and Panevėžys districts in 2007. Fiber flax variety 'Hermes' was cultivated in all tested fields. Weed problem in fiber flax crop rotation in Jurbarkas distr. was tackled by applying the black fallow like a flax preceding crop. Black fallow was harrowed twice in the spring before flax sowing so weed species composition in flax was not various. The *Sonchus arvensis* L. dominated, and less quantity of *Poa annua* L. *Convolvulus arvensis* L. and *Fallopia convolvulus* L. was found. In flax crop grown by the conventional technology weed number was very low, only 5-7 units in square meter. Perennial weeds were not found in these crops.

In Panevėžys district before flax sowing in the spring soil was cool and a lack of moisture was noted, therefore before harrowing weeds not sprouted. Further followed prolonged rainy period, weeds have raised faster than flax, and crop harrowing was impossible. The abundance of weeds in the flax crop was conditioned by weather conditions and by preceding crop – organically grown peas. The most widespread weeds were *Sonchus arvensis* L., *Cirsium arvense* L., *Centaurea cyanus* L., *Artemisia vulgaris* L., *Matricaria inodora* L., *Agropyron repens* L., *Chenopodium album* L., *Viola arvensis* Murray *Poa annua* L., *Myosotis arvensis* (L.) Hill, *Papaver rhoeas* L., and *Tragopogon pratensis* L.

Weed diversity investigations in the linseed crop were carried out on the Upytės eksperimentinis ūkis fields. Linseed variety 'Biltstar' was cultivated. The incidence of weeds was different in both years and depended upon meteorological conditions: there were 13-33 units of weeds in square meter in 2008 and in 2009 we found from 119 to 534 units of weeds

in square meter. The annual weeds *Chenopodium album* L., *Chenopodium polyspermum* L., *Raphanus raphanistrum* L., *Stellaria media* L. (2008) and *Chenopodium album* L., *Raphanus raphanistrum* L., *Poa annua* L. (2009) prevailed in linseed crop in both: in organic and in conventional farming systems. Perennial weeds had recessive position in linseed crop.

Results of our investigations showed that the preceding crop and weather conditions not depending on growing technology can determine diversity and the composition of the weed species in fiber flax and linseed crop.

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USE OF LIGNOSILICON TO IMPROVE THE HARVEST AND QUALITY PARAMETERS OF POTATO

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Abstract. *Lignosilicon (LSi), a plant growth activator, was synthesized at the Latvian State Institute of Wood Chemistry (LS IWC) on the basis of the wood lignocellulosic complex. It is shown that LSi, used for treatment of potato tubers before sowing at low application rates of 20-40 kg/ha, has a favourable action on the yield and quality of the tubers. In comparison with the control, the additional yield achieved on the background of LSi (20-40 kg/ha) was 18-20%. The best biochemical composition was for the tubers wetted with water and LSi-treated before the sowing, i.e., the content of dry matter and starch increased by 16% and 18%, respectively, but the content of nitrates in the tubers decreased 1.6 times. LSi can be recommended for potato cultivation under conditions of conventional and organic agriculture.*

Keywords: *lignosilicon, potato tuber yield, tuber quality.*

Introduction

The results of the investigation of Lignosilicon (LSi) - a plant growth and development activator, synthesized on the basis of the wood lignocellulosic complex, showed the efficiency of its use at low application rates (20-120 kg ha^{-1}) in conventional and organic agriculture for cereals and grain legumes such as oat [1], rye [2], buckwheat [3], and red clover [4, 5]. On the background of LSi, the activation of the development of the plant root system was observed at the early stages of vegetation (30-50 days after sowing), which later favoured higher crop, as well as its quality of crops and soil agrochemical parameters. In comparison with cereals, potato has less demand to siliceous consuming capacity.

Silicon uptake by cereals is around 120 kg of SiO_2 from 1 ha per year, whereas that by potato is 8 kg [6, p.122]. Setting of loss of a plant available silicon (at least partial) through soil treatment with siliceous compounds could have a favourable action on the soil, the crop and its quality. There are no scientific data on the use of silicon-containing growth activators in potato cultivation. Potato, besides wheat, rice and maize, belongs to the world's major food, fodder and industrial crops. The nutritional value of potato is determined by the presence of digestible carbohydrates, first of all, starch, as well as the qualitative and quantitative composition of minerals. In terms of the total content of minerals, potato exceeds various vegetables and fruits. Potato contains a whole range of microelements rarely met in other products. At a mean ash content of about 1% in tubers, more than a half of all ash elements fall on potassium. The greater part of potato minerals is represented by alkaline salts such as potassium, sodium, magnesium, calcium and iron, which are essential elements in human nutrition and important for maintaining the alkalinity of blood.

For the Baltic Sea region, potato is a very valuable product. It serves as one of the main sources of ascorbic acid (vitamin C). The content of ascorbic acid in tubers regionalised in Latvia varies from 10 to 26 mg %. While the content of vitamin C decreases in storage, the content of other vitamins (B_1, B_2, B_3, B_6, PP) and minerals remains practically the same. In modern farming technologies, potato yield can reach 50-70 t ha^{-1} [7]. However, only 15-20% of this potential is realized. In agricultural practice the average yield of potato in Western Europe and in Latvia is 40-50 t ha^{-1} [7] and 17 t ha^{-1} [8], respectively. An important reserve

for increasing potato yield as well as potato growth ecologization is the use of growth activators of natural origin, including products synthesized on the basis of natural organic raw materials.

From 2007, LSi (application rates 10-30 kg ha^{-1}) has been tested in cultivation of the potato varieties “Adora”, “Latona”, “Red scarlet”, “Asterix” in private Latvian farms. The farmers noticed an earlier ripening of tubers (by 5-7 days), the improvement of tubers’ taste and quality parameters, namely, decreased level of nitrates, and increased content of dry matter and starch. The tubers grown on the background of LSi differed from the control by better winter storing. In spring, 99% of tubers could be used as seed tubers. These experiments were used as the basis for setting microfield experiments in 2009-2010.

The aim of the work was to evaluate the effect of low rates of LSi application (10 kg ha^{-1}, 20 kg ha^{-1} and 40 kg ha^{-1}) on potato plant tuberization and productivity, improvement of the quality and biochemical composition of tubers.

Materials and methods

In the growing season of 2009-2010 field trials were carried out at the Research Institute of Agriculture of the Latvian University of Agriculture using the medium early table potato variety ‘Lenora’.

The variety 'Lenora' was bred by the Priekuli Plant Breeding Institute and grown in Latvia from 2003. ‘Lenora’ is a highly productive variety, suitable for cultivation in both conventional and organic agriculture, and resistant to viral diseases, nematodes, and cancer. The variety is characterised by round tubers with bright yellow skin and yellow flesh. The productivity of ‘Lenora’ can reach 40-45 t ha^{-1}.

LSi (5 % Si) is a silicon-containing product synthesised by the Latvian State Institute of Wood Chemistry (IWC) from the wood lignocellulosic complex.

Characteristics of the soil used: turf podsolic soil pH_{KCl} 6.1-6.2, organic matter content - 2.5%, P_2O_5 90-152 mg kg^{-1}, K_2O 121-150 mg kg^{-1}.

Planned plant density 47 619 plants per ha^{-1}, with the area of plant nutrition 0.21 m^2 (0.30 m x 0.70 m), according to the optimal potato growing conditions.

In **2009,** the complex fertilizer NPK 12:6:15 - 700 kg ha^{-1} was used. There were 3 variants with different application rates of LSi in 3 replications: 1. control; 2. LSi – 10 kg ha^{-1}; 3. LSi – 20 kg ha^{-1}.

Potatoes were planted by hand with the application of mineral fertilizers. The potatoes planted on 15 May, harvested on 17 September.

For limiting of pigweed (*Chenopodium album* L.) and buckwheat (*Fagopyrum esculentum*), the herbicide *Titus* (active ingredients *Rimsulfuron* 250 g kg^{-1}) was applied (19 June).

Late blight *(Phythophtora infestans* (Mont.) de Bary) control started on 29 June. Sprayings with the system and contact fungicide *Ridomil Gold* 2.5 kg ha^{-1} *(Mankoceb* 64%, *Metalaksil M* 4 %) took place with a 14-day interval. The next spraying was carried out on 14 July with a mixture of the fungicide *Ridomil Gold* 2.5 kg ha^{-1} and the insecticide *Fastak (Alfa-cipermetrin* 50 g l^{-1}). The third spraying took place on 30 July with the contact fungicide *Ditan* 2 kg ha^{-1} (*Mankoceb* 750 g kg^{-1}).

In **2010,** the complex fertilizer NPK 12:11:18 - 500 kg ha^{-1} was used. There were 3 variants with different application methods of LSi in 3 replications: 1. control; 2. LSi – 40 kg ha^{-1} - dry tubers mixed with LSi in a container; 3. LSi 40 kg ha^{-1} – tubers were moistened with water in a container, then mixed with LSi (“wet” treatment of tubers).

Potatoes were planted by hand with the application of mineral fertilizers. The potatoes planted on 17 May harvested on 14 September.

Late blight control started on 20 July (first spraying. The fungicide *Infinito* 150 ml ha^{-1} (*Propamokarb* 523.8 g l^{-1}, *Propamokarb hydrochloride* 625 g l^{-1}, *Fluopicolide* 625 g l^{-1}) was used. Subsequent sprayings (3 times) took place with 10-14 day intervals.
Harrowing was performed once before potato shoot emergence, and then three times after.
In each trial, 10 plants were analysed; production of commercial standard tubers (with the diameter 35 mm - 75 mm) from one plant (kg and % from the total yield) was estimated.
Potato samples were analysed using the corresponding ISO. The dry matter content in tubers was determined by weighing (ISO 6498:1998), ash elements - by LVS EN ISO 16472:2006, content of starch - by ISO 6493:2000, crude protein - by ISO 5983-2:2005, potassium - by LVS EN ISO 6869:2002, phosphorus – by ISO 6491:1998, the content of vitamin C - by LVS EN ISO 14130:2003. The nitrate content in tubers was determined by the ion-selective method [9].

Results and discussion

In **2009-2010**, the favourable action of LSi in potato cultivation revealed itself not only in increased yield, but also in improved quality of tubers at LSi application rates of more than 20 kg ha^{-1} (Tables 1, 2).
On the whole, the vegetation period of **2009** was favourable for potato cultivation. In June, the mean air temperature was close to the mean long-term standard of + 14.0ºC or lower by 0.7 degrees; in its turn, the precipitation rate was 120% from the standard. In July, the air became warm, the mean air temperature reached +17.4ºC (0.6 degrees higher than the standard), but the precipitation rate reached 120% from the standard. The high air temperature corresponded to the standard, but the precipitation rate was only 90% from the standard [10]. The warm weather with regular rains favoured not only the growth and development of the plants, but also the spreading of plants' infecting with fungal diseases, which demanded the 3-times treatment of plants with fungicides. The favourable weather conditions ensured a good yield of tubers.
The analysis of the potato yield in 2009 has shown its 6% and 20% increase at LSi rates of 10 kg ha^{-1} and 20 kg ha^{-1}, respectively (Table 1). In comparison with the control, the share of standard potatoes in the total yield in this case did not change (77-79%). An analysis of the quality characteristics of the potatoes grown on the background of LSi (20 kg ha^{-1}) has shown that the starch content increased from 16.0% to 17.3%, in comparison with the control. The content of vitamin C did not change, to be 18.0 mg % (Table 3).

Table 1.

Effect of LSi on the yield and crop structure of the potato variety 'Lenora' Skriveri, 2009

Variants	LSi, kg ha^{-1}	Total yield, t ha^{-1}	Yield structure					
			Tubers, <35 mm in diameter		Trade production of tubers, 35-75 mm in diameter		Tubers, > 75 mm in diameter	
			t ha^{-1}	% *	t ha^{-1}	% *	t ha^{-1}	% *
Control	0	45.7	5.7	12.5	35.3	77.2	4.7	10.3
LSi	10	48.3	8.7	18.0	36.5	75.6	3.1	6.4
LSi	20	55.0	7.4	13.5	43.3	78.7	4.3	7.8
$LSD_{0.05}$		*1.23*	*1.25*		*1.37*		*0.54*	

* - from the total yield

In **2010**, the LSi application rate was increased up to 40 kg ha^{-1}, and two methods of LSi application were tested, namely, addition to dry tubers and those to tubers wetted with water before the sowing (Table 2).

Table 2.

Effect of different methods of LSi application for tubers treatment of the potato variety 'Lenora', before sowing, on the yield, Skriveri, 2010

Variants	LSi, kg ha^{-1}	Total yield, t ha^{-1}	Yield structure			
			Tubers, <35 mm in diameter		Trade production of tubers, 35-75 mm in diameter	
			t ha^{-1}	% *	t ha^{-1}	% *
Control	0	26.9	7.1	26	19.8	74
LSi -1	40	27.6	5.1	18	22.5	82
LSi -2	40	31.9	7.0	22	24.9	78
$LSD_{0.05}$		*1.54*	*0.62*		*1.26*	

* - from the total yield

LSi - 1 - dry treatment of tubers with LSi;

LSi - 2 - "wet" treatment of tubers with LSi.

The use of LSi at the application rates 20 kg ha^{-1} and 40 kg ha^{-1} ensures the introduction of 1.5 kg and 3 kg of SiO_2, respectively, into the soil.

The vegetation period of 2010 was warm, with a sufficient amount of precipitations [10]. However, long periods of drought were observed. In the 1st and 2nd decades of June, at the mean daily temperature of air conforming to the standard, there were practically no precipitations, but on 19 and 21 June, the total amount of precipitation was 48 mm, which conforms to the monthly standard amount of precipitation. July was characterised by extremely hot weather: the average air temperature (+21.5^{o}C) exceeded by 4.8 degrees the long-term average standard. Rare heavy showers were observed: on 7 and 8 July, the amount of precipitation was 50 mm, which corresponds to the monthly standard. August, the month of the ripening of potato tubers, was characterized by the mean daily air temperature +18.8^{o}C, which exceeds the standard by 2.8 degrees. The amount of precipitation in August was 180% from the standard. Precipitation was very uneven, with prevailing heavy showers.

The weather conditions of 2010 were not favourable for tuber formation. A huge mass of foliage and a great quantity of small tubers (<35 mm) were formed, which did not manage to reach the sizes, corresponding to the trade production (Table 2). The majority of the tubers corresponded to the seed potato sizes, and there were no tubers with the diameter larger then 75 mm.

At the dry LSi treatment of tubers (variant LSi-1, Table 2) before sowing, the additional yield in 2010 was only 2.6%, although positive changes in crop structure were observed. The trade yield increased by 13.6% in comparison with the control, and yield of non-standard production decreased by 28.6%.

At the "wet" LSi treatment of potato tubers (variant LSi-2, Table 2), the additional yield, in comparison with the control, was 18% at a 78% share of trade yield. In the control, it was 74%. Hence, in the case of the application of LSi, the trade yield exceeded the control by 25%, but the yield of dry protein by 20% (Table 3).

Table 3.

Effect of LSi on the biochemical indices of the tubers of the potato variety 'Lenora'

Variants	LSi, kg ha^{-1}	Dry matter, %	Starch, %	Crude protein, %	Ascorbic acid, mg %	N-NO_3, mg kg^{-1}
2009						
Control	0	21.1	16.0	1.95	17.9	...
LSi	20	21.3	17.3	2.00	18.1	...
2010						
Control	0	23.3	16.8	2.00	18.0	71
LSi - 2	40	27.1	19.8	2.12	18.3	43
$LSD_{0.05}$		*0.5*	*0.7*	*0.05*	*0.8*	*16*

The obtained results testify that the "wet" treatment of potato tubers with LSi promotes the enhancement of the total yield and marketable yield. At such a method of treatment, better retaining of LSi on the tubers is ensured, which is very important at low application rates of LSi.

In 2010 the potato grown on the background of LSi had the better quality indices then the potato of control variants: the content of nitrates decreased by 1.6 times, but the contents of dry matter and starch increased by 16% and 18%, respectively. In the control, the content of dry matter was 23.3 %, including the contents of starch, protein and mineral salts 16.8%, 2.0%, and 1%, respectively. On the background of LSi, the content of dry matter was 27.1%, including the contents of starch, protein and mineral salts 19.8%, 2.1% and 1.1%, respectively. The content of ascorbic acid remained the same, to be 18.0 mg %. The potassium content tended to increase, but the phosphorus content tended to decrease.

Conclusions

- Lignosilicon, at the application rates more than 20 kg ha^{-1}, has a favourable action on the yield and quality of potato tubers.
- The additional yield of potato on the background of the 20-40 kg ha^{-1} of LSi, in comparison with the control, is 18-20%.
- The best biochemical composition were detected for potato tubers grown on the background of 40 kg ha^{-1}. In this case, the trade yield exceeds the control by 25%, and the yield of dry protein by 20%, the content of dry matter and starch increases by 16% and 18%, respectively, and the content of nitrates decreases 1.6 times.
- The technique of "wet" treatment of potato tubers before sowing can be recommended for more efficient use of low application rates of Lignosilicon.

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YIELDS AND QUALITY OF PEAS VARIETIES IN LATVIAN AGROCLIMATIC CONDITIONS FOR ORGANIC FARMING

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Abstract. *Article summarizes results of study detecting the best varieties of peas cultivated in Latvian organic farming conditions. Study was conducted with new varieties of two species of crop peas: Pisum arvense L. (Pink flower varieties) – Retrija, Almara and Vitra, and Pisum sativa L. (White flower varieties) – Lasma and Zaiga. All varieties were selected in Latvia. The best among white flower varieties in terms of crop productivity was Zaiga variety, where yield was 1.45-1.48 t ha^{-1}. Among pink flower varieties of peas, the most productive was Almara variety, with crop productivity of 1.36-1.69 t ha^{-1}. Retrija variety of peas excels other studied varieties by total protein content and taste properties.*

Keywords: *Organic farming, Peas, Protein, Yield.*

Introduction

Human-created artificial agroecosystems proved to be very efficient biologically. They allow providing food for constantly increasing population of the Earth. However, unlike natural systems, they are ecologically unsustainable. In order to maintain ecologically balanced agroecosystem, man must constantly maintain soil fertility, i. e., maintain or increase content of humus and nutrition elements of cultivated crops in soil. The most important peculiarity of organic farming is activation of natural nitrogen-fixing systems, which provide for nutrition of cultivated crops mainly at the account of biological nitrogen.

Pea is one of basic vegetable leguminous crops. Two species of crop peas are cultivated in the Republic of Latvia – *Pisum sativa* L. (White flower varieties) and *P. arvense* L. (Pink flower varieties). Ripe peas and unripe seeds as canned or fresh green peas are used in food. Boiled grey peas (*P. arvense* L.) are Latvian national meal. Therefore Latvian breeders give great consideration to its taste properties. Special value of peas is its high content of protein balanced by amino acid composition. It can successfully replace animal origin protein in human nutrition.

In organic farming, where mineral fertilizers cannot be used, crop peas are very important as soil improverishers. Its role in providing soil with biological nitrogen is especially important. In mineralizing plant residues, it improves also phosphoric nutrition of subsequent crops significantly, and is a good precursor. Therefore, study detecting the best varieties of peas cultivated in organic farming conditions has scientific and practical meaning.

Materials and methods

Field study was conducted in 2005-2006 on certified organic farming field in Research Institute of Agriculture at LUA. Soil of research field: sod-podzol, loam. Agrochemical properties of topsoil: pH – 6.2; humus composition – 2.0-2.4%; available phosphorus composition – 246 mg/kg of soil; available potassium composition – 140 mg/kg of soil.

Study was conducted with new varieties of two species of crop peas: *P. arvense* L. (Pink flower varieties) – *Retrija*, *Almara* and *Vitra*, and *P.sativa* L. (White flower varieties) – *Lasma* and *Zaiga.* All varieties were selected in Latvia. Soil tilth, norms of seeding, terms of planting and harvesting, as well as analyses and degustation were conducted in accordance with VAAD methodology [4].

Results and discussion

Meteorological conditions in years of study were different from average perennial values both by temperature regime and by amount of precipitation, which allowed us to assess studied varieties of peas objectively**.**

Length of phases of vegetative seasons differed by varieties and changed by years (see *Table 1*).

Table 1.

Phenological factors of peas in organic farming conditions

No	Variety	Field germination, %	Productive stems pieces, n. m^2	Plant height, cm	Vegetation period, days	Lodging, 1- 9 scale
2005.						
1	***Zaiga***	72	59	81	79	5
2	Lasma	72	56	86	79	6
3	Retrija	79	71	110	78	3
4	Almara	73	56	98	76	3
5	Vitra	75	53	97	81	3
2006.						
1	***Zaiga***	93	114	71	71	6
2	Lasma	89	111	74	71	7
3	Retrija	92	108	99	74	4
4	Almara	92	121	84	73	4
5	Vitra	92	108	82	76	4

From phase „*full shoots*" to phase „*full ripening*" peas varieties needed 76 to 81 days in 2005, and just 71 to 76 days in 2006. During sowing in 2005 conditions were cold and humid, shoots showed on the 12th date. Cold and humid spring season of 2005 affected development of peas, which blossomed in the first decade of July only. Accordingly, ripening was delayed, too. The first to ripe was *Almara* variety (18 August), ripening of other varieties was delayed by 3 to 5 days. During sowing (02.05) in 2006 conditions were dry and warm, but as soon as the second decade of May, precipitations were 156% of norm, average air temperature was normal. Peas shoots showed on the 7th day. Blossoming began on 24 June. Warm and humid July weather favoured peas development. On 25 August such varieties as *Zaiga*, *Lasma* have riped, length of vegetative seasons was 71 days.

Considering conditions of crop cultivation on organic fields, crop production of studied varieties of peas was relatively high (*Table 2*). The best among white flower varieties by crop productivity was *Zaiga* variety, where yield was 1.45 t ha^{-1} in 2005, and 1.48 t ha^{-1} in 2006. The most productive of pink flower varieties was *Almara* variety. Crop productivity was 1.69

All studied peas varieties had small seeds, but they had higher content t ha^{-1} in 2005, and 1.36 t ha^{-1} in 2006. However, by taste properties *Retrija* variety was noted during degustation (8 points), and high appraisal by this factor also had *Lasma* variety in 2006. Summer 2006 was dry and hot. All tested varieties of pea had small seeds. While TKW of *Almara* variety was 204.0 g in 2005, the same factor in 2006 was the lowest at 154.1 g. Large seeds are peculiarity of *Retria* variety, where TKW was 380.0 and 306.5 g (in 2005 and 2006, respectively). Similar pattern of TKW factor decrease was also observed with other varieties.of total protein, compared to 2005. The highest content among pink flower varieties had *Retrija* variety (31.4%). Average crop productivity, when seeding this variety in demonstration experiments, was 2.5 t/ha, content of total protein - 25.19%. Content of irreplaceable amino acids was 5.58 %, including, lysine 1.36%, tryptophan 0.21%, methionine 0.15%. [1] The highest content of total protein in all years of study among white flower varieties of peas had *Zaiga* variety and

was 26.6-26.7%. However, by taste properties it was worse than *Lasma* variety. Thus, all studied peas varieties give stable and quality yield in organic farming conditions.
Peas are used both in feed and food. Thanks to its balanced composition, pea protein can replace protein of animal origin in our menu.

Table 2.

Crop productivity and quality of peas seeds in organic farming conditions

No	Varieties	Species	Yield, t ha^{-1}	TKW, g	Taste properties (soaked), 1 - 9 scale	Protein %
2005.						
1	*Zaiga*	*Pisum sativum L.*	1.45	236.8	6	26.7
2	*Lasma*	*P.sativum L*	1.42	262.0	6	25.6
3	*Retrija*	*P.arvense L*	1.54	380.0	8	25.8
4	*Almara*	*P.arvense L*	1.69	204.0	6	26.5
5	*Vitra*	*P.arvense L*	1.59	223.7	6	26.8
2006.						
1	*Zaiga*	*P. sativum L.*	1.49	188.3	7	26.6
2	*Lasma*	*P.sativum L*	1.29	191.4	8	25.5
3	*Retrija*	*P.arvense L*	1.06	306.5	8	31.4
4	*Almara*	*P.arvense L*	1.36	154.1	7	29.0
5	*Vitra*	*P.arvense L*	1.25	197.9	6	28.8
		LSD_{05} (2005)	0.16			
		LSD_{05} (2006)	0.13			

Conclusions

1. All studied varieties of peas are suitable for organic farming cultivation in climatic conditions of the Republic of Latvia on sod-podzol sandy-loam soil.
2. The best among white flower varieties by crop productivity was *Zaiga* variety, where yield was 1.45-1.48 t ha^{-1}. The most productive among peas pink flower varieties was *Almara* variety with crop productivity of 1.36-1.69 t ha^{-1}. *Retrija* variety of peas excels the rest of studied varieties by content of total protein and taste properties.

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GENETIC RESOURCES OF FLAX IN LATVIA

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Abstract. *Flax is cultivated on small areas in Latvia. Flax gives dual-purpose production – fibre and seeds. Latvian flax has a high fibre and seed quality. The quantity of flax fibre and seed yield depends on many factors. Several qualitative and quantitative traits, such as technical stem length, resistance to lodging, vegetation period, yield of straw and seeds, fibre and oil content and quality were evaluated. For the further development of Latvian economy flax varieties and hybrids of Latvian origin are an important goal. Fibre flax varieties 'Blue di Riga', 'Priekuļu 665', 'Ošupes 30' and breeding lines 'S-64-17-93' and 'L11-11/11-94' are valuable material containing a qualitative and quantitative indicators of variety. 92 Latvian accessions of flax hybrids have been evaluated, and 12 accessions with the best seed and straw yield have been selected for further DNA analysis. This will simplify and accelerate the selection of new valuable hybrids that will provide particular advantages in agriculture. The genetic analysis of DNA determines the kinship and diversity of flax varieties and breeding lines which can be used further in flax breeding.*

Key words: *DNA, fibre, flax, genotype, oil.*

Introduction

Flax (*Linum usitatissimum* L.) is an annual herbaceous plant with a steep footstalk. This is an important fibre and oil crop. Flax is mostly cultivated in the east part of Latvia. In the thirtieth year of the last century Latvia was one of the largest growers and exporters of flax in Europe. In Latvia the area of flax was less than 400-500 hectares during the last years, but once it was from 20 000 to 80 000 hectares. In 2001 flax area was about 1500 hectares, or by 13 percent less than in 1999. Total production compared to 1998 increased by 2.5 times. In 2000 from a hectare were harvested 3.35 tons of flax middling stem [4, 5, 6, 7, 12].

One of the main problems there is the seed material luck in flax cultivation, and its purchasing from foreign countries is very expensive. Larger profits are necessary to purchase seed, but the state subsidizes 62% from payments. Growing of flax can be mechanized, but half of the work must be done manually. In 2001 in Latvia flax was grown by 72 farms, where the average size of the flax area was 10-20 hectares. The structure of flax area in 2001 according regions was following: 968 hectares of flax were sown in Eastern Latgale (Rezeknes and Ludzas district) (harvested 3409 tons of straw); 376 hectares – in South Latgale (Preilu, Daugavpils, Kraslavas district) (harvested 1195 tons); 145 hectares sown in a North-Eastern region of Latvia (Gulbenes, Aluksnes, Balvu district) (harvested 44 tons); 81 hectare – in North Vidzeme (Limbazu, Valmieras, Valkas, Cesu district) (harvested 168 tons); 10 hectares – in North Kurzeme (Ventspils, Talsu, Tukuma district) (none of ton was sold to a processing factory). There are four flax processing factories in Latvia – in Ludza, in Kraslava, in Rezekne and in Valmiera's district.

At least three tons of flax stem from one hectare must be harvested to keep profitable flax growing. Otherwise the money will be lost.

In 2008 and 2009 the weather during vegetation period was favourable for flax growing, but in Latvia the area of flax decrease during the last years. Flax is requested in the world. Jelgava's enterprise "Larelini", that processes flax straw into long fibre, sends products to the USA and Germany. But the short fibre, which is bought by flax factories, goes to Lithuania and from there further to France.

In Latvia in the Ltd „Agricultural Science Centre of Latgale" the morphological research of many varieties of fibre flax and breeding lines was done. The best fibre is gained from flax, whose stem technical length is 60cm.

For the further development of Latvian economy flax varieties and breeding lines of Latvian origin are an important goal. There is a large value of flax seeds not only for human food necessities, but also for forage [1, 2, 3].
Flax resistance to diseases, flax with good fibre and seed quality grows in Latvian climatic conditions and can be widely used for the manufacture of fabrics, linseed oil extraction, pharmaceutical, paper industry, construction, motor factory, and elsewhere. It promotes flax processing businesses in Latvia. It is therefore very important to grow and retain the best of flax genetic resources of Latvian origin and create new varieties of flax, which are ecologically flexible and adapted to local agro-climatic conditions, and will be identified for specific uses [6, 7, 8].
In the recent years, studying the site-specific and species within the plant genetic material, molecular markers method using primer pairs of PCR (Polymerase Chain Reaction) is applied; in result allele's combination describes appropriate variety of flax (RAPD-PCR) [8].
The aim of this research was to clarify the diversity of Latvian flax varieties and relationship between morphological, phenological, phytopathological parameters using molecular markers. Using biotechnology methods new genes are determined; regulating them better yields can be obtained [9, 10].
Now advanced technologies are used for the description of flax genomic, allowing to identify individual chromosomes with the morphological characteristics [11]. Studies show that the chromosomes of cultivated flax are very different from chromosomes of the wild species. Creation of the relationship between different flax varieties and obtaining a description of chromosomes simplifies and accelerates the discovering new valuable hybrids.

Materials and methods

The evaluation of 72 flax varieties and 20 breeding lines was done in this research (random block design, three replications). Accessions were compared with standard fiber flax variety 'Vega 2'.
Agriculturally important traits, such as technical stem length, resistance to lodging, duration of vegetation period, yield of straw and seeds, fibre and oil content were evaluated. The agricultural characteristic of soil at the site: sod podzolic sand loam with pH 6.4-7.0, phosphorus content P_2O_5 – 130-145 mg kg^{-1}, potassium content K_2O – 118-124 mg kg^{-1} soil. In the spring after first soil cultivation the complex mineral fertilizers NPK 6-26-30 (300 kg ha^{-1}) were applied. Seeds were sown in May manually, seed rate – 170 seeds on the m^{-1}. The distance between rows was 10 cm, sowing depth 2-3 cm. In the "fir tree" phase of the flax development N fertilizers at rate 15 g m^{-2} were applied.
The meteorological conditions differently affected growth and development of flax during the growing period from 2007 to 2009. The drought negatively affected germination of flax in spring.
Flax accessions were harvested in early yellow ripening phase. When the standards of flax were dry, flax was trashed with 'Eddi'. Flax straw yield was measured g m^{-2}. Seeds were cleaned with MLN sample cleaner; the yield of seed was weighed, and then re-calculated to the weight of 100 % purity and 9 % humidity. Oil content was determined by grain analyzer Infratec 1241tm with a special built-in machine for flax oil content in seed.
After flax morphological analysis 12 flax seed samples of the best qualitative and quantitative indices were selected to DNA analyse. Seed were sown, and for DNA genetic analysis six seedling of each variety were excluded.
To TE buffer shortly before distribution was joined ß-merkaptoetanol in ratio 1:0,004.
There was inserted raw material (0.2 g), joined 200µl 1.p. to made solution and 400 µl lysine solution.

Flax samples were cut up to a homogeneous mass and placed in the 1.5 ml Eppendorf micro test tubes, and they were incubated for 5 minutes in a +65°C temperature. After the 600 µl chloroform loaded in each tube, tubes were shaking in the centrifuge for 5 minutes (10000 rpm). The solution of precipitation was prepared: mixed up 720 µl of water with 80 µl of precipitations.
After centrifuging supernatant and precipitations which contained DNS were placed to other Eppendorf micro test tubes and later were joined to 800 µl made rein solution, mixed for 1-2 minutes at room temperature. Tubes were centrifuged for 5 minutes (10000 rpm) till being liquid layer was fully separated. Precipitations were dissolved in 100 µl 1.2 M NaCl solution till full decomposition. There was joined 4 µl RNA solution (0.1 mg/ ml) and maintained at +37-40°C temperature for about 30 minutes. There was joined 300 µl a 96% ethyl alcohol into a solution, it was get cool to +20°C and kept 20 minutes. Later tubes were centrifuged for 5 minutes (10000 rpm). After centrifuging ethyl alcohol was pour out and remains (substance with DNS) washed with 1 ml + 20°C temperature ethyl alcohol-water 70% solution.
Remains with DNS were fully suspended in solution (float free) and tubes were centrifuged for 5 minutes (10000 rpm). The liquid phase was separated and precipitate was dried in a room temperature for about 1 hr. The obtained DNS preparation was dissolved in 100 µl water and kept in -20°C temperature. The DNS quality verification was executed with electrophoresis, comparing preparation with characterizing mass markers (50 ng μl^{-1}) - Mass Ruler DNA Ladder Low Range #SM0383 (Fermentas, Lithuania). Quality verification was executed in 1.7 % agar culture medium with TAE buffer.
The DNS concentration was determined with Lambda spectrometer 25 Perkin Elmer.
From each flax variety DNS was portioned out and was tested with 12 primer pairs used in this method PCR (Polymerase Chain Reaction) which locus of products allele combinations characterize the variety suitability.
From 12 markers six LU002, LU013, LU021, LU023, LU31 and LU32 were used for further genotyping. The method of reiteration (SSR, Simple Sequence Repeats) of the simple sequences markers was used for a molecular passport system of flax varieties.
The each pair of genetic markers directed with primer marker F and was marked with one from fluorescing dyes: - 6-FAM; - NED; -HEX.
It enabled in the genotyping process to combine PCR products. All materials were stored in -20°C temperature and melted in small amounts shortly before use. Water for molecular biology was demineralised, purified from nucleases and protein impurities. To 10 nM primer was join 50 µl TE buffers, mixed carefully till fully dissolving. It was saved in darkness in -20ºC temperature. To 2 µl primer of storage solution was joined 98 µl TE buffer.
In PCR reaction obtained DNS fragments analysed with DNS 3100-Avant Genetic Analyzer Both, using programme GeneMapper v. 4.0.
There were combined the obtained with PCR fragments each 0.7 µl with different colours different (6-FAM, HEX, NED), added 0.8 µl GeneScan TM -350 ROX TM Size Standard and 8 µl Hi-Di TM formamids, denatured in a special device in 95°C temperature for 5 minutes.

Results and discussion

The flax fibre quantity depends on the sowing period and the fertilization of flax plants. The fibre of flax and its quality depend on climate circumstances and selected variety.
For Latvian climate are common long summer days, which are often cloudy, and it promotes appearance of longer, thinner stems, from which a high-quality fibre and yield of good seed are obtained. Early flax sowing allows to obtained flax with more qualitative fibre. In Latvia fibre flax needs to be planted from May 5th till May 20th, but the period for sowing of oil flax is the beginning of April [1].

