REZEKNE HIGHER EDUCATION INSTITUTION
INSTITUTION
FACULTY OF ENGINEERING

ISSN 2256-070X

ENVIRONMENT. TECHNOLOGY. RESOURCES

Proceedings of the 10th International Scientific and Practical Conference
June 18-20, 2015

VOLUME II

Rezekne
2015

ENVIRONMENT. TECHNOLOGY. RESOURCES: Proceedings of the 10^{th} International Scientific and Practical Conference June 18-20, 2015. *Volume II.* Rezekne: Rēzeknes Augstskola, 2015. p 346.

Recommended for publication by the Scientific Council of Rezekne Augstskola on June, 3^{rd}, 2015.

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II

ENVIRONMENT AND RESOURCES

CONTENT

Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 13-19

Sustainable Development Perspectives for Latvian Regions

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Abstract. **Regional economies is a relatively young branch of economics, whose theoretical aspects started to develop in the 20s and 30s of the previous century, but gained vivid manifestation in the EU Regional policy. Since the Rome Treaty (1957), the need for a coordinated community solution to regional problems and the correction of regional imbalances was also recognised in EU political documents. The end of the twentieth century was the beginning of important international political processes marked by the start of a new way of thinking. This new way was sustainable development. Sustainable development is a concept that has to combine economic growth with such a use of natural resources that benefits the society as a whole. The long-term development has three dimensions: environmental, economic and social. In this paper, the attention will be paid to relationship between these dimensions and the regional development.**

The aim of this paper is to take a closer look at the consideration of a new viewpoint, as it may seem, related to well-known things that deal with such economic concepts as regional development and sustainable development and evaluation of specifics of sustainable development in Latvian regions. To achieve the aim, the following tasks were selected: to examine the theoretical background and regional development preconditions of sustainable development; to analyse the present specifics of Latvian regions in the context of sustainable development; to consider future developments from the viewpoint of facilitation of sustainable regional development. The following research methodology was used: literature review, graphical method, focus group discussions and logically constructive approach – for making judgements and result analysis; synthesis method – to combine the elements in a unified system; social research methods – to obtain the primary information and to carry out its verification. Conclusions: the main reasons for misbalanced regional development are the differences in employment, levels of income and investment. The research proposes solutions to promote balanced regional development.

Keywords: **regional development, sustainable development, economic indicators.**

I INTRODUCTION

The Baltic region belongs to the regions that develop very quickly thanks its place at the crossroads of international trade and therefore attracts a considerable interest in business environment that should be used appropriately. The East European countries, including also Latvia, regained independence only in the end of the 20th century, and were forced to get involved into an inexorable competition. Latvia as a comparatively small country, possessing not considerable natural resources, is obliged to make use of all its intellectual resources, knowledge, human capital, and innovations to be able to compete in the global world and provide a sustainable development.

The adequate national regional policy becomes formed in Latvia, and it is aimed to create a balance in development levels all over the territory of the country, taking into consideration the basic principles of the regional policy of the European Union that defines the general framework of creation and implementation of regional policy in the Community.

The regional policy of the European Union is based on such values as *solidarity* and *cohesion.* In the TITLE XVII – Economic and social cohesion in Consolidated Version of the Treaty Establishing the European Community we can read next "In order to promote its overall harmonious development, the Community shall develop and pursue its actions leading to the strengthening of its economic and social cohesion. In particular, the Community shall aim at reducing disparities between the levels of development of the various regions and the backwardness of the least favoured regions or islands, including rural areas" [1]. A successful regional development may be achieved, when approach to it takes place through a complex and aimed to sustainability process.

Sustainable development has been defined in many ways, but the most frequently quoted definition is from Our Common Future, also known as the Bruntland Report: "Sustainable development is

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.265

development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [2]. It is generally accepted that there are three dimensions or pillars of a sustainable development: environmental or ecological, economic, and social and cultural.

The environmental or ecological pillar is related to substitution of non-renewable resources with renewable resources, to preserving of a healthy natural environment, providing of physical and intellectual health. The economic pillar has to provide economic growth, efficiency, stability, development, welfare, not forgetting at the same time about protection of environment, because exactly the environment forms the basis of support for other pillars. And, lastly, the social and cultural pillar has to provide social peace, united society, social justice, opportunities of education and development for people. Actually, we can recognize that the aim of a sustainable development is the improvement of the quality of life, developing the economy (instrument, with the help of which we can achieve the aim) in the framework of the renewable ability of the ecosystem (environment as basis for sustainable development). There should be paid attention to the culture aspect, because under conditions of the globalisation it is, exactly, the one that is regarded as one of the most essential elements favourable to wholesome existence. The research of the European Union "Sustainable Development in the Multi-shaped World" accentuates even that a mutual existence of different cultures may create the basis for development, because it facilitates maintaining of traditions as the main link between the healthy past and the possible future [3]. A high level stable social and cultural system means that in the centre of sustainable development there are exactly people, having a healthy and productive life in harmony with the environment.

Therefore, to provide that the development might be sustainable, it is necessary to keep balance between economic, social and environmental pillars, increasing getting of benefits in the present in such way that also the following generations would be able to provide their needs. And in this context, the sustainable development is one of the main challenges of the EU. Accordingly, it is understandable that in the future, it will be impossible to solve the problems of sustainability without developed sciences, without a sufficient knowledge about environment, economy and social aspects, and also without active participation of the population able to manage the implementation of the principles of sustainability. It may be added that some authors have remarked that the viewpoints related to the growth and development have changed. The new paradigm of sustainable development is based on the following preconditions:

1. the goal of viable, long-term growth;
2. conserving resources in production through energy efficient technologies and dispersed production centres of lesser scale;
3. a shift towards alternative energy sources, recycling and conservation of resources
4. the assumption that humans and the environment are mutually independent, acknowledgment that resources are exhaustible and often irreplaceable, and that conservation is a principle for long-term viability.

Sustainable development may be seen as improving the economy without undermining the environment of society [4].

Nowadays no one theory adequately or totally explains regional economic development, but we can say that the sum of different theories show as next important factors what promote development. This factors are: natural resources; labor; capital; investment; entrepreneurship; transport; communication; industrial composition; technology; size; export market; international economic situation; local institutional capacity; national, local and state government spending; development support schemes [4]. In different cases different factors has greatest weight. In our research we pay attention to relationship between the mentioned dimensions and regional development specifics. [4].

II RESULTS AND DISCUSSION

Sustainable development in Latvia and its regions, *proclaimed* to be oriented to the meeting of the needs today and to the ability to provide that the future generations can meet their needs, as well as to the keeping of the balance between economic, social and environmental pillars related to and depending on the actual social economic level and the tendencies of its changes, cannot be regarded as satisfactory and sufficient. It may be seen demonstratively, if the social economic situation in Latvia becomes compared with the developments and results achieved by other member states of the EU and its regions, as well as on the basis of a mutual comparison of Latvian regions.

In spite of continuous activities and regular measures aimed to achieve a higher economic growth and increase of the productivity, Latvia has, up to now, succeeded less than planned and ranks low among the other member states of the EU. According to the GDP per capita, Latvia in 2012, along with Poland, Hungary and Croatia, belonged to the countries, the GDP of which made less than 40 percent below the EU-28. The GDP per capita in Latvia in 2013 was 2 times lesser than in Netherlands, 1.9 times lesser than in Denmark and 1.8 times lesser than in Finland [12].

Similarly, the low labour productivity spread across eastern and northern Europe and being typical to the regions of Bulgaria and Hungary, to all Baltic States, to the regions of Poland and Romania, except the capital regions of Mazowieckie and Bucuresti-lifow, to four regions from the Czech Republic and two regions from Slovakia, makes lesser than 50 percent of the EU-28 average.

As it might be expected, the individual consumption, being related closely to the production level, was in 2013 in Latvia actually 1.7 times lesser than in Netherlands, Denmark and Finland.

As to the price level, the highest is typical to Denmark among the Member States, and it makes 42 percent above the EU-28 average. To other countries with the price levels more than 20 percent of the EU-28 average belong Sweden, Luxemburg, Finland and Ireland. The price levels in Belgium, the Netherlands, the United Kingdom, Austria and France are between 10 and 15 percent above the average. Italy and Germany have price levels of less than 5 percent above the EU-28 average. At the lower end of that table, may be found several Member States with price levels less than 40 percent below the EU-28 average: Latvia, the Czech Republic Slovakia and Croatia, followed by Lithuania, Hungary and Poland with price levels less than 50 percent. The lowest price levels – half the EU average and below – are typical to Romania, Albania and Bulgaria.

The economic, social and environmental development of every region depends on the density of population. In 2012, the EU-28 population density was estimated at 116.3 inhabitants per square kilometre. There were 117 NUTS 3 regions in the EU where the population fell. These regions were largely spread across: the Baltic Member States of Lithuania and Latvia; an arc in south-east Europe, starting in Croatia and moving through Hungary, Romania, Bulgaria and down into Greece; several inland regions of Portugal and Spain; and many eastern German regions. The biggest reduction of population (20.8 per thousand inhabitants per year) was registered in the Lithuanian region of Šiauliu apskritis, while Utenos apskritis was the only other region, which population declined by at least 20.0 per thousand inhabitants per year.

There were 481 NUTS 3 regions in the EU-28, where net migration during the period 2008-2012 was negative. These were spread across much of eastern Europe (particularly Bulgaria, Hungary, Poland and Romania), as well as across Latvia, Lithuania, eastern Germany north-eastern France, pockets of Spain and the southern and western regions of Ireland. The 14 NUTS 3 regions with the biggest negative crude rates of net migration featured 9 of the 10 regions contained within Lithuania. Population levels are also in decline across much in Bulgaria, Greece, Spain, Croatia, Hungary, Poland, Portugal, Romania and the Baltic Member States as a result of natural population decline – however, this development is often accentuated by net emigration, which has been particularly apparent in some regions following the financial and economic crisis.

The causes of the low position of Latvia among the other member states of the EU are sought in unbalanced development of the regions in our country. There are considerable disparities in social economic development between the regions. And these disparities turn out as being rather stable, without tending to diminish [10].

As the most unfavourable development factor has become the changes in the number of population (Fig. 1).

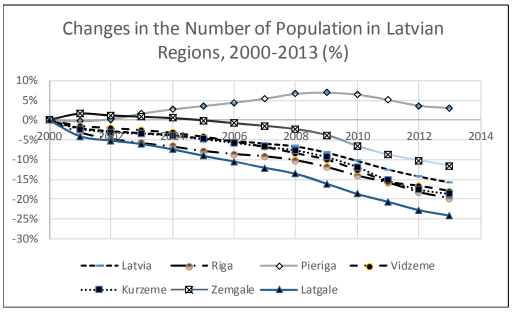

Fig. 1. Changes in the Number of Population in Latvian Regions, 2000-2013

As it is seen from the data in figure 1, during the period 2000-2013, Latvia has experienced a consequent gradual decrease in its population, having led to the loss of 15.9 percent of inhabitants in 2013. The situation in the regions differs. As to the proportion of the loss, Latgale has suffered mostly, having lost at the end of the period 24.2 percent of its inhabitants. Latgale is followed successively by Riga region (19.9 percent), Kurzeme region (18.6 percent), Vidzeme region (18.0 percent) and Zemgale region – 11.6 percent). The only region that has showed a small increase in the number of population (3.0 percent) is the Pieriga region. The changes in the number of population are related to the emigration and the migration to other regions of Latvia, mainly to Riga and Pieriga region. The departing of native locations becomes explained, for the most part, on the basis of impossibility to find employment at all, to find a suitable employment and because of insufficient wages. And, usually, there are departing the more skilled and better trained workers, with remaining of the less skilled, that results sometimes in appearance of unfavourable structural changes in both the labour force and the population [5].

The wages (Fig. 2), being mentioned as one of the main factors, having accelerated the diminishing of the number of population in Latvia, are comparatively low, as it was seen if compared with the wages in other countries of the EU.

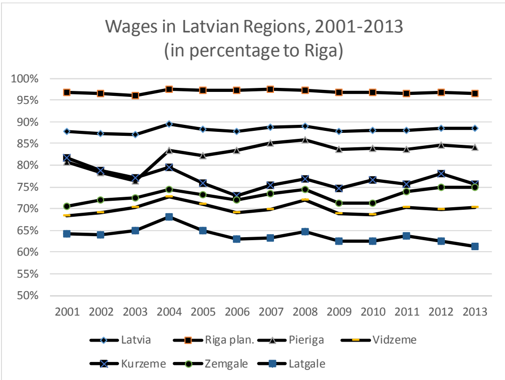

Fig. 2. Wages in Latvian Regions, 2001-2013

And being comparatively low as such, they show considerable disparities in Latvian regions. In comparison with the Riga region, the average of the wages fluctuates during the period 2001-2013: in Pieriga from 85.9 percent in 2008 to 82.3 percent in 2005, in Vidzeme – from 72.8 percent in 2004 to 68.4 percent in 2001, in Kurzeme – from 87.2 percent in 2003 to 72.9 percent in 2006, in Zemgale – from 75.0 percent to 70.6 percent in 2001, in Latgale – from 68.2 percent in 2004 to 61.4 percent in 2013. Such a rather low average of wages lets conclude that there is little place for savings.

At the same time, the income of the households depends mainly on the wages; therefore, as it may be expected, the distribution of the income has much in common with the level of the wages (Fig.3).

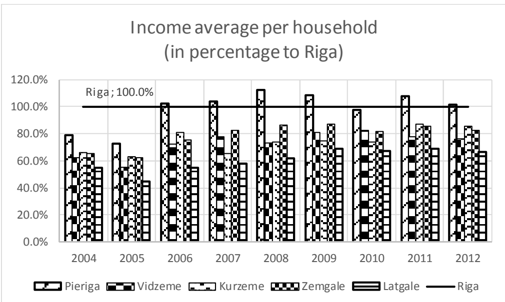

Fig.3. Income average per household

In comparison with the Riga region, the average of the income per household, during the period 2004-2012, has changed in Pieriga region from 112.6 percent in 2008 to 72.7 percent in 2005, in Vidzeme region – from 82.3 percent in 2010 to 55.6 percent in 2005, in Kurzeme region – from 86.8 percent in 2011 to 63.0 percent in 2005, in Zemgale region – from 87.3 percent in 2009 to 62.6 percent in 2005, in Latgale region – from 68.5 percent in 2009 to 44.9 percent in 2005. In all regions, the lowest level has taken place in 2005. Such disparities in the average of the income per household may turn out being critical for the families in the regions, where the average of the income per household is nearly two times or even by one third less than in the Riga region. Such families are subjected to the threat of poverty. To stand up to the poverty, people are seeking for additional work that, in its turn, may lead to the working of too long hours, to overstraining, and, as a result, to the changes in the health for the worse [13].

The development of the regions, the economic growth, being the basis of balanced and sustainable development, cannot be achieved without respective investments. However, as it is seen from the statistics, the distribution of the non-financial investments in Latvia is far from a desirable one (Fig. 4).