In 2007-2009 the duration of vegetation period was determined for 92 flax accessions. Summarizing results after a vegetation period, flax accessions were divided in 2 groups: the early ones (vegetation period 75-80 days (75 accessions) and for the serotinous accessions vegetation period was 86 days (17 accessions). During the vegetation period the more frequently flax diseases were anthracnose (caused by *Colletotrichum lini* (Westerdijk) Tochinai), bacteriosis (caused by *Clostridium (Bacillus) macerans* Schard.), flax seedling wilt (caused by *Fusarium oxysporum* Schlechtend.) and blight (caused by *Colletotrichum lini*). The phytopatalogical observations of flax were executed during all vegetation period. *Fusarium sp.* was established on isolated flax plants of 14 accession ('5586', '3686', 'Blue di Riga', 'Vietejais 1', 'Riga Freis', 'Riga Vilmorin', 'Rigaer LIN 780/81', 'N5' , 'Altgauzen 18×99', 'Altgauzen 16×90'; 'Vietejais 3'; 'L 19-6/15-95', 'T31-40-94', 'Vega 2'). *Clostridium macerans* was established on isolated plants of 3 varieties ('Vega 2', 'Vietejais 4'; 'N 116').
The stability of plants' lodging during vegetation period was determined. The determination of lodging was done in accordance with a method of 10 grade system. In 2009 flax lodging was established in 5 varieties: 'Osupes 30', 'Rigaer LIN 748/82', 'Riga Freis', 'Rigaer 6/5', 'Rigar B'.
The obtained yield of straw is shown in Figure 1. The yield of flax straw of standard variety 'Vega 2' obtained in 2007 was 660 g m^{-2}. In 2007 standard was exceeded only by 'S-64-17-93' (yield of straw 750 g m^{-2}) and by accession 'L11-11/11-94' (yield of straw – 703 g m^{-2}). In 2008 a higher yield of straw was obtained from varieties 'Priekulu 665' and 'Osupes 30'. In 2009 better straw yield was obtained from flax varieties 'Priekulu 665' – 753 g m^{-2} and accession 'T-36-26/4-8-94' – 837 g m^{-2}.

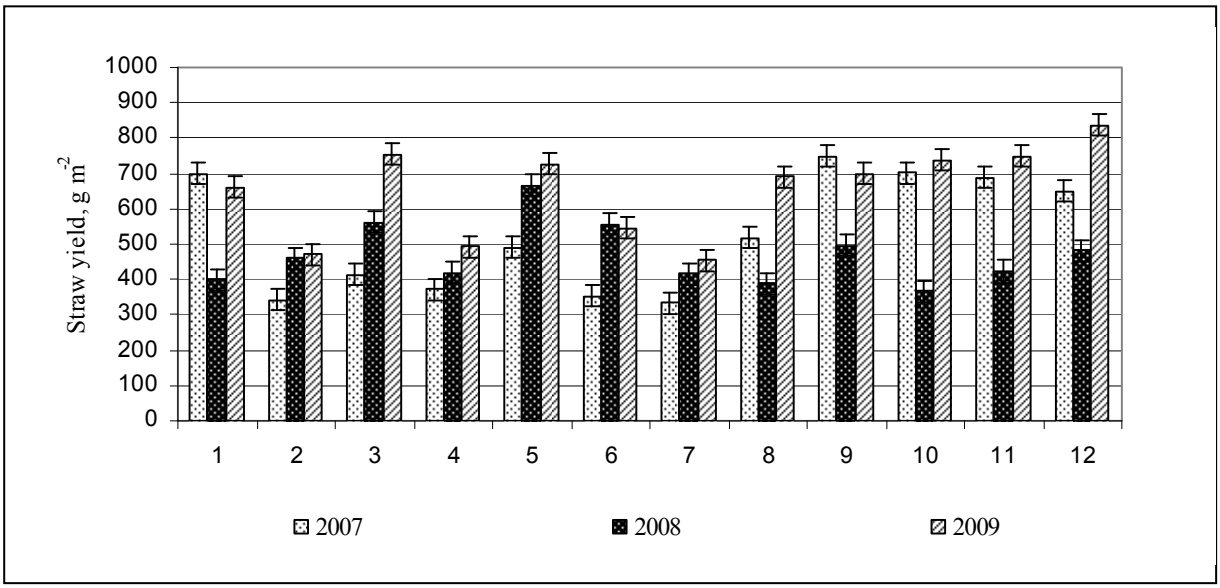

Fig.1. **The yield of flax accession in 2007-2009**
Names of varieties and accessions: 1 - 'Vega 2'; 2 - 'Blue di Riga'; 3 - 'Priekulu 665'; 4 - 'Riga Freis'; 5 - 'Osupes 30'; 6 - 'Vietejais 1'; 7 - 'Rigaer LIN 748/82' ; 8 - 'S-53/8-3-93'; 9 - 'S-64-17-93'; 10 - 'L11-11/11-94'; 11 - 'L19 - 6/15', 12 - 'T-36-26/4-8-94' ; (n=92)

The average data of three years show, that some of flax varieties and accessions had higher seed yield than that of standard variety of 'Vega 2': 'Osupes 30' – 628 g m^{-2}, 'S-64-17-93' – 649 g m^{-2}, 'L11-11/11-94' – 602 g m^{-2}, 'L19 - 6/15' – 620 g m^{-2} and 'T-36-26/4-8-94' – 656 g m^{-2}. In Latvian circumstances the straw yield of 3.3-7.5 t ha^{-1} can be obtained.

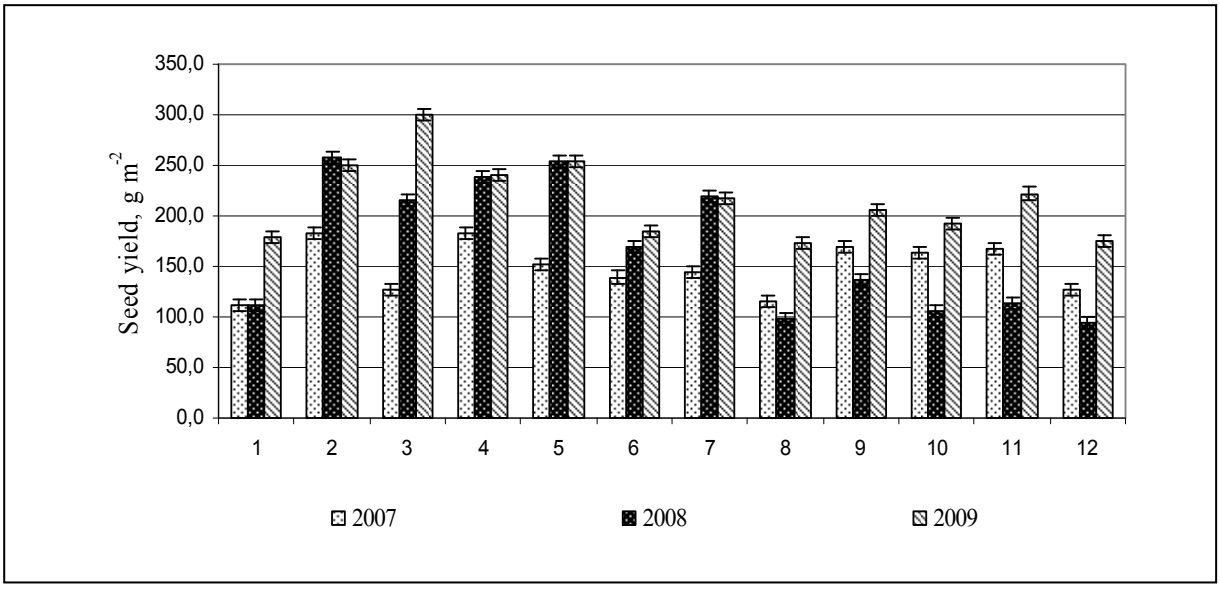

Fig.2. **Seed yield of flax accession in 2007-2008**

Names of flax varieties and accessions: 1 - 'Vega 2'; 2 - 'Blue di Riga'; 3 - 'Priekulu 665'; 4 - 'Riga Freis'; 5 - 'Osupes 30'; 6 - 'Vietejais 1'; 7 - 'Rigaer LIN 748/82' ; 8 - 'S-53/8-3-93'; 9 - 'S-64-17-93';10 - 'L11-11/11-94'; 11 - 'L19 - 6/15', 12 - 'T-36-26/4-8-94' (n=92)

Seed yield depends on many factors: amount of capsules from one plant, amount of seeds in a capsule and 1000 seed weight. In 2007-2009 the seeds of good quality from 54 accessions (59 % of all tested accessions) were obtained. These accessions had a higher seed yield than the standard 'Vega 2'. In 2009 yield of seed was 1.7-3.0 t ha^{-1}. In 2007 the highest yield of seed was obtained from 'Blue di Riga' – 182.3 g m^{-2} and 'Riga Freis' – 183.5 g m^{-2}, in 2008 – from 'Osupes 30' (Figure 2). In 2009 the best yield of seed was obtained from varieties 'Priekulu 665' – 300.6 g m^{-2}, 'Osupes 30' – 353.1 g m^{-2}, 'Blue di Riga' – 250.3 g m^{-2}. The average of three years show that the best yield of seed was obtained from the fibre flax varieties 'Blue di Riga', 'Priekulu 665' and 'Riga Freis'.

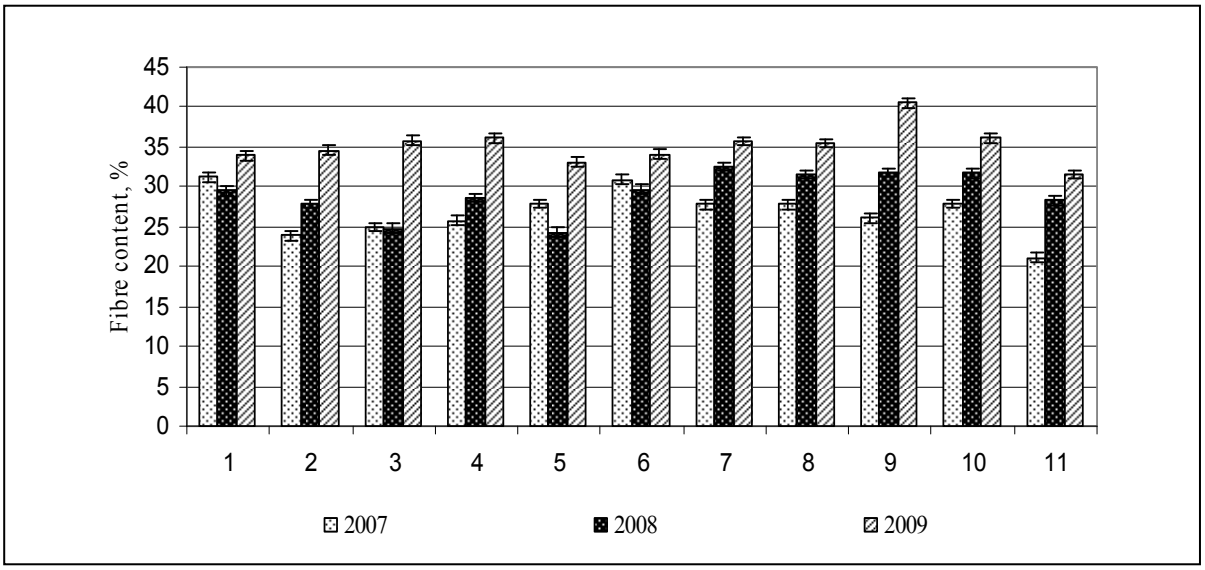

Fig.3. **Fibre content (%) of flax accessions in 2007-2009**

Names of varieties and accessions: 1 - 'Vega 2'; 2 - 'Blue di Riga'; 3 - 'Priekulu 665'; 4 - 'Riga Freis'; 5 - 'Osupes 30'; 6 - 'Vietejais 1'; 7 - 'Rigaer LIN 748/82' ; 8 - 'S-53/8-3-93'; 9 - 'S-64-17-93'; 10 - 'L11-11/11-94'; 11 - 'L19 - 6/15', 12 - 'T-36-26/4-8-94' ; (n=92)

One of the main yields forming factor was an amount of seed in a capsule. The maximal amount of flax seeds in a capsule can be 10, but an amount of seeds in a capsule of fibre flax reared in Latvia can be from 7.7 to 9.8. The climatic circumstances of the year 2007 were favourable for the development of flax seeds. Seeds are influenced by the weather.

More they are influenced by the amount of rain during the vegetation period, a superfluous humidity lowers quality of seeds; they will be mat and flat. In our investigation the weather conditions had contributed to seed yield and quality of the seed ripening period in 2008. High quality seeds were obtained, they were brilliant and smooth. In 2007-2009 the weight of 1000 seeds was from 4.80 to 6.78 g, and on average5.79 grams. This pointer was exceeded by 29 accessions.

Flax fibre is formed during the rapid growth phase and during the formation of buds and stalk. To ensure good fibre, plants should be well provided with moisture. Fibre quality is negatively influenced also by a superfluous humidity amount; a flimsy fibre appears then. In 2007 the best content of fibre was found in fibre flax varieties 'Blue di Riga' – 31.2 %, '55833' – 30.9 % and accession 'S-53/8-3-93' –27.8 % 'S-64-17-93' – 27.8 % and 'L23-26/3-97' – 27.9 %. In 2008 the best content of fibre was found in fibre flax varieties 'Blue di Riga' – 29.5 % and accession 'S-53/8-3-93' –32.5 %. In 2009 the best content of fibre was found in fibre flax varieties 'VN1'– 36.1%, '5581'– 35.8 % and accession 'T36-26/4-8' – 33.3 %, 'L23-26/3-97' – 32.0 %. In 2009 the best content of fibre was found in fibre flax accession to be 31.1-40.5% – in the accessions, the best fibre content of the standard 'Vega 2' was 31.5 %. This pointer was exceeded by 63 accessions (68 % of all tested accessions). Higher fibre content can be obtained from the varieties 'Blue di Riga', and accession 'T-36-26/4-8-94' and 'L-26 -47/1 -97'.

The seeds of flax are rich in lipids (33-45%), protein (18-33%), fibre substance (28-35%), mineral elements (~4%) and vitamins [2, 3]. Oil content in linseeds depends on variety. Oil content in varieties of fibre flax reared in Latvia is 40.6-45 % (Figure 3). From flax tested during three years, the largest oil content had the accessions of fibre flax 'Rigaer LIN 748/82', 'T 36-26/4-8-94' and 'L-19/15 -97'.

The DNS analysis was done 12 accessions of flax together with standard done (Figure 4.)

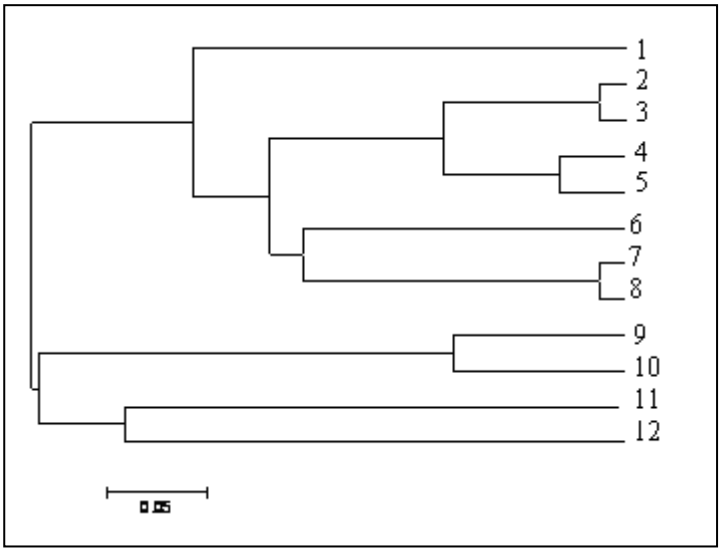

Fig.4. **Origin of flax, dendrogramma after Shared-allele, UPGMA programme**

Names of varieties and accessions: 1 - 'Rigaer LIN 748/82'; 2 -'S-53/8-3-93'; 3 - 'T36-26/4-8'; 4 - 'L19/6-15'; 5 -'Vega 2'; 6 - 'Vietejais 1'; 7 -'Blue di Riga'; 8 -'Riga Freis'; 9 - 'Osupes 30'; 10 - 'Priekulu 665'; 11 - 'L11-11/11'; 12 - 'S-64-17-93'

With use of the LU002, LU013, LU021, LU023, LU31 and LU32 markers the diversity of 12 flax accessions was determined. With the distances 0.05 of the DNS fragments flax differed by two alleles. Flax accesions 'Osupes 30', 'Priekulu 665', 'Rigaer LIN 748/82', 'S 64-17-93' and 'Vietējais1' were heterozygote. The variety 'Blue di Riga' contained vegetable population, which had the lowest multiplicity (homozygous). But the largest diversity had accessions 'S64-17-93' and 'Vietejais 1'. Of origin dendrogrammas of 12 flax accessions were divided into two kinds, and the nearest cognation had accessions 'L11-11/11-97' and 'S64-17-97'. The varieties of flax 'Priekulu 665' and 'Osupes 30' were supposed to be closely related and had a better possibility to obtain large and a stable yield of seed.

Conclusions

According to the investigation of three years, the highest seed yield was obtained from flax plants of varieties 'Blue di Riga', 'Riga Freis', 'Osupes 30' and accessions 'L- 19/6-15 – 97' and 'L-11-11/11-94', but fibre flax 'Riger LIN 748/82' and accession 'T36-26/4-8-94' and 'L-19/15 -97' had the highest oil content.

The highest straw yield was obtained from the variety 'Osupes 30' and accessions 'S64-17-93', 'S 13/5 -7/3–93', 'K 47–17/11-6-95', but 'Blue di Riga', 'Vietējais 1' and accessions of flax 'T-36 - 26/4-8-94', 'L -26 -47/1 -97' had the best content of fibre.

Following seven flax crop quality indicators (the technical stem length, yield of seed and straw, seed number per capsule, 1000 seed weight, fibre and oil content) the most suitable there were 5 varieties – 'Blue di Riga', 'Osupes 30', 'Riga Freis', 'Priekulu 665' and 'Vietejais 1', one line the 'Rigaer LIN 748/82' and 5 accessions – 'S-53/8-3-93', 'S-64-17-93', 'L11-11/11-94', 'L19 – 6/15' and 'T-36-26/4-8-94'. The DNS analysis showed, that the closest relationship was established between accessions ‘L11-11/11-97' and 'S64-17-97'. The largest diversity had accessions 'S64-17-93' and 'Vietejais 1'.

Acknowledgements

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GENETIC RECOURSES: EVALUATION OF THE VALUE OF SOME OLD LATVIAN FLAX ACCESSIONS

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Abstract. *In the resent years evaluation and conservation of genetic recourses becomes of great importance. Some of the genotypes could be lost when un-sufficient attention is given to them. Some old (created before WWII) Latvian flax accessions have been investigated at the collection nursery at the Upytė Experimental Station of the Lithuanian Research Centre for Agriculture and Forestry in 2007-2010. Phenological phases, plant height, flower colour, stem, seed and long fibre yield, fibre content and quality (flexibility, strength, quality number), duration of vegetation period, resistance to lodging, etc., have been investigated. The most valuable genotypes have been suggested to be used in further breeding programs.*

Keywords: *breeding, genetic recourses, flax, fibre, Latvian origin.*

Introduction

Latvians and Lithuanians have similar language, and being close neighbours have more or less similar pedoclimatical conditions to develop agriculture, so both countries (among many others) have been involved in flax growing long ago.

Before the World War II flax production was very important in Baltic countries [1; 2].

Fibre flax breeding in Lithuania has been carried out since 1922. Since 1922 to 2005 eighteen fibre flax varieties have been developed in our country, and in 2009 three new varieties have been registered [3].

Flax breeding in Latvia was started in 1923. After World War II, flax growing was not considered as an important task for the region, and, therefore, the flax area in the country was gradually reduced. In 1970, flax breeding in Latvia was cancelled [4]. Fibre flax breeding was started in Latvia again since 1992 [5], linseed (oil flax) growing and breeding has been started there in 1993 [6]. The repatriation and investigation of the Latvian flax genetic resources become a very actual task [1].

Several accessions of the Latvian origin, created and collected before the Second World War were repatriated from the N.I. Vavilov Institute of Plant Industry (Russia), Flax Research Institute of Russia, the Institute of Plant Genetics and Crop Plant Research (Germany) and Polish Seed Gene Bank [7].

Many authors report that plant genetic resources have a national value for each country [8; 9; 10; 11; 12; 13; 14]. Collection, storage and investigation of plant genetic resources have become a very important task in many countries [15; 16; 17; 9; 10; 12; 13].

Different local and foreign varieties, accessions, and breeding lines serve as a solid basis for the development of new plant varieties [9; 14; 15; 18]. The main targets when creating flax varieties are yielding capacity, fibre quality, good adaptability to local climatic and soil conditions, resistance to lodging and diseases [19; 20; 21; 22].

The task of the present study was to evaluate valuable characters of investigated fibre flax accessions with aim to include the best of them into fibre flax breeding programs as well as to confirm the value of genetic resources tested and to save them for coming generations.

Materials and methods

The investigation was carried out over the period 2007-2010 at the Upytė Experimental Station of the Lithuanian Research Centre for Agriculture and Forestry. Flax was grown on a sandy loam Endocalcari-Endohypogleic Cambisol [23]. The main agrochemical parameters of

the arable soil layer were following: pH_{KCl} – 6.7-7.5, humus content – 2.0-3.62 %, available P_2O_5 – 202-245 mg kg^{-1}, available K_2O – 122-152 mg kg^{-1}.
Flax was sown after winter wheat. Conventional cultivation practices were used.
In the collection flax was sown in a 1 m wide band with 10 cm interrows, without replications. The area of the plot was 1 m^2 and seed rate – 22-25 million of viable seeds per hectare.
Flax varieties for investigation were obtained from Agriculture Science Centre of Latgale (Director dr. V. Stramkale). The set of following flax accessions was investigated: 1. Altgauzen 3*19; 2. Altgauzen 5*30; 3. Altgauzen 12*80; 4. Altgauzen 16*90; 5. Altgauzen 17*93; 6. Altgauzen 23*112; 7. Dolgunec N 32; 8. Dolgunec N 115; 9. Dolgunec N 101; 10. Dolgunec N 116; 11. Dolgunec N 143; 12. Mestnyj belocvetkovyj N 580; 13. Mestnyj N 1; 14. Mestnyj N 3; 15. Mestnyj N 4; 16. Mestnyj N 6; 17. N 2; 18. N 5; 19 N 7. Accessions 7-12 were included to the list of VIR collection (obtained from Stendes breeding station) in 1930, and accessions 13-19 – in 1939, so they were developed many years ago. All the investigated varieties were compared to the standard fibre flax variety 'Kastyčiai' (productive, medium late, lodging resistant, distinguishing by good fibre quality) at present registered in Lithuania.
Insecticides were sprayed against flax flea beetles and herbicides were used to control weeds.
During flax growth period the phenological observations were conducted; before harvesting the resistance to lodging was assessed. Flax was pulled at the stage of early yellow ripeness, threshed by a MS thresher, the stems were retted in a warm (33-37˚C) water, then were scuthched by machine tool SMT-200, fibre was hackled with special combs. Quality number of long fibre was determined in the laboratory, flexibility – by a device G-2, strength of fibre – by a device DK-60. All field trials were conducted (with a few modifications) in compliance with published methodology [24; 25].
Over investigation years (2007-2010) meteorological conditions were diverse. The years 2007, 2008 and 2010 were less or more favourable for flax growing, but in 2009 we discarded the Collection nursery because of uneven germination, developing and ripening of flax plants. Of course, the meteorological conditions during flax growing period had influence on all tested parameters, but all the tested accessions were sown close each other, so they have similar pedoclimatical conditions.

Results and discussion

The average date from 2007, 2008 and 2010 are presented in the graphs. The tallest plants (besides of the standard 'Kastyčiai') in the field were that of the accession Dolgunec N 32 (76.2 cm) (Fig. 1). Very close to this mean was the height of plants of accessions Dolgunec N 101 (75.5 cm), Dolgunec N 116 (75.8 cm), Dolgunec N 143 (75.3 cm) and Mestnyj N 6 (74.9 cm). The shortest were plants of accessions N 7 (57.3 cm), Mestnyj N 4 (61.8 cm), Mestnyj belocvetkovyj N 580 (62.5 cm).
Plants of all tested accessions ripped earlier than that of standard variety 'Kastyčiai' (Fig. 2). The shortest growing period (from full germination to early yellow ripening stage) had plants from the set of Altgauzen accessions – 79-80 days. Those accessions could serve as the donors for the earliness.
Tested accessions were less resistant to lodging than the standard 'Kastyčiai' (Fig. 3). The most resistant to lodging were plants of Mestnyj belocvetkovyj N 580 (8.8 points), and plants of N 5 (6.3 points) and N 7 (6.5 points) were the most sensitive to lodging.
Old Latvian flax accessions were less productive than modern variety, and it is justifiable. The highest stem yield was produced by plants of accession N 2 (0.547 kg m^{-2}, or 5.47 t ha^{-1}) (Fig. 4).

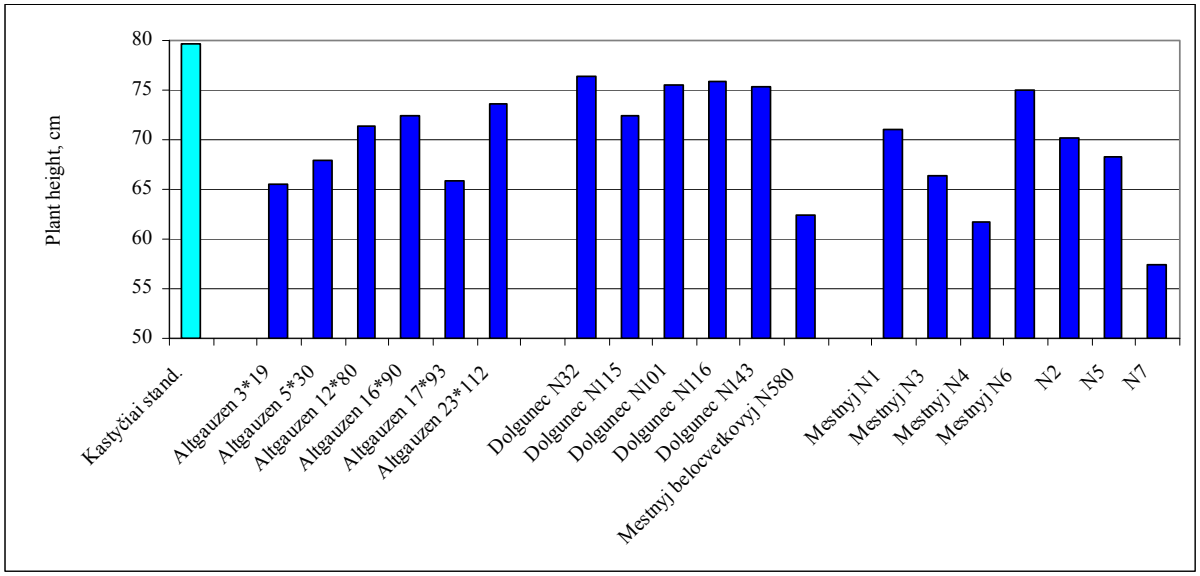

Fig. 1. **Plant height of tested accessions**

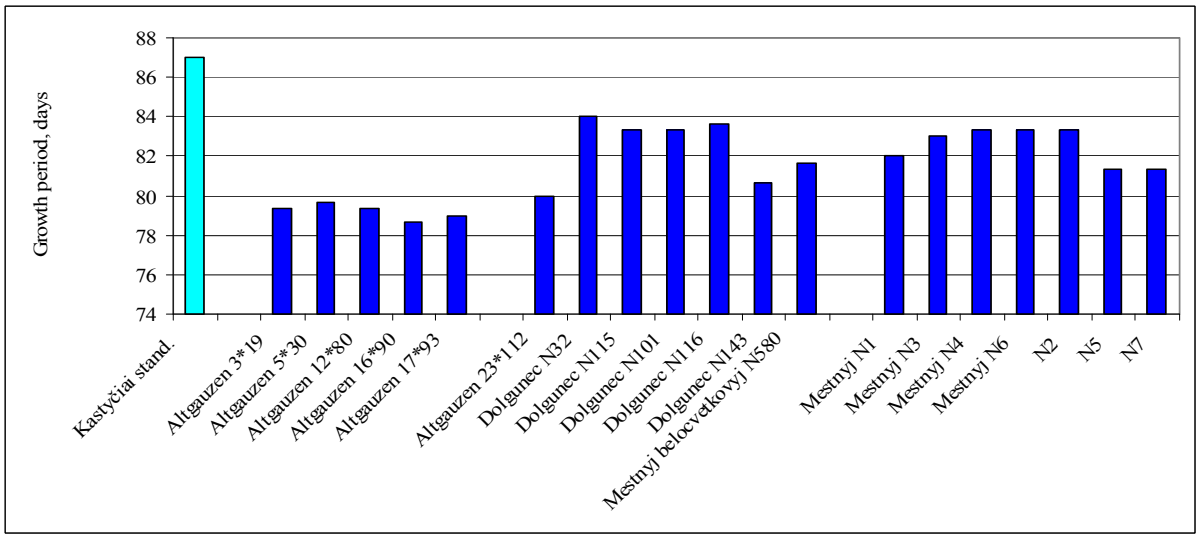

Fig. 2. **Growth period of tested accessions**

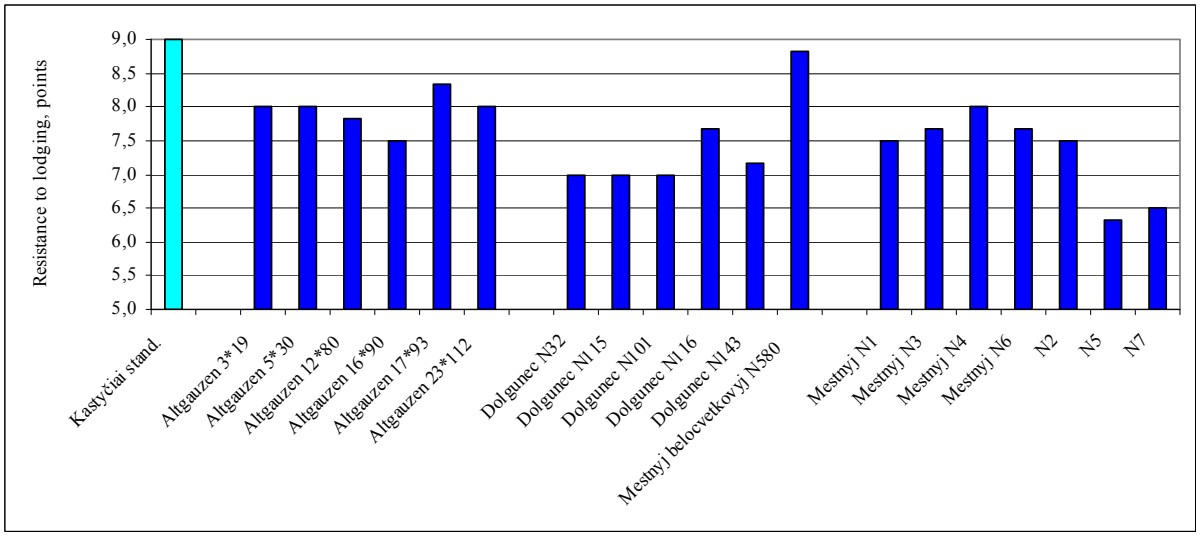

Fig. 3. **Resistance of tested accessions to lodging**

Very close results showed accessions Dolgunec N 116 (0.526 kg m^{-2}) and Mestnyj N 6 (0.525 kg m^{-2}). The highest seed yield was obtained from plants of accessions Dolgunec N 115 (0.087 kg m^{-2}, or 0.87 t ha^{-1}), Mestnyj N 4 and Mestnyj N 6 (0.081 kg m^{-2}, or 0.81 t ha^{-1}).
Long fibre yield (and fibre content in the stems) of tested accessions was rather lower than average yield of 'Kastyčiai' plants (782 kg ha^{-1} and 14.8 %, respectively) (Fig. 5). From tested accessions Dolgunec N 116 (496 kg ha^{-1}) and Mestnyj N 6 (431 kg ha^{-1}) gave the highest long fibre yield. Other accessions were less productive. Similar tendency could be noted for the fibre content data.
Very important character of the variety is fibre quality – flexibility, breaking tenacity (strength), divisibility (fineness), thus new varieties should be not only high yielding but also should have good fibre quality [26; 27; 28]. The data of evaluation of fibre quality are delighting. Variety 'Kastyčiai' is characterized as flax owning good fibre quality, but the majority of tested accessions prevailed over our standard variety. The most flexible fibre was obtained from flax of accessions N 2 (61.1 mm), Mestnyj N 1 (59.3 mm), Mestnyj belocvetkovyj N 580 (58.4 mm) and Altgauzen 17*93 (58.0 mm) (Fig. 6). The best results of fibre strength were shown by flax of accession Altgauzen 16*90 (16.2 kg F). Strong fibre was obtained from flax of accessions Altgauzen 23*112 (14.5 kg F) and Altgauzen 3*19 (14.4 kg F). The highest (from tested old Latvian accessions) long fibre quality number (Nb 11.0) was established for fibre of accessions Dolgunec N 115, Dolgunec N 101 and N 2 (Fig 7).
Also we investigated 1000 seed weight. Seeds of tested accessions were rather smaller than that of modern variety 'Kastyčiai' (5.24 g) (Fig. 8). Plants of accession Dolgunec N 101 produced largest seeds (1000 seed weight – 4.58 g) from all tested accessions.
In this context it would be fair to say, that the most valuable accessions from the tested set were Altgauzen 3*19, Altgauzen 5*30, Altgauzen 12*80, Altgauzen 16*90, Altgauzen 17*93, Altgauzen 23*112, Mestnyj belocvetkovyj N 580, Dolgunec N 32, Dolgunec N 101, Dolgunec N 116, N 2, Mestnyj N 6, Mestnyj N 1. Those varieties could be recommended to be included into fibre flax breeding programmes.

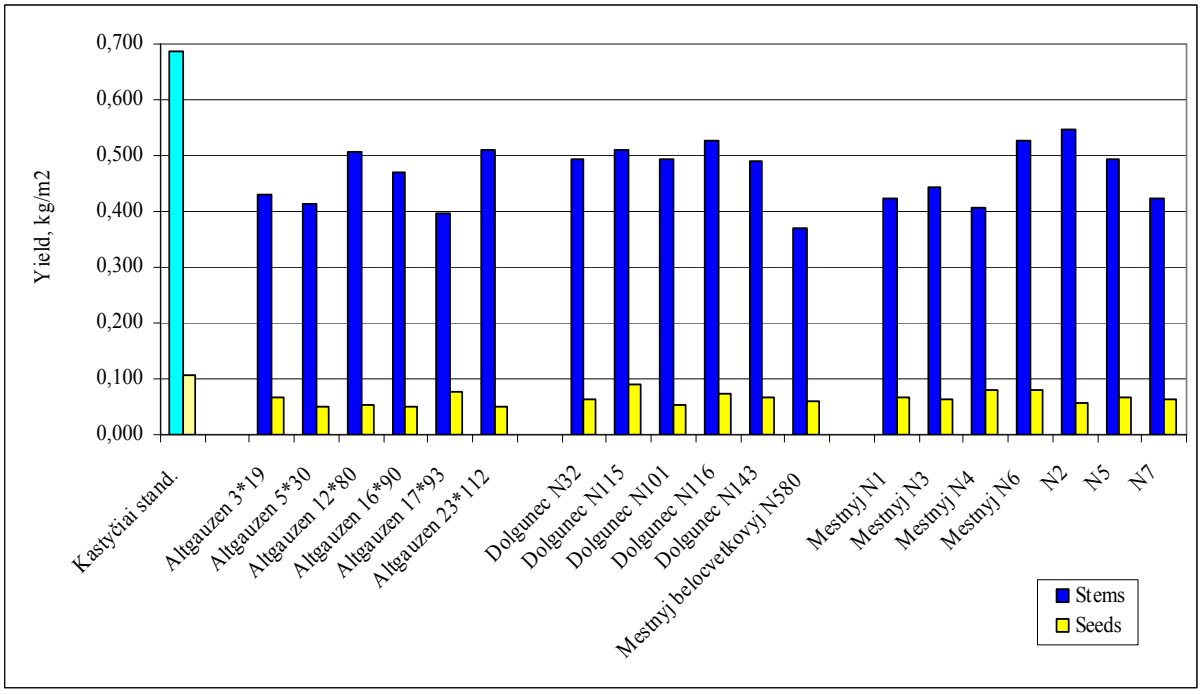

Fig. 4. **Stem and seed yield of tested accessions**

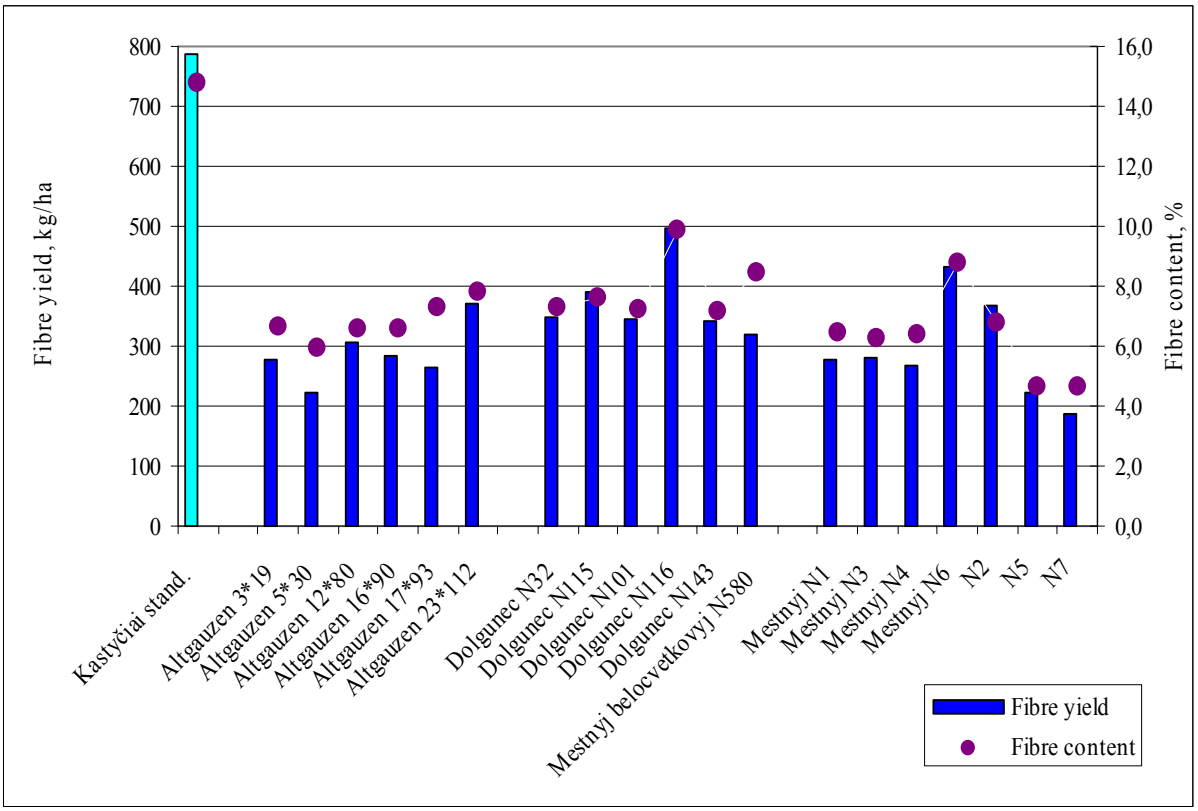

Fig. 5. **Long fibre yield and fibre content of tested accessions**

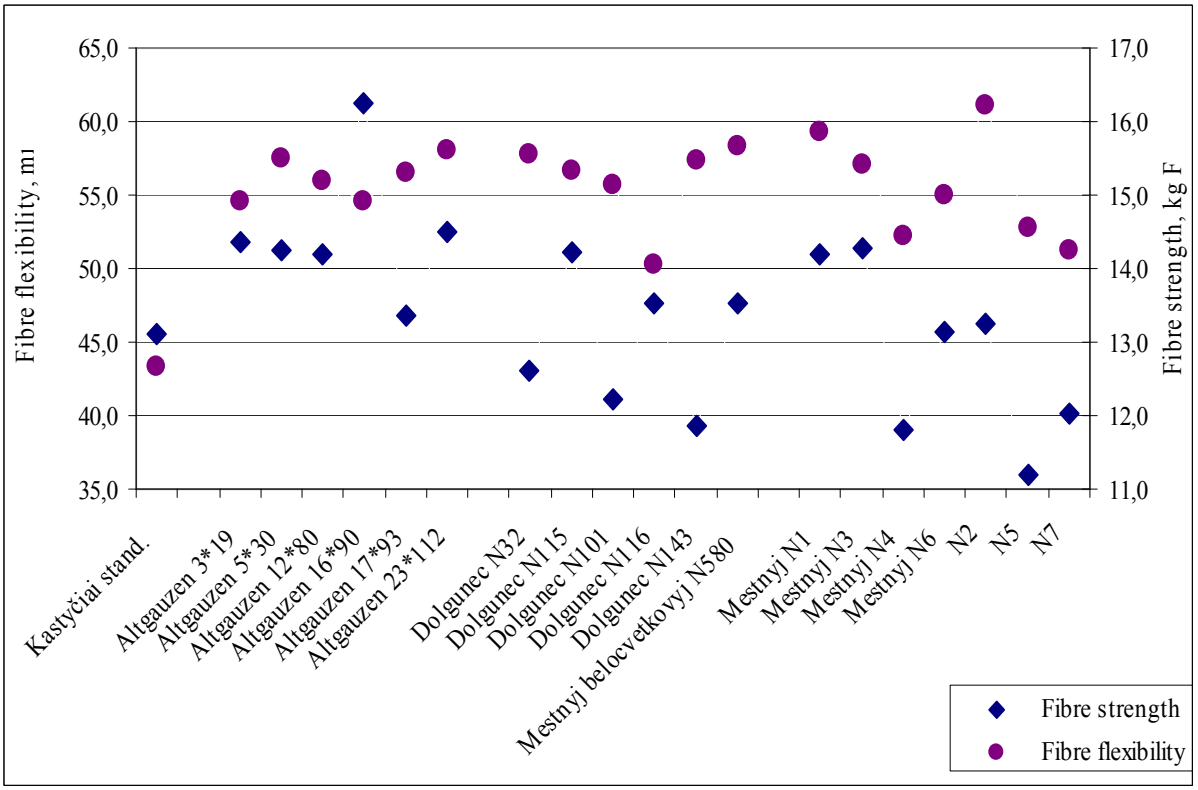

Fig. 6. **Long fibre flexibility and strength of tested accessions**

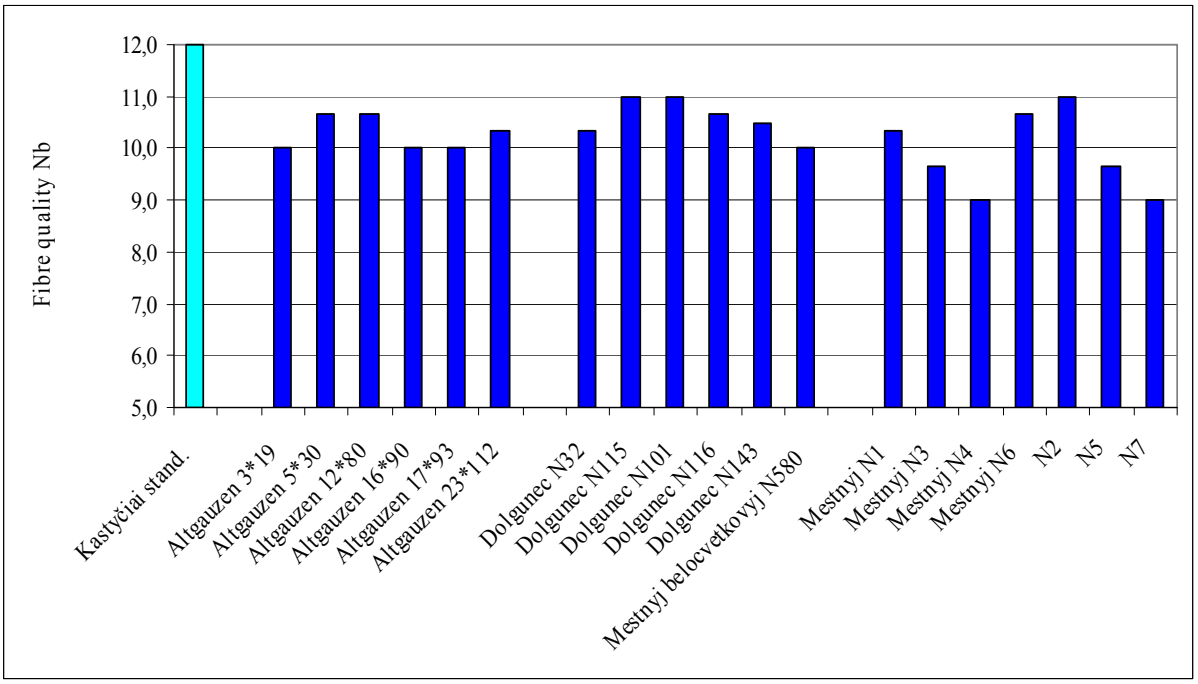

Fig. 7. **Long fibre quality number of tested accessions**

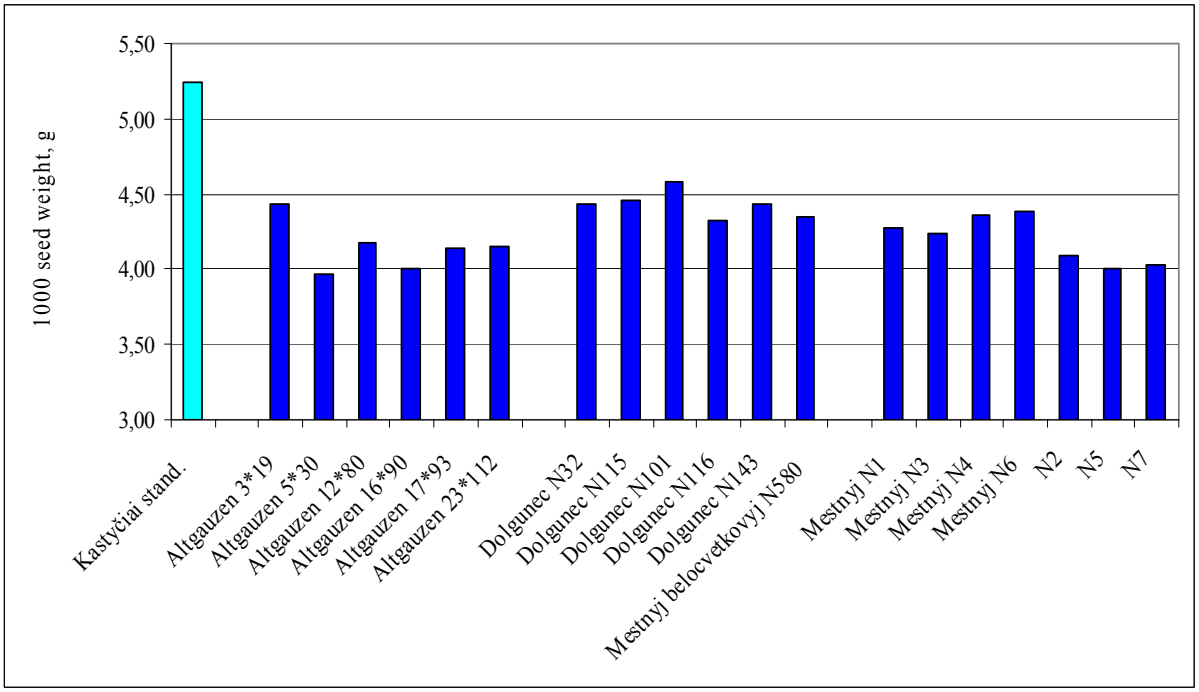

Fig. 8. **1000 seed weight of tested accessions**

Conclusions

The tallest plants (besides of the standard 'Kastyčiai') in the field were that of the accession Dolgunec N 32 (76.2 cm). The shortest growing period had plants from the set of Altgauzen accessions – 79-80 days. Tested accessions were less resistant to lodging than the standard 'Kastyčiai'. Old Latvian flax accessions were less productive than modern variety. The highest stem yield was produced by plants of accession N 2 (0.547 kg m^{-2}, or 5.47 t ha^{-1}). The highest seed yield was obtained from plants of accessions Dolgunec N 115 (0.087 kg m^{-2}, or 0.87 t ha^{-1}), Mestnyj N 4 and Mestnyj N 6 (0.081 kg m^{-2}, or 0.81 t ha^{-1}). From tested

accessions Dolgunec N 116 (496 kg ha^{-1}) and Mestnyj N 6 (431 kg ha^{-1}) gave the highest long fibre yield. The most flexible fibre was obtained from flax of accessions N 2 (61.1 mm), Mestnyj N 1 (59.3 mm), Mestnyj belocvetkovyj N 580 (58.4 mm) and Altgauzen 17*93 (58.0 mm). The best results of fibre strength were shown by flax of accession Altgauzen 16*90 (16.2 kg F). Plants of accession Dolgunec N 101 produced largest seeds (1000 seed weight – 4.58 g) from all tested accessions.

The most valuable accessions (Altgauzen 3*19, Altgauzen 5*30, Altgauzen 12*80, Altgauzen 16*90, Altgauzen 17*93, Altgauzen 23*112, Mestnyj belocvetkovyj N 580, Dolgunec N 32, Dolgunec N 101, Dolgunec N 116, N 2, Mestnyj N 6, Mestnyj N 1) from the tested set could be recommended to be included into fibre flax breeding programmes.

Summary

Before the World War II flax production was very important in Baltic countries. Fibre flax in Lithuania breeding has been carried out since 1922. Flax breeding in Latvia was started in 1923. In 1970, flax breeding in Latvia was cancelled and was started in Latvia again since 1992. The repatriation and investigation of the Latvian flax genetic resources become a very actual task. The task of the present study was to evaluate valuable characters of some old fibre flax accessions with aim to include the best of them into fibre flax breeding programs as well as to confirm the value of genetic resources tested and to save them for coming generations. The most valuable accessions (Altgauzen 3*19, Altgauzen 5*30, Altgauzen 12*80, Altgauzen 16*90, Altgauzen 17*93, Altgauzen 23*112, Mestnyj belocvetkovyj N 580, Dolgunec N 32, Dolgunec N 101, Dolgunec N 116, N 2, Mestnyj N 6, Mestnyj N 1) from the tested set could be recommended to be included into fibre flax breeding programmes.

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PHYSIOLOGICAL ASPECTS OF NITROGEN FERTILIZER IMPACT ON LATVIAN ORIGIN *CANNABIS SATIVA* L.

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Abstract. *The aim of the present study was to evaluate nitrogen fertilizer impact on photosynthesis and yield of hemp, applying modern non-destructive methods. The main object of the investigation – hemp cultivar of Latvian origin 'Pūriņi'. Laboratory and field experiments showed diverse effects of different nitrogen fertilizer doses on various parameters. Additional nitrogen fertilizer dose of 60 kg ha^{-1} is most effective as evaluated by chlorophyll content in hemp leaves and changes of chlorophyll a fluorescence parameters. Nitrogen fertilizer negatively affected fiber content in hemp stems, therefore while cultivating hemp only for fiber production use of nitrogen fertilizer should be reduced. According to the seed mass results, additional nitrogen fertilizer doses should be applied following the climatic conditions. In the vegetation period guided with higher rainfall levels, 60 kg of additional nitrogen fertilizer per hectare can be considered as optimal amount. In current investigation hempseed oil composition was not negatively affected by nitrogen fertilizer. Also significant difference between seed yield of N_{60} and N_{100} variants has not been observed. To avoid excessive nitrogen fertilizer usage, its negative impact on plant physiology and yield losses, we consider nitrogen fertilizer 60 kg ha^{-1} as additional fertilizer is optimal for hemp cultivar 'Pūriņi'.*

Key words: *Cannabis sativa L., nitrogen fertilizer, chlorophyll content, chlorophyll a fluorescence, yield.*

Introduction

All over the World hemp has both economic and pharmaceutical value [1], and is commercially cultivated in Europe, China, Japan and USA [2]. Minimal quantities or no herbicides, pesticides and fungicides are necessary to use while cultivating hemp [3]. According to the literary sources, hemp improves soil structure, suppress weeds and soil becomes free from diseases and pests [3, 4].

Nitrogen is quantitatively the most significant element for plant growth and development [5]. Nitrogen participates in cell growth and metabolism [6, 7], and it is considered to limit yield [7]. Nitrogen is the element that is most widely used in agriculture [8].

While breeding agricultural crops, it is important to take care of conservation and application of natural resources. That is why before starting the introduction of any new crop into national agriculture, it is necessary to develop scientifically reasoned recommendations according to existing soil and climatic conditions. Hemp fertilization methodology badly varies in different countries. For example, in Canada quoted nitrogen doses range from 60 to 90 kg ha^{-1} [9], while in EU countries doses vary between 80 – 160 kg ha^{-1}, depending on soil composition [10]. Recommendations for hemp breeding developed in EU are not considered to be suitable for Latvian climatic and soil conditions.

In the literary sources data about the importance of additional fertilizer in hemp is found [11]. To avoid loss of nitrogen, it is recommended to divide nitrogen fertilizer into several portions [12].

To provide local hemp breeders with essential information about hemp cultivation, in Latgale Agricultural science centre (LASC) experiments were arranged. Researchers determine hemp varieties that suit Latvian conditions and agrotechnical parameters of hemp breeding technology, and also develop environmentally friendly fertilization technologies. There is a lack of fundamental research on nitrogen impact on hemp physiological processes including photosynthesis as a major yield-forming factor.

The aim of the present study was to evaluate nitrogen fertilizer impact on photosynthesis and yield of hemp. The main object of the investigation – hemp cultivar of Latvian origin 'Pūriņi', grown since 1936 in Piksāru district of Rūjiena region.

We consider using modern non-destructive methods for indication of nitrogen supply efficiency is a perspective trend for agriculture. Because photosynthetic efficiency is linked to plant productivity, we consider measuring different photosynthetic parameters during vegetation period can provide significant information about plant physiological condition and prevent plant stress caused by excessive/insufficient fertilizer supply.

Materials and methods

Field experiment

Growth conditions / Experimental treatment

Field experiment was performed in LASC. The agricultural characteristics of soil are summarized in table 1.

Table 1.

Agricultural characteristics of soil in field experiments

Year	Organic matter content (%)	pH	Phosphorus content P_2O_2 (mg kg^{-1})	Potassium content K_2O (mg kg^{-1})	Preliminary plant	Complex fertilizer NPK, applied after first soil cultivation (kg ha^{-1})
2008	3,8	7,3	83	65	Spring rape	6:26:30 - 300
2009	4,5	7,3	134	122	Spring rape	18:9:9 – 330
2010	6,5	7,0	145	118	Bare fallow	18:9:9 - 350

Field soil - sod podzolic sandy-loamy soil. Before the arrangement of the experiment field was drained, relief equalized. Experiments were organized by randomized block method. Isolation between variants and isolation between duplications was 0,5 m.

Meteorological conditions

Data of meteorological conditions during experiment provided by *Adcon* meteostation, connected to *PlantPlus* computer program.

Overall, according to the air temperature data (fig. 1), 2008, 2009 and 2010 vegetation months were warmer, than generally in LASC. Average air temperature in 2008, 2009 and 2010 was 12,9 ^oC, 12,8 ^oC and 14,3 ^oC respectively, while long-term average result is 12,2 ^oC.

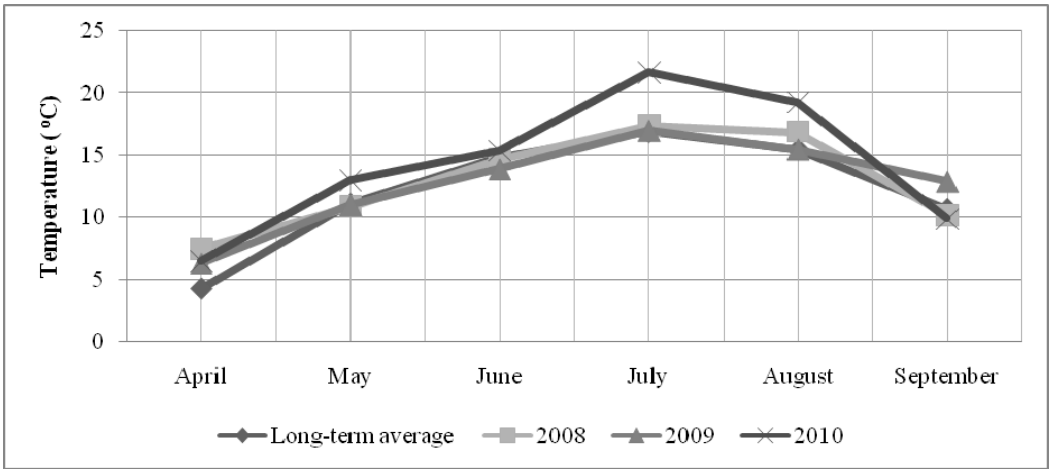

Fig. 1. **Air temperature during 2008 - 2010 vegetation months in LASC**

Total air temperature values in 2008, 2009 and 2010 were 77,6 ^oC, 76,6 ^oC and 85,8 ^oC respectively, comparing to the long-term average value equal to 73,3 ^oC.

According to the rainfall data, we must conclude that 2008, 2009 and 2010 were dryer years, comparing to long-term average data (fig. 2).

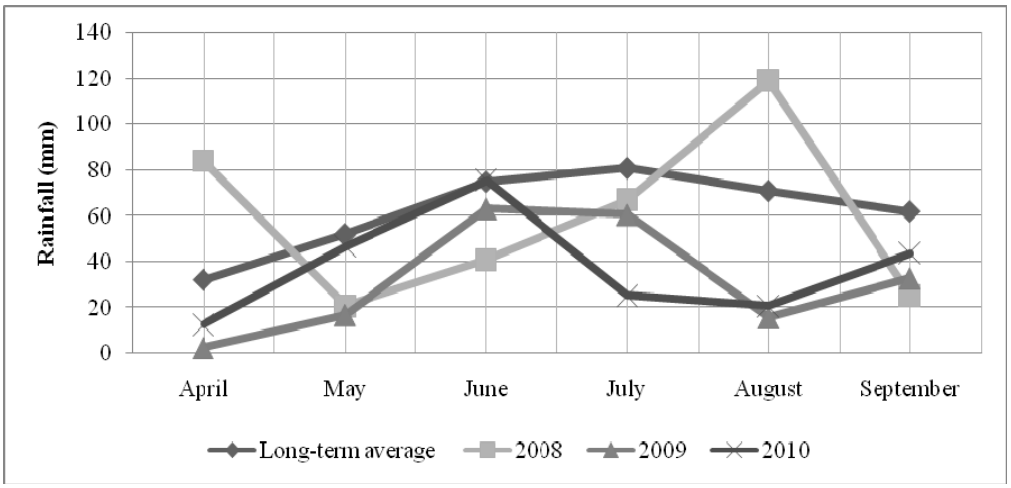

Fig. 2. **Rainfall during 2008 - 2010 vegetation months in LASC**

Total rainfall, comparing to long-term average 373 mm, in 2008 was per 4,3 % lower, in 2009 – per 48,7 % lower, and in 2010 – per 39,9 % lower.

Unsaturated fatty acid composition of seed oil

Unsaturated fatty acid composition was determined for hempseed oil using gas chromatography equipment (*SHIMADZU GC-2010* and *YL6100GC* (*Young Lin Instrument*)).

Laboratory experiment

Growth conditions/ Experimental treatment

Laboratory experiment performed in the University of Latvia, Plant Physiology department in 2009. Seeds sown into vegetation containers with total volume 0,59 L, filled with peat substratum *KANO* (pH (KCl) 5,5 – 7,0, N content 180 mg l^{-1}, K_20 content 400 mg l^{-1}, P_2O_5 content 245 mg l^{-1}). For plant fertilization 10 % ammonium nitrate (NH_4NO_3) solution was prepared. In experiment three nitrogen fertilizer doses were used: N_0 – control, N_{60} – 60 kg ha^{-1}, N_{100} – 100 kg ha^{-1}. All plants were divided into three variants with first fertilization time. Measurements of total chlorophyll content and chlorophyll *a* fluorescence were performed four times. During the first measuring time (I) majority of plants were in vegetative stage and had at least three pairs of leaves. All plants were in vegetative stage during the second measuring time (II), part of plants showed change of phyllotaxis. While performing measurements in the third time (III), plant transition to flowering stage was detected. During the fourth measuring time (IV) all plants were in intensive flowering stage.

Total chlorophyll content

Chlorophyll content was determined using non-destructive *Minolta SPAD-502* chlorophyll meter. At least 30 readings from a leaf were used to get one final average reading. In each variant final average readings of 30 leaves were analyzed (on average two leaves from 15 plants). The mean of the measurement was calculated using the internal function of the chlorophyll meter.

Chlorophyll *a* fluorescence

Chlorophyll *a* fluorescence was measured using non-destructive *Handy PEA* portable fluorescence measurement system (*Hansatech instruments*). Leaves were dark-adapted with leaf clips for 25 minutes before measurement. Measurements were repeated for all variants (20 measurements for each variant). The mean of the measurement was calculated using *MS Excel* program.

Results and discussion

Field experiment

According to the literary sources, fiber varieties of hemp demand higher rainfall levels then oil varieties [13]. Interestingly that in 2008, when rainfall amount was higher, average fiber content in hemp stems was lower, then in dryer 2009 and 2010 (fig. 3).

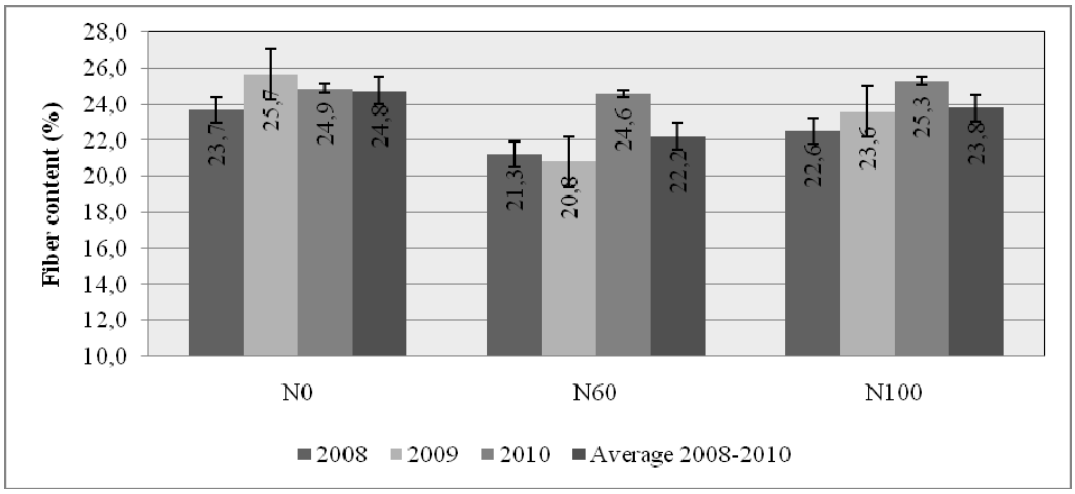

Fig. 3. **Fiber content (%) in hemp stems under different nitrogen fertilizer supply**

It is significant that in stems of unfertilized control plants average fiber content was up to 7,8 % higher than in fertilized plants. It could be explained by the fact that received nitrogen in fertilized plants promotes usage of photosynthetic assimilates in amino acid biosynthesis. As it is known, biosynthesis of carbohydrates competes with biosynthesis of amino acids for distribution of photosynthetic assimilates [14], therefore schlerenhyma cells, that form fibers, are produced in smaller amounts. Probably, while cultivating hemp only for fiber production, use of nitrogen fertilizer should be reduced.

According to the literary sources, in Latvian conditions hemp can produce from half of a ton up to one ton seeds from one hectare [11]. Substantially, that seed yield of local hemp variety 'Pūriņi' showed higher results (fig. 4.). For example, in 2009 N_{100} variant hemp plants produced more than 2,5 tons seeds from hectare.

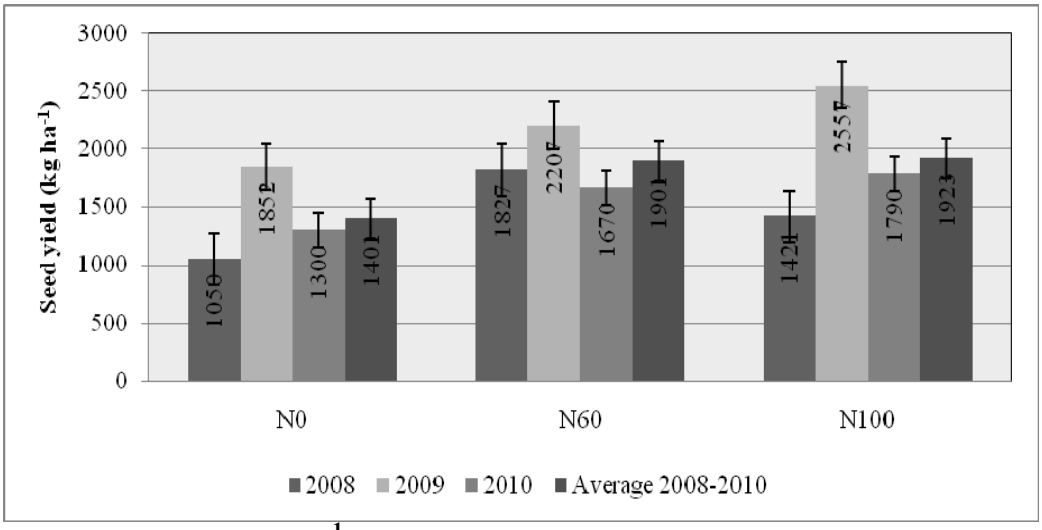

Fig. 4. **Seed yield (kg ha^{-1}) of hemp under different nitrogen fertilizer supply**

We should mention that in 2008 the highest seed yield was in N_{60} variant, while hemp seed yield in dryer conditions of 2009 increased both in fertilized and unfertilized variant plants. In

2010 fertilized plants produced 28,5 % (N_{60}) and 37,7 % (N_{100}) higher seed yield, than unfertilized plants.Comparison of average seed yield results showed that average seed yield of fertilized plant for 36,5 % exceeded seed yield of unfertilized plants.
In 2008 the highest seed mass was in N_{60} variant, in 2009 – in N_0 and N_{100}, but in 2010 the significant difference between variants has not been detected (fig. 5.).

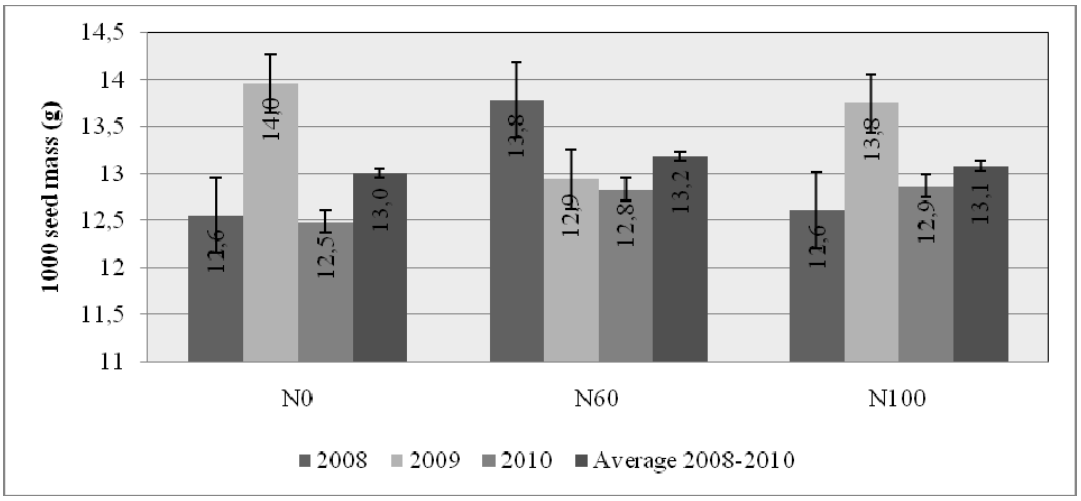

Fig. 5. **1000 seed mass (g) of hemp under different nitrogen fertilizer supply**

From average values we can conclude that seed mass was not materially influenced by fertilizer. Explicit impact on seed mass was detected for moisture conditions. In 2008, when total rainfall was only per 4,3 % lower than long-term average, N_{60} plant seeds were in average per 9,5 % heavier than N_0 and N_{100} variant plant seeds. In relatively dryer 2009 difference between seed mass of N_0 and N_{100} was not significant, and seed mass of N_{60} plants was about 8 % lower, than in non-fertilized N_0 plants. Therefore we must conclude that according to the seed mass results, additional nitrogen fertilizer doses should be applied, following the climatic conditions. In the vegetation period, guided with higher rainfall levels, 60 kg of additional nitrogen fertilizer per hectare can be considered as an optimal amount.
Determination of unsaturated fatty acid composition of cold pressed hempseed oil proved that it's very valuable because of the presence of linoleic, α-linolenic, γ-linolenic, oleic, eicosenoic and erucic fatty acids (fig. 6.)