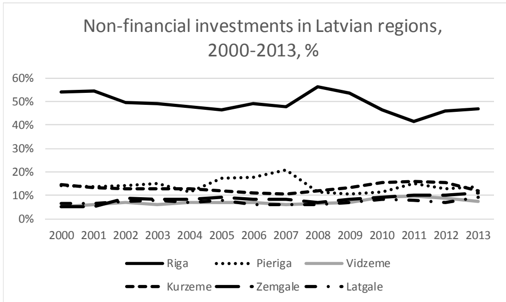

Fig. 4. Non-financial investments in Latvian regions, 200-2013

For the period 2000-2013, the proportion of investments received by Riga region, fluctuated from 56.4 percent in 2008 to 41.4 percent in 2011, by Pieriga region – from 21.1 percent in 2007 to 10.7 percent in 2009, by Vidzeme region – from 9.2 percent in 2010 to 5.1 percent in 2000, Kurzeme region – from 15.9 percent in 2011 to 10,4 percent in 2007, Zemgale region – from 10.8 percent in 2013 to 5.4 percent in 2000, Latgale region – from 9.4 percent in 2013 to 6.1 percent in 2006 and 2008. The biggest sum of investments Riga region received in 2008 – 3935.5 million Euros, the smallest in 2010 – 1576.2 million Euros. Respective sums in Pieriga region were: 1479.6 million Euros in 2007 and 417.4 million Euros in 2000, in Vidzeme region – 471.9 million Euros in 2006 and 150.2 million Euros in 2000, Kurzeme region – 840 million Euros in 2008 and 421.6 million Euros in 2001, Zemgale region – 580.7 million Euros in 2007 and 158.2 million Euros in 2000, Latgale region – 478.5 million Euros in 2005 and 193.6 million Euros in 2000.

Regional disparities and their negative impact on sustainable development in Latvia, being the subject of studies and researches for a long time, have led to discussions of different approaches and ways aimed to finding out of solutions how to overcome the unbalanced development in Latvian regions. The most discussed problems relate to what kind of historical, traditional and nowadays situations and circumstances have caused and continue to cause the present situation, being so unfavourable to social development in Latvia and, especially to its regions, and, naturally, what must be done to overcome this situation, being so unfavourable to Latvia's development. In these discussions, as preconditions, favourable to sustainable development of rural regions, turned out, among others in a rather vast complex, a developed entrepreneurship, a common methodological research approach to economic growth in Latvian regions, a distribution of funds in the regions according to the principle of fairness, a polycentric principle in attraction and distribution of investments in Latvian regions, an increasing role of local governments in formation of infrastructure, a growing employment and income of households facilitated by development of entrepreneurship [11].

The theoretical concepts, research results and discussions created the basis for finding of some conceptual approaches that may be taken as basics in further researches in development of regions in Latvia. To find out related to it priorities, there were carried out interviews with experts (Dr.oec. S. Keišs, Dr.oec. H. Jirgena, Dr.oec. M. Pelše, Dr.oec. Dz. Atstāja, MBA A. Vanags). The following topics were chosen and discussed: infrastructure, increase of household income, attraction of investments, initiatives of local governments, long-term planning, problems to be researched.

The infrastructure is a priority and an urgent problem that requires to be solved more in the interests of Latvian inhabitants all over the territory of the country. It is necessary to combine the local needs with others, for example with the *Rail Baltica*. At the same time, it must be taken into consideration that local governments have their own needs. It has been proposed that it would be advisable, in this context, to pay more attention to the polycentric development idea, however, it has remained on a too general discussion level, and, up to now, is without a sufficient answer. The specific of the needs of local governments require a well developed planning and honest distribution of funds, a suitable inventory and control mechanism. Much depends of possible structural reforms, change of social support system, and potential regional development with attraction of investments. And as the main aim there must be a simultaneous facilitating of entrepreneurship, involving of new enterprises, so increasing the employment and income of inhabitants, and, as a result, increase of tax revenues.

It is clear that development of infrastructure is related closely to welfare of people and income of households. With the increase of the wages in the country, the income will increase to a degree also in the regions. However, the fact that there will be a difference in the wages is unavoidable. It takes place also in other countries, but it is essential to decrease this disparity. It may be achieved, facilitating the entry of enterprises into regions, which produce with a higher added value, produce innovative products, facilitate tourism development in the regions, improving, adding to tourism supply choice, developing the entrepreneurship: with decreased taxes and long-term policy of entrepreneurship development, and with a favourable entrepreneurship environment. The present situation is far from facilitating of seeking for employment, if only it is possible to receive support and social support. An acceptable pension is necessary to provide that old people can leave their working place for the new generation. The money must be created, but not consumed.

As to the attraction of investments to regions, there is not to be expected that foreign investors will be interested in, except Riga, Riga area, Jurmala, Liepaja, Ventspils and, perhaps, Daugavpils. All is depending on businesspeople, seeking for opportunities to develop production objects with the aim to attract foreign investors or to sale the objects profitably. It means that local governments have to use every opportunity to apply their initiatives and resources, trying to find and keep qualified specialists. Further, attention must be paid to the problem that sustainable economic growth is based on strong, patriotic families. The problem of improvement of gene pool is not solved, respectively, with motivation of demographic situation facilitate directly for educated people and persons, being already tax payers (involved in social insurance system of the country). Therefore, it is essential to speak about it, how important it is to provide “rooting” of specialists in the regions. One of important ways there might be the cooperation with entrepreneurs.

It is important to orient the local government initiatives to diminishing of the gap between the administrative territorial units, receiving the lion share of support and the others, less developed territories of the counties. It may be facilitated by serious arrangements such as cooperation between the local governments, between the local governments and the ministries, and between the ministries. If the ministries will not be interested in to facilitate the activities of subjected enterprises in remote territories of the country, then it will be difficult to achieve a certain result. The balanced development of regions requires finishing of the started reform that, during the more than a ten-year period has remained unfinished. With planning coming from above, the initiatives from below must not be left understated. And they may find their place in patriotic upbringing, structural reforms, support to regional entrepreneurship, tax reliefs, cooperation with young, with entrepreneur, monitoring of the needs of enterprises, and actively work with the projects of the EU, related to increase of wages and building of infrastructure.

In the long-term planning, the principal task is to find ways, how to counteract the emigration and migration of population, leading to diminishing of the number of inhabitants, especially in the rural regions, to losing of the working force, the young going to foreign universities, mostly without aim to return to the native country. One of the ways in this context is to be sought in a considerate structural reform facilitating the attraction of investments for development of business in a long-term period, developing in the regions the ability to attract new, knowledgeable, wanting to work inhabitants, against offering a territory with clean air, water, picturesque and esthetical environment. An important role there may be played by differentiated reliefs for enterprise income tax, for example, on the basis: entrepreneurs > 100 km from Riga > 200 km from Riga.

To the tendencies that should be researched in the future to perceive the changes, taking place in social economic development on the local level in rural areas in the context of the research results must be ascribed the social dimension, focusing on primary needs of the people, the environmental dimension, oriented directly to the welfare of the people, being situated on the lowest level, and the economic dimension, reflected through satisfaction with the services received by inhabitants. But it requires adequate information about the changes in the number of inhabitants and the capital, in the GDP, employment, income and others. For regional structural analysis of especial importance will be: age, education, potential working opportunities, employment, insurance, income, credit reliabilities to show the tendencies and allow prognosticate the future. And it depends, a great deal, on the information possible to receive from the Central Statistical Bureau of the Republic of Latvia. The quality of expected research results will be related closely to the timeliness and fullness in reflection of the changes in administrative territorial formations by statistical data.

III CONCLUSION

Regional disparities and their negative impact on sustainable development in Latvia is the subject of studies and researches for a long time. There had been discussed different approaches and ways aimed to finding out of solutions how to overcome the unbalanced development of Latvian regions.

The theoretical concepts, research results and discussions created the basis for finding of some conceptual approaches that may be taken as basics in further researches in development of regions in Latvia, such as infrastructure, increase of household income, attraction of investments, initiatives of local governments, long-term planning, problems to be researched.

The specific of the needs of local governments require a well developed planning and honest distribution of funds, a suitable inventory and control mechanism. Much depends of possible structural reforms, change of social support system, and potential regional development with attraction of investments.

The increase in household income may be achieved, facilitating the entry of enterprises into regions, which produce with a higher added value, produce innovative products, facilitate tourism development in the regions.

As to the attraction of investments to regions, there is not to be expected that foreign investors will be interested in, except Riga, Riga area, Jurmala, Liepaja, Ventspils and, perhaps, Daugavpils. All is depending on businesspeople, seeking for opportunities to develop production objects with the aim to attract foreign investors or to sale the objects profitably.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 20-26

New Kinds of Sapropel and Peat Based Fertilizers

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Abstract. **New types of fertilizers based on peat and sapropel were developed and can be used as solid and liquid forms of organic and organicmineral fertilizers and preparations for different crop cultivation. It was shown that use of SAPROAgro and SAPROElixir fertilizers increases productivity of agricultural plants by 9-16 %. Use of EleGum liquid humic microelement fertilizers provides an increase of winter wheat grain yield up to 0.88 t ha^{-1} , maize green mass up to 5.0 t ha^{-1} and maize grain to 2.06 t ha^{-1}**

Keywords: **peat, sapropel, humic substances, macroelements and microelements, yield, agricultural plants**.

I INTRODUCTION

Many year experiences in a number of farms in Latvia and Belarus shows rather high efficiency of fertilizers application were obtained in result of peat and sapropel processing [9, 14, 15]. This is largely due to the favourable water-physical, agrochemical and biological properties, as well as a large variety in structure and composition of their organic matter.

As a high-quality organic-mineral fertilizer, sapropel can be used for many types of soils and plants, in order to increase the humus, nitrogen and microelements content in soil. It is classified as ecologically clean and efficient agricultural material of natural origin [2, 4]. Sapropel fertilizers, due to their high biological activity and preliminary technological treatment, resulted in the improvement of the structure of nitrogen-containing compounds in them and are able to make essentially better the quality of agricultural products as well [17].

Peat based organic fertilizers and preparations are even more widely used in agriculture in fact. Well known reason for that is a rich source of organic matter and biologically active substances [15]. Therefore, one of the most promising directions of peat use is its processing for obtaining such effective products as various biostimulants and plant growth regulators.

Microelements Cu, Zn, B, Mn, etc. participate in formation or activate action of enzymes, vitamins, regulate metabolism and many other processes effecting growth, development, reproduction, productivity and quality of plants [12]. They should be in a biologically available form in fertilizer and can be easily transformed and assimilated by plants. That is why the use of inorganic metal salts often is not efficient enough [10, 15]. The best results are generally achieved when using liquid forms of preparations and fertilizers containing biologically active humic substances and microelements jointly [1, 17].

As far as balanced plant nutrition by necessary macro- and microelements plays most important role in crop cultivation technologies the new types of fertilizers based on peat and sapropel have been developed and studied [8, 9, 13].

II MATERIALS AND METHODS

To study of the efficiency of fertilizers based on sapropel, studies in LLU ZZI were conducted in 2012-2014. For this purpose, vegetation experiments were carried out in a climatic chamber, where conditions

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.271

were simulated that are typical for a temperate climate, with such plants as alfalfa (*Medicago sativa L.)*, mixture of cereal perennial grasses *(Festuca rubra, 50%, Festuca ovina, 50%)*, tomato *(Solanum lycopersicum)* and lettuce *(Lactuca sativa)*. Influence of SAPRO Agro and SAPRO Elexir on these plants different by physiological properties was tested. 1 litre plastic containers were used for experiments, filled with types of substrates: 1. Control – sand (SM) 2. SAPRO Agro ($SA_{100\%}$) 3. SAPRO Agro ($SA_{1:7}$) 4. SAPRO Agro-L ($SA_{1:7}$ + $2xSE_{L}$) 5. SAPRO Agro-Ju ($SA_{1:7}$ + $2xSE_{Ju}$). Plants were additionally fertilized (2x) with SAPRO Eleksir (SE) as a working solution 1:200 twice 5 and 12 days after shoots (variant 4 and 5). Experiments were carried out during 45 days.

SAPRO Elexsir fertilizer was tested in a field experiment in 2011-2013, where *Rasa* variety of barley (*Hordeum vulgare* L) was studied as one of the earliest and most responsive to fertilizers crop (LLU ZZI). Experiments were laid by method of randomized blocks, efficiency of additional fertilizing by SAPRO Elexsir was studied. Repeatability in experiments was 4x. Variantss: 1. Control – no additional fertilizing,2. Sapropel (SAPRO), 3. SAPRO Agro-L ($2xSE_{L}$), 4. SAPRO Agro-Ju ($2xSE_{Ju}$). Additional fertilizing of plants was carried out by working solution of pure sapropel 1:20 (variant 2) and SAPRO Eleksir (SE_{L} and SE_{Ju}) as a working solution 1:200 (variant 2 and 3). Fertilizers were introduced by watering in tillering phase and 10 days after the first watering. Experiment plot soil in field experiment was slightly loamy sod-podzol and had a slightly acidic reaction pH_{KCL} 5.7. Content of humus -20 g kg^{-1}, P_2O_5- 90 mg kg^{-1}, K_2O- 125 mg kg^{-1}.

Field experiments of Institute on Nature Management and Institute of Soil Sciences and Agrochemistry of National Academy of Sciences of Belarus were carried out in 2011-2013 with Cubus winter wheat variety on sandy-loam sod-podzol soil with pH_{KCL} 6,5. Humus content in soil was 30 g kg^{-1}, P_2O_5 - 496 mg kg^{-1}, K_2O- 203 mg kg^{-1} [14]. The efficiency of liquid humic microelement EleGum fertilizers used for additional foliar treatment of plants was tested there.

Composition of liquid EleGum fertilizers based on preparation of humic acids (HA) as a biostimulant and complex former and microelements in helate form contained 10 g l^{-1} of HA and respective mineral substances, e. g., EleGum-Cu contained – 50 g l^{-1} of copper; EleGum-Zn – 50 g l^{-1} of Zinc and EleGum-Mn – 50 g l^{-1} of Manganese. These kind of fertilizers were developed by the Institute on Nature Management of National Academy of Sciences of Belarus [7, 8, 9].

Rate of fertilizer application was 1 l ha^{-1} (200 l ha^{-1} of working solution). The efficiency of humic microfertilizers was tested against the background of mineral fertilizers $N_{150}P_{70}K_{140}$ in variant for winter wheat and background of cow manure 50 t ha^{-1} and $N_{180}P_{90}K_{180}$ - in variant for Maize (Hybrid Dolphin). Experiments were laid by method of randomized blocks [3] and the repeatability in experiments as 4x. Versions: Winter wheat: 1. Background, 2. Humic preparation, 3. EleGum-Cu, 4. EleGum-Mn, 5. EleGum-Cu + EleGum-Mn; Maize: 1. Manure, 2. EleGum-Zn, 3. EleGum-Cu, 4. EleGum-Mn.

Studies, measurements and determination of dry matter, chemical and biochemical analyses according to generally accepted methods described by national and industry standards (US EPA, LVS ISO, LVS EN, STANDART). Content of amino acids (except tryptophan) was studied by method of hydrolysis (AOAS Official Method 985.28.). Tryptophan – by spectrophotometric method at oxidation of the sample (H_2SO_4 and HNO_3) [5]. Morphologic factors of plants were also determined [3].