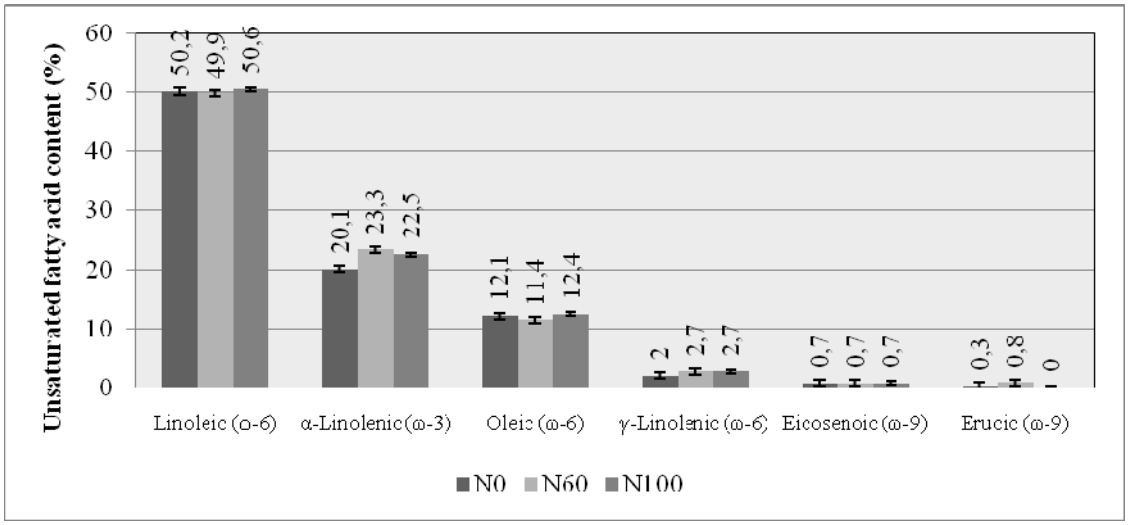

Fig. 6. **Unsaturated fatty acid content (%) in cold pressed hempseed oil, depending on different nitrogen fertilizer supply**

According to the literary sources nitrogen can negatively affect fatty acid composition of oil culture seeds [15]. In the current investigation hemp seed oil composition was not negatively affected by nitrogen fertilizer.

Laboratory experiment

During the current investigation we ascertained that chlorophyllmetry is a fast and non-destructive method, which can be repeated during ontogenesis, so we can join other authors' statement that this method is very useful [16, 17, 18, 19]. According to the dynamics of chlorophyll content changes we can conclude that both in fertilized and non-fertilized plants chlorophyll content gradually increased during ontogenesis (fig. 7.).

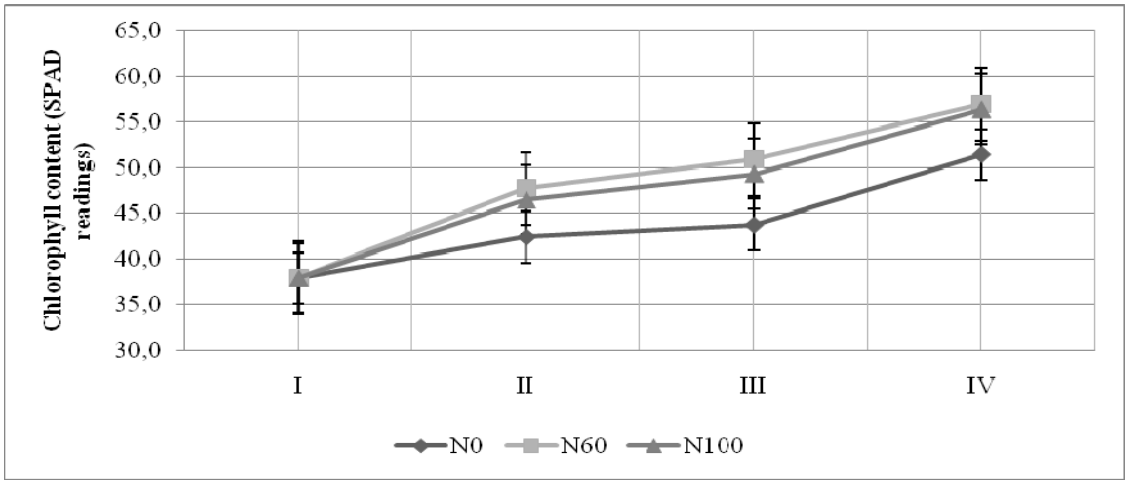

Fig. 7. **Chlorophyll content changes in hemp leaves under different nitrogen fertilizer supply, determined with chlorophyll meter Minolta SPAD-502**

Investigations of different cultivated plants, that were held out in recent years [17, 8, 20] showed SPAD reading correlation with absolute chlorophyll values, so these readings can be considered as reliable. Moreover, according to the opinion mentioned in literature, use of chlorophyll meter in laboratory conditions is especially effective [21]. Wherewith in current experiment chlorophyll content was determined in laboratory conditions, we can forecast that results are reliable and influence of the outward factors was minimal.

Schlemmer and others [8] write that photosynthetic potential is directly proportional to the chlorophyll content in plant tissues. Respectively, our data of chlorophyll content in hemp leaves describes photosynthetic potential of differently fertilized plants. Many authors recommend chlorophyll meter for determination of the nitrogen status and efficiency of nitrogen supply in plants [19, 22, 23, 21, 24]. It is necessary to mention, that starting with the first fertilization and until the last fertilization, higher SPAD reading values were established in N_{60} variant plants. Therefore, according to the data of chlorophyll content in hemp leaves we can forecast, that in N_{60} variant plants photosynthetic potential will be higher than in control and N_{100} variant plants, and that nitrogen fertilizer dose equal to 60 kg ha^{-1} is most efficient.

In addition to chlorophyll content different chlorophyll *a* fluorescence parameters were observed. PI (Performance Index) is considered to be one of the most valuable parameters that diversely describes common vitality of plant. Parameter combines several photosynthetic parameters such as the density of active reaction centers, efficiency of received energy transport in ETC and electron flux rate [25]. As nitrogen supply improves quantity of FSII reaction center and electron transport rate [7], but nitrogen deficiency decreases

photosynthetic chain reaction rate [6], PI parameter changes can characterize efficiency of nitrogen supply.
The highest performance index was established in N_{100} treatment plants (fig. 8.).

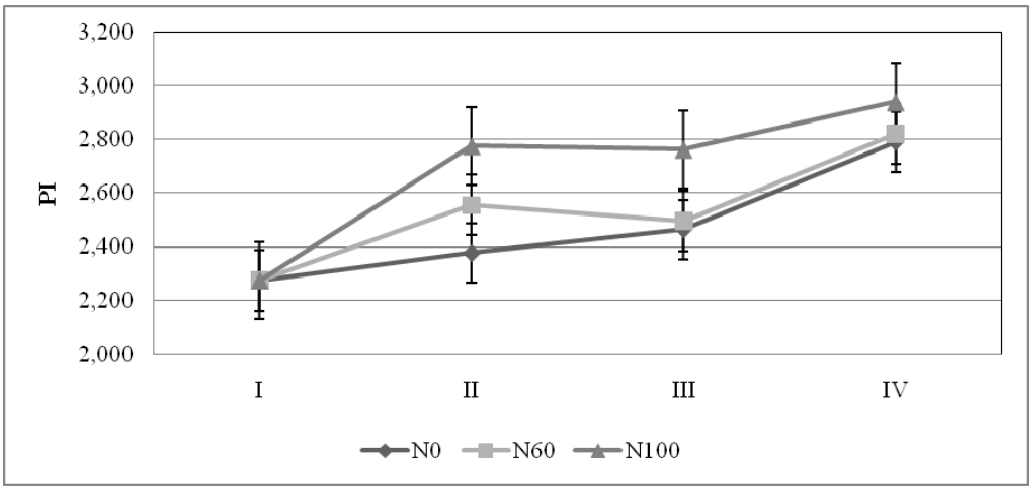

Fig. 8. **Chlorophyll a PI changes in hemp leaves under different nitrogen fertilizer supply, determined with Handy PEA**

During the whole investigation PI values in N_{100} exceeded PI values both in N_0 and N_{60} variants. But we must mention that statistically significant difference between PI ratios of N_{100} and N_0 was detected only when plants were changing from vegetative to flowering stage (II and III). We can conclude, that in spite of lack or presence of additional nitrogen fertilizer, performance index of hemp gradually increased during ontogenesis.
Nevertheless hemp plants showed higher vitality (performance index) under the highest additional nitrogen fertilizer supply, the analysis of the other photosynthetic parameters must be taken into consideration.
One of the rarely analyzed parameters is F_v/F_o – parameter that describes activity of FSII. Respectively, higher F_v/F_o values indicate more active FSII [26]. During the current investigation values of F_v/F_o parameter fluctuated (fig. 9.).

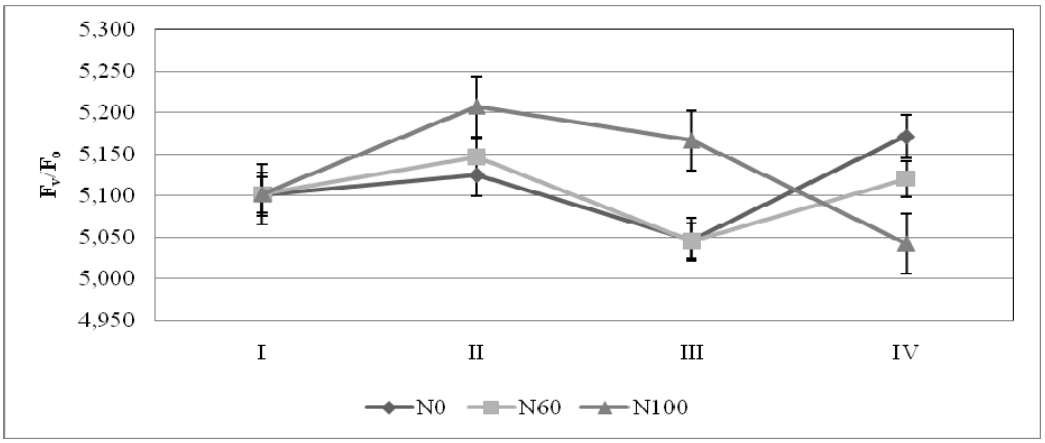

Fig. 9. **Chlorophyll a F_v/F_o changes in hemp leaves under different nitrogen fertilizer supply, determined with Handy PEA**

In the beginning of the experiment all variant plants showed an increase of FSII activity, and the highest value of F_v/F_o was detected in N_{100} plants. During the stage of generic organ development and in the beginning of flowering stage (II – III) in all variant plants decrease of

FSII activity was observed, however in N_{100} variant plants FSII was still most active. During the flowering phase (III – IV) a significant decrease of FSII activity in N_{100} variant plants was observed, in contrast to N_0 and N_{60} variant plants, where a rapid increase of FSII activity was observed. It can be explained with N_{100} plant reaction on final additional fertilizer, that probably negatively influenced plant photosynthetic apparatus. Changes of FSII activity in N_0 and N_{60} plants can be linked to the plant developmental changes.

F_v/F_m is the most frequently referred in literature chlorophyll *a* fluorescence parameter. F_v/F_m is considered to be "stress indicator" [27] and its changes can indicate a negative/positive impact of different fertilizer doses on plants. Hemp is C3 plant [28], and according to the literature data typical F_v/F_m parameter value for dark-adapted non-stressed C3 plants is 0,800 - 0,830 [29]. In experiments about hemp tolerance against cadmium impact F_v/F_m parameter values varied between 0,800 and 0,810 [30], other authors mention lower F_v/F_m parameter values - from 0,660 to 0,810 [31]. In the current investigation F_v/F_m parameter values substantially exceeded mentioned values (fig. 10.), and possibly these changes were caused by additional fertilizing with nitrogen.

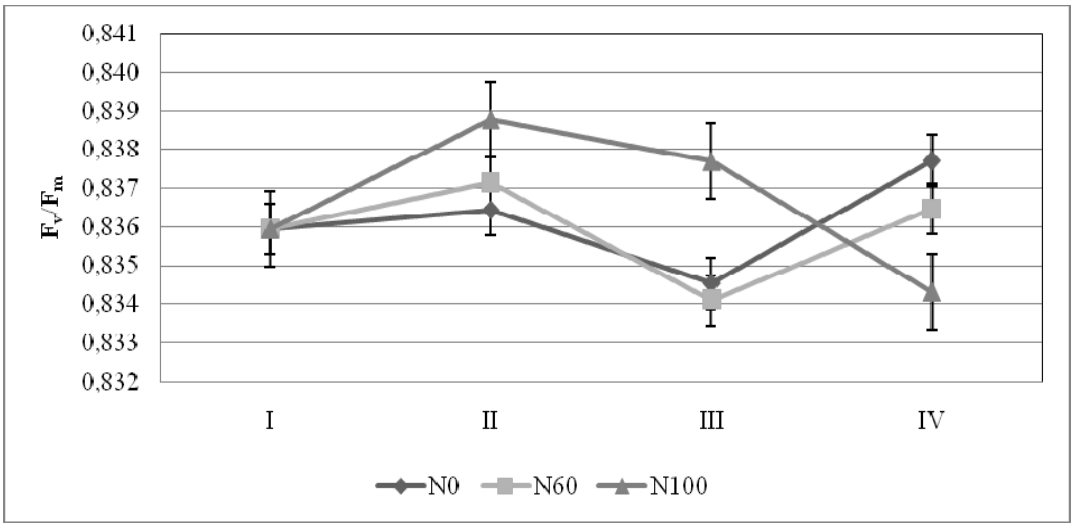

Fig. 10. **Chlorophyll a F_v/F_m changes in hemp leaves under different nitrogen fertilizer supply, determined with Handy PEA**

According to the literary sources, under disadvantaged environmental conditions that cause oxidative stress in plants, F_v/F_m value decrease is expected [31]. For example, nitrogen deficiency caused F_v/F_m parameter value decrease in spinach [32]. Previous investigations showed that F_v/F_m parameter values increased in plants, fertilized with nitrogen [33]. During our investigation F_v/F_m parameter value fluctuations were observed both in fertilized and non-fertilized plants. Initially, in all variant plants similar value fluctuations were established (I – III), with the highest parameter values in N_{100} variant plants. However final measurements (IV) showed that N_{100} variant plant F_v/F_m values continued to decrease, while N_0 and N_{60} variant plant F_v/F_m values increased. Between the control and N_{100} variant plant F_v/F_m parameter values statistically substantial differences persisted during the experiment.

There are references in literature that excessive nitrogen fertilizer supply can cause stress that resembles nitrogen deficiency features [7]. Therefore it is logical to assume that F_v/F_m value decrease in N_{100} variant plants in the beginning of current investigation, and increase in N_0 and N_{60} variant plants in the end of investigation (fig. 10) indicate improvement of the plant condition.

Conclusions

After the evaluation of the nitrogen fertilizer impact on photosynthesis and yield of hemp, we must deduce that recommendations in hemp fertilization developed in EU are not suitable for Latvian conditions. According to the results of the current investigation, several conclusions were made.

According to the chlorophyll content the most efficient additional nitrogen fertilizer dose for hemp cultivar of Latvian origin 'Pūriņi' is 60 kg ha^{-1}. Although the highest performance index was determined in N_{100} variant plants, evaluating of all chlorophyll *a* fluorescence parameters showed that physiological efficiency of N_{60} variant plants was higher.

In field conditions, seed yield of fertilized plants in average per 36,5 % exceeded control variant plant seed yield. In average, a significant difference between seed yield of N_{60} and N_{100} variants has not been observed. Nitrogen fertilizer negatively affected fiber content in hemp stems, therefore while cultivating hemp only for fiber production, usage of nitrogen fertilizer should be reduced. According to the seed mass results, additional nitrogen fertilizer doses should be applied following the climatic conditions. In the vegetation period guided with higher rainfall levels, 60 kg of additional nitrogen fertilizer per hectare can be considered as the optimal amount. In the current investigation hemp seed oil composition was not negatively affected by nitrogen fertilizer.

To avoid excessive nitrogen fertilizer usage, its negative impact on plant physiology and yield losses, we consider nitrogen fertilizer 60 kg ha^{-1} as additional fertilizer is optimal for hemp cultivar of Latvian origin 'Pūriņi'. Current hemp cultivar is potentially valuable and perspective hemp cultivar that in local conditions can produce both fiber and significant seed yield, containing oil with high nutritional and pharmaceutical value.

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Anotācija. *Pētījuma mērķis bija novērtēt slāpekļa mēslojuma ietekmi uz fotosintēzi un ražu sējas kaņepēm, pielietojot modernas nedestruktīvas analīzes metodes. Pētījuma objekts – Latvijas izcelsmes sējas kaņepes 'Pūriņi'. Laboratorijas un lauka izmēģinājumi parādīja atšķirīgu slāpekļa devu dažādo ietekmi uz daudzējādiem parametriem. Slāpekļa papildmēslojuma deva 60 kg ha^{-1} ir visefektīvākā, novērtējot pēc hlorofila satura kaņepju lapās, ka arī pēc hlorofila a fluorescences parametru izmaiņām. Šķiedras saturs augos slāpekļa mēslojuma ietekmē samazinās, tāpēc kaņepju audzēšanai tikai šķiedru ieguvei slāpekļa mēslojuma piegāde būtu jāsamazina. Attiecībā uz sēklu masu, papildmēslojums jāpiegādā, vadoties pēc klimatiskajiem apstākļiem. Veģetācijas periodā ar lielāku nokrišņu daudzumu slāpekļa papildmēslojuma deva 60 kg ha^{-1} uzskatama par optimālo. Slāpekļa mēslojums mūsu pētījumā kaņepju eļļas kompozīciju negatīvi neietekmēja. Būtiskās atšķirības starp sēklu ražu N_{60} un N_{100} variantiem nenovēroja. Lai izvairītos no pārmērīgas slāpekļa mēslojuma izmantošanas, to negatīvas ietekmes uz augu fizioloģiju un ražas zudumiem, mēs uzskatam ka optimāla slāpekļa papildmēslojuma deva sējas kaņepēm 'Pūriņi' būtu 60 kg ha^{-1}.*

Atslēgas vārdi: *Cannabis sativa L., slāpekļa mēslojums, hlorofila saturs, hlorofila a fluorescence, raža*.

VIII

ENVIRONMENTAL EDUCATION, BIOLOGY, CLIMATE

ESTIMATIONS IN DISTRIBUTION AND GROWING CHARACTERISTICS OF WILD HYPERICUM PERFORATUM L. (HYPERICACEAE) POPULATIONS DURING THE LAST DECADE IN ARMENIA

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Abstract. *The small mountainous country of Armenia has a rich flora of ca. 3600 species of vascular plants, which makes about half of entire Caucasian flora, distributed across desert and semi-desert, steppe, forest and alpine landscape. Anthropogenic threats to this biodiversity such as overpopulation, deforestation and urbanization have simultaneously hindered research and increased the need for it. Of the ca. 500 species in the Armenian flora with a record of medicinal and/or economic use, ca. 50 species are used in the folk medicine and include both wild-collected (Crataegus sp., Hypericum perforatum, Artemisia absinthium) and cultivated (Chamomilla recutita, Mentha piperita, Crocus sativus) species (1). Only limited information on the genetic biodiversity, population location, structure and size, and conservation status of most of these species is, however, at this time available. During 2007-2009, field studies were conducted to re-locate populations of wild Hypericum perforatum L. (common St. Johnswort, Hypericaceae) on the basis of historical (i.e. herbarium voucher, (2)) records, and to discover new populations. The plants habitat and phenological characteristics were estimated growing in different populations. GPS map of population distribution was created and its overall sizes were assessed. According to historical records this species had been widely distributed in the south regions of Armenia, however almost half of the populations no longer existed in the cited locations. However, 2 new populations were loacated in the south east regions. Evidence that the abundance and distributional range of H. perforatum is expanding in the north region was collected. This research provided baseline data that can be used for the development of further ex situ and in vitro strategies to conserve unique genotypes of this important medicinal and culinary species in Armenia.*

Introduction

The small mountainous country of Armenia has a rich flora of ca. 3600 species of vascular plants, which makes about half of entire Caucasian flora, distributed across desert and semi-desert, steppe, forest and alpine landscape. According to International Conservation Armenia is one of the 34 active areas of the earth in respect with being the most dangerous and having rich biodiversity. Anthropogenic threats to this biodiversity such as overpopulation, deforestation and urbanization have simultaneously hindered research and increased the need for it. Of the ca. 500 species in the Armenian flora with a record of medicinal and/or economic use, ca. 50 species are used in the folk medicine and include both wild-collected (*Crataegus* sp., *Hypericum perforatum, Artemisia absinthium*) and cultivated (*Chamomilla recutita, Mentha piperita, Crocus sativus*) species [1].Only limited information on the genetic biodiversity, population location, structure and size, and conservation status of most of these species is, however, at this time available. This sudies became more significant in order to have relevan data for assessing the risk impact on global climate change of these valuable wild medicinal plants population's conservation status.

Materials and methods

The genus Hypericum l. (St. John's wort) belong to Hypericaceae family. Includes at the most resent count 484 species that are either naturally occuring on, or which have been introduced to, every continent in the world except Antarctida. *Hypericum perforatum* (St. John's Wort;) is considered a noxious weed in many countries, but its medicinal use dates back to ancient Greece. It has a 2400 year history from ancient Greece. The name Hypericum is derived from Greek "hyper" meaning above and "eikon" meaning picture. This refers to a practice of

placing flowers above religious images to keep away evil. In modern medicine, standardized Hypericum extracts are commonly used for treatment of mild depression and anxiety disorders, and in some countries (e.g. Germany) more so than synthetic antidepressant medication.In Armenia it grows only in a wild form and more then 7 species of Hypericum known in Armenia. Records about its cultivation no found here. It grows wild from 600 to 1800 elevations in Aragats, Igevan, Kotayk, Stepanavan and other regions. During 2007-2009, field studies were conducted to re-locate populations of wild *Hypericum perforatum* L. on the basis of historical (i.e. herbarium voucher) records, and to discover new populations. The selection of researching territories has been realized by taking into account the existing data and theoretically possible existence of new population. These territories vary with their geographical location, elevation, soil types, climatic conditions etc.

The growth, phenological and habitat characteristics of the plants, and overall population size were assessed. GPS maps of present and past population distribution were created. During the growing seasons we have realized many field trips almost all regions of Armenia.

For accounting population density we have applied a systemantic sampling method, where population density and number of samples could be large(100<). Population density estimated according to traditional statistical methods, where population density (N) standard deviation (S.D.), and standard error (S.E.), which is the standard deviation of the sample mean.

$$SE = \frac{SD.}{\sqrt{N}} \qquad \text{or} \qquad S_{\bar{x}} = \frac{S_x}{\sqrt{N}}$$

Results and analysis

According to the result of conducted field trips and expeditions, it has been estimated changes in distribution and abundance of *H. perforatum L*. Populations. The following map, which is created according with experimental data has shown current population disrtibution and structure of this plant.

Distribution and Changes of Wild *Hypericum perforatum L*. Populations

(in regard with implemented field trips in 2007-2009)

Although historical records indicated that this species had been widely distributed in the northern and south regions of Armenia, nearly half of the populations no longer existed in the south region. However, one of the new populations as it is obvious from the map is distributed in the south region of Armenia. Others are located in North and Central regions. Evidence that the abundance and distributional range of *Hypericum Perforatum L* is expanding in North region was collected. It also, has trend to increase its distributional areas into central regions.

Some anthropogenic threats that were identified as part of the study included poor land management (erosion, overgrazing), increasing population pressure (impact of livestock overpopulation, improper human development), and excessive or inappropriate collection for the purposes of local sale/usage (due to lack of knowledge/training of collectors).

Realized different multiple observations over the populations have exposed phenological and habitat characteristics of the plants as well as assessed population size, its abundance and the number of ripen plants. The following table 1 shows certain data in respect with them.

Fig. 1.

♦ New population
● Population re-located from historical records
○ Historical population not re-located (presumed extinct)

Table 1.

Populations' Sizes, Abundance, Plant Highness, Grow intensity

(2007-2009 field trips)

Population		***Size, m^2***	***Location , m (above sea level)***	***Population Density, plant/$1m^2$***	***Plant highness, cm***	***Seedlings quantity/$1m^2$***
Region	***Place***					
Sjuniq	*Tjakaten*	400	1050	3	80-90	2
	Sisyan	207	2099	2	15-20	4
Vajoc Dzor	Jermuk	226	2103	1	70-80	1
Lori	*Stepanavan*	363	1400	4	65-70	3
	Margahovit	305	1761	2	65	4
Aragatsotn	*Aparan*	298	1885	3	25-30	2
Tavush	Idjevan	427	730	3	75-85	3
	Dilijan	449	1450	3	75-80	3
Gerarkunik	Drakhtic	170	1850	3	55-65	2

From 9 populations 4 are distributed in the Northen regions of the country and among them there is recorded a new Stepanavan population, 1400 m above sea level. According to table 1, the biggest populations with relatively high density are found in Northen part of the country (Idjevan, Dilijan, Margahovit) .

Although historical recors shows that *H. Perforatum L*. populations had been widely distributed in the south regions of Armenia, however almost half of the populations no longer existed in the cited locations (e.g. in 1956 it has been recorded a population in Herher area, which is no longer existed in the cited location). Antropogenetic threaths in south regions have more negative influence on the conservation status of this species by comparision in Northen regions. On the other hand, a new population is recorded at Tjakaten (South Region) a new highway area from Kapan, in the South Part of the country. Distributed at 1050 m above sea level this population is demonstrated intensive growing capacity. Plant highness is the highest one and density is also a relatively high. Population in Jermuk, is identified as the old one (seedlings number very the lowest recorded in this population). The area of this population tends to decrease as the population wildy collected this plant for remedies.

Conclusion and inference

This research provided baseline data that can be used for the development of further *ex situ* and *in vitro* strategies to conserve unique genotypes, as well as to assess the sustainability of wild populations with regard to the IUCN Red Book Criteria, of this important medicinal and culinary species in Armenia.

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CHANGES IN DISTRIBUTION AND STRUCTURE OF WILD *MELISSA OFFICINALIS* L. POPULATIONS DURING THE LAST DECADE IN ARMENIA AND IMPLICATIONS FOR CONSERVATION

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Abstract. *Armenia has a strong interest in examining the biodiversity of native plant species and assessing their conservation status. Anthropogenic threats to this biodiversity such as overpopulation, deforestation and urbanization have simultaneously hindered research and increased the need for it. Only limited information on the genetic biodiversity, population location, structure and size, and conservation status of most of these species is, however, at this time available. During 2006-2009, field studies were conducted to re-locate populations of wild Melissa officinalis L. on the basis of historical (i.e. herbarium voucher) records, and to discover new populations. The growth, phenological and habitat characteristics of the plant, and overall populations size were assessed. GPS map of present and past population distribution were created. This research provided baseline data that can be used for the development of further ex situ and in vitro strategies to conserve unique genotypes, as well as to assess the sustainability of wild populations with regard to the IUCN Red Book Criteria, of this important medicinal and culinary species in Armenia.*

Key words: *wild, medicinal plant, conservation, new population.*

Introduction

The small mountainous country of Armenia has a rich flora of ca. 3600 species of vascular plants, which makes about half of entire Caucasian flora, with both Caucasian and Iranian elements, distributed across desert and semi-desert, steppe, forest and alpine landscapes. As one of the first countries to join the Convention on Biological Diversity (CBD), Armenia has a strong interest in examining the biodiversity of native plant species, particularly those with potential or existing economic value (e.g. medicinal plants), and assessing their conservation status (1). Anthropogenic threats to this biodiversity such as overpopulation, deforestation and urbanization have simultaneously hindered research and increased the need for it. Of the ca. 500 species in the Armenian flora with a record of medicinal and/or economic use, ca. 50 species are used in the folk medicine and include both wild-collected (*Crataegus* sp., *Hypericum perforatum, Artemisia absinthium*) and cultivated (*Chamomilla recutita, Mentha piperita, Crocus sativus*) species (2). Only limited information on the genetic biodiversity, population location, structure and size, and conservation status of most of these species is, however, at this time available.

Materials and methods

Melissa officinalis L. belongs to Lamiaceae family. The wild form of plant is native to Northern Africa, Caucus, South western Asia, Europe, Persia and Mediterranean regions. In Armenia it grows only in a wild form. There are no records about its cultivation in Armenia. It grows wild from 600 to 1600 elevations in Aragats, Igevan, Zangezur and Mekhri floristic regions (3). I have been collaborated with "Environmental Conservation and Research Centre" of American University of Armenia and „Botanical Garden" of National Science Academy. During 2006-2009, field studies were conducted to re-locate populations of wild *Melissa officinalis* L. on the basis of historical (i.e. herbarium voucher) records, and to discover new populations. The selection of researching territories has been realized by taking into account the existing data (The Botanic Garden of RA) and theoretically possible

existence of new population. These territories vary with their geographical location, elevation, soil types, climatic conditions etc.

The growth, phenological and habitat characteristics of the plants, and overall population size were assessed. GPS maps of present and past population distribution were created. During the growing seasons we have realized many field trips almost all regions of Armeniaa. Our goal is to create vulnerable data about wild Melissa officinalis L., which in turn would provide as a basic material for its future domestication experiments in Armenia.

Results and Analysis

In the results of conducted field trips and expeditions, it has been identified the changes in respect with the distribution and abundance of Melissa officinalis L. Populations, as well as drew new pattern for it. So, the following map demonstrates this plant populations changes during last decade, as well as the current condition.

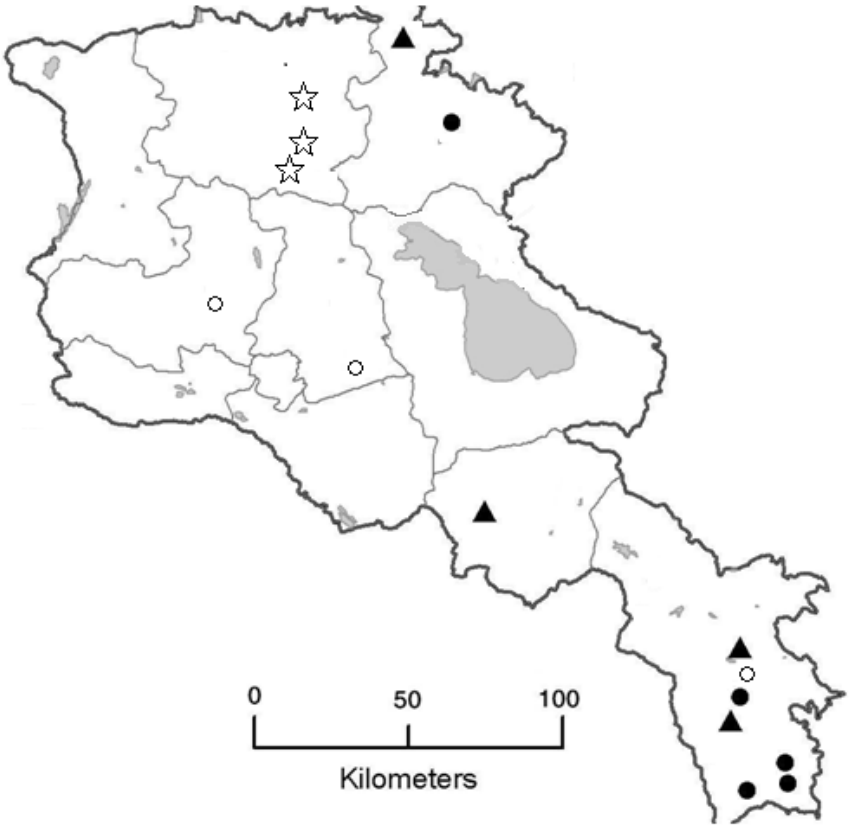

Fig.1. **Distribution and Changes of Wild *Melissa Officinalis L.* Populations**
(in regard with implemented field trips in 2006-2009)

- ● existing population
- ▲ new population
- ○ reducing or/and eliminating population
- ☆ extinct population

Even though, historical records indicated that this wild plant's populations had been widely distributed in the northern and central regions of Armenia, nearly half of the populations no longer existed in cited locations. Remaining populations in these regions displayed trends of reduction in overall size, during the study period. 3 new populations were located in the south regions and 1 new population in the northern region of the country, and evidence that the abundance and distributional range of *Melissa officinalis L.* is expanding in the southern region was collected.

Some anthropogenic threats that were identified as part of the study included poor land management (erosion, overgrazing), increasing population pressure (impact of livestock overpopulation, improper human development), and excessive or inappropriate collection for the purposes of local sale/usage (due to lack of knowledge/training of collectors).
Realized different multiple observations over the populations have exposed phenological and habitat characteristics of the plants as well as assessed population size, its abundance and the number of ripen plants. The following table shows certain data in respect with them.

Table 1.

Populations' Sizes, Abundance, Plant Highness, Grow intensity
(Estimations have been done according to the average data of 15 plants)

Population		***Size, m^2***	***Location, m (above sea level)***	***Density, plant/$1m^2$***	***Plant highness, cm***	***Stems quantity/plant***
Region	***Place***					
Aragatsotn	Orgov	95	1610	1	80	1-3
Kotayq	Garni	90	1310	1	70	1-3
Vajoc Dzor	Germuk	480	2104	5	145	2-5
Tavush	Getahovit	210	905	4	100	2-3
	Ajrum	165	375	2	95	1-3
Sjuniq	Artsvanic	250	1666	4	100	3-7
	Srashen	520	1025	6	150	3-7
	Shikahogh	280	957	3	65	2-5

So, if we draw analysis from table 1, populations, in the central part of the country (Aragatsotn, Kotayq), do not demonstrate intensive grow capability, they are small with their overall sizes, number of plants etc. In fact, the study shows that there are many factors, which affect negatively on the conservation of these populations (e. g. anthropogenic influence, climatic condition, plant habitat). What is more, the condition of these populations is now alarming in respect with frequently occurred early spring frost and the abrupt changes of weather in these areas. Study has shown that the seedlings of Melissa officinalis L. are very susceptible towards early spring frost, which prohibits their growing and affect negatively on the overall sizes, abundance of populations. By comparison, the populations growing in the northern part (Getahovit, Ajrum) have middle overall sizes. However, it is obvious that in the southern part of the country they are flourishing. Study has shown, that here the plant exhibits high grow capacity and there is recorded the increase of populations abundance and distributions. In fact, it is connected with soil, weather and climatic conditions. The following table shows certain data in respect with it.
So, we have found out certain habitat or biological characteristics of this wild plant by the comparison and analysis of data based on historical and study records. In fact, Melissa grows very well in moisture, temperate climatic condition (southern regions of the country). In case of relatively low annual precipitation it exhibits drought-resistant capability. Though, wild Melissa grows in various soils, however it demonstrates high grow capacity in reach, slight mechanical structure and acid pH bearing soils.

Table 2.

Soil Characteristic and Annual Precipitation

Population		***Genetic zone of soil***	***Annual precipitation mm***	***Soil pH***	***Humus concentration, %***
Region	***Place***				
Aragatsotn	Orgov	Steppe black	470-530	7	3-6
Kotayq	Garni	Dry steppe	430	6.9-8.1	2-4
Vajoc Dzor	Germuk	Mountain-meadow	900-1000	4.8-5.5	13-19
Tavush	Getahovit	Forest-gray	570-750	5-6	5-9
	Ajrum	Forest black soil	470	6-7	4
Sjuniq	Artsvanic	Steppe black soil	700-900	4.3-5.5	11-12
	Srashen	Steppe black soil	750-900	4.2-5	12-13
	Shikahogh	Steppe	450-500	5.1-6.2	5-8

Summary

Although historical records indicated that populations of wild Melissa officinalis L. had been widely distributed in the northern and central regions of Armenia, nearly half of the populations no longer existed in cited locations. Remaining populations in these regions displayed trends of reduction in overall size, plant number and fragmentation during the study period. 3 new populations were located in the south regions and 1 new population in the northern region of the country, and evidence that the abundance and distributional range of *Melissa officinalis L.* is expanding in the southern region was collected. Melissa is drought-resistant, but grows better in soils with enough moisture. It is susceptible towards early spring frosts and abrupt weather changes. Also, it demonstrates high grow capacity in the temperate climatic condition as well as in reach, slight mechanical structure and acid pH bearing soils.