III RESULTS AND DISCUSSION

Content of nutrients in sapropel and studied fertilizers*

Three components can be allocated in sapropel that interact with each other: biologically active, organic and mineral.

TABLE I.

COMPONENT COMPOSITION OF SAPROPEL

Parameter	**Mean ± SD**
Organic Matter,%	77.3± 4.90
Humic Acids, %	20.70± 2.22
Fulvic Acids, %	32.70± 3.15
Fatty acids ω-6 / ω-3, g kg^{-1},	14.40± 2.2
Carbohydrates,g kg^{-1},	6.00 ± 0.5
Lipids, %	12.25± 1.40
Cellulose, %	22.42± 1.80
Vitamins, mg kg^{-1}	
A (retinol)	26.51± 1.82
B_1(thyamine)	1.45± 0.02
B_2 (ribiflavin)	2.35± 0.08
B_3 (PP.nicotinic acid)	59.78± 4.16
B_6 (pyridoxine)	0.72± 0.01
B_{12} (cyancobalamin)	0.03± 0.00
Provitamin for vitamin *A* (β-carotene)	2.20± 0.13
E (α-tocopherol)	25.42± 1.35
Ń(ascorbic acid+ dehydroaskorbic acid)	490.00± 23.00

Organic matter of sapropel is the aggregate of plant and animal residues and their decay products. It contains products of biopolymer hydrolysis, polymeric compounds formed in the process of biotic and abiotic destruction, products of organic synthesis, as well as waste products of microorganisms – vitamins and other biologically active substances.

Component composition of sapropel is shown in Table I. Amount of fulvic acids improving availability of nutrients to plants was 32.70 %, which is by 12 % higher than content of humic acids.

Total amount of carbohydrates – 6.00 g kg^{-1}, include monosaccharides, disaccharides, oligosaccharides and polysaccharides, which is useful for plants: both for winter hardiness and resistance to other adverse weather conditions.

Composition has valuable B_{1-12} group vitamins, as well as vitamin C and carotenoids, they not only provide for nutrition of plants, but also favourably affect development of microflora and increase biological activity of the environment. Fats make 12.25 % of dry matter and mainly are polyunsaturated fatty acids ω-3 и ω-6, participating in restoration of telomeres in DNA cell molecules and preventing aging of the organism [11]., which favourably affects development of plants during the vegetation period.

Amount of amino acids in sapropel was 11.93 % (Table II). When using sapropel as a component of organic fertilizers, they are not only a physiologically active binder of the base having high ion exchange and sorption properties [10], but also an additional supplier of humic substances, amino acids, including aspartic (1.41%), glutamic (1.47%), as well as glycine (0.79%), alanine (0.85%) and leucine (1.08%), into nutrient medium of plants.

TABLE II.
AMINOACID COMPOSITION OF SAPROPEL

Amino acids	Mean ± SD
Glycine	0,79±0.08
Alanine	0.85±0.08
Valine	0.16±0.02
Leucine	1.08±0.10
Isoleucine	0.17±0.01
Methionine	0.03±0.01
Tryptophan	1,06±0.01
Proline	0.31±0.03
Serine	0,68±0.07
Threonine	0.59±0.06
Aspartic acid	1.41±0.13
Glutamic acid	1.47±0.14
Lysine	0.49±0.04
Arginine	0.40±0.04
Histidine	0.71±0.07
Phenylalanine	0.29±0.02
Tyrosine	1,44±0.14
Sum	11.93±0.18

Mineral complex includes main macro elements as nitrogen, phosphorus, potassium as well as considerable amount of microelements Mn, Cu, Zn, etc. (Table III). Anions of mineral substance of sapropel are mainly represented by carbonates, phosphates, sulphates. Components of mineral substance of sapropel participate in biologic processes, are transformed in redox reactions into substances easily available to plants.

TABLE III.
MINERAL COMPLEX OF SAPROPEL

Macroelements	Mean ± SD
N tot %	2.80± 0.30
P_2O_5, %	0.15± 0.02
K_2O, %	0.22± 0.01
CaO, %	0.70± 0.01
MgO. %	0.17 ± 0.00
Microelements	**Mean ± SD**
S, mg kg^{-1}	1.06±0.80
Fe, mg kg^{-1}	7745.00± 775
B, mg kg^{-1}	0.85± 1.38
Mo, mg kg^{-1}	0.43± 0.03
Cu, mg kg^{-1}	13.00± 1.45
Mn, mg kg^{-1}	32.00± 3.40
Zn, mg kg^{-1}	70.00 ± 4.10

This has an important practical meaning when using sapropel as a fertilizer. Amino acidic composition, increased level of linolenic acid ω-3, optimal content of minerals allows using sapropel not only in plant cultivation, but also in medicine and zootechny [1, 12].

In result of studies, agrochemical supplements were developed (LLU ZZI) for colloidal SAPRO Elixir fertilizer based on dispersed sapropel (100 %) and for SAPRO Agro fertilizer in form of nutritional substrate (sapropel 55 %; peat 45 %).

As a nutritional substrate, SAPRO Agro (SA) contained 86.8 % of organic matter, pH-5.3. Fertilizer dry matter had macroelements necessary for plants: N_{tot} – 0.41 %; P_2O_5 – 0.28 %; K_2O – 0.30 %, and Mg – 0.17%, CaO – 0.7 %, as well as microelements (1m HCl): Mn – 60 mg l^{-1} ; Cu – 11 mg l^{-1}, Zn – 9 mg l^{-1}; Fe – 2150 mg l^{-1}; Mo – 0.43 mg l^{-1}; B – 4 mg l^{-1}. This is an average level of nutrients sufficient for early growth and development of plants.

Composition of liquid colloidal fertilizers was: 1. SAPRO Elixir $_L$ (SE_L): N_{tot} – 9.11 %; P_2O_5 – 10.50 %; K_2O – 5.30 %, and 2. SAPRO Elixir $_{Ju}$ (SE_{Ju}): N_{tot} – 4.61 %; P_2O_5 – 8.38 %; K_2O – 10.81%. Both types of these fertilizers contained equal amounts of microelements (1m HCl): Cu – 13 mg l^{-1}, Zn – 70.00 mg l^{-1}, Mn – 32.5 mg l^{-1}; B – 0.85 mg l^{-1}, S – 14.0 mg l^{-1}, as well as 20.7 % of humic and 32.7% of fulvic acids. Organic matter was 77% and pH 6.4.

Based on humic preparation, as a biostimulant and complex former, mineral salts of microelements and some additives, *NAS INM* developed liquid Ele Gum fertilizers for additional foliar fertilizing of plants, composition of which contained humic preparation 10 g l^{-1} and respective mineral substances, e. g., Ele

Gum–Copper contains Cu – 50 g l^{-1}; Ele Gum–Zinc – Zn – 50 g l^{-1}, and Ele Gum–Manganese – Mn – 50 g l^{-1}.

*) The Evaluation of Sapropel from the Lake Ubogovo, Rezekne of Latvia

Influence of sapropel-containing fertilizers on development of plants

Need of plants for specific amount of nutrients depends on their physiology, heredity, and varies depending on conditions of growing [15]. This approach was taken as a base of experiment for forming substrate and solutions for studied crops as a method of increasing their productivity.

To develop it, influence of nutritional substrate SAPRO Agro in pure form ($SA_{100\%}$) and mixed with sand ($SA_{1:7}$) on growth and development of plants was studied in climatic chamber conditions. Various types of plants with different requirements of soil environment were selected for the experiment (Table IV).

TABLE IV.
DEVELOPMENT OF AGRICULTURAL PLANTS IN CONDITIONS OF VEGETATION EXPERIMENT.

Dry matter Yield	Above ground mass		Under ground mass	Above ground mass		Under ground mass
	g. vg.s $^{-1}$	%	g. vg.s $^{-1}$	g. vg.s $^{-1}$	%	g.vg.s $^{-1}$
Festuca rubra,+ F. Ovina				*/ Medicago sativa*		
1. SM	1.95	100	1.06	2.83	100	1.62
2. $SA_{100\%}$	2.26	116	1.45	1.28	45	1.12
3. $SA_{1:7}$	2.45	126	1.75	2.94	104	1.96
4. $SA_{1:7}$ + 2x SE_L	2.50	128	1.81	3.31	117	2.96
5. $SA_{1:7}$ +2x SE_{Ju}	2.46	126	1.95	3.40	120	2.94
$RS_{0.05}$	0.03		0.02	0.06		0.03
Solanum lycopersicum				*/ Lactuca sativa*		
1. SM	1.69	100	1.18	2.20	100	1.30
2. $SA_{100\%}$	1.72	102	1.23	2.42	110	1.40
3. $SA_{1:7}$	1.73	102	1.60	2.56	116	1.46
4. $SA_{1:7}$ + 2x SE_L	1.94	115	1.83	2.64	120	1.96
5. $SA_{1:7}$ +2x SE_{Ju}	1.97	117	1.79	2.59	118	1.99
$RS_{0.05}$	0.04		0.03	0.02		0.03

Grasses, as the least demanding to environment reaction, grew and developed on all studied types of substrate. Increase of dry matter by 16-28 % compared to control was observed in all versions of the experiment. Weight of overground part in the best version 4.$SA_{1:7}$ + 2xSE_L was 2.50 g veg.s^{-1}(vg.s), which is by 28 % higher than that of control, weight of roots was 1.95 g veg.s^{-1}

Based on results of experiment, alfalfa reacted to additional fertilizing well. Therefore, the most efficient were variants 5. $SA_{1:7}$ + 2xSE_L and $SA_{1:7}$ + 2xSE_{Ju}. In these variants, height of plants was 13 cm, and dry matter of grass – 3.31 to 3.40 g veg s^{-1}, which was by 17 to 20 % higher than that of control. Well-developed root system was 2.96 to 2.94 g. In variant 2. $SA_{100\%}$, alfalfa results were by 35 % lower than those of control.

Vegetables positively reacted to differences in nutrition. Tomato overground weight increased from 1.69 g veg. s^{-1} in control to 1.97 g veg. s^{-1} in 5. $SA_{1:7}$ + 2xSE_{Ju}, which constituted increase by 17 %. For lettuce, the highest weight was in variant 4. $SA_{1:7}$ + 2xSE_L (2.64 g), which is explained by responsiveness of this plant to content of nitrogen in fertilizer, where in fertilizers 2xSE_L and 2xSE_{Ju} content of N_{tot} was 9.11 and 7.10 % respectively. Regardless of type of plants, the best results in all factors were obtained in variants 3. $SA_{1:7}$; 4. $SA_{1:7}$ + 2xSE_L and 5. $SA_{1:7}$ + 2xSE_{Ju}, which proves efficiency of using SAPRO Agro and SAPRO Elixsir fertilizers Inhibitory action was detected in variant 2. $SA_{100\%}$, where growth of plants were slightly delayed. This was affected by both content of iron and acidity of environment. However, after mixing with sand in proportion 1:7, overground weight of plants is increased by 2-16 % compared to that of control. Thus, in 2. $SA_{100\%}$ this factor was: cereals – 2.26, alfalfa – 1.28, tomato – 1.72, and lettuce – 2.42 g veg. s^{-1}, and in variant 3. $SA_{1:7}$ – 2.45, 2.94, 1.73, 2.56 g veg. s^{-1} respectively. Correlation coefficients were determined based on the experiment data. Increase in overground weight of studied crops and content of nutrients in fertilizers are in close correlation (r=0.60-0.75).

Influence of studied fertilizers in field experiments on development of spring barley

Meteorological conditions in vegetation period in certain years of studies differed from average, but did not affect crop capacity of barley considerably.

After evaluating efficiency of each variant of the experiment depending on the studied factors, it was determined that variants 3. 2xSE_L and 4. 2xSE_{Ju} gave significant increase of grain yield 0.53–0.60 t ha^{-1}, compared to that of control, which was 14-16% (Table V). Thus, yield in control was 3.68, and in variants 3 and 4 – 4.21 and 4.28 t ha^{-1}, respectively. In variant, where additional fertilizing was carried out by sapropel solution, grain yield increased by 9%.

After additional fertilizing by SAPRO Elexsir fertilizer with different nutritional composition, quality of spring wheat grains changed. Variants with their use resulted in increased fullness of grains. Weight of 1000 grains differed in variants and was 49.2 g in control. The highest results were obtained in variant 4. 2xSE_{Ju} – 54.5 г (11 % of control). In variant 2. SAPRO and 3. 2xSE_L, this result was slightly lower – 50.3 (2%) and 52.0 (6%), respectively. Nature of grains in additional fertilizing was 651-660 g l^{-1}, by 8-17 g l^{-1} higher than in control.

TABLE V.
AVERAGE PRODUCTIVITY OF SPRING BARLEY IN 2 YEARS

Parameter	Variants			
	1. Control	2. SAPRO	3. 2x SE_L	4. 2x SE_{Ju}
Yield * t ha^{-1},	3.68	4.02	4.21	4.28
% of control	100	109	114	116
Plant height, cm	60	64	66	68
Vegetation period, days	95	94	96	96
TKW,g	49.2	50.3	52.0	54.5
Volume weight,g l-1	643	651	657	66.0
Protein**, %	11.9	12.0	12.3	12.4
Starch, %	64.2	62.8	61.6	55.3

*$RS_{0.05}$=0.18, ** N_{tot}% x 5,70

Protein in spring barley is the most important component, on which high quality of agricultural animal feed depends when using grains in zootechny [1]. SAPRO Elexsir favoured increase of protein content in grains, which was the highest in variant 4. 2xSE_{Ju} – 12.4 %

Starch content varied from 55.3 % in variant to 64.2 % in control. Introduction of SAPRO Elexsir fertilizers decreased starch content by 8.9 % compared to that of control, since protein was accumulated more actively on additionally fertilized plots. Regression connection between protein and starch contents is inverse, average, r = -0.63

Numerous literature data show that fresh sapropel is not an effective fertilizer and requires additional processing [2, 6, 18]. Its positive effect is manifested in subsequent years of crop cultivation. In our experiments, no negative effects were observed after watering with working sapropel solution 1:20, yield increase was 9% compared to the control. Working solution on leaves and open root system additionally feeds plants and causes no negative consequences.

Influence of studied fertilizers in field conditions on development of winter wheat and maize

One of the most common and economically substantiated methods of using microfertilizers today in majority of countries is additional foliar fertilizing of crops during the periods, when their need for microelements is the highest. Important agrotechnical and ecologically neutral method in practice of plant cultivation is use of growth stimulants of humic nature, which improve life processes in plants, but are not sources of nutrients [16].

The abundance of tillable area in Republic of Belarus *(*NAS INM, NAS ISSA*)* is characterized by the content of main microelements as not sufficient enough for stable high yield of crops production. Currently, microfertilizers for crops cultivation are only used within 30-40% of their need.