This research provided baseline data that can be used for the development of further *ex situ* and *in vitro* strategies to conserve unique genotypes, as well as to assess the sustainability of wild populations with regard to the IUCN Red Book Criteria, of this important medicinal and culinary species in Armenia. Created data could be served as indispensable materials for the appropriate approaches of domestication experiments of wild Melissa. This would foster the improvement of its conservation and use and the development of traditional medicine as well.

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GEOGRAPHIC DISTRIBUTION OF PROTECTED SEDGE SPECIES *Carex Pilosa* Scop. IN LATVIA WITH REFERENCE TO FOREST ECOSYSTEMS

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Abstract. *The results of field studies, laboratory research and desk-based GIS geospatial analysis of ecological factors which determine geographic distribution of hairy sedge (Carex Pilosa Scop.) in Latvia with reference to forest ecosystems are presented in this article. Hitherto such a complex studying of chorology and ecology of this protected forest herb has not been performed before in Latvia, nor has it been attempted in the other Baltic states. The obtained results demonstrate that this protected plant species ecologically is quite plastic regarding its growing conditions and can be found in different forest ecosystems, however the most vital and largest cenopopulations of Carex pilosa are associated with the old deciduous forests, particularly those growing within erosion landforms on the slopes of the southern or south-eastern aspect. This research is important both from the scientific and practical view point, allowing to work out recommendations for the protection and conservation of this rare species in Latvia.*

Keywords: *Carex pilosa, chorology, ecological factors, forest ecosystems.*

Introduction

Hairy sedge *Carex pilosa* Scop. ranges in the temperate climate zone of Eurasia, and occurrence of this herb in the northern part of the continent in general corresponds to the biogeographic regions of oak distribution. Although hairy sedge is rather widespread in Central Europe, where in Oak-Hornbeam woods this species can form large, even square-kilometres stands within which any other herbaceous plants can grow [1, 2], in Latvia it is very rare, because the north-western edge of this plant growing areal crosses the south-eastern part of Latvia. This species of sedge belonging to the family *Cyperaceae* is included in the 1st category of the Red Data Book of Latvia [3], as well as in the list of protected plant species of Latvia [4]. According to Ellenberg [5], *Carex pilosa* is hemicryptophyte species of the thermophilic – close to partially thermophilic group, with moderate demands on nutrients. At a distance this forest herb looks similar to other sedges. However, with a closer look, this species can be distinguished easily from other common sedges by evergreen leaves, which are the best indicators of this species - in contradistinction to other Carex species growing in Latvia it has hairs alongside the central string and margin of the narrow leaf blade. This species is early flowering plant, which in Latvia usually flowers in the end of April – beginning of May. During flowering flower stalk usually carries one male inflorescence spike on the top and one or two female spike lower down; the female spike has more subtle white stigmas.

Carex pilosa for the first time was recorded in south-eastern part of Latvia in 1939 [6], within one of the gullies which dissect the right slope of the Daugava valley near the Juzefova village and for a long time had been regarded as rarity of Latvia flora. However, since 2002, when inventory of species of EU Habitat Directive (Annex I and II) [7] was performed in Latvia, six new records of this sedge were found in south-eastern part of country. In recent years complex research programme is undertaken at Daugavpils University to study chorology and ecology of this forest plant, and since 2008 authors found two more records [8]. Thus at the present moment 10 records of this protected plant species are documented in Latvia [8, 9]. Although documenting of all known *Carex pilosa* records in Latvia for botanical data bases and herbariums is completed, the extent to which ecological factors controlling the

distribution of this species and regularities of its chorology are currently studied is insufficient.

In order to get insight into these issues and to elucidate the regularities of geographic location of hairy sedge with reference to forest ecosystems, detailed studies of all records were performed *in situ*. The specific objectives of the study presented in this article were (1) to aggregate information stored in data bases about precise geographic location of *Carex pilosa* records in Latvia; (2) to carry out reconnaissance and survey of all cenopopulations of sedge by precise delineation and mapping of them by high-accuracy GPS; (3) to obtain data on the physiogeographic, ecological and habitat characteristics of all *Carex pilosa* populations during the field expeditions; (4) to perform laboratory analysis of soil samples from *Carex pilosa* records in order to estimate nutrient content and pH; (5) to process GPS survey data and to digitize GIS thematic layers with subsequent preparing of large-scale maps of hairy sedge records, including maps of digital elevation models and slope aspects; (6) to carry out complex mathematical and geospatial analyses of the obtained data by GIS tools in order to elucidate ecogeomorphological aspects and abiotic factors controlling spatial distribution of this perennial evergreen sedge in respect of landforms type, slope aspect and gradient, and forest habitat.

Hitherto such a complex studying of factors controlling geographic distribution of this protected forest herb has not been performed before in Latvia, nor has it been attempted in the other Baltic countries. Consequently, the obtained data contribute to a better understanding of the ecology of *Carex pilosa* in Northern Europe and enhance our knowledge about chorology of this species with reference to forest ecosystems.

Materials and methods

The results presented in the article are based on original data obtained in course of 33 expeditions and the research programme carried out in 2008 – 2010. Various methods and techniques were applied in order to achieve the objectives stated in Introduction of this article. In general, research was done in four main directions, i.e. aggregation and analysis of the data, field studies, laboratory research and desk-based studies by GIS tools.

Aggregating and analysing of the data about records of *Carex pilosa* in Latvia was carried out by searching through data bases of the Ministry of Environment of Latvia and Latvian Botanical Society, as well as by examination of herbariums of University of Latvia (LATV) and Daugavpils University (DAU). It allows to get precise geographic location of hairy sedge records within the study area for further field research.

Thereafter field studies of the identified *Carex pilosa* records were carried out including reconnaissance all cenopopulations, survey and precise delineation of them by THALES MobileMapperCE GPS (a maximum error up to several meters), description of tree and plant species composition of forest, soil sampling and identification of topographic characteristics of records (e.g. aspect of slope, its gradient and profile, type and morphometry of landforms etc). The last tasks were done with the help of standard geomorphological techniques [10, 11]. Slope profiles with location of *Carex pilosa* records on them were generated by AutoCAD 2008 LT software from the data collected during measurement of slope gradients along the sampling line. In turn these measurements were performed by precise oil damped AngleLevel clinometer (error ±0.5°) placed on the rod of 1 m length, hence reducing impact of microtopography. The description of tree and plant species composition recognized in records further was used to identify the type of forest habitats.

Field studies of the sedge *Carex pilosa* was performed in ten records situated in the south-eastern part of Latvia (Fig 1.). Three of these records are located in the Daugava spillway valley within the Nature Park “Daugavas Loki”, one in the river Lazdukalna valley (left tributary of the Daugava in the Nature Park “Daugavas Loki”), one in the river Puņiška valley

(right tributary of the Daugava in the Nature Park "Daugavas Loki"), another two in the Rubeņu brooklet and the Dubezers tunnel valley within the Nature Reserve "Pilskalnes Siguldiņa", large record consisting of many smaller patches located in the Nature Reserve "Raudas Meži", one on the Lakstīgalu island in the Nature Reserve "Zvirgzdenes ezera salas", and the last one near Dūdeļi village on the southern edge of the Latgale upland.

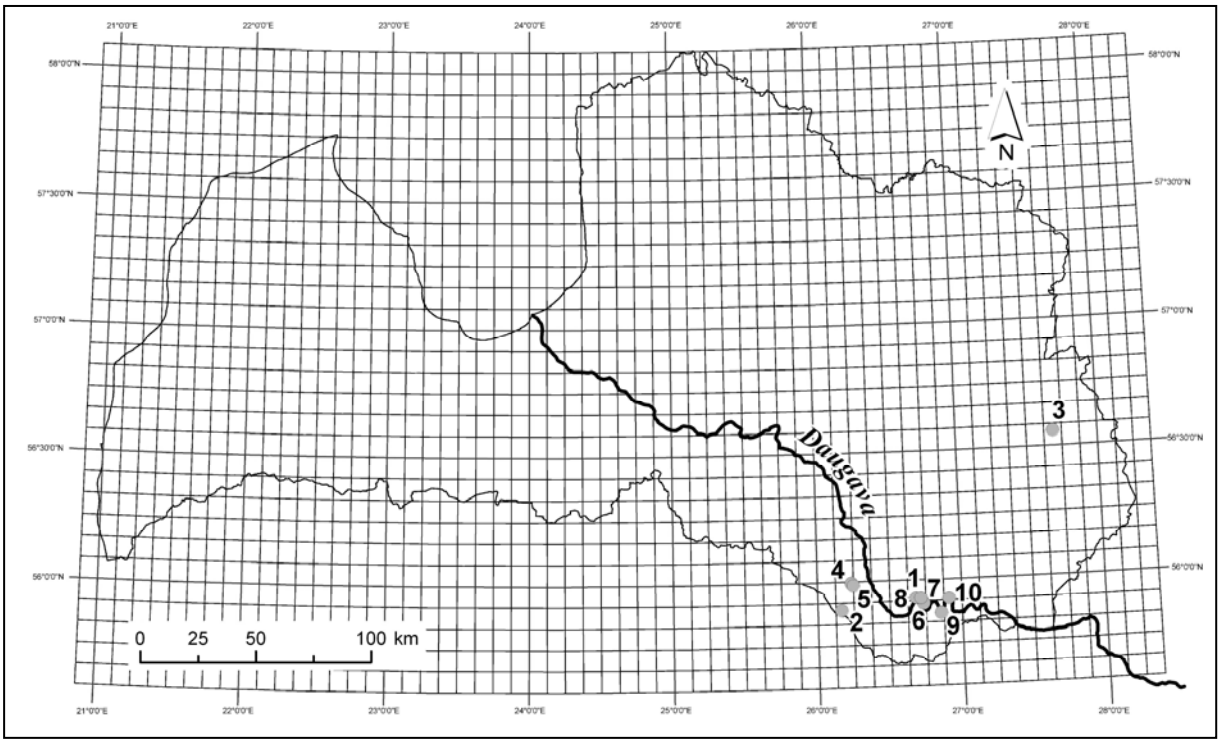

Fig 1. **Location of all records of the hairy sedge *Carex pilosa* Scop. in the south-eastern part of Latvia.**

Number of record in the map in chronological sequence of finding: 1 – the gully Baznīcas grāvis (the Nature Park "Daugavas loki"); 2 – the river Ilūkste valley (the Nature Reserve "Raudas Meži"); 3 – the Lakstīgalu island (the Nature Reserve "Zvirgzdenes ezera salas"); 4 – the Dubezers tunnel valley (the Nature Reserve "Pilskalnes Siguldiņa"); 5 – the Rubeņu brooklet (the Nature Reserve "Pilskalnes Siguldiņa"); 6 – the gully Peščanij ručej (the Nature Park "Daugavas loki"); 7 – the park Juzefova (the Nature Park "Daugavas loki"); 8 – village Dūdeļi (the edge of the Latgale upland); 9 – the river Lazdukalna valley (the Nature Park "Daugavas loki"); 10 – the river Puņiška valley (the Nature Park "Daugavas loki")

During field expeditions ten soil samples were taken from O-horizon of each *Carex pilosa* record. These samples subsequently were analysed according to standard methods (LVS ISO 10390:2006) in the Laboratory of Environmental Chemistry, Daugavpils University, in order to identify chemical parameters of soil, pH_{KCl} and pH_{H_2O} in particular.

Finally, mathematical and geospatial analyses of the obtained data were carried out by GIS tools. For these purposes as data processing platform was used ESRI ArcGIS software, which was applied for procedures of digitizing, for converting and integrating GPS data into GIS thematic layers, for creating digital elevation models and preparing of maps, as well as for calculation of topographic parameters and geospatial analysis of ecogeomorphological aspects and abiotic factors controlling spatial distribution of *Carex pilosa*.

Results and discussion

Obtained results, first of all, show direct interconnection between location of *Carex pilosa* records and landforms, in particular negative erosion forms. In fact the largest part, i.e. seven from ten known records of hairy sedge are located exactly within river valleys, gullies, tunnel valleys and spillway valleys. Secondly, data obtained during direct reconnaissance *in situ* and large scale analysis of information derived by overlaying of GIS thematic layers show, that large stands of this plant spatially is associated with forest ecosystems, i.e. forest habitats of different types (Table 1.).

Canopy vegetation in the records under study mainly is represented by broad-leaved or deciduous forests. The main stand-forming tree species in the Daugava spillway valley, the river Lazdukalna valley, the Lakstīgalu island and the Rubeņu brooklet study sites are wych elm (*Ulmus glabra* Huds.), linden (*Tilia cordata* Mill.) and oak (*Quercus robur*), hazel (*Corylus avellana* L.) occur only in undergrowth, whilst in the river Ilūkste valley record within the Nature Reserve "Raudas meži" and the Dubezers tunnel valley prevails aspen (*Populus tremula* L.) with admixture of ash (*Fraxinus excelsior* L.) and oak (*Quercus robur* L.). In such broad-leaved or deciduous forests during the sedge flowering and development in spring sunlight can penetrate through the open structure of the tree layer right to the ground where the xero-thermophilous *Carex pilosa*, which is dominating in the herb layer, can find acceptable conditions.

Considering such combination of abiotic geomorphological factors and composition of forest habitats, it is possible to assume that recognized geographic distribution of *Carex pilosa* had formed as result of human activities, when broad-leaved forests on nutrient-rich soils were cut off in order to establish fields of arable land. In this case remnant patches of broad leaved forest on the steep slopes unsuitable for soil cultivation and other agricultural needs became as a kind of refuge for hairy sedge. Partially this assumption was proved by the desk-based studies of historical topographic maps published in 1917, 1928, 1936 and 1972, and comparison of them with aerial photographs flown in 2005. Cartographic analysis of this information sources reveal the long-term presence of woodlands in majority of localities, where records of *Carex pilosa* had been found. However, to get better understanding about ecological factors controlling geographic distribution of this species, detailed analysis of topographic characteristics were performed by GIS.

The GIS analysis of digital elevation models of the study sites show that to a great extent distribution of the sedge is related to the sunniest and warmest forest habitats on southern, south-eastern and south-western slopes of river valleys and gullies in the region under study (Fig 2.). The influence of dryness and warmth can be well observed by comparing similar canopy vegetation with that of the slopes of north-, north-western- or north-eastern-spacing where *Carex pilosa* occurs sporadically and does not form large stands. Simultaneously it is necessary to highlight, that inclination of slopes within records, where the sedge was found, varies from 5° to 20°, however, in majority of sites it exceeds 15° (Table 1.).

In this case topographic features, i.e. aspect and gradient of slope determine the spatial distribution of *Carex pilosa* within landforms, because steeper slopes of S, SE or SW aspect receive more solar energy and thus warm up faster and to higher degree than gentler slopes of other exposure.

Laboratory analysis of soil samples demonstrates that soil type in records is mainly presented by luvisol, developed on stony and gravelly sandy loam of glacial origin (moraine). These relatively dry soils have pH_{KCl} and pH_{H_2O} values, which ranges from 5.36 to 7.58 and 5.83 to 8.0 respectively.

Table 1.

The characteristics of main records of hairy sedge in south-eastern part of Latvia

Geographical location of record	Location with reference to land form	The average slope (in record)	The dominant slope aspect	Habitat
The gully Baznīcas grāvis (The Nature Park "Daugavas loki")	Slope of the gully	23°	S; SE	Wych elm-oak rich broad-leaved forest
The gully Peščanij ručej (The Nature Park "Daugavas loki")	Slope of the gully	31°	SW	Mixed deciduous forest
The river Puņiška valley, record No 1 (The Nature Park "Daugavas loki")	The left slope of the river Puņiška valley	20°	S; SE	Grey alder forest
The river Lazdukalna valley (Daugava spillway valley)	Slope of the river valley	18°	SW	Wych elm-lime rich broad-leaved forest
The Rubeņu brooklet (The Nature Reserve "Pilskalnes Siguldiņa")	Slope of the gully	26°	SE	Mixed deciduous forest
The Dubezers tunnel valley (The Nature Reserve "Pilskalnes Siguldiņa")	Slope of the tunnel valley	16°	SW	Mixed deciduous forest
The river Ilūkste valley, patch No 1 (The Nature Reserve "Raudas Meži")	The right slope of the Ilūkste valley	12°	SW	Aspen rich deciduous forest
The river Ilūkste valley, patch No 2 (The Nature Reserve "Raudas Meži")	The right slope of the Ilūkste valley	15°	SW	Aspen rich deciduous forest
The river Ilūkste valley, patch No 5 (The Nature Reserve "Raudas Meži")	The slope of the gully within Ilūkste valley	21°	S; SE	Mixed deciduous forest
The river Puņiška valley, record No 2 (The Nature Park "Daugavas loki")	The right slope of the river Puņiška valley	5°	SW	Grey alder forest
The Lakstīgalu island (The Nature Reserve "Zvirgzdenes ezera salas")	The middle part of the SE slope of the island	4°	SE	Lime rich broad-leaved forest

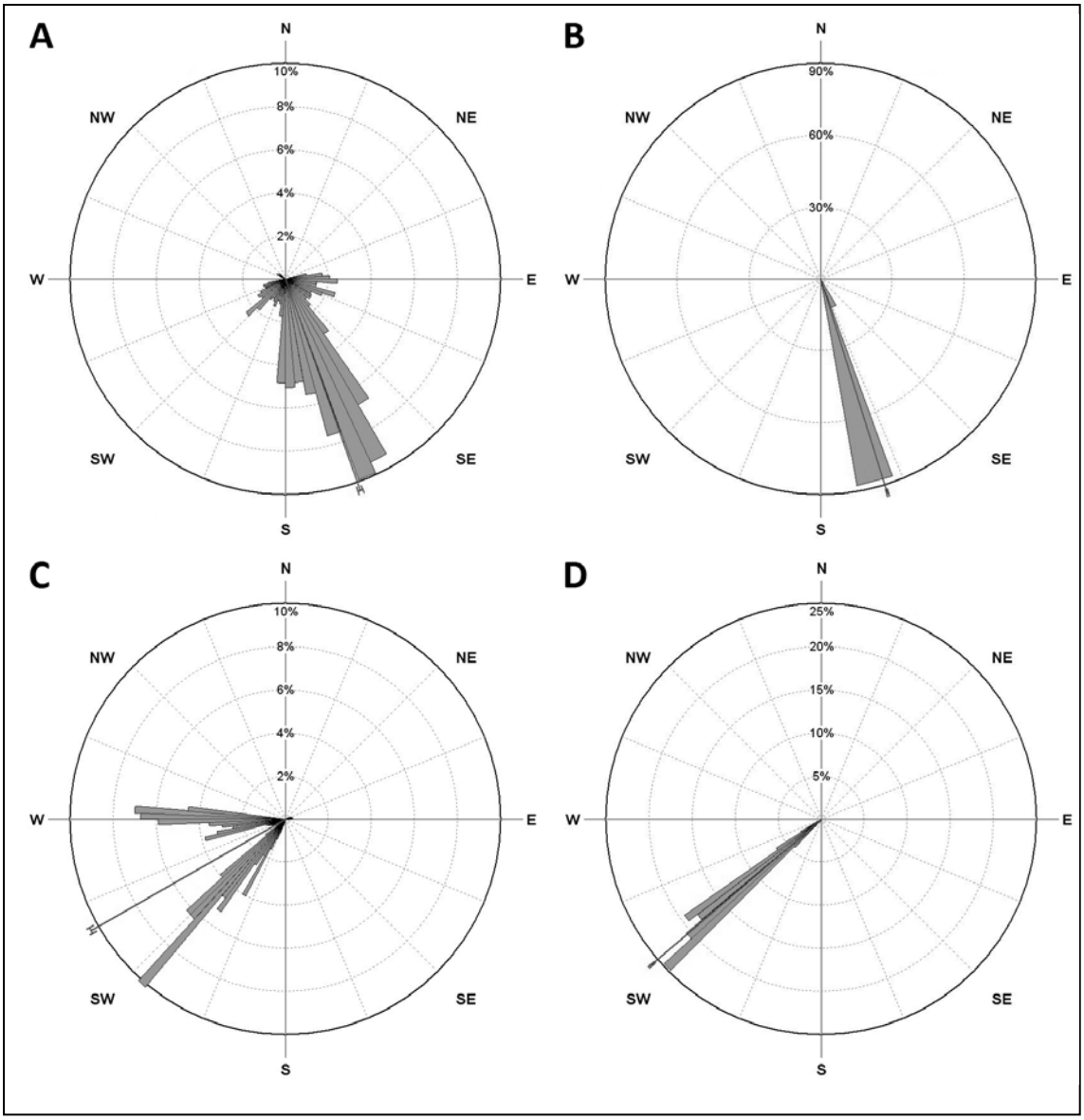

Fig 1. **Rose diagrams of hairy sedge *Carex pilosa* relative distribution (in percents from total area of record) on the slopes of different aspect within selected records:**
A – the gully Baznīcas grāvis (the Nature Park "Daugavas loki"); B – the Rubeņu brooklet (the Nature Reserve "Pilskalnes Siguldiņa"); C – the river Lazdukalna valley (the Nature Park "Daugavas loki"); D – the Dubezers tunnel valley (the Nature Reserve "Pilskalnes Siguldiņa")

Conclusions

The results of the given research permit to draw several important conclusions about the factors controlling geographic distribution of *Carex pilosa* with reference to forest ecosystems in south-eastern Latvia.

1. Alongside topography and soil type, forest habitat of the record is the principal one that affects spatial distribution of *Carex pilosa*, because the ecology of this species determine the presence of forest ecosystem as prerequisite for its favourable growing, in contrary the decreasing of *Carex pilosa* cenopopulations was observed in places, where former woodlands had been transformed into clearings after forest cut-off.
2. The spatial distribution of *Carex pilosa* can be explained as result of interaction of indirect and direct controlling factors. On the one hand, growing of the sedge within erosion forms is a result of preservation of forest habitats due to steep slopes. On the

other hand, development of erosion landforms within landscape causes formation of environment favourable for existence of *Carex pilosa* due to slope aspect, slope gradient, soil properties and amount of solar radiation. Hence results highlight the positive role of geomorphological factors in formation of different habitats and increasing of biodiversity.

3. *Carex pilosa* is growing mainly on the steeper sunlit slopes of south, south-eastern or south-western aspect under broad leaved or deciduous vegetation where solar radiation can reach the ground through the tree layer.
4. The hairy sedge grows in relatively dry places with soil pH values near to neutral, or slightly alkaline or acid, where in spring, before formation of leaves, soil surface are warmed up by direct sunlight.
5. Further findings of this species can be expected in similar habitats in neighbouring areas of Latvia and Lithuania, particularly in V-shaped deep river valleys and gullies within uplands of Baltic morainic ridge, e.g. the Augšzeme Upland and the Aukštaitijos Upland.

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Anotācija. *Rakstā ir izklāstīti lauka, laboratorisko un kamerālo pētījumu un GIS ģeotelpiskās analīzes rezultāti par ekoloģiskajiem faktoriem, kuri nosaka augu sugas - matainā grīšļa (Carex pilosa Scop.) ģeogrāfisko izvietojumu Latvijā saistībā ar meža ekosistēmām. Līdz šim padziļināti kompleksa rakstura šīs aizsargājamās augu sugas horoloģijas un ekoloģijas pētījumi nedz Latvijā, nedz citās Baltijas valstīs nav veikti. Iegūtie rezultāti parāda, ka suga ekoloģiski ir diezgan plastiska augšanas apstākļu ziņā un ir sastopama dažāda tipa mežu ekosistēmās, tomēr vitālākās un lielākās matainā grīšļa audzes ir saistītas ar veciem platlapju mežiem, it sevišķi tiem, kas aug erozijas reljefa formās uz dienvidu-dienvidaustrumu ekspozīcijas nogāzēm. Veiktie pētījumi ir nozīmīgi gan no zinātniskā, gan no praktiskā viedokļa, jo ļauj izstrādāt ieteikumus šīs retās sugas saglabāšanai un aizsardzībai Latvijā.*

EDUCATION OF COMPETENCIES OF ORGANIC PRODUCTION: POSSIBILITIES AND PROBLEMS

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Abstract. *Organic farming must seek profitability, social goals and ecological balance. Not only farmers and processors but also consumers are responsible for this, subsequently, education of every segment is very important. In order to modernize technologies of organic farming it is necessary to have qualified and experienced employees for industrial areas as well as for organisation of environmental protection.*
The article is trying to assess development of organic farming and to evaluate education of specialists of organic production in Lithuania. Therefore, there are analysed the results of certification of farms, carried out by the public organisation "Ekoagros", and a particular interest is paid to educational establishments which educate specialists of organic production. The article also analyses development of organic farms in Lithuania, presents basic problems and examines possibilities to educate specialists of organic agricultural production.

Keywords: *ecology, certification, education, organic products.*

Introduction

The European Union's common agricultural policy is more and more aimed at organic farming. It is so, mainly, because this particular farming enables to preserve nature and gives social and economic benefit.

Organic farming (ecological, biological, and bioorganic) is agricultural system based on the set of ecological, social and economic concepts which ensure constant manufacturing of high quality products. What is more, this system sustains natural balance and uses natural resources sustainably. This is the highest form of environmentally friendly farming [2].

Organic farming ensures implementation of basic principles of harmonious development. Firstly, ecological: reduction of pollution created by organic farming, preservation of biological diversity, cultivation of safe food and raw materials. Secondly, economic: usage of local recourses, reduction of energy expenditures and more favourable solutions of economic problems that are faced by farms. Then, social: increase of workplaces in rural areas. Finally, cultural: development of a farmer's spiritual culture and nurturance of Lithuanian ethno culture [3].

Interest in organic farming is determined not only by consumers' interest in food safety but also concern about quality of environment and constant and balanced development of farming. Application of EU and national support for organic production farms induces this way of production in Lithuania. In 1997 the Ministry of Agriculture alongside with the Ministry of Health established public enterprise "Ekoagros" and appointed it to carry out inspection and certification of organic production under the regulations for organic farming. Control and certification of organic production is carried out in accordance with European Union Council Regulation (EC) No. 834/2007, Regulation (EC) No.889/2008 and rules for organic farming. Since 2008 "Ekoagros" has a permission to certify agricultural and food products of exceptional quality, according to the rules of recognition of agricultural and food products of exceptional quality, which were approved on 29 November in 2007 by the Minister's of Agriculture of the Republic of Lithuania order No. 3D-524. Since 2005 certification establishment has been accredited by National Accreditation Bureau of Ministry of Environment of the Republic of Lithuania. In January 18 in 2007 the Bureau gave public enterprise "Ekoagros" accreditation to certify, according to the requirements of BS EN

45011:2000 standard, processes of organic production: processes of production of organic plant-growing, husbandry, apiculture, wild vegetation and fishery as well as food of non-animal and animal origin [5].
In order to modernize technologies of organic farming it is necessary to have qualified and experienced employees not only for administration of environmental protection but also for industrial areas [1]. In Lithuania knowledge of environmental protection is provided to all target groups: for students of universities, pupils of agricultural schools as well as of general secondary schools, listeners of special courses, farmers and teachers (lectures).
Aim: to analyse and to support theoretically possibilities and problems of the education of specialists of organic production in Lithuania.
Research methodology: system and comparative analysis of scientific literature, comparative analysis of statistic data.

Results

The beginning of organic farming in Lithuania dates back to 1993. In that particular year there were certified 9 farms of organic production (148 ha of soil being used). Lithuanian government began to support organic farming only in 1997, when the fund "Tatula" was established. In 2009 certification establishment "Ekoagros" received 2732 requests to certify organic production. 166 requests were submitted by new applicants. Over 100 farms have been certified in the districts of Biržai, Ukmergė, Raseiniai, Šalčininkai, Trakai, Telšiai and Varėna (Figures 1 and 2).

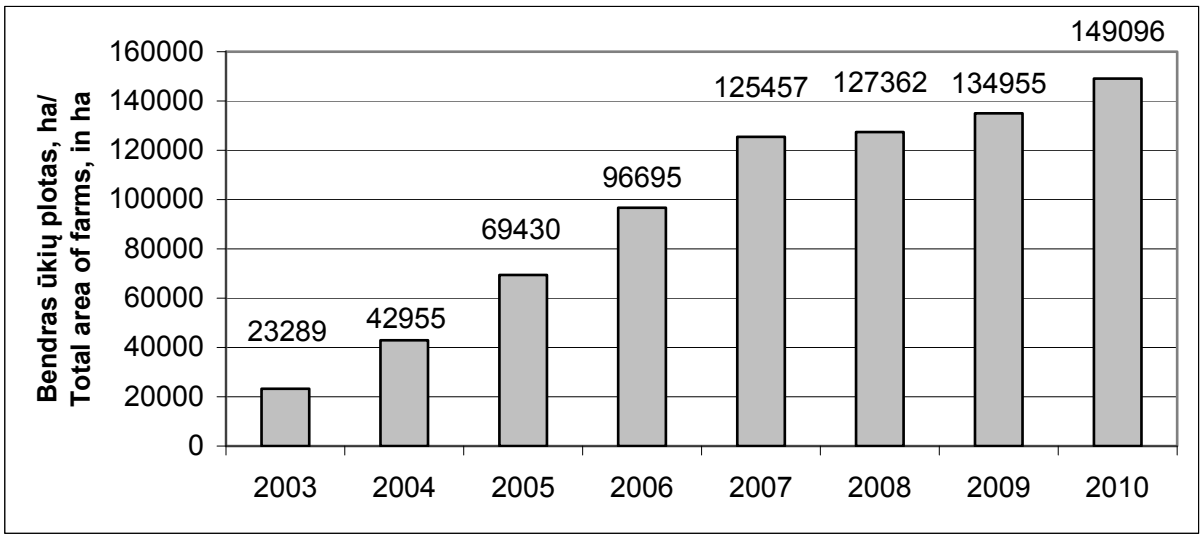

Fig. 1. **Area of organic farms certified in Lithuania between the years 2003-2010 [5]**

A particular growth of certified organic farms can be seen in the years 2007 (2956) and 2009 (2679). In the receant two years the number of organic farms remained stable, however, there can be traced an increase of 23639 ha in the area of farms (from 125457 ha in 2007 up to 149096 ha in 2010), this is, mainly, due to the fact, that a number of large farms decided to start organic production. Nowadays an avarage organic farm embodies about 41 ha and is, actually, larger than a typical country farmer's farm. In 2009 there were certified 35 farms of apiculture and 20 collectors of wild vegetation bring to the market 400 names of organic, certified products of wild plants (Table 1).

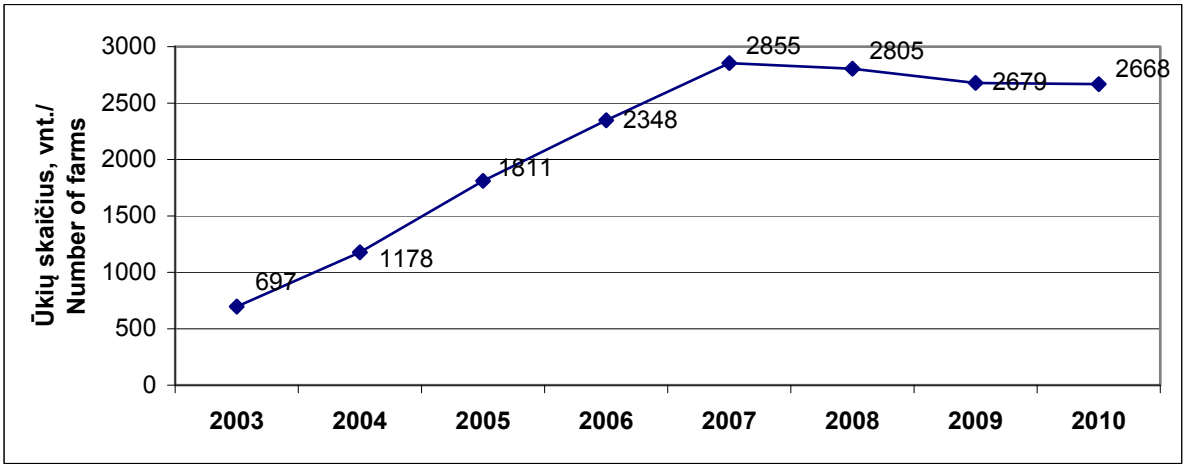

Fig. 2. **Number of organic farms certified in Lithuania between the years 2003-2010 [5]**

Table 1.

Structure of area of certified crops in Lithuania in 2010 [5]

Certified areas	Part, percent
Cereals	45.72%
Perennial grasses	20.98%
Legume crops	12.64%
Grass legume crop mixture	6.19%
Herbs, aromatic spice plants	5.01%
Stocked ponds	3.67%
Berries	2.68%
Fallows (black and manure)	1.58%
Gardens	0.96%
Vegetables (including fodder beet)	0.32%
Crops not meeting required density	0.25%

Structure of crops consists of approximately 45.72% of cereals and 12.64% of legume crops. In organic husbandry there are grown just 275 pigs and 1500 birds.

In 2007 720 husbandry farms were certified. The number of old breeds of farm animals and birds was about 4391. In 2009 there were 817 organic husbandry farms registered in Lithuania. If compared to 2006 the number has increased by 13.5%.

There are more and more large organic husbandry farms. Expansion of certified areas influences augmentation in the growth of organic production. Because of the increase of raw material and society's interest in organic products, involvement of processors have also become bigger. More and more enterprises are becoming interested in the possibilities to process organic products. As the number of growers of organic products is increasing there, naturally, appear more and more food processing enterprises which are able and willing to process or handle organic products in any other way. A demand for organic products is constantly growing in Lithuania.

Because of the increase of raw material and society's interest in organic products, involvement of processors have also become bigger. More and more enterprises are becoming interested in the possibilities to process organic products. In 2009 there were certified 59 farm units processing organic products, which were involved in processing of herbs, milk, meat and corns, production of forages and transportation of organic products as well as engaged in trade activities. In 2010 71 farm units were certified.

In the project of Lithuanian Rural Development Programme for 2007-2013 it is presumed that in 2013 the number of organic farms should reach 6000 units and the area of organic farms should expand up to 240000 ha. It is supposed that in the coming years it should make up to 10 - 15% of all agricultural farms of our country.

As the development of organic agricultural and food production increases and there is a need to solve the problems that may arise because of this, there is a growing demand for specialists of organic production. In Lithuania it is possible to acquire ecological knowledge:

- while studying at colleges and universities;
- studying at the institutions of vocational training and acquiring qualification of employee of an organic farm;
- after fulfilment of educational programme on the fundamentals of organic farming.

These days it is essential to presuppose the demand of the specialists based on the changes in the labour market. Specialists' competitive competencies must be achieved through active cooperation with employers, renewal of training base and development of educational programmes.

In Lithuania there are 7 educational institutions training specialists of organic production (Table 2).

Table 2.