TABLE VI.
WINTER WHEAT GRAIN YIELD, IN AVERAGE FOR 2 YEARS,

The timing	of tillering		in the pipe		of earing	
Variants	Yield, t ha^{-1}	mean +Kontr.	Yield, t ha^{-1}	mean + Kontr	Yield, t ha^{-1}	mean + Kontr
1.Control	5.90	-	5.90	-	5.90	-
2.Humic preparation	6.35	0.45	6.22	0.32	6.00	0.10
3.EleGum-Cuprum	6.46	0.56	6.42	0.52	6.00	0.10
4.EleGum-Manganese	6.56	0.66	6.35	0.45	6.07	0.17
5.EleGum- Cuprum EleGum-Manganese	6.78	0.88	6.69	0.79	6.14	0.24

*$RS_{0.05}$=0.31; **$RS_{0.05}$=0.42; ***$RS_{0.05}$=0.36

The most important microelements for winter wheat in conditions of sod-podzol soils are copper and manganese, for maize – zinc. As a biostimulant, humic preparation, extracted from peat during its water alkaline processing, is chosen.

Use of compositions containing, simultaneously with microelements, biologically active compounds is seen as the most efficient poly functional medium for increasing crop capacity and quality of plant products.

As seen from the data of Table VI, the most efficient is use of humic preparation and microelement fertilizers for foliar treatment of winter wheat in the period of plant tillering in spring and in stem elongation phase. Increase of grain yield after application of humic preparation only was 0.45 and 0.32 t ha^{-1}, and after application of these fertilizers in tillering phase – 0.56-0.88 t ha^{-1}, in stem elongation phase – 0.45-0.79 t ha^{-1}. After using liquid fertilizers and humic preparation at the ear beginning, only the tendency to increase of crop capacity is retained, since obtained increase in grains of 0.1-0.24 t ha^{-1} is statistically unreliable.

Use of humic preparation favoured increase in protein and gluten content in winter wheat grains (Table VII).

Maximum increase of protein and gluten content was obtained after treatment with humic preparation at the beginning earing, although improved quality of grains was observed even after using the preparation at earlier time.

TABLE VII.

GRAIN QUALITY OF WINTER WHEAT

The timing	of tillering		in the pipe		of earing	
Variants	Protein*,%	Gluten,%	Protein*,%	Gluten,%	Protein*,%	Gluten,%
1.Control	11.3	27.4	11.3	27.4	11.3	27.4
2.Humic preparation	11.4	28.8	11.5	28.0	12.2	29.6
3.EleGum-Cuprum	11.4	32.2	11.5	30.0	11.8	35.6
4.EleGum-Manganese	11.8	28.5	11.5	28.2	11.8	29.7
5.EleGum-Cuprum EleGum-Manganese	11.9	32.9	11.8	33.7	12.1	33.8

* N_{tot}% x 5,70

Additional foliar spraying wheat plants by liquid humic fertilizers with microelements in the experiment variants favoured increase in content of protein from 0.5 to 0.8%, gluten which is the main component of protein – from 2.4 to 4.2%. In our experiments, the highest its level was reached in variant 3. EleGum-Cu – 35.6%, after treatment in the ear beginning phase. Amount of gluten defines quality of flour and baked bread. Stability of shape, volume and porosity of bread also depends on it. In average, by the time of fertilizer application, protein and gluten content in grains increased more at the beginning of ear. Therefore, treatment of plants in this period of growth is quite reasonable. In optimal conditions of plant nutrition, correlation between output of raw gluten and content of protein may reach the best result - 2.5 %. Additionally, significant increases the gluten-forming ability of protein complex (weight fraction). In terms of quantity this ability may be characterized by relation of gluten content to protein content in non-metric units. In results of the studies, gluten-forming ability of protein complex varied from 2.42 in reference variant to 2.79 in variant 5.

TABLE VIII.

EFFECT OF ELEGUM HUMIC MICROELEMENT FERTILIZERS ON AVERAGE MAIZE GREEN MASS YIELD

Variants	Yield * tha^{1}	mean+ **kontr.**	$^{-}NO_3$ mg kg^{-1}
1. Manure	56.5	-	168 - 355
2. EleGum-Zinc	65.0	8.5	89 - 305
3. EleGum-Cuprum	59.0	2.5	120 - 308
4. EleGum-Manganese	59.2	2.7	310 - 390

$^{*}RS_{0.05}$=1.45

Results of studies showed that additional foliar fertilizing of maize by EleGum-Zn, EleGum-Cu and EleGum-Mn fertilizers favoured increase in capacity of green mass and grain of corn (Table VIII and IX).

In background variant, average capacity of green mass and grain of maize in two years of studies was 56.5 and 9.98 t ha^{-1}, respectively.

After using studied fertilizers, capacity of green mass increased by 2.5-8.5 t ha^{-1}, and capacity of grain – by 1.00-2.06 t ha^{-1} (Table IX). After using EleGum-Zn, EleGum-Cu and EleGum-Mn fertilizers during maize cultivation, content of nitrates in green mass did not exceed the established maximum concentration.

TABLE IX

EFFECT OF ELEGUM HUMIC MICROELEMENT FERTILIZERS ON AVERAGE MAIZE GRAIN YIELD

Variants	Yield * t ha^{-1}	mean + **St**
1. Manure	9.98	-
2. EleGum-Zinc	12.04	2.06
3. EleGum-Cuprum	10.98	1.00
4. EleGum - Manganese	11.06	0.08

$^{*}RS_{0.05}$=0.83

Application of EleGum-Zn, EleGum-Cu, EleGum-Mn fertilizers as additional foliar spray fertilizing maize crop provided increase for microelements content in green mass and grain at levels of: Cu – 2.8-4.1 and 1.3-1.5 mg kg^{-1}; Zn – 13.0-15.3 and 14.2-16.7 mg kg^{-1}; Mn – 23.0-28.1 and 2.1-4.0 mg kg^{-1}, respectively.

IV CONCLUSION

Extremely rich and varied composition of organic and mineral substances of peat and sapropel allows using these natural materials as the base in creation of new types of solid and liquid organic and organicmineral fertilizers and preparations for crop cultivation.

Use of SAPROAgro and SAPROElixir fertilizer increases productivity of agricultural plants by 9-16 %. Sapropel in composition of fertilizers participates as physiologically active binder of the base having high ion exchange and sorption properties. It is also an additional supplier of humic substances, amino acids, including aspartic, glutamic, as well as glycine, alanine and histidine, into nutrient medium of plants.

Obtained data show efficient use of humic preparation and highly concentrated liquid EleGum fertilizers with microelements developed on its base on sandy-loam sod-podzol soils. Use of compositions containing, simultaneously with microelements, biologically active compounds is seen as the most efficient poly functional medium for increasing crop capacity and quality of plant cultivation products, provides for obtaining increase in winter wheat grains to 0.88 t/ha, green mass of maize to 5 t ha^{-1} and grains of corn to 2.06 t ha^{-1}.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 27-34

Management of current assets in the context of increasing the Enterprise's Profitability

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Abstract. **In order to ensure the financial sustainability of companies under current economic conditions successful management of current assets is crucial. In practice it is quite often observed that the decisions related to current assets management in Latvian companies are made in the short-term aspects without making analysis. Efficient management of working capital is an essential condition of rise in profitability of a company. Potentialities of working capital management in the context of efficient running of business have not been studied in Latvia up until now. The main aim of this article is to examine the effect of working capital on profitability of Latvian companies. The results of the research that has been performed in relation to Latvian enterprises confirm the existence of a correlation between components of working capital and profitability. The developed regression equations meant for forecasting profitability of a company applying working capital management methods can be used by Latvian enterprises. It follows that managers of an enterprise can forecast indexes characterizing profit, managing components of working capital and maintaining it on the optimum level**

Keywords: **current assets, current assets management, profitability.**

I INTRODUCTION

Sustainable development of the economic subjects in the economic space largely depends on the ability of efficient management of their financial resources; on a basis of the scientific findings of the theory of economics and management it is focused on three basic directions: capital investments, capital structure and management of the working capital. Investments of financial resources into current assets is creation of the future capital value in long-term, which is important for company's shareholders; the management of current assets, which is directed to ensuring the company's solvency within the entire operating cycle, in is turn, is essential for the company's profitability and ability to discharge its liabilities, which is a precondition for general sustainable development of the enterprise.

The economic category – current assets – is interpreted within the framework of the management of finances in scientific and practical research. The author believes that functions of the current assets in entrepreneurship and their significance in economic growth of the national economy are not less important.

On the macro level, the current assets are elements of economic growth, their definite quantity and quality may influence changes in demand and supply within a definite geographical area. From the point of view of entrepreneurship, current assets is an important precondition for company's development and value creation. From 2008 to 2013, the specific gravity of the current assets in enterprises' total assets made 42.3% - 36.95%.

The topicality of the research is defined by the fact that in the modern conditions of growing competition the management of current assets has become an important function of the enterprise management influencing results of the economic activity. The large number of elements of current assets in their material and financial composition requires the individual and dynamic management's approach in the decision making process. The important component of management of the enterprise's current assets is increasing of the profitability of the economic activity. Significant changes in macroeconomics create the necessity for the management to take strategic decisions in management of current assets to achieve the main target of entrepreneurs – to get profit.

II LITERATURE REVIEW

Historically the relationship of current assets management and corporate profitability has been studied by various authors for example, Shin and Soenen [18] (1998); Deloof [3] 2003; Lazaridis and Tryfonidis [9] (2006), Padachi [13] (2006), Garcia-Tereul and Martinez-Solano [6] (2007); Raheman and Nasr [16] (2007); Mathuva [10] (2009); Dong and Su

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.264

[4] (2010); Sharma and Kumar [17] (2011) and others. Studies focused on the relationship between working capital and profitability in different respects (Table 1).

Successful management of current assets of a company plays an essential role in ensuring financial sustainability of an enterprise under current economic conditions. Current assets and potentialities of their management in the context of business activity practically have not been studied in Latvia up. In their turn, such studies are widely represented in Russia, EU, America and other countries.

During her research the author summarised various scientists' studies related to the interrelations between management of current assets and profitability.

TABLE 1
Results of research of correlation of profit/profitability with turnover indicators

Author	Indicator of profit/ profitability	Correlation of receivables collection period(RCP) with profitability	Correlation of inventory conversion period(ICP) with profitability	Correlation of payables' deferral period(PDP) with profitability	Correlation of cash conversion cycle (CCC) with profitability
Deloof (2003) [3]	GOP	Negative	Negative	Negative	Negative
Karaduman (2004) [8]	ROA	Negative	Negative	Negative	Negative
Lazaridis, Tryfonidis (2006) [2]	Gross Profit	Negative	Negative	Negative	Negative
Padachi (2006) [13]	ROA	Negative	No significant relationship	Negative	Negative
Garcia-Tereul, Solano (2007) [6]	ROA	Negative	Negative	No significant relationship	Negative
Raheman, Nasr (2007) [2]	ROA	Negative	Negative	Negative	Negative
Mathuva (2009) [10]	ROS	Negative	Positive	Positive	Negative
Nobanee, (2009) [12]	GOP	Negative	Negative	Positive	Negative
Enqvist (2009) [5]	ROA, GOP	Negative	No significant relationship	Negative	Negative
Gill (2010) [7]	Gross Profit	Negative	No significant relationship	No significant relationship	Positive
Dong, Su (2010) [4]	GOP	No significant relationship	Negative	Negative	Negative
Sharma, Kumar (2011) [17]	ROA	Positive	Negative	Negative	Positive (not significant)

* Gross Operating Income – GOP; Return on

Assets – ROA; Net Operating Profit - ROS
Source: author's summarised information

In their research, authors used various profitability indicators or also gross profit, which is substantiated with the research aim and reflects the connection with the turnover of elements of working capital.

Return on Assets (ROA) is one of the most important indicators of the enterprise's activity. These indicators give possibility to judge how efficiently the company uses its assets to get profit. Gross Operating Income (GOP) shows the enterprise's ability to get profit from the basic activity, i.e. from performing enterprise's economic operations. Gross Operating Income excludes incomes derived from selling assets or other enterprises' ownership. As enterprise's current assets are only a part of assets that is used every day in the company's working process, the author believes that this indicator reflects the connection with the indicators of the turnover of working capital elements in the best way.

III THE METHODOLOGIE AND MODEL

The author used the method of survey in her thesis. The data that she received showed quite unvaried results and do not express significant difference in opinions, attitudes and assessments amongst entrepreneurs. Stability of the results in relation to application of various analysis tools points to tendencies of current asset management at enterprises in Latvia.

The research can be conventionally divided into two parts; in the first part, the author brings forward six conditions and several explaining criteria of factors influencing current asset management and characterising indicators of current asset types. In the second part, there are 10 statements about actual aspects of management of current assets at a concrete enterprise, as well as the author asks to name annual account indicators characterising the enterprise's activity.

The data were obtained after summarising enterprises' managers' assessment. 226 questionnaires were received. When doing primary processing of the questionnaires, the author selected 194 questionnaires (85.83% of the total number of the questionnaires) according to the company's sphere, dividing respondents into spheres:

- production sphere NACE codes: A, B, C, D (further in the text – 1) – 66 respondents (29.2%);
- trade sector NACE codes: G, J (further in the text – 2) – 70 respondents (30.97%);
- service sector NACE codes: E, H, I, K, M, N, O (further in the text – 3) – 58 respondents (25.66%).

The estimates of average indicators reflect similar evaluation both in the entire selection and in separate sectors. Average assessments indicate similar evaluation to define tendencies, then counted aggregated factors according to condition groups are standardised according to the average, which is 0, but the mean squared deviation is 1. After standardisation the average indicators get 0.

When comparing the enterprises' assessments of current asset management using Kruskal Wallis test, the author came to the conclusion that there are differences between sectors. Assessments in the trade sphere are lower than the average, but assessments in the production and services spheres are above the average. The statistical significance by the spheres is observed in relation to actual aspects of current asset management at the enterprise (AA) (*Kruskal Wallis Test, $p<0.082$*). The author concludes that at enterprises working in the sphere of services, management of current assets is not paid much attention to, and on the contrary, the evaluation done by production and trade companies reflects application of methods of current asset management.

For doing the research the author used data that she had acquired with help of the survey conducted among management of concrete enterprises. The choice of variables was stipulated by the research that had been done in the theoretical part, empirical studies and taking Deloof's [3] (2003), Raheman, Nasr's [15] (2007) studies as a basis, as well as taking into account available data. In Table 2, all variables that were used in the research are summarised; their abbreviations and estimate formulae are given in the same table.

TABLE 2.
Formulae of variables and abbreviations

Variable	**Abbreviation**	**Formula**
The dependent variable		
Gross Operating Profitability	GOP	(Sales - Cost of Goods Sold) / (Total Assets - Financial Assets)
Return on Assets	ROA	Neto income / Total assets
The Explanatory variables		
Receivables Collection Period	RCP	(Accounts receivable / Sales)*365
Inventory Conversion Period	ICP	(Inventories / Cost of Goods sold)*365
Payables Deferral Period	PDP	(Accounts payable / Cost of Goods sold)*365
Cash Conversion Cycle	CCC	RCP + ICP – PDP
The control variables		
Size of Companies	LnS	Natural Logarithm of Sales
Debt Ratio	DR	Total Debt / Total Assets
Current Ratio	CR	Current assets / Current liabilities
Working capital in relation to turnover	WCS	Current assets - Current liabilities / Sales %

Source: author's summarised information

IV RESULTS AND DISCUSSION

Correlation analysis of selected enterprises' indicators.