Educational institutions training specialists of organic production

(Jurkšaitienė, Markevičienė, 2010)

No.	Educational institution	Educational programme or field
1.	Lithuanian University of Agriculture	Bachelor in Agroecology and environmental protection Master in Agroecosystems
2.	Kaunas University of Applied Sciences	Organic production
3.	Marijampole College	Organic agriculture
4.	Utena College	Agroecology: Organization and development of organic farm, preparation and realization of organic products, waste management
5.	Vilnius University of Applied Sciences	Management of agribusiness (field: trade of organic products)
6.	Alanta School of Technology and Business	Worker of an organic farm
7.	Joniškis Agricultural School	Worker of an organic farm

Specialists of organic production are trained at 4 colleges, 2 vocational schools and at Lithuanian University of Agriculture. In the Department of Plantations and Agrotechnologies in the Faculty of Landscaping at Kaunas University of Applied Sciences there is implementation of educational programme of technologies of agribusiness, with specialization in organic production.

Educational activities are carried out by the Chamber of Agriculture of the Republic of Lithuania and the Ministry of Agriculture of the Republic of Lithuania: informal farmers' trainings, projects, seminars and courses. According to the long term strategy of Lithuanian Agricultural Development till 2015 as well as to the data of 2010 presented by Associated Chambers of Trade, Industry and Handicrafts of Lithuania, Lithuanian Free Market Institute and National Farmers' Union, in the future there will be a great demand for specialists of organic farm.

While examining geographical position of the educational institutions training specialists of organic production, it became vivid that all those educational institutions are in the districts where the number of organic farms is the biggest (Figure 3).

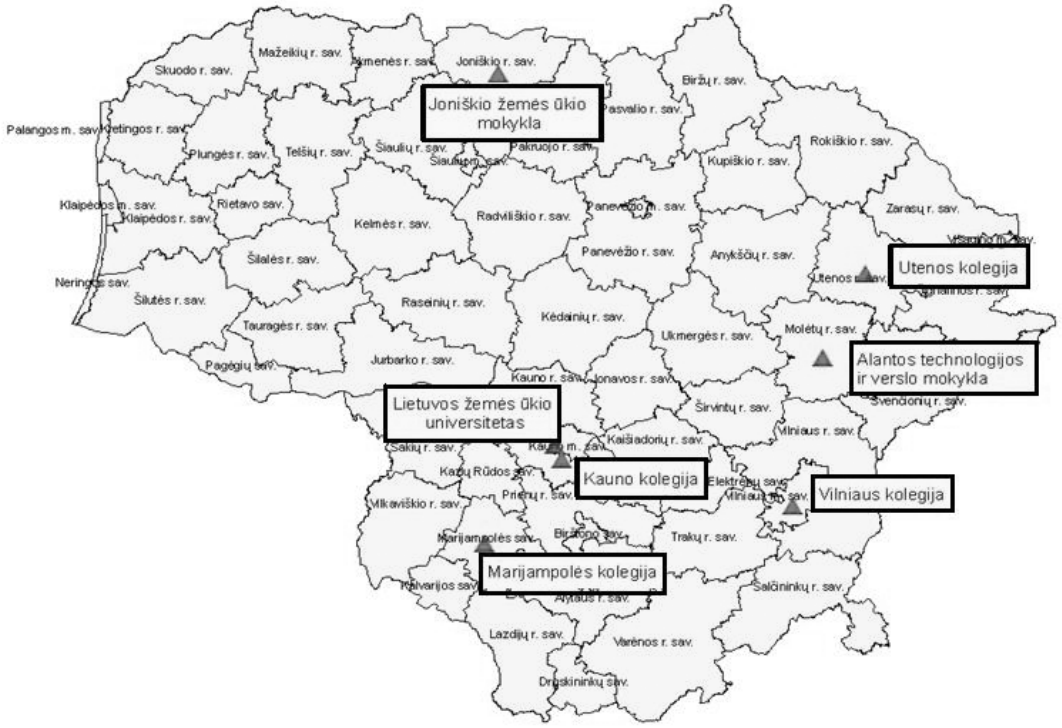

Fig. 3. **Places in Lithuania where specialists of organic production are trained**
(Jurkšaitienė, Markevičienė, Sikorskytė, 2010)

The Chamber of Agriculture of the Republic of Lithuania, which is situated in Kaunas, with the help of their representatives in all the municipalities, provide a possibility to participate in informal professional farmers' training as indicated in the project "Farmers' informal vocational education under technological programmes" and to attend 24-hours courses of basics of organic farming.

The European Union's common agricultural policy is more and more aimed at organic farming which brings environmental, social and economic benefit. However, there are lots of problems in farms of organic production and it does not look like they are going to disappear:

- uncompleted agricultural reform;
- farmers having organic farms have no right of seniority while leasing state land;
- no law about processing of organic products on a farm is prepared;
- instances of farms that do not follow principles of organic farming;
- growing of seeds of plants appropriate for organic farming is not organized and developed;
- insufficient supply of organic fertilizers, plants security facilities and equipment;
- no sampler organic farm has been established;
- very weak farmers' cooperation;
- promotion of usage of organic products is not good enough;
- sufficient and constant provision of organic products to supermarkets is not ensured;
- there would be a possibility to create more workplaces in rural areas, to expand areas of vegetables, gardens and berries and to increase consumption of such products, unfortunately, these opportunities are not employed.

Conclusions

Issue of environmental protection is very vital these days. Importance and influence of organic farming to the development of society is often perceived through the prism of principles of cohesive development. Subsequently, it is vivid that way of organic production creates circumstances suitable to solve economic and social problems as well as those related to protection of environment. In Lithuania organic farming began in 1993. In the period of 20 years there has been acquired some practice and system of certification created. Output of production of organic farms is constantly growing in Lithuania: approximately 60% a year. Just 9 organic farms were certified in 1993, whereas in 2009 there were received 2732 requests to certify production. In the project of Lithuanian Rural Development Programme for 2007-2013 it is presumed that in 2013 the number of organic farms should reach 6000 units and the area of organic farms should expand up to 240000 ha. It is supposed that in the coming years it should make up to 10 - 15% of all agricultural farms of our country.

In order to accelerate development of organic production in Lithuania, the Ministry of Agriculture support farmers' training, education, scientific researches and improve certification system.

Development of organic farming is influenced by a range of various problems. It should be mentioned that young specialists, farmers and inhabitants of rural areas have little motivation to participate in trainings. There are a lot of institutions that propose educational courses in the same places and on similar topics. What is more, participants of the courses have very different level of education; their understanding of technological, economic and legal agricultural issues also diverges.

Summary

Nowadays competitive economics demands new ideas, modern technology, and constant development of professional competences and, of course, a mature and universal personality. High professional requirements in the labour market entail new methods of development and education of a specialist.

Organic farming differs from other ways of farming as farms of organic production must obey strict rules for organic farming, and products of such farms must have certificate of their origin. Actually, a huge demand in the market was determined by certification and labelling of organic products. Only certified farms and enterprises can trade products which are labelled with a sign of organic products. In Lithuania certification of organic farms is carried out by the public enterprise "Ekoagros".

In Lithuania specialists of organic production are trained in 7 educational establishments. Their geographical position is optimal and they all are in the districts having the biggest number of organic farms.

It is possible to acquire knowledge in organic farming while participating in various courses, trainings, seminars and projects that are organised by the Ministry of Agriculture of the Republic of Lithuania and the Chamber of Agriculture of the Republic of Lithuania.

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ANALYSIS OF PLANTS INCLUDED INTO LITHUANIAN RED BOOK

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Abstract. *55 plant species included into the Lithuanian red book were chosen and analyzed. The analysis revealed that the plants of a medium height (20 species) dominate. The flowers of 17 plant species are violet, and 48 species have green leaves. After analyzing bio ecological properties of rare plants it is possible to say heliouphilous plants dominate (37 species), majority of plants flower from the beginning of June until the end of August (50 species).*
25 rare plants under research are allocated to category 2 (V) and are considered to be quickly extinct, endangered species, the population number of which and the number of individual plants decrease rapidly. The main reasons of the plant disappearance are the overgrowing of habitats by trees and bushes (58,18 %), irrigation and drainage (36,36 %) as well as intensive farming (29,09 %). The research identified that the main protective measures of rare plants are the support of the traditional farming, the limitation of hay harvesting and grazing, the maintenance of water hydro chemical , hydrological and hydrographic regime, etc.

Keywords: *biological diversity, tax, anthropogenic activity, protection of rare plants, ecology, Lithuanian Red book.*

Introduction

Lithuanian biological diversity includes about 30 thous. species of plants, mushrooms and animals. Over 2000 vascular plant species, the habitats of which are in the forests, fields, meadows, bogs, sandy places, live in the natural environment [7]. Three Red books have been published in Lithuania; they are the legal document, on the basis of which the protection of rare and disappearing plants is organized in the country. 30 endangered plant species were included in the first Red book in 1981 [2]. In 1992 the second Red book was published in Lithuania which included 210 plant species [3]. The third edition of the Red book included 339 endangered plant species in the year 2007 [4].
The year 2010 was the year of biological diversity, and encouraged everyone to take interest in plants included into the newest edition of Lithuanian Red book. First of all it is essential to get to know rare endangered plants because it determines their protection as the life of every specie is influenced by natural factors and nowadays anthropogenic activity in particular.
The third Red book includes descriptions of 3 Club mosses, 1 Horsetail, 8 Ferns, 1 Conifer, 221 Flowering plants, 1 Red algae, 1 Brown algae, 10 Charophytes, 93 Mosses. The plant species in Lithuanian Red book are divided into five categories according to the level of extinction (0 (Ex), 1 (E), 2 (V), 3 (R), 4 (I), 5 (Rs)). Endangered plants are divided the following way: 14 into zero, 79 into first, 84 into second, 99 into third, 53 into fourth and 10 into fifth category. [4]. In the book plant species are described by analyzing their status (when the specie was included into the Red book for the first time), spread (taxon areal), biology and ecology (morphological properties and bio ecology), amplitude of populations (quantitative and qualitative indicators of the country population), threats and protection (the reasons for specie population state degradation and protection measures), map (spread of taxons represented using dot method) [4].
Today because of rapid decline in biological diversity the scientific aim to describe the present biodiversity before it finally disappeared is set. It is also important to provide conditions for the biodiversity survival. For the protection of biological diversity and sustainable resource management the convention of biological diversity was signed in Rio de

Janeiro, Brazil, 1992. Every country should prepare national strategy for the preservation of biological diversity, integrated into the political tendencies of appropriate sectors. Special attention should be given to the preservation of biological diversity under natural conditions. For this purpose the system of protected territories has been created. Lithuania has also established the system of protected territories which allows to preserve biological diversity; they are reserves - 6, reserve parks – 254, national parks – 5, regional parks – 30 [1].
The main goal of EU environmental protection policy is the protection of natural habitats and wild plants. There are 15 plant species in Lithuania included into the second annex of EU habitation directives [5].
The aim: To get to know rare and endangered Lithuanian plants and to identify their extinction reasons and methods of their protection.

Materials and methods

55 plant species included into the Lithuanian Red book (2007) were chosen and analyzed using J. Vaidelys (2005) methodology presented in the publication „Methodology of phonological observations, biometric measurements and assortment formation of ornamental herbaceous plants“ [6] and the information from the publication „Lithuanian Red book“, according to the following aspects:

1. assessment of morphological and bio ecological characteristics;
2. distribution of plant species according to categories;
3. identification of plant extinction causes;
4. identification of plant protection methods.

Results

Table 1 contains the data of morphological characteristics of rare.

Table 1.

Evaluation of morphological peculiarities of plants from Red Book of Lithuania

No	Plant name	Plant height, cm	Leaf color	Blossom color
1.	*Nymphaea alba* L.	70-80	green	white
2.	*Nuphar pumium* (Timm) DC.	70-80	green	yellow
3.	*Pulsatilla patens* (L.) Mill.	35	green	violet
4.	*Corydalis cava* (L.) Schweigg. Et Korte	20-30	green	violet
5.	*Agrostemma githago* L.	50-100	grey	red
6.	*Dianthus arenarius* L.	50-100	green	yellow
7.	*Dianthus borbasii* Vandas.	30-50	green	red
8.	*Dianthus superbus* L.	30-60	green	red
9.	*Primula farinose* L.	10-20	green	violet
10.	*Viola uliginosa* Besser.	7-20	green	blue
11.	*Alyssum gmelinii* Jord.	10-20	green	yellow
12.	*Trifolium rubens* L.	20-80	green	violet
13.	*Lathyrus laevigatus* (Waldst. Et Kit.) Gren.	20-60	green	yellow, red
14.	*Astrantia major* L.	50-80	green	yellow
15.	*Eryngium maritimum* L.	20-60	grey	yellow
16.	*Scabiosa columbaria* L.	40-80	green	violet
17.	*Succisella inflexa* (Kluk) Beck.	50	green	violet
18.	*Centaurium littorale* (Turner ex Sm.) Gilmour	3-15	green	red
19.	*Gentiana pneumonanthe* L.	25-60	green	blue
20.	*Gentianella amarella* (L.) Borner	15-40	green, brown	blue
21.	*Nymphoides peltata* (S. G. Gimel.) Kuntze	200	variegated	blue
22.	*Polemonium caeruleum* L.	35-120	green	blue

No	Plant name	Plant height, cm	Leaf color	Blossom color
23.	*Pulmonaria angustifolia* L.	20-30	green	blue
24.	*Linaria loeselii* Schweigg.	10-40	green	yellow
25.	*Pedicularis sceptrum-carolinum* L.	30-80	green	yellow, red
26.	*Ajuga pyramidalis* L.	20-30	green	violet
27.	*Scutellaria hastifolia* L.	10-40	green	blue
28.	*Dracocephalum ruyschiana* L.	40-60	green	blue
29.	*Prunella grandiflora* (L.) Scholler	10-60	green	violet
30.	*Salvia pratensis* L.	20-80	green	Violet, blue
31.	*Campanula bononiensis* L.	60-81	green	violet, blue
32.	*Lobelia dortmanna* L.	40-80	green	blue
33.	*Centaurea phrygia* L.	60-81	green	violet
34.	*Tragopogon Gorskianus Rchb*. f.	40-60	green	yellow
35.	*Aster tripolium* L.	40-60	green	violet
36.	*Alisma lanceolatum* With.	100	green	white
37.	*Iris sibirica* L.	30-80	green	Violet, blue
38.	*Gladiolus imbricatus* L.	40-60	green	red
39.	*Allium vineale* L.	60-80	green	violet
40.	*Gagea pratensis* (Pers.) Dumort.	10-20	green	yellow
41.	*Allium angulosum* L.	15-40	green	white, yellow
42.	*Allium ursinum* L.	20-40	green	white
43.	*Cypripedium calceolus* L.	50	green	yellow, violet
44.	*Cephalanthera logifolia* (L.) Fritsch	20-30	green	white
45.	*Gymnadenia conopsea* (L.) R. Br.	30-60	green	violet
46.	*Coeloglossum viride* (L.) Hartm.	20-30	striped	yellow
47.	*Ophrys insectifera* L.	20-60	green	yellow with dark edging
48.	*Orchis mascula* (L.) L.	50-80	green	violet
49.	*Orchis militaris* L.	10-20	green	violet
50.	*Dactylorhiza incarnate* (L.) Soo	60-80	variegated	violet
51.	*Dactylorhiza ochroleuca* (Wustnei ex Boll) Holub	60-80	green	white, yellow
52.	*Liparis loeselii* (L.) Rich.	15-20	green	yellow
53.	*Bolboschoenus maritimus* (L.) Palla	10-30	green	dark brown
54.	*Eriophorum gracile* W. D. J. Koch ex Roth	15-25	green	white
55.	*Hammarbya paludosa* (L.) Kuntze	10-20	green	white

The height of the researched plants is given in picture 1 .

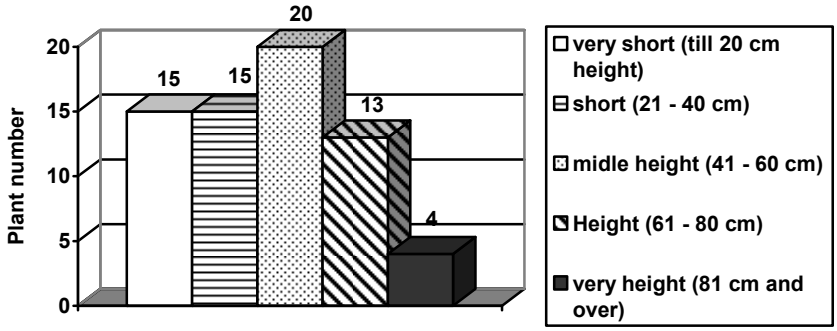

Fig. 1. **Plant height**

From the data presented (picture 1) it is obvious that the plants of a middle height dominate - 20 plants: *Dianthus borbasii*, *Aster tripolium*, *Dianthus superbus*, *Tragopogon Gorskianus, Scabiosa columbaria* etc. There are 15 short plants: *Allium angulosum*, Gentianella amarella,

Allium ursinum, *Linaria loeselii, Scutellaria hastifolia* etc. There are 15 very short plants: *Liparis loeselii*, *Hammarbya paludosa*, *Alyssum gmelinii*, *Orchis militaris* etc.
The flower color of the plants is presented in picture 2.

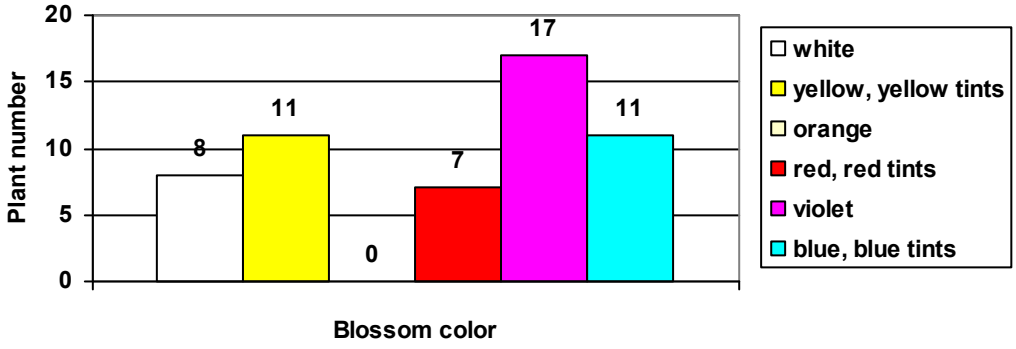

Fig. 2. **Plant blossom color**

Diagram (picture 2) shows that the prevailing color of the endangered plants, included into Lithuanian Red book, is violet - 17 plants. (*Linaria loeselii, Centaurea Phrygia*, *Succisella inflexa*, *Allium vinele*, *Pulsatilla patens* etc). 11 plants have yellow blossoms: *Liparis loeselii*, *Cypripedium calceolus*, *Nuphar pumium* etc.
The range of plant leaf color is given in picture 3. It is natural that the green leaf color dominates among the plants (48 plants).

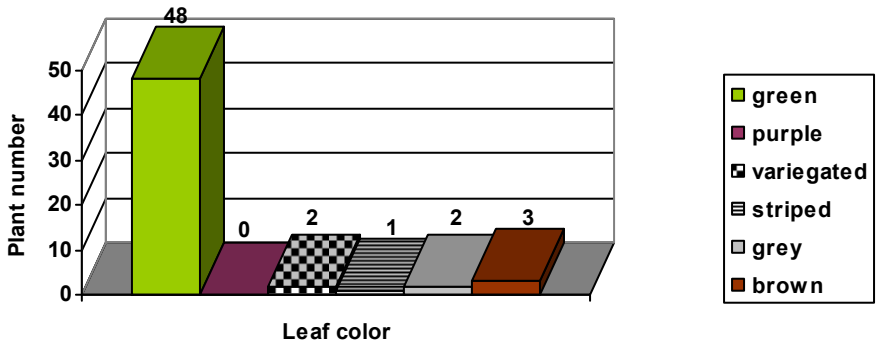

Fig. 3. **Plant leaf color**

The need for light of the plants is presented in picture 4.

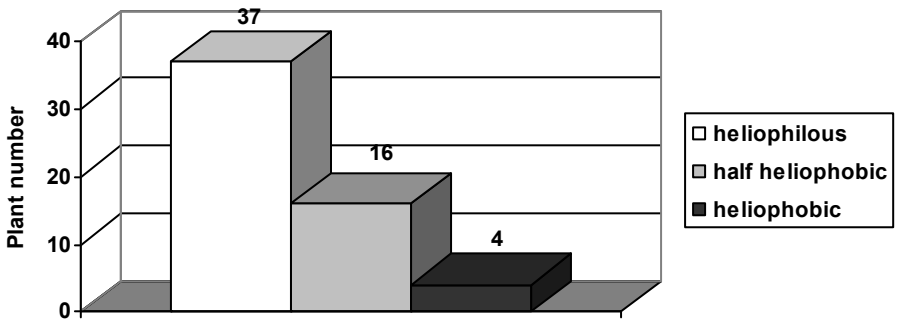

Fig. 4. **Plant lightening**

Picture 4 shows that majority of plants are heliouphilous (37 plants.): *Dactylorhiza ochroleuca*, *Prunella grandiflora*, *Nymphoides peltata*, *Centaurium littorale* etc. There are fewer plants that grow in a shade (16 plants.): *Hammarbya paludosa*, *Coeloglossum viride*, *Allium ursinum*, *Corydalis cava* etc.
Evaluation of plant blooming time is given in picture 5.

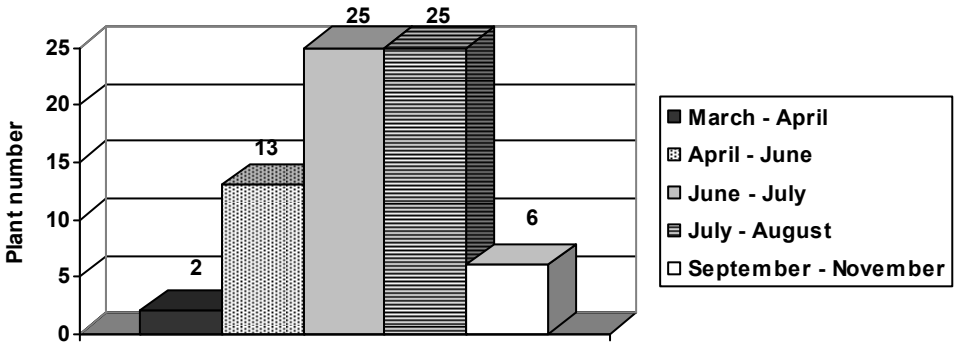

Fig. 5. **Plant blooming time**

In Lithuania endangered plants most often bloom from June till August (50 plants): *Ophrys insectifera*, *Scutellaria hastifolia*, *Nymphaea alba*, *Dianthus arenarius* etc. There are fewer plants that bloom from April till June (13 plants): *Coeloglossum viride*, Iris *sibirica*, *Pulmonaria angustifolia* etc.
The analysis revealed that 25 plants are allocated to category 2 (V) and are quickly becoming extinct, endangered species, the number of populations and individual plants of which is decreasing rapidly.
The majority of rare plants become extinct because of overgrowing of habitats by trees and bushes (58,18 %), irrigation and drainage (36,36 %) as well as intensive farming (29,09 %). The less threat is caused by grazing (21,82 %), plant picking for medicine and plant cutting (20 %) and grass stab (16,36 %).
The main protective measures of rare plants are the following:
1. The support of the traditional farming, the limitation of hay harvesting and grazing.
2. The maintenance of water hydro chemical, hydrological and hydrographic regime.
3. The maintenance of open areas, their protection from overgrowing.
4. Limitation of farming and recreational activity.
5. Limitation of clean forest fellings.
6. Artificial restoration of species.

Conclusions

After assessing morphological properties of 55 endangered plant species it was identified that the plants of a middle height dominate (20 species), even 17 plant species have violet blossoms; and green color leaves characteristic to 48 plant species. After researching the bio ecological properties of rare plants it is possible to say that the heliouphilous plants prevail (37 species) that bloom from the beginning of June till the end of August (50 species).
The analysis of rare plants showed that the majority of researched endangered plants belong to the 2 (V) category and are fast disappearing endangered species the number of populations and individual plants of which is decreasing rapidly.
The main reasons of the plant disappearance are the overgrowing of habitats by trees and bushes (58,18 %), irrigation and drainage (36,36 %) as well as intensive farming (29,09 %). The research identified that the main protective measures of rare plants are the support of the

traditional farming, the limitation of hay harvesting and grazing, the maintenance of water hydro chemical, hydrological and hydrographic regime, etc.

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ANALYSIS OF INVASIVE FLORA IN CEMETERY TERRITORIES OF THE CITY OF DAUGAVPILS

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Abstract. *Alien species are reaching different areas, including also cemeteries. Inventory of invasive flora of cemeteries of the city of Daugavpils actually is the first such type of work to such level of detail on the Latvian scale.*
Field studies were conducted in 10 cemeteries of the city of Daugavpils. The obtained results are indicative of a comparatively high proportion of invasive plant species in the cemeteries. 49 invasive alien species were found. In the cemetery areas these are spreading mainly from greeneries, but there are also such taxa, which have accidentally reached the cemeteries. The most frequent plant in the Daugavpils cemeteries is Spiraea chamaedryfolia. Taking into account the trends of migration, sex-age structure of population, climate change, availability of exotic and new ornamental plants, it is most likely that the number of invasive species will grow in the future.

Key words: *invasive alien plants, cemeteries, plantations, Daugavpils.*

Introduction

The primary role of any cemetery is to provide a place to bury and to commemorate the dead, and to provide a focal point for mourning and religious observance. However, because they provide green oases within built-up areas, cemeteries are also places for rest and contemplation in a more general sense, offering opportunities for fresh air and exercise, or simply a place for quiet communion with nature. The coexistence of nature and art, sometimes in an uneasy alliance, accounts for much of their character and makes them a unique historical, cultural and natural resource [1]. For that reason cemeteries are often an object for research for researchers of culture and historical heritage [1, 2].
Taking into account the significant impact of human activities in cemeteries, the microclimatic, soil et al. characteristics of site, which are essential for plants, specific flora is forming here. However research of flora in cemeteries and speed and nature for introduction of alien invasive plants, geospatial distribution in cemeteries and adjacent territories both in Latvia and worldwide is a direction being explored to comparatively small extent. Globally studies of the invasive alien species has been commenced with C. Elton, a pioneer of Invasion Biology as a field of science, in 1958 having published a book with regard to ecology of invasions by plants and animals. Research of the invasive plants of cemeteries was started significantly later, for example, in England the first results of studies regarding these matters have been published only in 2002 [1]. Research of invasive alien taxa in the territory of Latvia began in the 80s of the 20th century, but the studies were fragmentary and realized mainly in the central part of Latvia. Actually the only research of invasive flora of cemeteries in Latvia has been conducted by M. Laiviņš and S. Jermacāne (1999). Much more attention both from geospatial and historical distribution of plants to these matters is devoted in Lithuania [3].
The first inventory of the flora in Daugavpils was compiled in 1975–1983 [4] and the first paper on alien invasive trees appeared twenty years later [5]. The research performed with regard to invasive flora of the Daugavpils cemeteries is the first study of such type and degree of detail in Latvia.

Materials and methods

Study area

Daugavpils is situated in the south-eastern part of Latvia. The city is the second largest in Latvia with 102,496 inhabitants [6], situated on the banks of the river Daugava and covers an area of 72.48 km^2. The city is situated at the cross-roads of important motorways and railways. The flora of the city of Daugavpils is unique and one of the richest in Latvia. From E. Lehmann's [7] investigations at the end of the 19th century until 2009, 1014 species have been found here, 250 of them - invasive alien species [8]. Such a number of species in the city can be explained by a high diversity of natural habitats encountered here.

Field research

The field research was carried out from spring to autumn in 2007 till 2010. In course of research 10 cemeteries of the city of Daugavpils were surveyed. The data were processed using the GPS equipment THALES Mobilemapper CE. Data of records were obtained from examining specimens in the Daugavpils University Herbarium (DAU).

Results and discussion

In total, 49 invasive plant species were found in the Daugavpils city cemetery areas.

From the found caulescent plants (27 species), the highest frequency had *Erigeron canadensis* (Table 1) *Jovibarba globifera*, *Euphorbia cyparissias*. With a lower frequency were found *Sedum sexangulare*, *Phalacroloma annuum* and *Impatiens glandulifera.*

Erigeron canadensis is frequent alien species that easily spreads in different habitats. *Euphorbia cyparissias* and *Jovibarba globifera* are used as the ornamental plants and from plantations often go wild. *Jovibarba globifera* can tolerate drought, is modest in terms of soil fertility. *Euphorbia cyparissias* is also able to adapt to different growth and environmental conditions. According to the data of Laiviņš and Jermacāne, in Latvia on the year 1999 in the aggregate 28 *Sedum sexangulare* and 96 *Euphorbia cyparissias* fields were known. Since the data of Laiviņš and Jermacāne (1999) have so far been the only data on the cemetery flora and their field studies were mainly carried out in cemeteries of the western part of Latvia, acquiring information with regard to the remaining part of Latvia from the existing herbaria, the authors believes that the main cause for such an essential increase in quantities of these plant fields most likely is insufficient flora studies of the territory of Latvia.

Table 1.

Summary table of alien species recorded in 10 analysed cemeteries

Species	Number of records	Mean of introduction in cemetery	Frequency[1] (%)
Spiraea chamaedryfolia L.	92	I	100%
Syringa vulgaris L.	90	I	100%
Euphorbia cyparissias L.	66	I	80%
Sorbaria sorbifolia (L.) A.Braun	56	I	80%
Spiraea x billardii Hérincq	52	I	60%
Caragana arborescens Lam.	49	I	70%
Phalacroloma annuum (L.) Dumort.	44	U	70%
Erigeron canadensis L.	41	U	90%
Sedum sexangulare L.	39	I	70%
Aquilegia vulgaris L.	38	I	60%
Sambucus racemosa L.	36	I	60%
Impatiens glandulifera Royle	34	U	70%
Cotoneaster lucidus Schltdl.	31	I	60%

Species	Number of records	Mean of introduction in cemetery	Frequency[1] (%)
Amelanchier spicata (Lam.) K.Koch	27	I	70%
Jovibarba globifera L.	24	I	90%
Asparagus officinalis L.	20	I	60%
Solidago Canadensis L.	18	I	60%
Lupinus polyphyllus Lindl.	16	I	30%
Helianthus tuberosus L.	14	U	40%
Impatiens parviflora DC.	14	U	60%
Malus domestica Borkh.	11	U	60%
Erysimum hieracifolium L.	11	U	50%
Medicago falcata L.	11	U	60%
Bunias orientalis L.	10	U	50%
Sedum rupestre L.	9	I	40%
Sedum album L.	9	I	40%
Caragana frutex (L.) K. Koch	8	I	40%
Spiraea x rosalba Dipp	8	I	40%
Acer pseudoplatanus L.	6	I	20%
Sisymbrium loeselii L.	4	U	20%
Armoracia rusticana P.Gaertn., B.Mey. et Scherb.	4	U	30%
Acer negundo L.	4	U	20%
Galinsoga parviflora Cav.	4	U	40%
Echinocystis lobata (Michx.) Torr. et A.Gray	3	U	30%
Lamium album L.	3	I	30%
Spiraea alba Duroi.	3	I	30%
Physocarpus opulifolius (L.) Maxim.	3	I	30%
Populus laurifolia Ledeb.	3	U	10%
Medicago lupulina L.	2	U	20%
Populus alba L.	2	U	20%
Rosa rugosa Thunb.	2	I	20%
Robinia pseudoacacia L.	2	I	10%
Bellis perennis L.	2	I	20%
Lepidium densiflorum Schrad.	1	U	10%
Rumex confertus Willd.	1	U	10%
Populus x canadensis Moench.	1	U	10%
Sedum spurium M.Bieb	1	I	10%
Salix daphnoides L.	1	I	10%
Spiraea media Schmidt.	1	I	10%

[1] Plant occurrence frequency was calculated according to the formula ((number of cemeteries, where the plant was found / total number of cemeteries)*100).

From shrubs (15 species) in all the cemeteries were found (Table 1) *Spiraea chamaedryfolia* and *Syringa vulgaris*. With a lower frequency were found *Sorbaria sorbifolia*, *Caragana arborescens*, *Amelanchier spicata*, *Cotoneaster lucidum*. *Spiraea chamaedryfolia* and *Sorbaria sorbifolia* are widely distributed decorative bushes rapidly multiplying via root offshoots and occupying large areas, as well as creating dense groups around greeneries, for that reason their delimitation is recommended by walkways, waters [9]. While cemetery areas are remaining unmanaged, spiraeas are quickly spreading around the original plantations. Also *Syringa vulgaris* and *Caragana arborescens* as decorative shrubs are used in greeneries,

wherefrom they are spreading also over wider surrounding areas. Many of shrubs used in the greeneries are not only ornamental, but also fast-growing, winter-hardy, able to tolerate shade, etc. *Cotoneaster lucidum* is the most popular malleable hedge plant in Latvia [10].
From tree plants in cemetery areas were found 7 species (Table 1). *Malus domestica* is a food crop, culture escapee and wild self-sown trees have been found in very different habitats. *A Robinia pseudoacacia is grown* as an ornamental plantation tree. *Acer negundo*, *Populus balsamifera*, *Populus alba* and *Populus laurifolia* in the cemetery areas most likely have come from roadside greeneries. It should be noted that *Acer negundo* is an aggressive invasive species, which distribution is rather difficult to bring under control [11], because the plant is characterized by rapid distribution during the first years of growth. The seeds are easily spread during the leaf fall. In Latvia the plant is naturalized and a large number of fields are found in roadside areas [12].
20 (41%) (Table 1) from the invasive species found in the cemetery areas can be classified as unintentionally introduced species. These species are mainly accidentally introduced, for example, via transport or used in greeneries (however, not in cemeteries, but, for example, along the roadsides), and via either root offshoots or animals have reached the cemeteries – *Erigeron canadensis, Lepidium densiflorum* and *Populus* species. This group includes also *Amelanchier spicata* - food plant, which could have reached the territory of cemeteries by the bird-distributed seeds. *Impatiens parviflora* and *Impatiens glandulifera* in the cemetery territories most likely have also arrived with seeds from the surrounding area. Although the latter two species have reached the Latvian flora as ornamental garden escapees, however in the cemeteries these are not used in greeneries.
The remaining 29 species (59%) can be classified as intentionally introduced species, which are used as ornamental plants in the cemeteries. This category is mainly represented by the genus *Rosa*, *Sedum*. Genus *Sedum* are garden escapees, having adapted to growth in dry areas, therefore quite often found outside the cemetery greeneries [13]. Genus *Rosa* in many areas is used in greeneries, and is characterized by an aggressive root system - *Spiraea chamaedryfolia, Sorbaria sorbifolia* [10].
Much of the intentionally introduced taxa in cemeteries are spreading under influence of human activities – during the cemetery is put in order the plant vegetative parts, flowers, seeds, roots are getting outside the graves. Many of these plants continue to grow and to integrate into the local plant communities in the cemeteries, as well as outside their territories.
The highest number of invasive species was found in the Orthodox Cemetery (Table 2) and in the Communal Cemetery, while the lowest - in the Brethren Cemetery.
The most frequent plant in the Old Military Cemetery is *Sorbaria sorbifolia*. Since this is one of the oldest cemeteries of the city, a large part of the territory is not managed any more, *Sorbaria sorbifolia* is forming spacious stands in many places. In the cemetery also greenery plants, such as *Syringa vulgaris*, *Caragana arborescens, Spiraea chamaedrifolia, Spiraea x billardii* are widespread. Of the caulescent plants the most frequently met - *Aquilegia vulgaris, Erigeron canadensis, Aquilegia vulgaris* in cemeteries is cultivated as the grave greenery plant.