The correlation analysis describes relations between the dependent variable, explanatory and control variables. The analysis has been done using Pearson's correlation analysis. In research related to interconnections between working capital and profitability, Pearson's correlation analysis was used by several researchers: Deloof [3] (2003), Padachi [14] (2006), Mathuva [10] (2009), Gill, Biger, Mathur [7] (2010), Enqvist, Graham, Nikkinen [5] (2010). Pearson's correlation analysis shows the relation between variables, but does not indicate its reasons (Shin, Soenen [18] (1998); Deloof [3], (2003), Mathuva [10] (2009), Dong, Su [4] (2010)).

TABLE 3.

Results of Pearson's correlation of enterprises' variables, n=194 enterprises of Latvia, 2013

	GOP	RCP	ICP	PDP	CCC	LnS	DR	CR	WCS
GOP	1								
RCP	.235*	1							
ICP	.348*	-.133	1						
PDP	.507**	-.034	.768**	1					
CCC	-.354**	.046	.046	-.600**	1				
LnS	.330**	-.151	.267**	.239*	-.057	1			
DR	-.476**	-.032	-.041	.017	-.092	-.286**	1		
CR	.072	-.047	-.032	-.066	.060	.044	-.189	1	
WCS	.222*	.325**	.241*	-.124	.502**	.089	-.351**	.082	1

*significant at 0.05 level
** significant at 0.01 level
Source: author's data calculations from SPSS software
*** GOP – Gross Operating Profitability, RCP – Receivables Collection Period, ICP – Inventory Conversion Period, PDP – Payables Deferral Period, CCC – Cash Conversion Cycle, LNS – Natural Logarithm of Sales, DR – Debt Ratio, CR – Current Ratio, WSC –relation of working capital to turnover.

Pearson's correlation ratio in relation to all variables (Table 3). In the selected enterprises there is correlation between almost all the variables, with the exception of total liquidity and gross operating profitability. Analysing the correlation between GOP and explanatory variables, it is seen that there is significant positive correlation with the payables deferral period (r = 0.507). Though some researchers proved negative correlation between GOP and PDP in their works, in some studies (Mathuva [10], Nobanee [12]) there is also positive correlation between these indicators. The author concludes that the positive correlation indicates that enterprises are realising the creditors' debt paying policy, which is directed to slow payments. It is also proved by results of the primary data analysis. Such a creditor management policy gives opportunity to use available cash assets longer and increases profitability.

There is significant negative correlation between GOP and CCC (r = -0.354). Research in this sphere certifies that this correlation is usually negative. It shows that the enterprises' cash policy is directed to shortening of the cash conversion cycle.

Positive correlation is observed between GOP and RCP (r = 0.235). The largest part of studies prove that this correlation is negative. It means that it is possible to improve profitability by managing receivables collection period. Positive GOP and RCP correlation was proved in Sharma, Kumar's [17] (2011) works about enterprises in India.

There is positive correlation between GOP and ICP (r = 0.348). Like in the case above, the largest part of studies prove negative or insignificant correlation. Positive correlation was noted by Mathuva [10] (2009) at enterprises in Japan, and he concluded that excessive concentration on reduction of inventory cannot be evaluated positively. The author of the thesis draws a conclusion that the excessive concentration on reduction of inventory and the conversion period can give an opposite effect, i.e. decrease of profitability. Maintaining of the inventory level can decrease delivery costs, prevent from price variation, ensures continuity of the production process. Sufficiently high level of finished commodity and goods positively influences the enterprise's ability to keep customers and the profit without decreasing the production amount.

Analysing controlling variables, it was discovered that there is significant correlation between the size of the enterprise and profitability (r = 0.330). This connection proves that the size of the enterprise influences its profitability. Growth of the enterprise and increase of the turnover are one of the most important entrepreneurs' aims, which is also proved by the correlation analysis.

Negative correlation between DR and GOP (r = -0.476) characterises the influence of the external financial risk on possibilities of profitability increase. In various authors' studies, negative correlation between CR and GOP was discovered, but it has not been found in the given selected group.

Regression Analysis

The regression analysis is used to investigate possibilities of gross operating profitability forecasting using methods of management of current assets. In order to perform this analysis the Fixed effects model (FEM) was applied. FEM explains possibilities of profitability forecast at enterprises. The choice of this model is useful, when a concrete group Nof enterprises is investigated – it is random and impossible to influence. FEM method was used in other researchers' works Deloof [3] (2003), Padachi [13] (2006), Mathuva [10] (2009), Dong, Su [4] 2010).

For expressing gross operating profitability (GOP) they use multiple factor correlation – regression equation in the linear form, where the dependent variable is GOP, as well as explanatory variables, that can influence GOP.

The formula for calculation of GOP is developed as equations of multiple linear regression, where GOP is used as the dependent variable, but the following groups of factors are used as the independent variables:

- *RCP, LnS, DR, CR;*
- *ICP, LnS, DR, CR;*
- *PDP, LnS, DR, CR;*
- *CCC, LnS, DR, CR.*

An impact of working capital management upon corporate profitability was modelled using the following regression equations:

$$GOP = f(RCP, ICP, PDP, CCC, LnS, CR, DR, \lambda) \quad (1)$$

$$GOP = \beta0 + \beta1(RCPit) + \beta2(CRit) + \beta3(DRit) + \beta4(LnSit) + \varepsilon \quad (2)$$

$$GOP = \beta0 + \beta1(ICPit) + \beta2(CRit) + \beta3(DRit) + \beta4(LnSit) + \varepsilon \quad (3)$$

$$GOP = \beta0 + \beta1(PDPit) + \beta2(CRit) + \beta3(DRit) + \beta4(LnSit) + \varepsilon \quad (4)$$

$$GOP=\beta0+\beta1(CCCit)+\beta2(CRit)+\beta3(DRit)+ +\beta4(LnSit) + \varepsilon \quad (5)$$

TABLE 4.

Determination coefficients for gross profitability forecasting according to various explanatory variables

Model	Determination coefficient	Determination error	Standardised coefficient Beta
Constant	-15.038	20.551	
RCP	0.117	0.404	0.257
DR	- 25.769	5.818	-0.398
LnS	4.023	1.460	0.251
Constant	35.408	4.906	
PDP	0.033	0.005	0.514
DR	-32.284	4.449	-0.524
Constant	38.388	5.690	
ICP	0.026	5.149	-0.502
DR	-30.944	0.007	0.325
Constant	3.267	16.964	
CCC	-0.039	0.008	-0.388
DR	-30.288	4.998	-0.492
LnS	3.197	1.239	0.209
Constant	-15.038	20.551	
RCP	0.117	0.404	0.257
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Source: author's data calculations from SPSS software

* GOP – Gross Operating Profitability, RCP – Receivables Collection Period, ICP – Inventory Conversion Period, PDP – Payables Deferral Period, CCC – Cash Conversion Cycle, LNS – Natural Logarithm of Sales, DR – Debt Ratio.

Regression equations are solved for the entire selected group. In Table 4, determination coefficients for various explanatory variables are summarised.

As a result of the analysis, four regression equations were made, which are expressed with every explanatory variable.

TABLE 5.

Regression models of gross profitability forecasting according to various explanatory variables

Regression equation	R	R^2
GOP = - 15.038 + 0.117*RCP – 25.769*DR + 4.023LnS	0.576	0.331
GOP = 35.408 + 0.033*PDP – 32.284*DR	0.728	0.530
GOP = 38.388 + 0.026*ICP – 30.944*DR	0.610	0,372
GOP = 3.267 – 0.039*CCC – 30.288*DR + 3.197*LnS	0.685	0.469

Source: author's data calculations from SPSS software

* GOP – Gross Operating Profitability, RCP – Receivables Collection Period, ICP – Inventory Conversion Period, PDP – Payables Deferral Period, CCC – Cash Conversion Cycle, LNS – Natural Logarithm of Sales, DR – Debt Ratio.

Regression models were made using the Fisher F-test. F-test is applied, when statistical models are compared for a set of data to define a model which better suits for usage. As a result of the F-test the acquired models fit the data using a smaller square. In Table 5, GOP variance is expressed with:

- RCP for 33%, which is related to DR and LnS;
- PDP – 53%, related to DR;
- ICP – 37% related to DR;
- CCC – 47%, related to DR and LnS.

In general, we may conclude that all regression coefficients are important. Developed regression equations can be used for gross profit cost-efficiency forecasting and decision-making in relation to management of current assets, or while implementing management of current assets, it is possible to forecast gross operating profitability.

In order to make more exact regression models, as well as to guarantee better forecasting significance, the author conducted the regression analysis by spheres. During the analysis the author concluded that in none of the spheres there is a significant relation between GOP and RCP.

In Table 6, determination coefficients are shown for variances for enterprises working in the production sphere. For the production sphere determination coefficients were found for variances PDP, ICP and CCC.

For the production sector, the regression models were made expressing GOP with:

- PDP – 82%, related to DR;
- ICP – 69%, related to DR and LnS;
- CCC – 84%, related to DR.

On basis of the data in Table 7, it is possible to conclude that the acquired regression coefficients are significant with credibility limit 70% and more. Regression equations can be used at production companies for gross profit cost-efficiency forecasting using possibilities of current asset management.

TABLE 6.

Regression models for gross profitability forecasting according to various explanatory variables in the production sphere

Model	Determination coefficient	Determination error	Standardised coefficient Beta
Constant	47.083	5.851	
PDP	0.033	0.004	0.581
DR	-49.050	5.547	-0.695
Constant	62.081	9.431	
ICP	0.043	0.011	0.396
DR	- 54.917	8.076	-0.778
LnS	-0.374	0.147	-0.291
Constant	57.215	5.324	
CCC	-0.51	0.006	-0.597
DR	-52.829	5.317	-0.748

Determination coefficients for forecasting gross profitability according to various explanatory variables in the production sphere

Source: author's data calculations from SPSS software

* GOP – Gross Operating Profitability, ICP – Inventory Conversion Period, PDP – Payables Deferral Period, CCC – Cash Conversion Cycle, LNS – Natural Logarithm of Sales, DR – Debt Ratio.

TABLE 7.

Regression models for gross profitability forecasting according to various explanatory variables in the production sphere

Regression equation	R	R^2
GOP = 47.083 + 0.033*PDP– 49.050*DR	0.906	0.82
GOP = 62.081 + 0.043*ICP – 54.917*DR – 0.374Lns	0.832	0.69
GOP = 57.215 – 0.51*CCC – 52.829*DR	0.915	0.83

Source: author's data calculations from SPSS software

* GOP – Gross Operating Profitability, ICP – Inventory Conversion Period, PDP – Payables Deferral Period, CCC – Cash Conversion Cycle, LNS – Natural Logarithm of Sales, DR – Debt Ratio.

TABLE 8.

Determination coefficients for forecasting gross profitability according to various variables in the trade sector

Model	Determination coefficient	Determination error	Standardised coefficient Beta
Constant	-20.341	11.269	
PDP	0.027	0.004	0.688
LnS	2.253	0.940	0.260
Constant	-18.793	12.476	
ICP	0.021	0.004	0.688
CR	- 0.102	0.046	-0.253
LnS	2.331	1.007	0.269

Source: author's data calculations from SPSS software

* GOP – Gross Operating Profitability, ICP – Inventory Conversion Period, PDP – Payables Deferral Period, LNS – Natural Logarithm of Sales, CR – Current Ratio.

In the selected group of the trade sector determination coefficients were acquired only in relation to PDP and ICP (Table 8). No connection was found between other explanatory variables and GOP.

TABLE 9.

Regression models for gross profitability forecasting according to various explanatory variables in the trade sphere

Regression equation	R	R^2
GOP = -20.341 + 0.027*PDP + 2.253*LnS	0.825	0.680
GOP = - 18.793 + 0.021*ICP – 0.102*CR + 2.331Lns	0.810	0.656

Source: author's data calculations from SPSS software

* GOP – Gross Operating Profitability, ICP – Inventory Conversion Period, PDP – Payables Deferral Period, LNS – Natural Logarithm of Sales, CR – Current Ratio.

In the trade sphere, the regression models were developed with (Table 9):

- GOP, expressing it with PDP of 68%, related to LnS;
- ICP – 66% related to CR and LnS.

The credibility of the regression equations is high – 70%. It allows us to conclude that the equations can be used at trade companies for GOP forecasting using methods of inventory and payables management.

TABLE 10.

Determination coefficients for gross profitability forecasting according to various explanatory variables in the sphere of services

Model	Determination coefficient	Determination error	Standardised coefficient Beta
Constant	-122.588	41.429	
CCC	-0.188	0.039	0.396
DR	- 39.680	8.133	-0.696
LnS	15.579	3.931	0.530

Source: author's data calculations from SPSS software

* GOP – Gross Operating Profitability, CCC – Cash Conversion Cycle, LNS – Natural Logarithm of Sales, DR – Debt Ratio.

Significant interconnection can be proved if only GOP is expressed with the explanatory variable CCC.

In the selected group of the trade sector determination coefficients were acquired only in relation to CCC (Table 10).

TABLE 11.

Regression models for gross profitability forecasting according to various explanatory variables in the sphere of services

Regression equation	R	R^2
GOP = -122.588 - 0.188*CCC– 439.68*DR + 15.579Lns	0.811	0.657

Source: author's data calculations from SPSS software

* GOP – Gross Operating Profitability, CCC – Cash Conversion Cycle, LNS – Natural Logarithm of Sales, DR – Debt Ratio.

The regression model for the sphere of services was developed expressing GOP with:

- CCC of 66%, related to DR and LnS (Table 11).

The credibility of the acquired regression equations is sufficient to be used for forecasting profitability (GOP) at enterprises working in the sphere of services, managing the cash asset cycle influenced by all other indicators of management of current assets.

As a result of the empirical research the author worked out mathematical models with a high credibility for forecasting gross operating profitability using indicators, which characterise management of current assets at companies working in the sphere of production, trade and services. Realising purposeful policy of management of some types of current assets, managers of various enterprises can influence indicators of the turnover of current assets. Regular analysis and planning of these indicators, using the developed regression equations can facilitate achieving the enterprise's target, i.e. the desired level of profitability.

The author has proved the hypothesis that was brought forward in the beginning of the research – enterprise managers can forecast and influence profitability of economic activity using management of elements of current assets.

V CONCLUSION

Pearson's correlation analysis results show that between aspects of the management of various elements of current assets there is a close connection. As a result of the correlation analysis, the author proved that at enterprises in Latvia there is significant correlation between profitability and indicators characterising current asset management. The correlation analysis proved that there are differences between the spheres. The acquired analysis results about enterprises in Latvia differ from the studies done at companies in other countries, but it can be explained and characterises specific features of the management of current assets realised at enterprises in Latvia.

In scientific research, much attention is paid to the analysis of financial indicators within the aspect of management of current assets and diagnosing the financial situation of the enterprise. Managers more often perceive analysis results as a fact and wish to improve each separate indicator without their complex evaluation. Doing the regression analysis the author developed possible forecasting models allowing of predicting enterprise's activity profitability using indicators of management of current assets.

All acquired regression coefficients are significant. Developed regression equations can be used for forecasting gross profit cost-efficiency and in decision making in relation to management of current assets, or, when implementing current asset management, gross activity profitability can be forecasted. The author offers more exact regression models divided into spheres of production, trade and services, which also ensures higher forecasting significance.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 35-40

Development of an Automated Approach for Updating of the Annual Runoff Module Map

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Abstract. **Several Russian Hydropower Design and Research Institutes have recently fulfilled studies of hydropower potential estimation for NorthWest, Caucasian and Angara River's regions in Russia. An approach to automate the calculation of river flow characteristics, based on the usage of annual flow rate map, was proposed and tested by the authors for the aims of the studies.**

Annual river flow characteristics together with the terrain data are the most important data sources for evaluation of the hydropower potential.

A set of requirements was made for the approach and for automation of annual flow rate maps creation in order to provide ability for updates in every 5-10 years.

A problem of lack of hydrological data for small and medium sized rivers was faced. To determine the hydrological characteristics the Russian code specification "Determination of Design Hydrological Performance" was used for the conditions of the lack of hydrological data, methods of spatial interpolation were also used.

To solve the problems it is necessary to define the parameters of the annual flow distribution: average annual flow, variation coefficient, coefficient of skewness.

Mapping is based on the assumption of a smooth change of annual flow rate for any territory in accordance with the distribution of climatic and physiographic factors (topography, soil, groundwater depth, etc.).

Milestones of flow rate mapping included: preparation of hydrological initial data; creating of the updated flow rate maps; determination of the corrections to the influence of local azonal factors; estimation of the accuracy of flow characteristics calculations.

In order to update the annual flow rate maps a special GIS application "Hydrologist" was created. The GIS application includes computer-assisted tool for processing the hydrological data, import/export tools, tools for analysis of area zoning data, tools for analysis of annual flow rate values in centroids of drainage-basins, location of water stage gauges, also the old and updated flow rate maps.

The article deals with the approach description, main problems that were faced and presenting the results.

The technology has been applied for North-West, Volga and Siberian Federal Districts in Russia. Comparison of the created annual flow rate map with the previously used map shows that the updated map is better of acquiring hydrological data for small and medium sized rivers.

***Keywords*: runoff module map, GIS-technologies.**

I INTRODUCTION

Large-scale studies for identifying locations of prospective small hydropower plants (SHPP) are currently conducted in Russia [1]. Within the scope of works authors have developed automated approaches for hydrologic data calculations. Hydropower potential calculations and SHPP siting were performed based on this hydrological characteristic.

According to analysis of world experience in automated hydropower potential calculations, the most common hydrological characteristic used for this kind of works is values of mean annual flow [2].

Authors have analyzed possible ways to obtain the annual flow rate data of Russian rivers, and the decision to update the runoff module map was made (Fig. 1).

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.259

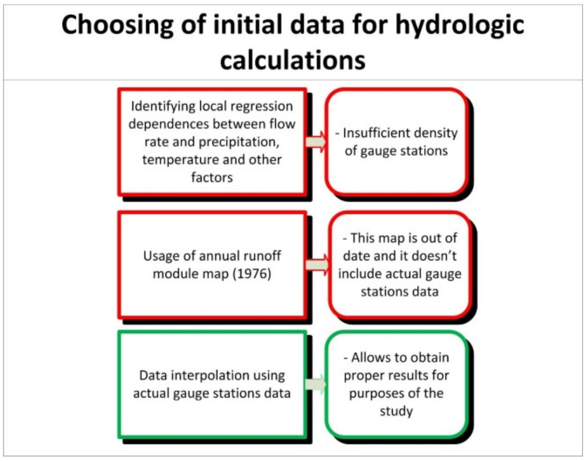

Fig. 1. Choosing of initial data for hydrologic calculations.

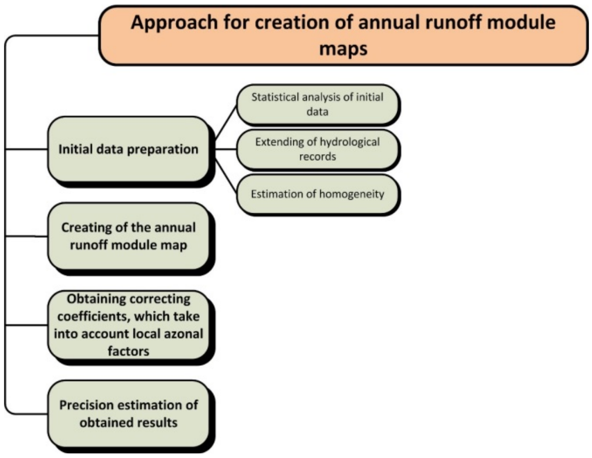

Fig. 2. Approach for creation of annual runoff module maps.

Development of software application was needed to provide the ability to update runoff module map every 5-10 years. This application allows storing initial data for calculations, provides tools for hydrologic data processing, tools for import/export of hydrologic records and other information stored, such as runoff module in watersheds gravity centers, locations of gauge stations, previous and updated versions of runoff module maps.

Taking into account insufficient exploration degree of medium and small rivers in Russia, method of spatial interpolation was used to obtain hydrologic parameters (this method is recommended by regulatory document [3] in case of a lack of hydrological measurements).

II PROPOSED APPROACH

To solve the problems of the research, calculations of distribution of annual flow rate parameters are needed. So, mean annual flow rate, spread coefficient and ratio of skewness coefficient to spread coefficient should be calculated [4, 5].

The annual flow rate distribution depends on zonal climatic factors changes and elements of natural landscape [6]. Climatic zones and altitudinal zonation gives grounds for creating flow rate distribution maps. An ability of creating runoff module maps is based on an assumption of smooth spatial changes of annual mean flow rate in accordance with distribution of climatic and physiographic factors [7].

The main work stages of creating maps of annual flow rate distribution are shown on Fig.2:

Creation of annual flow rate distribution maps was performed based on hydrological data of medium rivers with watershed area from 2 000 to 50 000 km^2, because flow rate of these rivers depends on zonal factors. Hydrologic records were extended for all gauge stations with period of measurements more than 6 years using method of regression dependence.

Excluding of systematic decrease of extended hydrologic records dispersion was achieved by using correcting value of annual mean flow rate [4]:

$$Q_i' = (Q_i - Q_{mean})/R + Q_{mean}, \qquad (1)$$

Where:

Q_i' – annual values of hydrologic characteristics, calculated using regression equations,

Q_{mean} – mean value of hydrologic records for the same period as in gauge station analogue

R – coefficient of correlation between studying river flow rate and flow rate in gauge station analogue

Annual flow rate distribution values were normalized to watershed gravity center of the river.

In purpose to create contour maps of flow rate distribution parameters the GIS-based WEB-application was developed. This application allows user to place an interpolative conjunctions between the centers of the watersheds. The necessity of adding the conjunction is determined by user and is based on mean watershed altitude.

The interpolation is carried out only between watersheds gravity centers, which are located in similar climatic and zonal conditions. Interpolation was performed by taking into account distance between points and altitude zonation.

Figure 3 shows a map fragment with interpolative conjunctions.

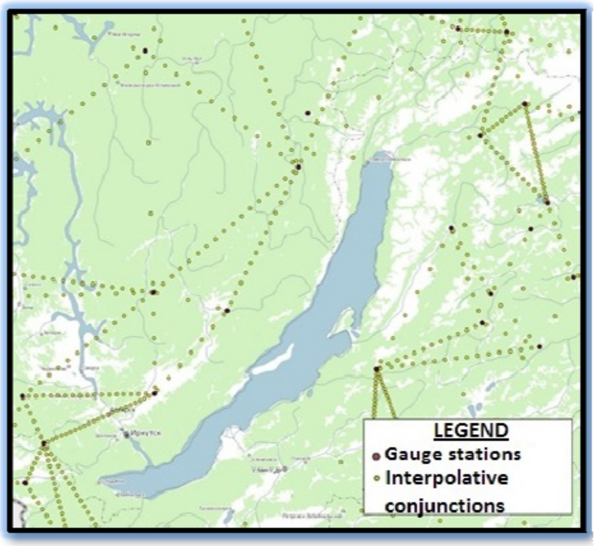

Fig. 3. Interpolation of annual average runoff module values (Russia map fragment).

After adding the conjunctions, added points were stored in the database.

Contour maps of flow rate distribution parameters were created using obtained values of runoff module in watersheds' gravity centers and interpolated values.

The accuracy of contours delineating and precision of calculated values of runoff module are depend on the river network density, smoothness of surface topography changes, precision of specifying watersheds gravity centers and spatial structure of annual flow rate.

Authors have plotted charts of flow rate distribution parameters versus watershed area and obtained deviations of small rivers' flow rate from zonal mean annual flow rate. Taking into account obtained charts; correcting coefficients for runoff module of small rivers with lack of hydrological measurements were obtained.

For mountainous study areas a local dependences between runoff module and watershed altitude were identified: $q = f(H_{wtrshd})$.

Changes of spread coefficient (C_v) and mean annual flow rate depend on latitude. Based on a C_v values, a map of rivers annual flow rate variability were created.

Spatial generalization of skewness coefficient (C_s) is hardly possible in most cases, because of significant random errors of this parameter caused by insufficiency of initial data. Therefore, the ratio (C_s/C_v) was calculated and this parameter was regionalized.

Mean annual flow rate for control point located on a plain territory can be obtained using linear interpolation between contours [8]. But in case of significant elevation changes between runoff module contours, the linear interpolation will give incorrect results. To avoid this problem, runoff module can be obtained using following equation (in case of two or more contours intersecting studying watershed) [3]:

$$q_{\text{cp}} = (q_1 \cdot A_1 + q_2 \cdot A_2 + \cdots + q_n \cdot A_n)/A, \qquad (2)$$

Where:

q_1, q_2, ... , q_n – mean values of runoff module between adjoining contours;

A_1, A_2, ... , A_n – watershed areas between contours;

A – aggregated watershed area in point of interest.

Local azonal factors affecting runoff module should be taken into account for small rivers. These factors consist of incomplete draining of ground waters, karst, watershed landform features, geology aspects and some other aspects.

Depending on ratio of surface to subsurface watershed area, annual mean flow rate of rivers, especially small-sized, may vary upwards (if subsurface watershed is larger than surface watershed) or downwards (in case of karst). Flow rate module of rivers located in karst regions can be reliably obtained only through hydrometric measurements or using method of hydrological analogy [9].

III APPROBATION OF PROPOSED APPROACH

This section represents an approbation of approach described above with North-West federal district as a study area.

First, gauge stations data was gathered and stored in a database and long-term hydrologic records were analyzed. As a result of the analysis, it was considered to take into account only gauge stations with the natural flow formation conditions. Also, gauge stations with statistically unreliable or heterogeneous by Student's test or by F-test hydrologic records were excluded. After exclusion, 482 gauge stations remained and were used for runoff module calculations. Most of gauge stations on the study area (60.3%) have hydrologic records for more than 30-year period.

Extending of short-period hydrologic records was performed for all gauge stations with 6 and more years of hydrologic measurements with the help of charts of annual flow rate correlation. Coefficients of correlation to annual flow rate in most cases (45.5%) vary from 0.70 to 0.80, in 39.8% - from 0.81 to 0.90 and in (14.7%) – from 0.91 to 0.99.

A fragment of summary table containing list of analogues, regression equations and coefficients of correlation is shown in Table 1.

Extended hydrologic records had passed verification of homogeneity by Student's test and by F-test. Calculated relative standard deviation for annual mean flow rate – (1.4 ÷ 12.3)%, for C_v – (1.0 ÷ 12.2)%.

The maps of flow rate module, variability of annual mean flow rate and ratio C_s/C_v were created. Gauge stations with anomalous flow rate values caused by local physiographic factors were excluded.

In regions with absence of hydrologic measurements, contours were delineated based on precipitation data, orography and climatic parameters.

Fragment of runoff module map is shown on the Figure 4.

Zonal distribution of annual flow rate correlates with distribution of precipitations and evaporation.

Runoff module varies largely on study area – from 2.9 to 37.2 l/(sec*km^2). This large range of values is determined by significant size of study area (1686968 km^2). In addition, mountainous regions of Ural and Kola Peninsula determine the wide range of runoff module values.

TABLE 1

FRAGMENT OF SUMMARY TABLE "RIVERS-ANALOGUES, REGRESSION EQUATIONS AND COEFFICIENTS OF CORRELATION

№	River – gauge station	Gauge station code	River-analogue		Equation	Coefficient of correlation
			Code	River – gauge station		
1	Mologa – Vesgonsk	36469	70334	Pinega – Kulogori	Y = 0.5498 X + 31.2974	0.78
			72169	Syas – Yahnovo	Y = 4.3117 X + -5.607	0.85
			36480	Sheksna – Krohino	Y = 1.2632 X + 81.1655	0.72
2	Sheksna – Krohino	36480	36469	Mologa – Vesgonsk	Y = 0.4132 X + 29.6137	0.72
			70002	Onega – Nadporozhskiy Pogost	Y = 0.7272 X + 39.0832	0.81
			70531	Pizhma – Borovaya	Y = 2.7784 X – 32.1576	0.71
			72327	Uver – Megletsi	Y = 10.2409 X – 14.2069	0.77
			75155	Lid – Turgosh	Y = 11.1382 X – 21.7919	0.89
			75169	Suda – Kurakino	Y = 4.8691 X – 73.4054	0.93

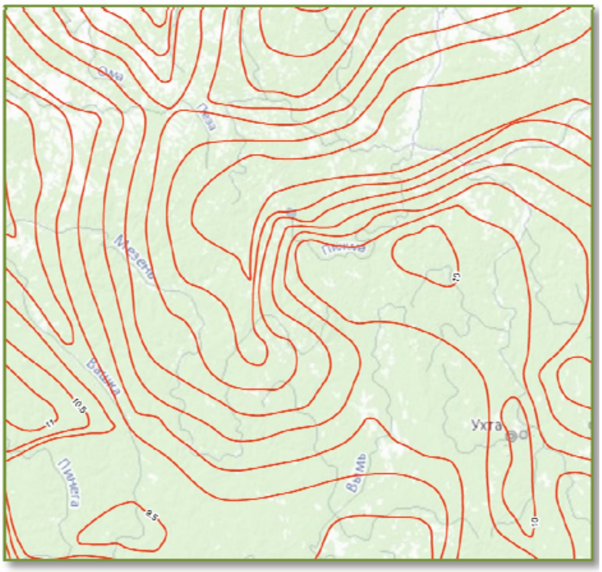

Fig. 4. Fragment of the annual runoff module map on North-West federal district study area.

Calculated runoff module values were compared with actual gauge stations data (25 gauge stations were analyzed). Mean deviation for runoff module – 6.0%, minimum deviation – 0.7%, maximum – 24.2%. In general, obtained runoff module values are proper.

The approach described above was applied for several federal districts in Russia. Correcting coefficients for small rivers and dependences between runoff module and flow formation factors were identified. This approach allows to calculate annual flow rate parameters of rivers and to make a preliminary justification of stream reaches hydropower potential development [10].