In the most shaded part of the Griva cemetery (the oldest part of cemetery) bushy plants are more frequent - *Syringa vulgaris*, *Caragana arborescens*, while in the sunniest areas frequent are such species as *Phalacroloma annuum, Euphorbia cyparissias, Lupinus polyphylla* and several species of *Crassulaceae*, which is widely distributed beyond the grave plantations. *Sedums* in the cemeteries are used as covering plants both on the graves, and around the said [14].

Table 2.

Invasive alien plant species in cemeteries of the city of Daugavpils

Cemeteries	Area of cemetery (ha)	Number of species	Number of the families found	The most widely distributed families	Number of the woody plant species	Number of the bushy plant species	Number of the caulescent plant species
Brethren cemetery	1	8	6	Rosaceae (2 species) Leguminosae (2 species)	1	4	3
Old military cemetery	8	25	9	Rosaceae (8 species)	1	10	14
Griva cemetery	12	28	13	Asteraceae (5 species)	2	5	21
Communal cemetery	22	30	13	Asteraceae (5 species) Rosaceae (7 species)	1	9	20
Catholic cemetery	12	24	12	Rosaceae (6 species) Asteraceae (4 species)	2	10	12
Lutheran cemetery	4	20	11	Rosaceae (3 species)	1	6	9
Liģinišķi cemetery	3	11	7	Rosaceae (4 species)	1	5	5
Orthodox cemetery	13	33	12	Rosaceae (10 species)	2	12	19
Old Believers' cemetery	8	28	14	Rosaceae (7 species)	3	10	15
Common graves and Babtist cemetery	3	12	7	Rosaceae (5 species)	1	7	4

In the Brethren cemetery the most frequent taxa are *Syringa vulgaris, Medicago falcata, Caragana arborescens*. Small number of species in the Brethren cemetery could be explained by small area of the cemetery, as well as the fact that in the cemetery there is a large solid lawn, separate plantations are not formed (which also explains the dominance of *Medicago falcata*) and there is also a single operator.

The most frequent Communal cemetery plants - *Cotoneaster lucidum, Impatiens glandulifera, Euphorbia cyparissias, Sedum sexangulare, Cotoneaster lucidum* is very widely used in the W part of the cemetery in order to isolate individual burial places and in this area invasion of the said plant outside greeneries is also observed. Quite interestingly, many authors [10] refer to the fact that *Cotoneaster lucidum* is an expressed sun-loving plant, but the performed studies are presenting evidence that the plant feels very well also in strongly shaded areas. In this cemetery there is one of the largest diversities of invasive caulescent plants on the city scale. Comparatively high overall proportion of invasive plant species could be related to the fact that the cemetery area today continues to expand rapidly, to the number of existing denominations are added new ones, for example, Islam, and also in the greeneries from time to time certain "fashion plants" are observed, which are used more frequently than other ornamental plants. The said facts in future could significantly contribute to the growth in the proportion of invasive species.

In the Catholic cemetery most frequently found are *Spiraea x billardii, Euphorbia cyparissias, Spiraea chamaedrifolia, Sorbaria sorbifolia, Syringa vulgaris, Caragana arborescens*. Large proportion of *Rosaceae* bushy plants is attributed to the fact that in the E and N part of the cemetery *Sorbaria sorbifolia, Caragana arborescens* are forming wide-growing stands and spreading well beyond the cemetery area in the undergrowth.

The most frequently found in the Lutheran cemetery are *Syringa vulgaris, Caragana arborescens, Spiraea chamaedrifolia, Spiraea x billardii, Aquilegia vulgaris*. Dominance of

the invasive bushy plants can be explained by the fact that part of this cemetery is not under operation any more, and these plants are forming dense monodominant stands.
The most frequently found in the Old Believers' cemetery are *Euphorbia cyparissias, Spiraea chamaedrifolia, Syringa vulgaris* Since the cemetery area is not extending anymore and more new burials are not made, "entering" of new species from the greeneries is actually not occurring any more. Number of species in the future may increase mainly on account of the accidentally introduced species. Similar situation is observed also in the Common graves and the Baptist cemetery. Here, the most frequently found plant - *Sambucus racemosa*.
The largest number of species was found in the Orthodox cemetery, the most frequent - *Spiraea chamaedrifolia, Caragana arborescens, Sambucus racemosa*. There the highest proportion of invasive bushy plants was also listed.
In the Liginišķi cemetery the most frequently found - *Impatiens glandulifera*, *Sambucus racemosa* and *Impatiens glandulifera*. Interestingly that historical data on the age of the cemetery are different - it is mentioned that this is one of the oldest cemeteries in the city, but it is not marked on the city maps neither in 1917, nor 1928 [15]. Number and composition of the invasive species is presenting more evidence, however, that is a comparatively new cemetery, since here more dominant are invasive plants, the primary use whereof is not the cemetery plantations.
In general, all the cemeteries were dominated by the *Rosaceae* (12 species), *Leguminosae* (6), *Asteraceae* (5) and *Crassulaceae* (5) plants. The orpine family (*Crassulaceae*) was dominated by the *Sedum* species. Comparatively wide distribution of the *Sedum* could be explained by the fact that as ornamental plants they are widely used in the grave greeneries, and they do not require special care [16, 17]. The highest concentration of these was observed in the sunny and sandy cemetery areas. Plants have adapted to grow in dry places [9]. Many of the *Asteraceae* species, which are popular in cemeteries as ornamental plants, have also been adapted for seed dispersal through wind and frequently escape into the surrounding environment [3].
Correlation diagram shows that a significant positive linear correlation exists between the area of cemeteries and the number of invasive species found (correlation: r = 0.838472). Conclusion can be drawn that in the majority of the cemeteries number of species is dependent on the cemetery area. However, there are also other factors that are having an impact on the number of species in the cemeteries - human influence, circumstances of growth, habitats.
Upon analysis and correlation of the data on the number of species and age of the formation of cemetery, no significant correlation was observed. Practically no correlation exists between the age of the cemetery and the number of species found (correlation: r = 0.021322).
Data obtained are indicative of increase in the numbers of invasive plant species.
Proportion of the number of invasive species in the cemetery is not affected also by the represented denomination. Perhaps, some plants are planted in cemeteries with symbolic meaning, however, majority of the plants are having highly ornamental mode of application. Plants found in the cemeteries of all denominations are *Jovibarba globifera, Spiraea x billardii, Euphorbia cyparissias, Spiraea chamaedryfolia, Erigeron canadensis*, *Sedum sexangulare, Sorbaria sorbifolia, Impatiens parviflora, Phalacroloma annuum*. Bushy plants of the Rose family are widely distributed in majority of the cemeteries, in many places forming also big stands outside the greeneries.
Invasive plants are spreading also beyond the graveyards - on roadsides, in nearby meadows, edges of a forest, in ditches. Plant distribution is facilitated both by natural elements - wind, water, birds, as well as human activities, when landfills adjacent to the cemeteries are reached by the plant flowers, seeds, parts of roots, new offshoots, some of which survive, continue to grow and to spread [3, 16, 17].

Plants cultivated in gardens, other ornamental plantations, and in cemeteries particularly, possess no danger to the environment until they remain in cultivation. However, any plant that has escaped from cultivation should not be neglected because this process can be the start of species naturalization and future invasion [18].

Conclusion

49 invasive alien plant species have been found in cemetery areas of the city of Daugavpils, which amounts to 5% from the total number of species in Daugavpils.

The identified plants are representing 16 families, of which the largest number of species is for the *Rosaceae*, *Crassulaceae* and *Leguminosae*.

There is a strong correlation between the area of cemeteries and the number of invasive species in them. Age and religious affiliation of cemeteries has no effect on the diversity of species.

Majority of the invasive species have entered the cemetery areas from the grave or hedge greeneries.

Many of the identified species have adapted to conditions of growing in cemeteries and their spreading continues. Distribution of invasive species was also observed outside the cemetery territories - in neighboring meadows, edges of a forest, in ditches, where plants are getting both under impact of natural factors and with human assistance. As an important intermediate for the migration of species from cemeteries to the surrounding areas can be considered the landfills adjacent to the cemeteries.

During the research also the opposite process was observed that species (*Acer negundo*, *Erigeron canadensis*, *Bunia orientalis*, etc.), which are not used for cemetery greeneries, are getting into cemeteries from the surrounding areas.

Species such as *Sorbaria sorbifolia*, *Acer negundo*, *Erigeron canadensis* etc. may be considered to be aggressive, which are not only spreading without human involvement; however it is difficult to impose restrictions on their distribution.

Number of invasive species in the future will tend to increase as the species adapt to the specific growing conditions in cemeteries, are occupying increasingly new niches, displacing the local plant species.

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RELATIONSHIP BETWEEN HYDROBIOLOGICAL AND HYDROCHEMICAL PARAMETERS OF LAKES OF KARELIA AS INFLUENCED BY THEIR GEOECOLOGICAL CHARACTERISTICS

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Abstract. *On the data on 110 lakes of Karelia the role of natural and anthropogenic factors in the forming of hydrochemical and hydrobiological regimes is discussed. It is shown that the prognoses of hydrobiological parameters on the base of hydrochemical data using regression analyses is not possible due to high variability of data. For the purpose of reconstruction hydrobiological data the complex indexes were worked, then the classification of lakes of Karelia was done. Using the methods of multivariate statistics and the contingency tables the connections between chemical and hydrobiological parameters were investigated. The prognoses tables were calculated to reconstruct the zooplankton and zoobenthos biomass on the base of total phosphorous concentration. The precision of the prognoses varied within 55-86%.*

Keywords: *lakes of Karelia, hydrochemical and hydrobiological data, regression analyses, contingency tables, prognosis.*

Introduction

One of the major tasks for hydroecology is assessment of the bioresource potential of waterbodies. The dynamic state of aquatic ecosystems, their heterogeneity, the impossibility to survey the whole waterbody make this task very complex. Lack of information about the biological resources of lakes poses the task of reconstructing them using expert information systems [2, 4].

The study objects in our research were lakes of Karelia. The climate predetermines their distinctive features (short growing season, fairly low temperature in summer, high precipitation in the catchment, high percent cover of wetlands in the catchment), and the underlying rock geology (slight weathering of mineral components from basic rocks). This, in turn, tells on the hydrological regime (high flowage) and water chemical composition (very low content of mineral substances in the water, low nutrient concentrations; low pH, elevated humic matter content). The action of the climatic and the geological factors results in low productivity of the aquatic ecosystems. Geoecological characteristics of the water ecosystems of Karelia should be taken into account in reconstruction of the missing hydrobiological data from available indices.

The aim of the present study is to investigate the relationship between hydroecological parameters of lakes of Karelia, and to work out a technique for reconstructing hydrobiological data using hydrochemical indices.

Materials and methods

The input material in the study was archival data on 110 lakes available from the Northern Water Problems Institute (total phosphorus, suspended matter, chlorophyll “a”, zooplankton and benthos biomass). The data were obtained in the period 1960-2008. The most of the hydrochemical data were calculated as an average values for the summer season. The samples of water were processed according to standard methods which were described in the Guide [6]. The hydrobiological data were collected mainly in July-August.

The data were mathematically processed using multivariate statistics methods: correlation, regression, cluster analyses, as well as nonparametric criteria – Spearman's rank correlation coefficient [1, 3, 5].

Results and discussion

To forecast the parameters at the first stage we employed regression analysis, which exposes relations between the characteristics and enables computation of indices from other ones through regression equations. Correlation between total phosphorus content in the water of Karelian lakes and the zooplankton biomass was studied (Fig.). The linear regression equation was calculated, where both coefficients had a reliable value ($p<0.05$):

$$LOG\ (Bzpl) = (0.877 \pm 0.116) * LOG\ (Ptot) - (1.254 \pm 0.149),$$

where: Bzpl – zooplankton biomass, g/m^3; Ptot – total phosphorus content, µg/l.

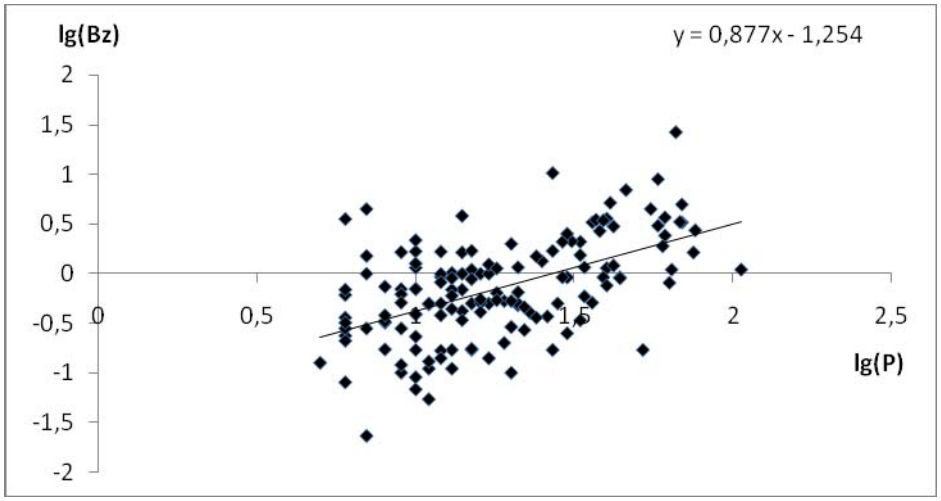

Fig. **Dependence of zooplankton biomass values on total phosphorus values (both in logarithmic form); lg(P) – the logarithm of the concentration of the total phosphorous in the water (µg/l); lg(Bz) - the logarithm of the zooplankton biomass (g/m^3)**

Prognostic values of zooplankton biomass were calculated from different total phosphorus values corresponding to the lake status: 10 µg/l – oligotrophic; 20 µg/l – mesotrophic; 30 µg/l – transitional between meso- and eutrophic; 50 µg/l – eutrophic type. Estimates of mean values of the indices, as well as confidence limits for 95% probability are shown in Table 1.

Table 1.

Values of zooplankton biomass calculated from total phosphorus concentration

Total phosphorus concentration, µg/l	Zooplankton biomass, g/m^3		
	mean	left-hand confidence limit	right-hand confidence limit
10	0.420	0.126	1.406
20	0.772	0.197	3.027
30	1.102	0.256	4.741
50	1.726	0.357	8.343

You can see the calculated values do not properly reflect the status of zooplankton communities at different phosphorus concentrations in the water. E.g., when phosphorus

concentration is 10 μg/l mean prognostic values of the biomass (0.42 g/m^3) correspond to low nutrient content, i.e. reflect the oligotrophic status of the lake. The confidence interval however comprises a range of zooplankton biomass values – from the oligotrophic to the α-mesotrophic (0.126–1.406). The forecast becomes less accurate as the phosphorus concentration increases.

The low accuracy of zooplankton biomass values forecasted using total phosphorus content in the water is due to some features of regression analysis. Calculations by regression equation can yield only mean values of the sought index (function) for a specific value of the independent variable. When input data are highly variable the dispersion of the indices and the regression coefficient error increase, wherefore the forecast accuracy (scattering of values within the confidence interval) decreases. This is the situation observed when regression analysis is applied to the data set on lakes of Karelia. Although regression coefficients in the relation between hydrobiological indices and phosphorus content in the water are reliable, zooplankton biomass is quite variable, which makes its accurate forecast based on phosphorus concentration in the water impossible.

Since the distribution of traits in the data set of lakes of Karelia features distinct asymmetry (values typical of low-productivity lakes prevail), one may presume that in the forecast of values of the traits sought not all of them would have equal probability of manifestation for the given value of the independent variable from available data. A differentiated approach is needed for the different statistical significance of the input data to be taken into account, i.e. the whole range of values should be split into gradations and the algorithm should be developed to reconstruct the missing data for each specific gradation. This approach would notably enhance the accuracy of the forecast.

The approach can be implemented through contingency tables [5]. To build contingency tables one should perform the procedure of indexing the waterbodies in question. We developed two indexes based on the following groups of parameters: hydrochemical index (HCh_{troph}) – from the values of total phosphorus, total nitrogen, suspended matter, chlorophyll "a"; and hydrobiological index (HB) – from zooplankton and zoobenthos biomass values. These parameters were chosen because of reliable correlation detected between them (their values in logarithmic form).

The indexes for each group of parameters were determined through cluster analysis, which brings several traits down to one – the generalized measure of distance between each pair or a greater number of study objects. The objects were combined into three groups by the distance (Euclidean measure) and each group was assigned an index – a number from 1 to 3, with the parameters in the series increasing.

The next step was to analyze the table of contingency between the hydrochemical (HCh_{troph}) and the hydrobiological (HB) indexes (Tab. 2).

According to the χ^2 test value (25.7), the two indexes are confidently ($p<0.05$) related. Hence, independent assessments of the lakes (their indexing) by hydrochemical and by hydrobiological parameters coincide. Indeed, the first gradation of the hydrochemical index HCh_{troph} comprises a greater number of lakes (22 out of 44) also falling into the first gradation by the hydrobiological index HB (15 from the second HB gradation, 7 – from the third one). Correlation between hydrochemical and hydrobiological parameters is manifest also within the second HCh_{troph} gradation. Thus, most lakes (21 out of 40) fit into the second gradation by the HCh_{troph} and HB indexes. A similar conformant pattern is observed for lakes of the third gradation by the HCh_{troph} index. It contains no lakes falling into the first gradation by the HB index, 12 out of 26 lakes of the second HB gradation, and 14 – of the third HB gradation.

Thus, the contingency table reflects the regular relationship between the indexes based on the change in the concentration of nutrients (mainly phosphorus) in the water and the corresponding increase in the lakes' zooplankton and zoobenthos production. Since the

indexes are confidently related, one group of parameters can be forecasted relying on the other one.

Table 2.

Contingency table based on lake gradation by hydrochemical (lines) and hydrobiological (columns) indexes

Line gradation – trophicity classes by the HCh_{troph} index	Column gradation – trophicity classes by the HB index			Line total
	1	2	3	
1	22	15	7	44
2	12	21	7	40
3	0	12	14	26
Column total	34	48	28	110

Zooplankton biomass was forecasted using total phosphorus content in the water. The forecast accuracy ranged for different gradations within 55-86% (the accuracy averaged for the whole lake sample set was 66%). Accuracy was the highest (86%) for the third gradation of lakes with the highest phosphorus content in the water. This fact proves the sample set under analysis contains a distinct group of lakes with elevated trophicity. Stability of the lakes' parameters and high correlation between them ensured the highest accuracy of the forecast. On the other hand, the forecast accuracy for lakes of gradations 1 & 2 is lower – 55-56%. The reason for that is the group of "transitional" lakes. Because of their variable status, correlations between hydrobiological and hydrochemical parameters there are fuzzier. The accuracy of zoobenthos forecast by total phosphorus content in the water was 71-78% (the accuracy averaged for the whole sample set was 74%).

Summary

Analysis of data on lakes of Karelia has shown oligo-mesotrophic lakes prevail in the sample set under study, whereas eutrophic lakes are rather few. Regression analysis did not enable reconstruction of hydrobiological data because of their high variability. We therefore developed integrated hydrochemical and hydrobiological indexes reflecting the trophic status of the lakes. Multivariate statistics and information analysis methods were employed to trace correlations between the hydrochemical and hydrobiological indexes. Predictive tables and keys were computed to enable reconstruction of data on zooplankton and zoobenthos biomass relying on data on total phosphorus content in the lake water. The accuracy of reconstruction of the hydrobiological data ranges within 55-86%.

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REGIONAL CLIMATE CHANGE (KARELIA, RUSSIA)

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Abstract. *The overview of climatic conditions in Karelia is based on the data from meteorological observations carried out in 1951-2009 at Roskomgidromet weather stations situated in the study area. Taking the period in question into account, the mean annual air temperature norm has increased by 0.2-0.3°C. The greatest deviation from multiyear averages of mean monthly air temperature is observed in January and March. The investigation of the changes the basic regional climate characteristics is very important in present time because the global climate is changed. The analysis the data about air temperature and precipitation, that were obtained for the different meteorological stations in the investigated region, shows that the regional climate is changed and the main tendencies are directly proportional to the change of the global characteristics.*

Keywords: *regional climate change, air temperature.*

Introduction

A topical problem of today is climate variability and change in the context of global warming. Tendencies of climate change at the regional level are of particular interest. According to observation data, the global climate system has been changing since the early 20th century. Climate data for Russian Karelia were summarized in the 1960s-1980s. Obviously, changes of the last 15-20 years remained unaccounted. And it is during this time that patterns of change appear most interesting in view of global climate warming. Close analysis of regional climatic distinctions, study of the response of natural systems to climate change through representative observations is a good way to address the challenges of climate change.

Materials and methods

The temperature regime in Karelia was studied on the basis of data from air temperature monitoring at the republic's weather stations (WS) in the period from 1951 to 2009.

Results

Among-year averages of mean annual air temperature range from 0 °C in northern parts of the study area to + 2.6…+ 2.8 ^{0}C in the south of the republic. The highest mean annual air temperature norms were recorded from Lake Ladoga area (+3.0 ^{o}C at Sortavala WS & +3.3 ^{0}C at Valaam WS). In the second half of the 20th and first decade of the 21st century, mean annual air temperature had a positive trend throughout Karelia. Since 1988, annual air temperature means have nearly always been higher than the climatic norm determined for the period of 1961-1990 (Fig. 1).

The rise in mean annual air temperature over the territory has been uneven. The highest linear trend coefficients were obtained from the weather stations located in southern parts of the republic, on Lake Ladoga coast: Olonets WS – +0.34 ^{0}C/10 yrs., Sortavala WS – +0.3 ^{0}C/10 yrs. (Fig. 2). In central parts of Karelia, the upward trend in mean annual air temperature is not so explicit: +0.26 …+0.27 ^{0}C/10 yrs. Values of the linear warming trend coefficient of mean annual air temperature are the lowest in the northern part of the study area: ca. + 0.2 ^{0}C/10 yrs. Thus, the intensity of mean annual air temperature rise in the region grows gradually from higher to lower latitudes.

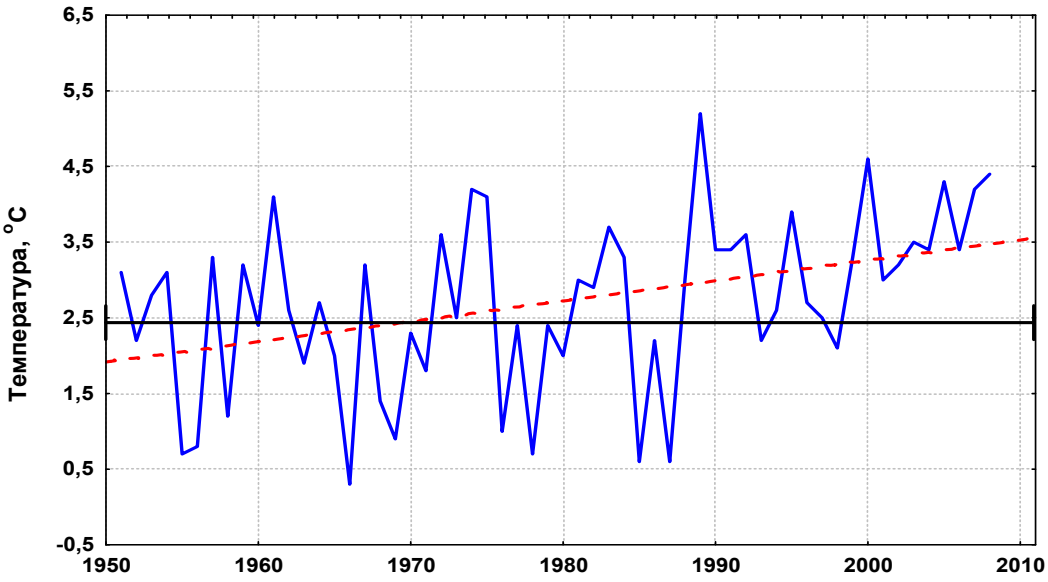

Fig. 1. **Changes in mean annual air temperature at Petrozavodsk WS from 1951 to 2009** (dash line – linear trend, solid line – climatic norm for 1961-1990)

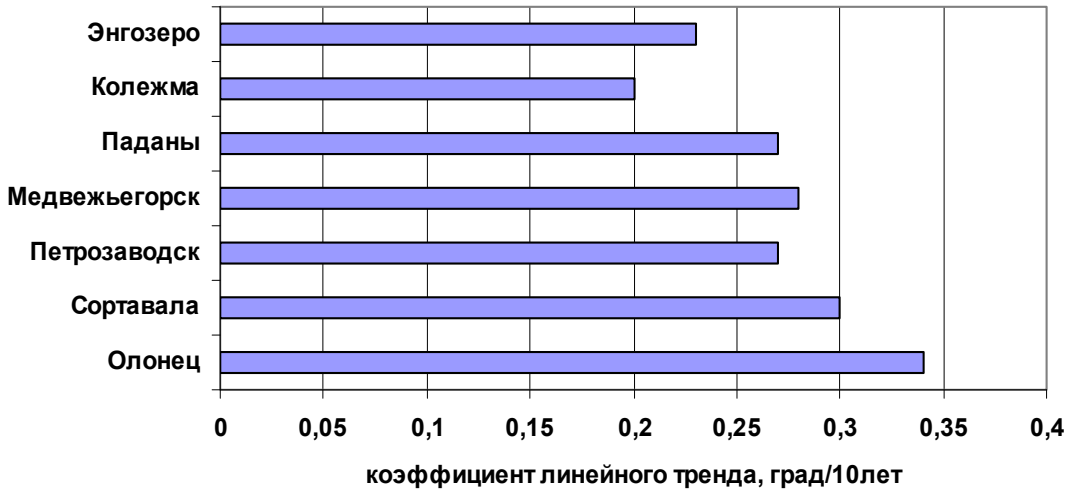

Fig. 2. **Values of linear trend coefficients of main annual air temperature based on data from weather stations of Karelia recorded in 1951-2009**

In contrast to the Leningrad, Pskov and Novgorod Regions, the climate in Karelia features zonal distribution of all temperature characteristics throughout the year: mean monthly air temperature, dates of temperature transition across certain points, total temperatures, and other meteorological characteristics. The temperature conditions are the most severe in northern areas, higher than 64° N. Winter is the coldest in the north-western part of the republic, which is dissected by spurs of the Maanselkä ridge; winter in the White Sea lowland is quite mild. Further towards the south of the region, temperature conditions become less harsh. The temperature conditions most favourable for people to live in are in the southern part of the republic, the climate being the mildest in south-western districts, which adjoin Lake Ladoga. Air temperature in the coldest month ranges from -9°C close to Lake Ladoga to -12°C in the north-west of the republic. In the vicinity of large lakes and on islands of Lakes

Ladoga and Onega, February is colder than January by an average of 0.2-0.5°C. July temperatures range from +16°C in southern parts to +14°C in the White Sea area.
Mean monthly air temperatures change unevenly within a year (Fig. 3). Warming has been most intensive is March (+0.5 …+0.6 ^{0}C/10 yrs.) and January (from +0.3 ^{0}C/10 yrs. in northern to +0.6 in southern districts). The February temperature increase is also quite significant, 0.4 ^{0}C/10 yrs. over the whole of the republic. From May to December, with the exception of July and August, warming proceeds evenly throughout the region. In August, cooling tendencies have been reported from northern and central Karelia.

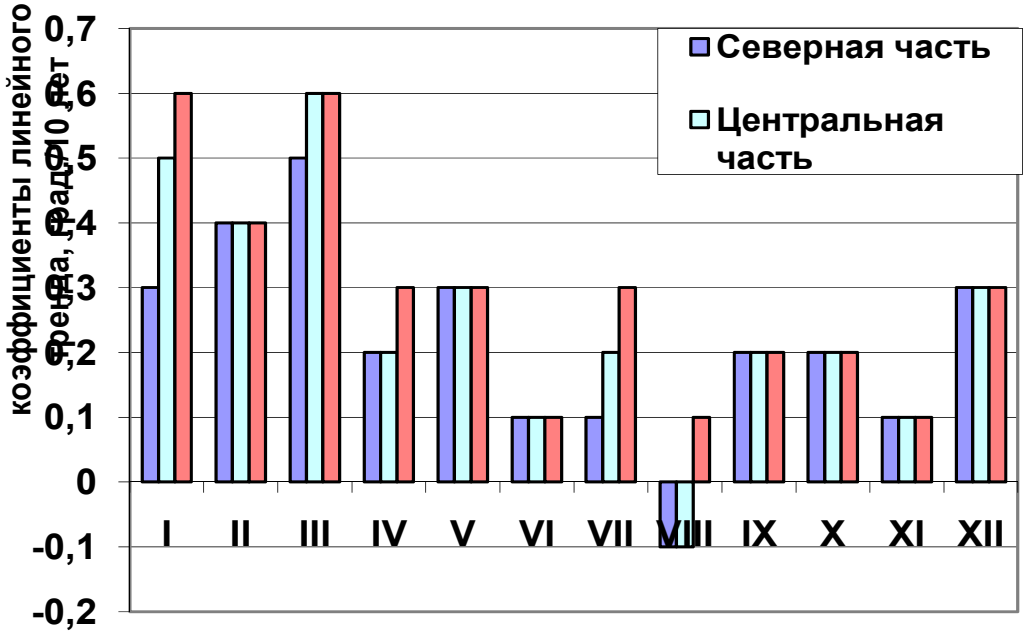

Fig. 3. **Values of air temperature linear trend coefficients (°C/10 yrs.) by months over the period of 1951-2009 in the study area**

For a more comprehensive description of the region's temperature regime one should consider mean and annual dates when climatic seasons of the year begin and end. Computations have shown the dates when air temperatures established above or below 0, 5 & 10 °C in years 2000-2009 had a shift relative to multiannual averages. The greatest deviations from the climatic norm were demonstrated by the dates of the warm season beginning and end (above 0 °C). The cold season arrived 5-23 days later than the average multiannual date. The exception was year 2002, when mean daily air temperature established below 0 °C ten days earlier than the climatic norm. In 2000-2008, the cold season ended 10-20 days earlier than the multiannual average, except for 2007, when it ended a month earlier, and 2008, when mean daily air temperature established above 0 °C exactly on the average multiannual date. As the result of the deviations from average dates of steady air temperature transition across 0 °C, the duration of the warm season averaged for the time segment in question was 215- 225 days vs. the 192-210 days of the climatic norm.
A rise in air temperature and average number of days with air temperature above certain points is characteristic of the temperature regime throughout Karelia. Thus, the number of days with mean daily air temperature steadily above 5 ^{0}C in the first decade of the 21st century on average was 148 days in the north of Karelia, and 170 days in central and southern parts, the climatic norm being 134 & 151-159 days, respectively. The number of days with air temperature above 10 ^{0}C was 7-13 days greater than the norm.
Changes in the temperature regime in Karelia have influenced the ice regime of lakes. The duration of the ice-free period on Lake Onega has increased from an average of 215 days/year

late in the 19th century to an average of 227 days/year early in the 21st century (Fig. 4). The weightiest factor behind the extension of the ice-free period has been air temperature increase in March, which made the ice cover disintegrate 8-10 days earlier.

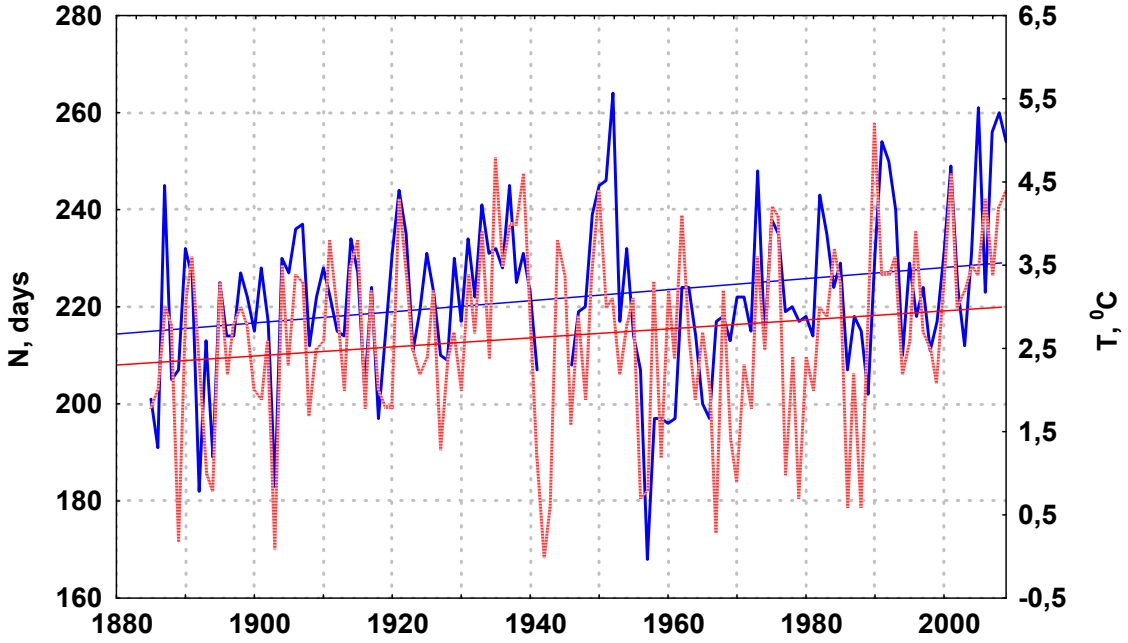

Fig. 4. **Duration of the ice-free period (days) for Lake Onega according to data from the Town of Voznesenje (solid line), and mean annual air temperature** (^{0}C) according to data from Petrozavodsk WS (dash line)

Summary

The analysis the data about air temperature and precipitation, that were obtained for the different meteorological stations in the investigated region, shows that the regional climate is changed and the main tendencies are directly proportional to the change of the global characteristics.

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THE ROLE OF PUBLIC PARTICIPATION AND ENVIRONMENTAL ACTIVISM IN ENVIRONMENTAL GOVERNANCE IN LATVIA

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Abstract. *The paper discusses engagement of non-governmental organisations and activist groups in environmental governance in Latvia. The research is based on desk research, a number of case studies and action research. Author attempts to analyse to what extent environmental NGOs and groups of activists have contributed to environmental governance and what role public participation plays in that. Author concludes that identification of problematic issues and policy planning are those stages where public participation and activism in environmental governance plays most crucial role. Contrary to common public believe about informal groups and environmental activism only attempting to oppose any proposed projects or new developments, these groups can and do play and important role in environmental governance. Author also concludes that institutional system that supports public participation is crucial in facilitating public involvement in environmental governance. Author also suggests that participatory environmental governance can better meet challenges of sustainability.*

Keywords: *environmental activism, environmental governance, non-governmental organisations, public participation.*

Introduction

There are multiple interpretations of environmental governance, but in broad terms it can be seen as attempts by governing bodies or combinations to alleviate recognized environmental dilemmas [1]. Unlike top-down decision making and enforcement in environmental protection, environmental governance involves a reallocation of power so that citizens and other civil society actors are involved in all aspects of the policy process from issue identification to implementation and monitoring [2].