Also, the comparison of calculated runoff module values with existing runoff module map (was created in 1976 year [11]) was performed. Results of comparison are shown on the Figure 5 and Figure 6.

As shown on Figure 5, maximum deviations of runoff module are less than 10.0 l/(sec*km^2), mean deviations – 3.0 l/(sec*km^2). Maximum deviations appeared in Ural foothills.

To provide ability for updating runoff module maps, WEB-application was developed. The architecture of the application is shown on Figure 7.

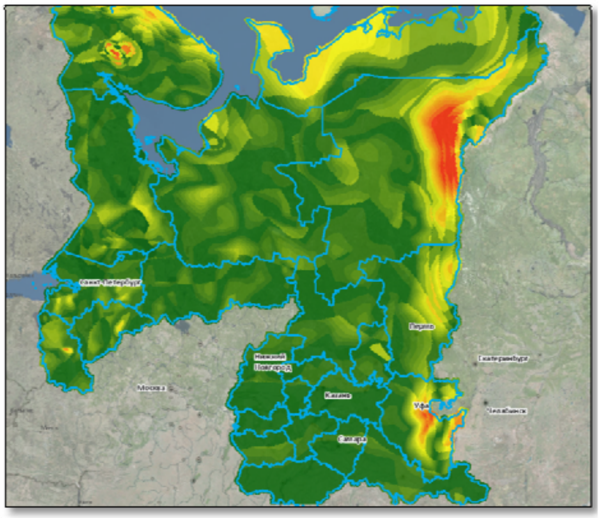

Fig. 5. Differences between runoff module values (comparison of 1976 and 2014 year data).

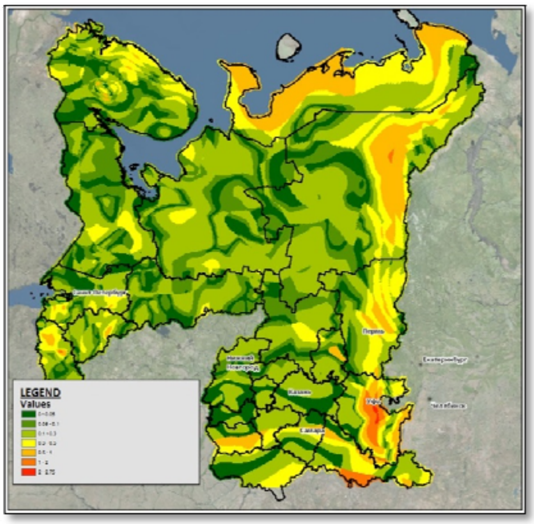

Fig. 6. Relative differences between runoff module values (comparison of 1976 and 2014 year data).

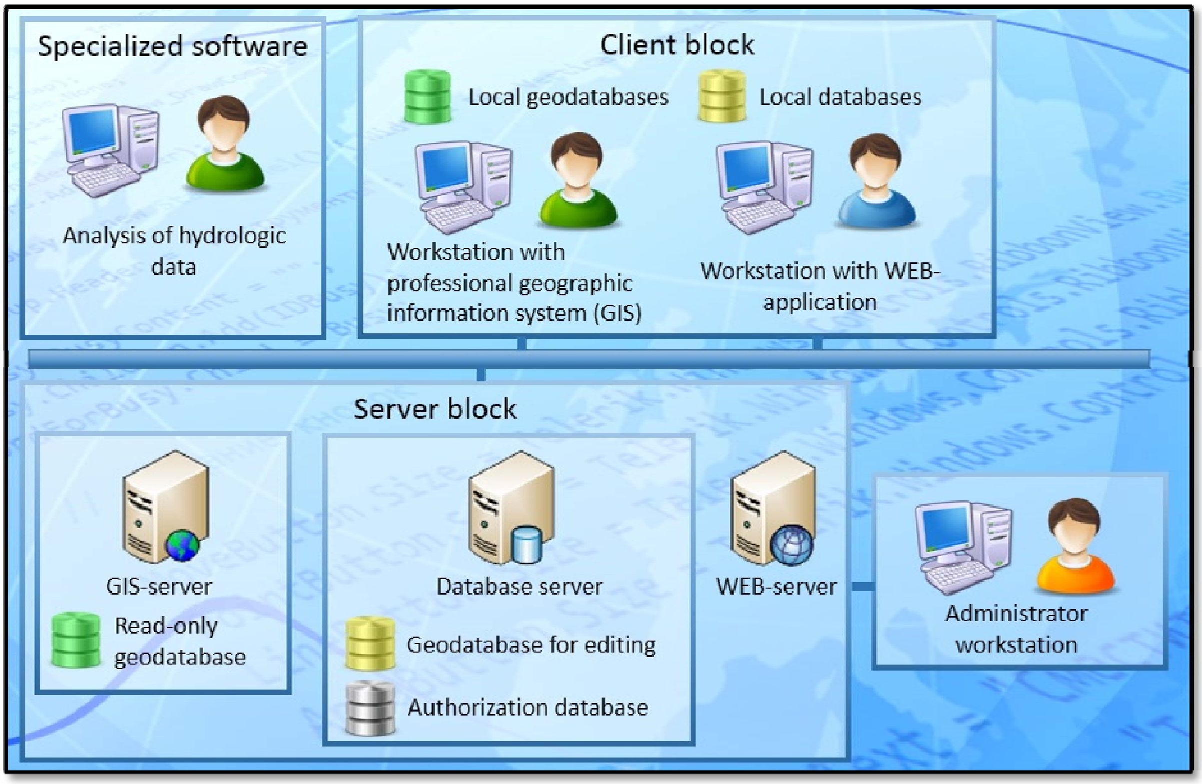

Fig. 7. Architecture of developed WEB-application

IV CONCLUSION

The approach for creating runoff module maps was developed based on Russian regulatory document [3]. The approbation of proposed approach was carried out. Runoff module map for several federal districts in Russia was created; obtained results were compared with previous versions of runoff module map and with gauge stations data. Also, maps of C_v and (C_s/C_v) distribution were created. Described approach allows calculating runoff module for all Russian territory and provides the ability to update the runoff module map every 5-10 years using up-to-date gauge stations data.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 41-50

Development of Automated Approaches for HydropowerPotential Estimations and Prospective Hydropower Plants Siting

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Abstract. **Hydropower potential studies usually include estimation of hydropower resources and creating propositions for hydropower development on study area. The current paper describes authors' study, dedicated to development of methodological approaches and software designed for solving problems stated above. Process automation is achieved by using geographic information systems (GIS) and additional programs (Python language was used).**

Hydropower potential estimation is the key element for understanding future prospects of hydropower development within the study area. The latest large-scale hydropower potential studies of Russian territories were held in 1940-1980. In those times, such researches were carried out almost without any automation, so calculation process was time-consuming. As a result, only hydropower potential of large and several medium-sized rivers was estimated; hydropower potential assessments of small rivers were conducted only using approximate approach.

Nowadays, implementation of technologies and software products, such as geographic information systems, contributes to development of methodologies, which can be used to automate business-processes in different scientific disciplines, including processes of hydropower potential estimation and prospective hydropower plants siting. In comparison with former studies, GIS allow to reduce labor work significantly and to perform analysis of large study areas and large number of streams (including small rivers) in relatively short time using up-to-date topographical, hydrological and hydrographical information.

Authors have developed and tested methodological approach and GIS-tools for automated hydropower potential estimation. Re-estimation of hydropower potential was fulfilled by the authors for the most part of Russia. The data for more than 10 000 river's was compared to the results of prior studies (data, such as river basin area, annual river flow, hydropower potential). The gross hydropower capacity of rivers and gross hydropower potential were estimated as 350 GW and 3,07*103 TWh respectively.

The next step in hydropower potential studies is prospective hydropower plants siting. Authors developed methodological approach and GIS-tools to automate this process. The GIS-tools provide comparison of site alternatives based on their hydropower parameters; transport, infrastructure, electricity network proximity; topographic situation and other factors affecting site suitability. Algorithm of automation and results of the search siting are presented.

Keywords: **Geographic information systems, Hydropower potential, Hydropower plants siting.**

I INTRODUCTION

A. Relevance of the research

Large-scale studies of Russian rivers hydropower potential are currently conducted in order to identify locations of prospective small hydropower plants [1], [2].

Previous large-scale studies of hydropower potential of large and medium-sized rivers in Russia were conducted in 1940-1980. These studies were held by Grigoriev S.V. (1946, [3]), Voznesensky A.N. (1967, [4]), Feldman B.N. (1985, [5]).

Due to insufficient amount of annual rivers flow data (especially in the eastern regions of the country) and poor precision of topographic data, assessment of hydropower potential in these studies was approximate and it was performed only for large and medium-sized rivers [4].

In addition, due to complexity of these researches and a large amount of rivers studied (for example,

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.260

4702 rivers in study [4]), estimations of hydropower potential performed in 1940-1980 have required a lot of time and labor.

Usage of modern computer technologies, such as geographic information systems (GIS), allows building tools which provide partial automation of hydropower potential calculations. However, analyzing of recent researches and developing methodology of automated hydropower potential calculations was needed to build these tools.

Present paper describes approaches of automated hydropower calculations, based on ESRI ArcGIS Desktop and modules for interactive data processing (GIS server ESRI technologies), developed and implemented by the authors. Comparisons of catchment areas, flow rates and gross hydropower potential values obtained in this research and the results of past years studies are given.

Presented approaches allow partially automated calculation of Russian rivers hydropower potential using updated hydrological data and relevant digital terrain models.

B. Analysis of other GIS-based studies of hydropower potential

Estimation of hydropower potential using GIS was lately performed for a set of countries (USA, France, Italy, Norway, Canada, Scotland and others) – examples are shown in [6,7,8,9,10]. Brief review of these researches was described in [6]. Also, paper [6] overviews some GIS-based tools for hydropower assessments.

The main difference between the GIS-based tools described in [6] is in the initial data which was used for hydropower assessment. The key initial data that is necessary for hydropower potential calculations includes hydrographic data, terrain data and hydrological data (in particular, mean annual flow rates). The studies mentioned in [6] use GIS-layers for hydrographic data, digital elevation models (DEM) as terrain data and annual river runoff or annual river runoff module (liters per sec. / sq. km.) values for flow rates calculation.

Paper [7] describes methodology of calculating gross, available and economic potential of the United States of America. National Hydrography Dataset [11] (synthetic rivers network for territory of the entire country) was used as hydrographic data, SRTM [12] was used as DEM and runoff data was derived from precipitation data.

C. Purpose of the research

The main purpose of this study was to develop and implement methodology and GIS-based tools to automate the calculation of the hydropower potential of rivers and stream reaches.

Based on the analysis of previous studies authors have performed the following tasks:

1. Methodology of partially automated hydropower calculation was proposed and requirements for initial data (terrain, hydrographic and hydrological) for calculation were described;
2. Terrain, hydrographic and hydrologic data was gathered and systemized;
3. ArcGIS Desktop based tools for calculating hydropower potential were developed;
4. Several Esri GIS-server technologies based applications were developed for automating calculations, for verification and presenting of the results;
5. Proposed approaches were implemented on a set of hydrological units in Russia, the results for a selected hydrological unit (Ket river watershed, basin of upper Ob) are presented in the paper;
6. Results of calculations (watershed areas, flow rates, gross potential values) were compared to the results of prior studies.

II METHODOLOGY DESCRIPTION AND REQUIREMENTS FOR INITIAL DATA

A. Proposed approach for dividing territory into calculating zones

Hydropower potential estimations are usually performed for large areas, so there is a need in organizing data using hierarchical structures. Territory of Russian Federation is divided into hydrological units based on rivers' watersheds.

In present research basin-landscape approach was used for calculating of hydropower potential. The advantage of this approach is that boundaries of hydrological units are coincident with natural watersheds, which is necessary for delineating catchments inside the study area.

Currently classification of water use zoning in Russia includes 4 levels of classification of hydrological units: regions, basins, sub-basins and the so called water management areas (Figure 1). Water management area is selected as the smallest area for calculation of hydropower potential.

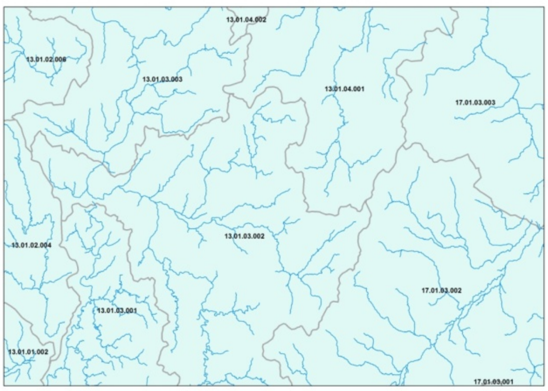


Fig. 1. Example of Russian water use zoning map (zones with identifiers)

B. Categories of hydropower potential

According to [4] there are 3 categories of hydropower potential:

Gross hydropower potential is the full theoretical sum of water flow energy.

Gross hydropower potential of a river can be calculated by summing potentials of its stream reaches:

$$P = \sum_{i=1}^{n} Ni * t = \sum_{i=1}^{n} [g * (\frac{Q_{1i} + Q_{2i}}{2}) * H_i] * t$$

P – gross hydropower potential, kWh
Ni – gross capacity of a stream reach, kW
i – number of stream reach
g – the acceleration of gravity, m/s^2
Q_{1i} - flow rate in beginning point of stream reach, m^3/s
Q_{2i} - flow rate in ending point of stream reach, m^3/s
H - elevation difference on stream reach, m
t = 8760 hours - the number of hours per year

In this study the same approach as in [4] was used: streams are divided by the sections (stream reaches) between the tributaries where the flow rate significantly increases.

Technical hydropower potential is a part of theoretical hydropower potential that can be technically used.

In most cases estimation of technical potential is based on analysis of empirical data of the studied rivers [4]. According to [5], rivers in Russia may be classified by annual mean power (N), which can be obtained from annual mean flow rate of stream reach:

N< 2 MW – first group (Theoretical usage coefficient is set as 0,17);

2 MW <N< 100 MW – second group (K_i= *0,35*);

N> 100 MW – third group.

Theoretical usage coefficient for the third group in the current study was set to 0,4; 0,5; 0,6 for rivers with the slope of less than 1,0 m / 1,0 km; 1,0-2,5 m / 1 km; over 2,5 / 1,0 km respectively.

Economical hydropower potential is a part of technical hydropower potential that is feasible for usage. This study doesn't cover economical potential estimation. Traditionally estimation of economical potential is a complex work due to the necessity of analyzing many factors affecting the feasibility studies of HPP sites [4, 5, 13, 16].

In many studies researchers also estimate *available hydropower potential*, which is the gross hydropower potential for all the river sections (stream reaches) that are not situated in excluded areas [7]. Usually the stream reaches, where flooding territories is prohibited or where the potential is already used are excluded.

In the current study the following territories are excluded: ecologically protected areas; reservoir territories; territories that are classified as improper for creating HPPs due to geotechnical conditions.

C. Initial Data for gross hydropower potential calculation

In the current study authors used the following data to calculate gross hydropower potential:

1. Russian water register database [14]

Russian water register is a systemized information catalog of water objects, situated in Russia. The register holds information about the river basin areas, lengths, identifiers of water management areas and etc.