In environmental governance there are several conceptual perspectives that have developed during the past several decades – one of it is pluralism. The approach of pluralism is guided by the premise that public policy is the outcome of competing interests and limited resources and that the appropriate role of state institutions is to provide fair framework within which these social decision-making processes play out [3]. Pluralism is an important approach also in contemporary environmental governance, particularly given the increasing emphasis on public participation in environmental policy making. It has been stressed by practitioners that citizens and organisations of civil society have become increasingly vocal, bringing forward issues and demands and trying to influence policy-makers [4]. The engagement of civil society actors, primarily non-government organisations (NGOs), has become an accepted aspect of environmental governance in democratic systems. Environmental governance promotes collaboration among diverse parties in order to develop creative and effective solutions to environmental problems and generate commitment to the outcomes that are achieved [2]. However there are two distinct visions about the role NGOs play i.e. on one hand NGOs are seen as representing public interests or certain group of people, while on the other hand they are also seen as partners to governmental institutions and working collaboratively with officials.

In countries where democratic institutions are weak, authorities fear that NGOs might take on too many responsibilities and their administrative power could exceed the one of government. For instance in recent crisis in Haiti authorities have pointed out to the situation where government was weak and unable to deliver appropriate services to the population whereas NGOs were very strong with lots of resources and thus in many communities NGOs exercise

more political clout than government [5]. Thus there can be even situations when NGOs actually dominate in the governance.
Environmental NGOs and activist groups in Latvia play different roles if one considers approaches they use, working methods and activities and thus environmental NGOs can act either as watchdogs or partners or both. Here author sees public participation as somewhat institutionalised form of civic participation i.e. using opportunities provided by Latvian legislation and various institutions such as submitting comments to draft legislation, policy document or taking part in a public hearing meeting. However environmental activism is seen by author as a more pro-active form of activities and creating of new opportunities and approaches in environmental governance. Notwithstanding the focus on environmental governance of Latvia, author stresses that also broader picture of development of civil society and public participation traditions in Latvia should be considered.

Materials and methods

The paper attempts to review and analyse public participation activities of formally registered NGOs and civic initiative groups (activist groups) or activists that are involved in environmental issues and define their role in Latvian environmental governance. By officially registered NGOs author understands officially registered societies or foundations that are registered according to Associations and Foundations Law and whose aim (or one of aims) is related to environmental protection. By environmental activist groups author understands either so called NIMBY ("not-in-my-backyard") groups, who oppose certain investment projects that are seen as harmful to environment, public health or in other way negatively affecting the quality of life, or they can be civic initiative groups that aim to preserve certain natural habitats, natural resources etc. Author also aims to identify in which stages of environmental governance public involvement is most influential and with highest added value. It also reviews methods they use and looks to their interaction with other target groups such as public administration institutions, local governments and businesses.
Author uses desk research studying academic literature (academic books, journals, critical reviews), as well as applied literature such as handbooks, manuals, presentations from meetings, policy papers, reports, news articles and national legislation such as regulations, laws and international conventions. In empirical research the author uses interviews, case-study research and action research methods to examine how NGOs are using participation opportunities secured by national legislation and whether institutional system promotes or hinders that. The author also attempts to analyse which participation methods environmental NGOs use, what are the key factors that determine and influence efficiency of public participation in environmental issues and environmental advocacy.
There are several limitations to methods applied that limit the scope of research to some extent. It has been difficult to use quantitative research data during research as for environmental NGOs, there is no separate register thus it is difficult to assess the number of NGOs that are involved in environmental issues. According to data from Lursoft data base, there are 12,441 societies and 889 foundations registered in Latvia [6], however it is not clear how many of those are dealing with environmental issues. When Ministry of Environment organised annual environmental forums, there were not more than 100 participants. The data about number of environmental NGOs is also not available at Civic Alliance – Latvia which "*advocates the interests of Latvian non-governmental sector on the state level cooperating with ministries and inter-governmental councils and providing expertise and recommendations in the law-drafting process*" [7]. Furthermore there is no register of informal action groups although they also play certain role in environmental governance. Thus author based analysis and discussion as well as conclusions on qualitative research

methods i.e. case studies, interviews and professional knowledge connected to author's long-term engagement in activities of environmental NGOs.

Results and discussion

Public participation is often viewed as activities carried out by NGOs who attempt to influence policy processes at national or local level, but it can also be related to local inhabitants taking part in a public hearing meeting or writing a protest letter to their government. Thus when discussing public participation in environmental governance, one should first clarify terms and definitions. First of all it should be stressed that public participation doesn't imply participation of masses in decision making processes thus distinction should be made between "public at large" and "organised public". Organised public is seen to be composed of NGOs, associations and other types of civic groups who have certain aims and who use various methods in achieving those.

While doing research, author reviewed and explored deeper various concepts of NGOs, their interactions with other stakeholders and their potential role in national environmental governance. What are environmental NGOs and what is their constituency? Do only formally registered NGOs count or also informal groups composed of concerned people and activists should be seen as NGOs and stakeholders? Are those organisations to be seen as representatives of public or they are rather partners to public institutions and businesses? These are some of the research questions that author attempted to find answers to.

When defining „the public", the Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (Aarhus convention) makes a reference to national legislation or practice mentioning that it may include one or more natural or legal persons, their associations, organisations or groups [8]. This however is also rather vague concept when it comes to explaining public participation and defining the place for NGOs in it. Another way of defining scope of NGOs is to talk about „the public concerned". According to Aarhus convention "the public concerned" involves:

- The public **affected or likely to be affected** by environmental decision-making,
- The public **having an interest** in environmental decision-making;

The Convention further explains that NGOs promoting environmental protection and meeting any requirements under national law shall be deemed to have an interest and thus should be also considered as "the public concerned".

National Environmental Protection Law stipulates that „*The public has the right to participate in the taking of such decisions and the preparation of such planning documents, also the preparation of amendments therein, which may affect the environment. The public may implement this right before the relevant decision or document has been taken*". The Law also specifies (Section 6) that "public" could be a private person, associations, organisations and groups of persons. Thus also activist groups are recognized as stakeholders that have right for participation in decision-making and decision-taking processes. Also looking from legal point of view, it has to be stressed that there are no criteria set for NGOs and no separate NGO recognition procedure introduced in the country, and there is no need for it [9]. National legislation in Latvia provides wide rights in access to environmental information, participation and legal protection.

The concept of governance in very general terms distinguish between governments (state), businesses (market) and civil society as three main categories of actors that interact with each other. However scholars emphasize that civil society should not be seen as a coherent group, but that it is comprised of non-state, non-economic actors. However when it comes to environmental governance, environmental policies and their implementation, scholars and researchers highlight NGOs as one of the key target groups. Some researchers point to NGOs as one of important groups that reflect public interests [10], NGOs as representatives of more

active part of society, who is interested in involvement [11] or providing voice for marginalised populations and minority views [2]. State Chancellery of Latvia sees NGOs as representatives of the society who have joined together in NGOs to protect their interests and voice their opinion have better opportunities to influence the decision-making process [11]. However some scholars would stress the expertise of NGOs and their ability to be partners to national governments [2] thus NGOs can play various roles – being a watchdog, a partner or both.

It also has to be highlighted that environmental NGOs do not form a coherent group – they might have diverse or even conflicting approaches or methods in their activities. Some scholars point out to various clusters within NGO community i.e. that in the first cluster there are environmental NGOs that are highly professional and in other cluster is composed of NGOs that take action on behalf of their members and play role at the local level [2]. Another approach of categorising NGOs and activist groups is by looking at their tactics. There can be two tactical poles identified: success-oriented versus value-oriented NGOs. The first group of NGOs involves those organisations and activists who prioritise the achievement of specific aims, such as defeating a specific government plan or business proposition. However the latter group of value oriented NGOs are more interested in intentions and in the expressions of specific values and way of life thus here their aim often is to set a good example, to change values and people, than to restrict the actions of others [12].

All in all the results of desk research suggest that there should be careful distinction made between "public participation" and "NGO participation", because NGOs can play various roles and have various functions or identities. Although they might overlap, the author considers that NGO functions and those of activist groups can be categorised in following way:

- **Representation:** representing concerned public, groups or public at large; representing and defending interests of nature;
- **Partnership:** cooperating with public authorities and/or local governments in environmental governance, including awareness raising on environmental issues;

As for representation function it has to be considered that although NGOs are part of public, their involvement can't replace wider public participation, because each NGO has certain agenda that is connected to the goals of that specific NGO. Public participation measures should be broad enough in order to allow various interests to be represented, not only interests of certain groups [10].

The function of NGOs being partners is also often mentioned both in national legislation as well as national strategies. Latvian Environmental Policy strategy for 2009-2015 has to be considered as major policy document of national environmental governance. The strategy outlines that one of the principles integrated in the strategy is „*public information and participation principle*", meaning that environmental institutions promote public education and information, listen to and evaluate public opinion. Similarly also other national legal acts and strategies often emphasize „partnership principle". Regional Development Law stresses the importance of partnership principle – cooperation between public administration institutions, international institutions, planning regions, municipalities, NGOs and entrepreneurs. Thus regulatory framework assigns different roles to NGOs.

The results of empirical study however alert that often there are difficulties in drawing a clear line between various interest groups thus it causes a challenge in trying to look at environmental NGOs, activist groups and environmental activists on one side and other target groups or actors on the other side. Specific target groups or interest groups are often used when discussing specific environmental issues and describing positions of various actors. Most common categories are government institutions (national, local), businesses, media etc. NGOs themselves would often split target groups into smaller ones and map specific actors

along with their power – that is a common approach during planning of certain activities or NGO campaigns.
An issue worth mentioning here is that there are people and groups with so called 'double identities' i.e. representatives of businesses or public administration are joining NGOs or forming NGOs themselves to undertake certain activities. In some cases these 'double identities' can be natural i.e. an public official might also be an active citizen in his or her town and take part in a public hearing organised as part of environmental impact assessment process. For example, during several public hearing meetings about proposed new territorial plan of Jūrmala that took place in January of 2011 in Jūrmala town, also several publicly well-known politicians, officials and businessmen participated there and expressed their opinions. Within civil society this is to be seen as normal development when in different occasions one person can play different roles i.e. a person can be environmental activist, but at the same time it can also a consumer, parent, employee etc.
However there are cases when public authorities, local governments or businesses get involved in establishing NGOs and pursue some of their interests through these types of organisations. These activities can be motived both by some financial opportunities or benefits i.e. in situations when public grant money is available to NGOs, but not to public institutions or businesses, then these institutions might be interested in establishing and NGO that would formally fulfil the role of a project partner. Another reason for representatives of other target groups to establish an NGO might also be related to gaining a platform for defending their interests because NGOs are widely recognized as actors or representatives of public whose opinion should be taken into account. If quantitative research methods would be applied in the research, it would not possible to make a distinction between genuine NGOs and those that are of formal nature and serve business interests for example. Thus using of qualitative research methods are fully justified here.
Further author reviews general institutional system supporting public participation in environmental issues in Latvia i.e. both public participation opportunities that are ensured by national legislation as well as institutions that facilitate participation. Still only major aspects are mentioned here. Environmental Protection Law stipulates that "*When developing a policy planning document and draft regulatory enactments, the developer shall evaluate in the annotation of the planning document or draft regulatory enactment the impact thereof on sustainable development and the environment. The strategic environmental impact assessment shall be performed for draft policy planning documents if it has been specified in the regulatory enactments regulating the environmental impact assessment."* [13] Also other environmental acts and regulations lay down number of requirements with regard to public participation such as Law on Environmental Impact Assessment, Law on Pollution etc.
When it comes to institutional structures, Environmental Protection Law also defines the role of Environmental Consultative Council (ECC) – that is a council consisting of 20 environmental NGOs that wish to contribute to environmental policy making through identifying problematic issues, taking part in policy planning and evaluation of implementation. The Law [13] states that "*The Ministry of Environment shall financially ensure the operation of the Environmental Consultative Council, as well as co-operate with the Environmental Consultative Council, by submitting drafts of regulatory enactments regarding the environment for discussion and the submission of proposals and shall be involved in the preparation of documents, which are associated with the environment*." Also Aarhus Convention III National Implementation Report emphasizes the importance of Environmental Consultative Council stating that „*To promote cooperation between public authorities and public, the ECC was established, which is comprised of representatives of 20 NGOs; NGOs are also represented, e.g. in the Councils of Specially Protected Nature Territories, Agricultural and Environmental Protection, Forest Consulting, River Basin*

Management and Radiation Safety, as well as in the Biologic Safety Coordination Centre."
Thus the institutional structures are seen as crucial in facilitating public participation – both representatives of environmental NGOs and public administration have acknowledged that during interviews.
As next author seeks to find answers to questions on what is the role that environmental NGOs and activist groups play in environmental governance looking at various cycles of environmental governance – issue identification, policy planning, implementation and monitoring. Looking from legal point of view environmental governance in Latvia is regulated by Environmental Protection Law. This Law states that the goal of it is to ensure the preservation and recovery of the quality of the environment, as well as the sustainable utilisation of natural resources. Does public participation and NGO involvement help achieving goals of environmental governance? Further author also assesses whether there are significant differences in contributions between officially registered NGOs and informal activist groups in the context of environmental governance.
In the stage of issue identification both environmental NGOs and activist groups play significant role. Environmental NGOs are providing feed-back to implementation of various environmental regulations, identify gaps in the system and alert other actors about issues. Participation structures such as ECC, advisory boards or working groups facilitate NGO involvement, provide certain platform and allow regular interaction with Ministry of Environment and its subordinated institutions, as well as other line ministries. Activities of environmental NGOs are not always bringing immediate or visible results. There have been tireless efforts by some nature protection NGOs to raise issues about sustainability of forest management or preservation of natural habitats in agricultural areas however those have not resulted in substantial change in the policy implementation. At the same time activist groups can expose some issues. For instance big clean-up actions have helped to foster public discussion about waste management issues and packaging system or fierce protests against building of large-scale pig farms have sparked debates about precautionary measures and environmental standards, as well as opened debate among other actors on how much public participation results should be taken into account and who is entitled to participate.
Another example of role of environmental activism is the campaign on creation of specially protected nature area in Grey Dunes in Pāvilosta. The group of local activists ensured an indefatigable campaign involving many other actors and trying various creative approaches to attention of the public, public officials and celebrities to the natural habitat of that particular grey dune through organising clean-up actions, exhibition, media events, submitting expert statements, organising expert visits and even organising a concert. As a result the Cabinet of Ministers approved the status of that area to be a natural reserve. This is an example when environmental activism has resulted in a substantial impact in the context of environmental governance.
In the stage of policy planning and looking for solutions mostly environmental NGOs play role by providing comments to draft legislation, reports and policy documents. On one hand this stage can be seen more as a routine work i.e. ECC prepares submissions and comments on various documents prepared by Ministry of Environment or other ministries. However it has to be noted that there are 20 environmental NGOs in the EEC and less than half of them are active in environmental policy work. Thus there are actually only handful of environmental NGOs that regularly follow environmental policy and its implementation. This work is mostly voluntary. Lack of capacity often prevents NGOs to look to environmental governance in a more strategic way. Representatives of environmental NGOs have pointed out on number of occasions and during interviews that sometimes they feel they are "extinguishing fire" i.e. preparing comments and opinions on papers that are open for comments and try to meet deadlines instead of looking to issues from more strategic point of

view. As for activist groups, their involvement is rather poor in this stage. Even though some activist groups might fierce-fully oppose building of pig farms in their neighbourhood and organise protest actions, they might not show any interest in amending legislation to have stricter rules and regulations.

When it comes to describing NGO role in implementation of environmental regulations, the State Administration System Law states that "*public authorities have the right to transfer certain tasks, along with allocated financing to NGOs*". For example Engure Lake Nature Park is managed by an NGO [9]. Similarly environmental NGOs are involved in development of nature protection plans, as well as in working groups for development of policy documents an regulatory enactments" [9]. In the stage of implementation NGOs and activists can also act as partners to state environmental institutions. For instance State Environmental Service may involve public environmental inspectors – persons authorised by the State Environmental Service in environmental control. In 2008 around 145 public environmental inspectors participated in inspector's training, whereas in 2009 – there were 60 persons. These public inspectors often are linked to environmental NGOs or are seen as activists concerned about preservation of quality of environment and their field of work has often been into controlling and preventing illegal angling and use of motorised vehicles in coastal protected strip area.

Situation however is slightly different with environmental monitoring. According to Environmental Protection Law „*The purpose of environmental monitoring shall be to specify the state of the environment, to evaluate the tendencies and perspective, to develop environmental policy measures and to evaluate the usefulness and efficiency of the previous measures*". Further the EPL mentions that "*Environmental monitoring shall be organised and performed by the State and local government authorities, and merchants in accordance with the requirements of the regulatory enactments regarding the environment*". Thus environmental NGOs are not explicitly considered as important stakeholder in this part of cycle of environmental governance unless they would be contracted to do certain job. Environmental monitoring is considered to be primarily a function of a state. Still there are also some exceptions and some environmental NGOs are maintaining data basis and systematically collecting monitoring data. For example society "Latvijas Ezeri" ("Latvian Lakes") regularly collects data about state of environment of various lakes and maintains a data-base.

Conclusions

Author concludes that environmental governance in Latvia can be characterised as participatory. Public participation opportunities and NGO involvement are possible in all stages of environmental governance and NGOs and activist groups make use of those opportunities. Nonetheless limited NGO capacity can be a significant obstacle in providing continuous input and contribution to environmental governance.

When defining the role that NGOs and activist groups play, there are some differences between those groups. Although activist groups often are seen by other actors as the ones denying everything and eternal opponents, their activities can actually contribute to environmental governance in a meaningful way, though sometimes indirectly rather than directly. Thus activist groups should not be overlooked in their role in environmental governance. Environmental activism is more likely to play role in problem identification stage and providing feed-back to implementation of national policies and legal acts. Sometimes activist groups can bring issues into political agenda and thus provide platform for other actors, including environmental NGOs to step in and through participatory approach discuss possible solutions.

On other hand institutionalised public participation carried out by environmental NGOs is crucial in all three stages of environmental governance, including proposing solutions and

planning policies. Official environmental NGOs are also more likely to be seen also as partners to government institutions, more reliable as a source of information or expertise and NGOs can provide support when stricter regulations need to be approved or helping with expert knowledge and provide feed-back about implementation of certain environmental regulations. In short environmental NGOs are seen as more reliable counterparts versus activist groups whose involvement is somewhat more ad-hoc.

An institutional system facilitates public participation i.e. there might be participation opportunities provided by national legislation but without structures in place, they might not be utilised. For example the functioning of Environmental Consultative Council composed of 20 environmental NGOs is outlined in the Environmental Protection Law and it facilitates involvement of environmental NGOs in environmental policy making. Similarly also specific requirements laid down in national legislation about certain forms of public participation facilitate public involvement i.e. a requirement to organise public hearing meetings is something that mobilises NGOs and public at large to provide feedback about environmental impacts of certain investment project or policy paper.

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ASSESSMENT OF FISH HEALTH STATUS UNDER LONG-TERM WATER POLLUTION: VYGOZERO RESERVOIR, NORTH-WEST RUSSIA

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Abstract. *Environmental pollution and its effects on the health of aquatic ecosystems is a great problem that has been studied intensely in the last years. The Vygozero reservoir is one of the largest water bodies of the Karelian Republic. Its ecosystem has undergone significant changes since the 1930s mainly due to anthropogenic influence from the development of pulp and paper mill industry leading to accumulation of toxic contaminants and eutrophication. At present, the water body has been shown to be also polluted by hydrocarbon products and heavy metals. Among the huge changes in Vygozero ecosystem is the decrease of some fish populations and partial loose of commercial fishing importance. Despite the obvious changes in fish population the chronic biological effects of the Vygozero reservoir pollution on fish organism are poorly studied. This study is concerned with the evaluation of pollution influence on fish health status and establishment relation between fish health and environmental quality. The parameters selected for this aim were the occurrence of gills, liver and kidney alterations, as histopathological changes are widely used as biomarkers in the evaluation of the health of fish exposed to contaminants. Our findings confirm chronic pollution of the Vygozero reservoir. Histological analysis of fish tissues revealed a variety of progressive, regressive, inflammatory, circulatory disturbances and neoplastic changes. Observed histological alterations indicate that organism of fish from Vygozero reservoir responses to the impaired environment quality. Revealed histopathologies are sings of metabolic disorders, immunity suppression, compensatory reactions development and functional abnormalities in vital organs of studied fish. The results of the study correspond to the prior research devoted to ascertain tissue changes in different fish species taken from an area with chronic multiple anthropogenic impact. So it can be concluded that histopathological lesions are result of long-term effect of toxic xenobiotics.*

Keywords: *gill, liver and kidney histopathology, pollution.*

Introduction

The Vygozero reservoir is one of the largest water bodies of the Karelian Republic. Its ecosystem has undergone significant changes since the 1930s mainly due to anthropogenic influence from the development of pulp and paper mill industry leading to accumulation of toxic contaminants and eutrophication [1]. At present, the wastes discharging to the water body has been shown to be polluted by excessive concentrations of hydrocarbon products, ammonia, heavy metals [2,3]. The increase of anthropogenic load on Vygozero ecosystem determines the necessity of investigations devoted to adverse effects of pollution and its potential risk for aquatic ecosystems.

Deleterious effects of the water body pollution have already been detected on populations of different organisms inhabited Vygozero reservoir [3]. The decrease of some fish populations and partial loose of commercial fishing importance are among of the huge changes in Vygozero ecosystem. It is a well known fact that biochemical, cellular, tissue, and organism modifications underlines different types of ecosystem changes; however the chronic biological effects of the Vygozero reservoir pollution on fish organism are poorly studied. The exposure of fish to chemical contaminants induces a number of modifications in different organs, particularly gills, liver and kidney. Therefore a wide range of histo-cytological alterations in fish have been developed and recommended as biomarkers for monitoring the pollution [4-6]. This study is concerned with the evaluation of pollution influence on fish health status and establishment relation between fish health and environmental quality on the base of histological examination.

Materials and methods

In the autumn of 2007 and 2010 a total of 26 individuals of bream (*Abramis brama* L.), roach (*Rutilus rutilus* L.), perch (*Perca fluviatilis* L.) and sander (*Stizostedion lucioperca* L.) were caught. Sex, standard length, and weight of all fish were recorded. Fish were dissected directly in the field, and the target organs (liver, kidney and gills) were quickly removed. Histological techniques were performed according to Bucke [7]. After fixationin Bouin's solution for a week at room temperature, tissues were dehydratedand routinely processed for paraffin embedding. Then, 5–7 mm thick sections were made in a rotary microtome and stained with hematoxylin and eosin. Tissues were screened for a variety of histopathological features and lesions under 50, 100, 200 magnification.

Results

A variety of histopathological changes were found in all organs examined. The gill, liver and kidney structure of species used in this study are well known and similar to those in other teleosts (Fig. 1a, e, i).

The microscopic structure of almost all investigated fish showed similar gill lesions with variable severity. In the gills, epithelial cells hyperplasia, marked by proliferation epithelium on the tips of the secondary lamellae (Fig. 1b) and interlamellar zones, epithelial lifting, accompanied by the enlargement of the intertissue space between the epithelium and underling pillar cells, and hyperemia of blood vessels were the predominant alteration. Focal areas of necrotic epithelial cells found at the base of the respiratory lamellae (Fig. 1c) as well as necrosis of respiratory epithelium associated by full destruction of respiratory lamellae were also a very common finding.

Some fish from Vygozero reservoir shows cellular vacuolization and hypertrophy, lamellar shortening and clubbing, aneurisms and local hemorrhages with rupture of epithelial cells (Fig. 1d), intravascular breakdown of erythrocytes, eosinophilic deposits and mucus secretion. Rarely inflammatory reactions, marked by infiltration of the inflammatory cells, and fibrosis, resulted in partial destruction of filaments and gills function loss, were revealed.

Another kind of gill pathology was induced by parasite invasion. Several kinds of endo- and ecto-parasites infesting studied fish gills were observed. The most common includes unspecified microsporidia and ciliates. Ciliates usually did not elicit any visible host response, while microsporodia led to the formation of xenomas – hypertrophied host cells which contain spores and other developmental stages of parasite. Usually xenomas induced cellular hypertrophy, and as nuclear fragmentation, organelles changes others structural alterations.

The microscopic structure of fish liver also shows a number of injuries. In the liver of fish from Vygozero reservoir necrotic lesions, indicated by pyknotic hepatocyte nuclei, focal and single cell necrosis (Fig. 1f), were more common than other pathologies. In several fish degenerative changes also include appear of vacuolated cells, characterized presence of large lipid vacuoles, which usually occupied the whole cell and displaced nuclei to the periphery, and cystic degeneration. Many fish from Vygozero reservoir also exhibited inflammatory alterations, judged by macrophages aggregates and inflammatory cell infiltration around blood vessels, hyperemia of blood vessels and erythrocytes destrcution.

Some studied fish had sings of liver neoplastic changes. Affected hepatocytes had features of varying degrees of cellular pleomorphism, nuclear atypia, high mitotic activity and abnormal architecture. Presence of non-neoplastic proliferative changes, represented by small islands regenerating hepatocytes, which were markedly basophilic and lacked cytoplasmic vacuoles, was also seen in fish (Fig. 1h). In a few fish small foci of hemorrhages, thickened walls of blood vessels and initial stage of thrombus formation were revealed.

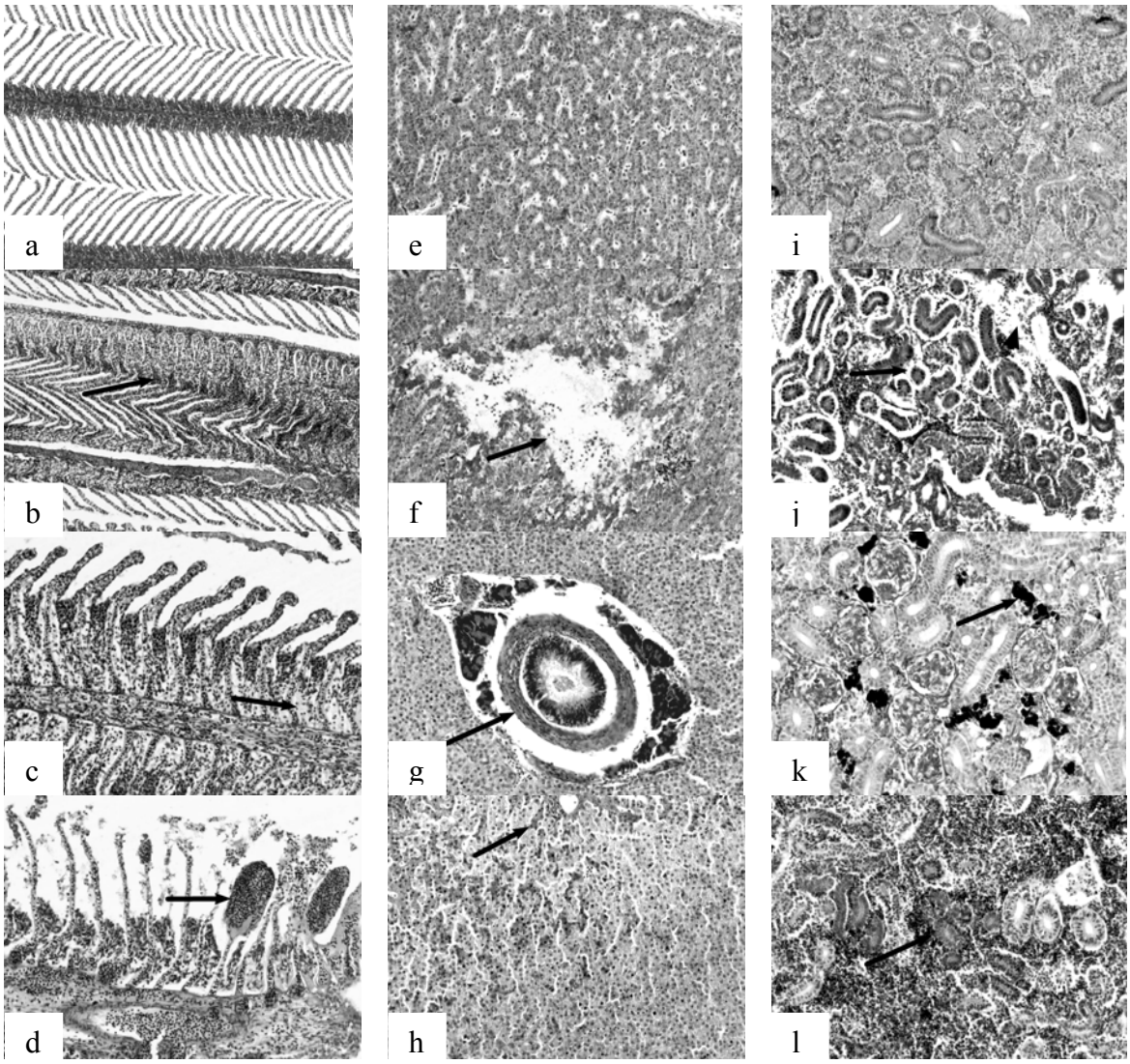

Fig 1. **Histological sections of gill, liver and kidney of fish from the Vygozero reservoir (H&E):**

(a) Gill tissue without lesions, x100; (b) epithelial hyperplasia (arrow), x100; (c) necrosis of epithelial cells (arrow), x200; (d) aneurisms (arrow), x200; (e) hepatic tissue without lesions, x200; (f) necrosis area (arrow), x200; (g) bile duct fibrosis (arrow), x200; (h) regenerative islands of hepatocytes (arrow), x200; (i) kidney tissue without lesions, x200; (j) foci of interstitial tissue necrosis (arrowheads) and detachment of epithelial cells from the underlying tubular basement membrane (arrow), x200; (k) melanomacrophage centers (arrow), x200; (l) developing nephrons (arrow), x200

The bile ductules of studied fish were frequently damaged. Mild to moderate bile ducts fibrosis and necrosis of epithelial cells, evidenced by the presence of epithelial desquamation and small amounts of debris, was frequent enough (Fig. 1g).

Another pathology observed in the liver of Vygozero fish was parasite invasion. Usually infected fish contain from 1 to 3 parasite cysts, which induced inflammatory connective tissue proliferation.

In the posterior kidney of fish alterations were observed in all segments of the nephron, the interstitial tissue, the vascular system and the immune system. The most consistently observed histopathologies in interstinal tissues were hemorrhages, foci of necrosis (Fig. 1j), and

increased number of macrophages aggregates with two types of pigments (melanin and hemosiderin) (Fig. 1k). Such pathologies as blood vessel hyperemia, thickened walls of blood vessels, breakdown of erythrocytes, fibrosis of interstitial tissue, appearance of lipid cells, and development of granulomas and new nephrons (Fig. 1l) were also a common finding.
Among the signs of glomerular injury, mesangial cells proliferation and capillary dilation were the most common, while glomerular 'hyalinization' and shrunken glomerular tuft with dilation of Bowman's space was observed quite rare. In studied fish species glomerular necrosis was also frequent enough.
The tubular effects include detachment of the epithelial cell form the underlying basement membrane (Fig. 1j), debris and eosinophilic mass accumulation in tubular lumina, fibrotic proliferation around tubules, epithelial cells necrosis, vacuolization and nuclear piknosis. It should be noted that all mentioned pathologies were focal or even single.
In kidney of several fish parasite cysts and unspecified myxosporea in renal collecting ducts were also observed.

Discussion

This paper presents the results of gills, liver and kidney histopathological investigation of fish from Vygozero reservoir. Being among the first organs to be affected by contaminants and very sensitive to changes, gill, liver and kidney, are important indicators of fish health and, therefore, environmental pollution [8-10].
The high incidence of histological alterations in the gill, liver and kidney is an evidence of the poor environmental quality. The types of histopathological lesions observed in this study indicate that fish from Vygozero reservoir respond to both direct toxicant effects of contaminated water and sediments and secondary stress effects caused by factors such as parasitism. Most of the histopathologial alterations observed in the present study (e.g. hyperplasia and lifting of epithelial cells in gills; hepatocellular necrosis, vacuolization and cystic degeneration in liver; glomerulonephritis, haemorrages and necrosis in kidney, etc.) could be interpreted as a nonspecific response to stress and are described in fish exposed to a wide spectrum of pollutants.
Thus most of the gill structural modifications found in this study were previously reported for many unrelated toxicants such as heavy metals [11, 12], pulp and paper mill effluents [13, 14], crude oil [15], excessive ammonia concentrations [18, 19]. A number of investigations have showed that many of observed liver alteration, e.g. focal and diffuse vacuolar degeneration of hepatocytes, foci of necrosis, regenereation and inflammation, hepatocytes with piknotic nuclei, etc., can be a result of fish exposure to a variety of different chemical compounds, such as crude oil, pulp and paper mill effluents, excessive ammonia concentrations, heave metals and complex environmental pollution [9, 12, 14, 15, 16, 18]. In the kidney, different signs of tubule and glomerular degenerations, developing nephrons and macrophage aggregates were also described in fish exposed to heavy metals [12, 17], excessive ammonia concentrations [18], effluents of pulp and paper mill [14], and mixed environmental contaminants [9, 20]. Thus, all of known pollutants of Vygozero reservoir could induce revealed histopathological alterations in studied fish.
As some parasites of fish are sensitive to environmental changes, they can also be useful as biomarkers of environmental health [21, 22]. Ectoparasites (e.g. gill ciliates) are good examples of this effect since they intensity or prevalence increase with oil pollution, pulp and paper mill and industrial effluents [14, 21-25]. On the whole, observed abundance of the parasites coincided with pathological changes on the one hand suggest prolonged exposure and on the other hand confirm the fact of the reservoir pollution.
Revealed structural changes in gills, liver and kidney testify that environmental changes induce fish organism response. And there are two main types of structural changes: one is

direct toxic effect of the pollutant leading to tissue degeneration and necrosis, and the other is the development of compensatory mechanisms to deal with the stressors. Thus, such pathological changes as epithelial hyperplasia, hypertrophy, and lifting are considered as defense mechanisms, as they increase the distance between external environment and the blood and thus serve as barrier to the entrance of xenobiotics [8, 26]. However development of such alterations also leads to decrease of total diffuse surface and oxygen uptake, and, therefore, hypoxia. So hepatic degeneration and necrosis of fish liver partly may be due to oxygen deficiency as a result of the gill changes in the gill surface area.

Our findings demonstrate strongly that fish of the Vygozero reservoir were under long-term chronic pollution as much as accidental exposure. Such pathologies as aneurysm, hepatocellular vacuolization, new developing nephrons and swelling of tubular epithelium are known to be an acute response of organism. At the same time, the presence of epithelial hyperplasia and fibrosis in the gills; fibrosis and tubule degeneration, coupled with necrosis in the kidney; and fibrosis of bile duct, necrosis, vacuolization and cystic degeneration in the liver indicates that studied fish are exposed to long-term chronic pollution.

Summary

Histological alterations indicate that organism of fish from Vygozero reservoir response to the impaired environment quality. Revealed histopathologies are sings of metabolic disorders, immunity suppression, compensatory reactions development and functional abnormalities in vital organs of studied fish. The results of the study correspond to the prior research devoted to ascertain tissue changes in different fish species taken from an area with chronic multiple anthropogenic impact. So it can be concluded that histopathological lesions are result of long-term effect of toxic xenobiotics.

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