2. Terrain data

The study uses digital elevation models (DEM) as the terrain data. Authors used the following DEMs in the current study: SRTM; DEM based on digital maps (scale 1:100000).

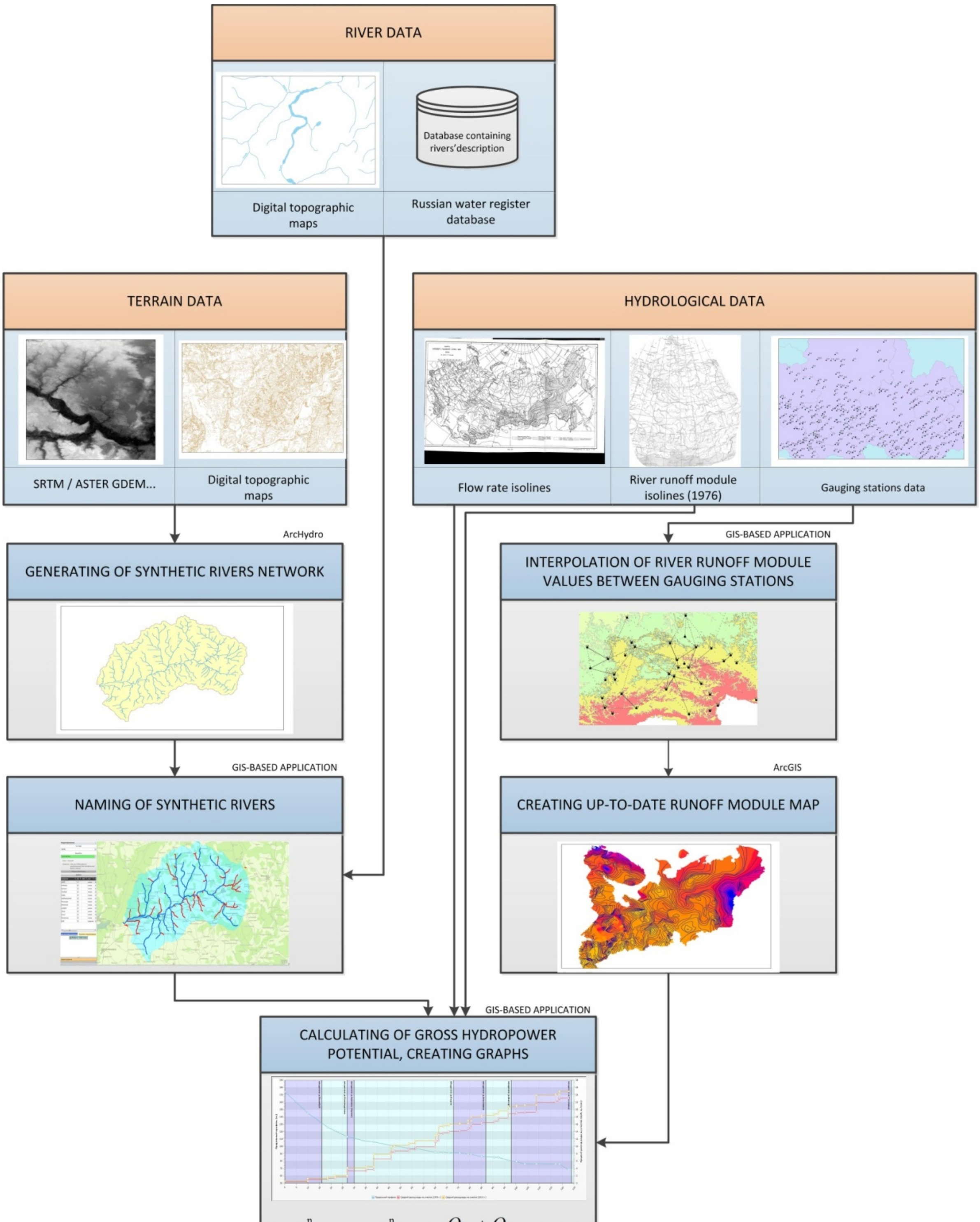
3. River's flow rate.

For estimating hydropower potential using (1) a river flow rates at every tributary inflow site are needed. Two possibilities of flow rate calculation were taken into account:

- Usage of 1976's annual river runoff module (q, liters per sec. / sq. km.) map.
- Creating an up-to-date annual river runoff module (q, liters per sec. / sq. km.) map.

D. Algorithm for theoretical hydropower potential calculation

Algorithm implemented for gross hydropower potential calculation is as follows (Figure 2).



$$P = \sum_{i=1}^{n} P_i * t = \sum_{i=1}^{n} [g * (\frac{Q_{2i} + Q_{1i}}{2}) * H_i] * t$$

Fig. 2. Algorithm for gross hydropower potential calculating

1. Synthetic river creation. The latest studies of hydropower potential estimation deal with synthetic rivers, which are mathematical models of river flow networks, calculated from the terrain data using a set of algorithms.

ArcHydro Toolset for ArcGIS Desktop was used and extended for the needs of this study.

Comparison of synthetic rivers and rivers obtained from digital maps showed that the tributary's sites match well, but the source of real rivers and synthetic rivers don't match. This is due to the fact, that finding a source of a real river always needs a complex study. At the same time source of a synthetic river placement (as well as synthetic rivers network density) depends on a set of thresholds in the algorithm [15].

2. In present study the partially automated algorithm for synthetic rivers naming was created to have the possibility for verifying current study results with the results obtained in previous researches. GIS-based application was created to match synthetic stream reaches with GIS-layers containing rivers. When all stream reaches which belong to the same river are selected, the name of this river is automatically assigned to them. Besides this, length and watershed area taken from Russian water register database are assigned to synthetic rivers.
3. For synthetic rivers' named stream reaches gross hydropower potential can be obtained using formula (1), where:

$$H_i = H_{2i} - H_{1i} \tag{3}$$

DEM is used to obtain beginning and ending point elevations of stream reach.

$$Q_{1i} = q_{1i} * F_{1i} \tag{4}$$

$$Q_{2i} = q_{2i} * F_{2i} \tag{5}$$

Where:

Q – annual flow rate , m^3/s;

q – the average annual river runoff module inside a watershed area, $l/(s*km^2)$

F – watershed for a selected site at a river, km^2

Runoff module in beginning and ending point of stream reach is a mean value of runoff module raster cells inside respective catchment area.

III APPROBATION OF PROPOSED METHODOLOGY FOR CALCULATING THE HYDROPOWER POTENTIAL USING GIS-TECHNOLOGIES

For approbation of proposed methodology water management area with hydrologic unit code (HUC) 13.01.06.001 was chosen. This water management area belongs to Upper Ob basin and presents river Ket's watershed. This water management area was chosen because there is a possibility for comparing obtained in current study values of gross hydropower potential for river Ket with results obtained in the previous study [4, p.89]. Also, flow rates and watershed areas for several Ket's tributaries are known.

Approbation of proposed methodology included following steps:

1. Creating synthetic river network (Figure 3)

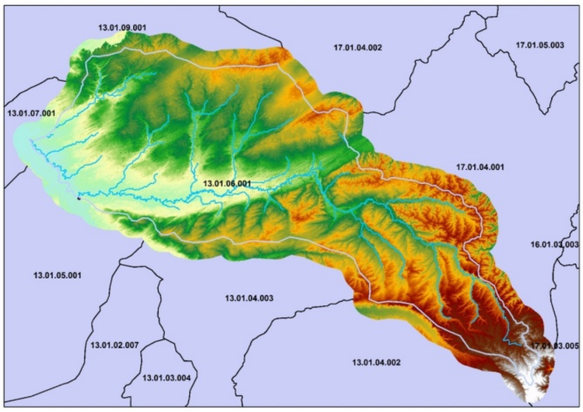


Fig. 3.Synthetic river network created for water management area 13.01.06.001

Naming of synthetic rivers according to digital map GIS-layer for "real" rivers. Real values of lengths and watershed areas were assigned to synthetic rivers using data from Russian water register database (Figure 5).

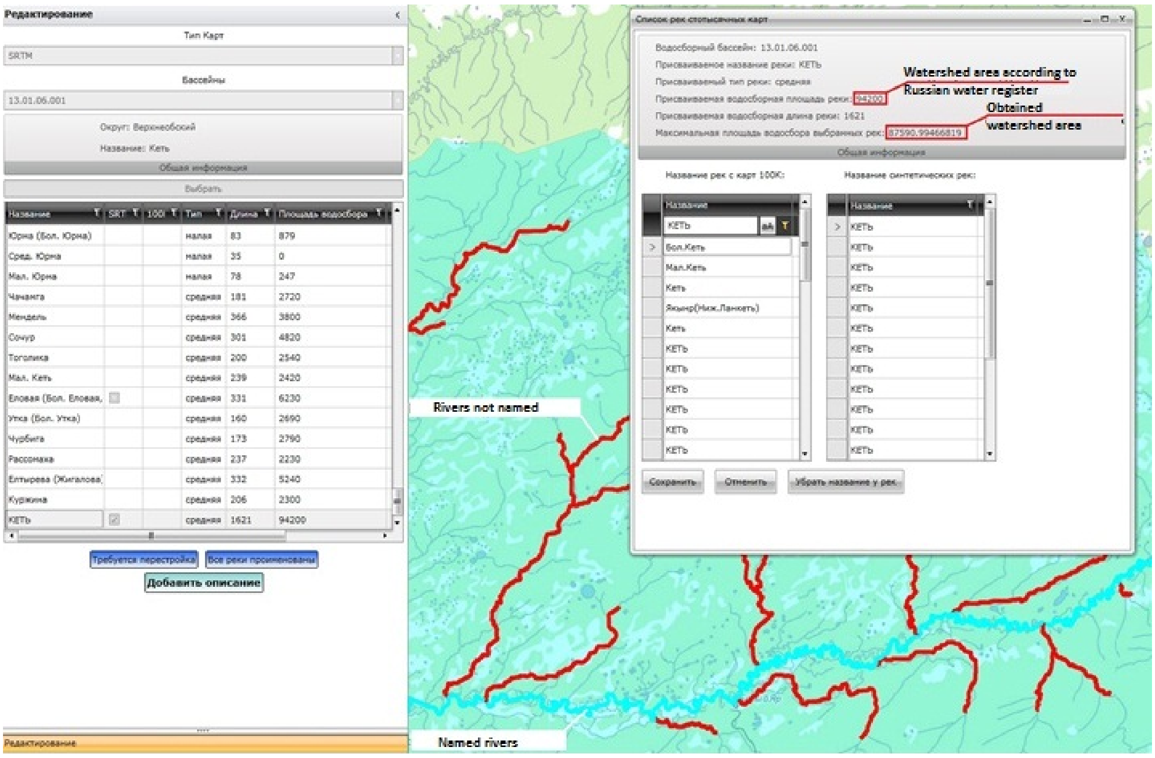


Fig. 4. Naming of synthetic rivers

2. Automated calculation of hydropower potential for all created synthetic rivers was performed.

Calculation results are presented on Figure 7. Process of calculation is rapid: 81 stream reaches were processed in 1,5 minutes (the study area is over 90 000 sq.km).

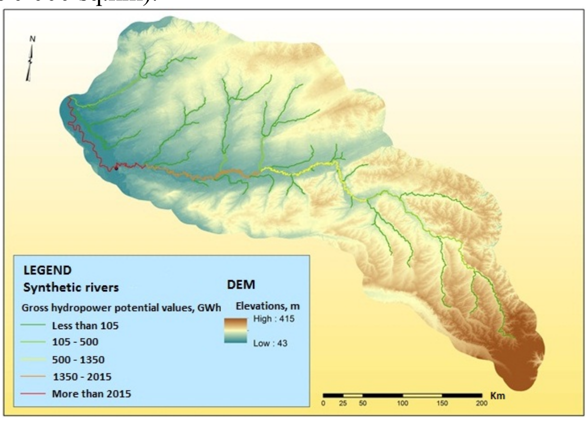


Fig. 5.Hydropower calculation results for water management area 13.01.06.001

Automated creation of graphs presenting longitudinal profile of rivers, increase of flow rate over the river and increase of hydropower potential over the river can be done using the GIS-based application, developed by the authors.

3. There were no excluded zones (ecologically protected areas or territories improper for creating HPPs due to geotechnical conditions) and existing reservoirs inside the study area, used for approbation. Hence, available potential is equal to gross hydropower potential of the rivers.

4. For each stream reach theoretical usage coefficient was calculated automatically and technical hydropower potential was obtained.

5. Verification of obtained results was performed including:

- Verification of watershed areas.

Obtained results were compared with Russian water register data [14] (Table 1).

- Verification of flow rates in pour points.

Verification of obtained based on up-to-date runoff module flow rate values was performed. These values were compared with relevant gauge stations data and collected from prior studies data (Table 2).

- Verification of gross hydropower potential.

Gross hydropower potential of river Ket obtained in this study was compared with [4]. Calculation of hydropower potential in [4] was made only for river trunk (river itself); tributaries were not included in calculations. Comparison of the results is shown in Table 3.

TABLE 1
VERIFICATION OF WATERSHED AREAS

River name	Obtained watershed area, sq.km	Watershed area according to Russian water register database, sq.km	Discrepancy, %
Orlovka	8804	9010	2,3
Churbiga	2647	2790	5,1
Kelma	1347	1390	3,1
Sochur	5079	4820	5,1
Yelovaya	6067	6230	4,0
Ket	87591	94200	7,0

TABLE 2
VERIFICATION OF FLOW RATES IN POUR POINTS

River name	Obtained flow rate, cubic meter per second	Flow rate according to relevant gauge stations data, cubic meter per second	Flow rate according to [4], 1967 year., cubic meter per second	Discrepancy of obtained and relevant flow rates, %
Orlovka	62,0	63,5	-	2,3
Ket	572,5	560	531	2,1

TABLE 3
COMPARISON OF GROSS HYDROPOWER POTENTIAL OBTAINED IN CURRENT STUDY AND IN STUDY [4]

River name	Gross hydropower potential obtained in current study, GWh	Gross hydropower potential obtained in [4], GWh	Discrepancy, %
Ket	2490	2129	14,5

Discrepancy in gross hydropower potential obtained in the present study and in [4] is due to updating of hydrological data and using DEM, that can cause some discrepancies in obtaining watershed areas as compared with traditional methods of delineating watersheds.

Also, the methodology used in the current study allows to automatically calculate the hydropower potential for a river itself and for the basin (the gross hydropower potential of a river and its tributaries are summed). Total Ket's river basin hydropower potential was estimated as 3387 GWh.

IV APPLYING PROPOSED METHODOLOGY FOR ESTIMATING HYDROPOWER POTENTIAL OF RIVERS IN RUSSIA

Authors created synthetic rivers networks for entire territory of Russia and hydropower potential calculations were performed. Density of synthetic rivers networks corresponds to second-third order tributaries. Russian rivers gross hydropower capacity and gross hydropower potential were estimated as 350 GW and $3{,}07*10^3$ TWh respectively.

Obtained results subsequently will be used for purposes of small hydropower plants siting. Generalized algorithm of this process is provided in Section 5.

V GENERALIZED ALGORITHM FOR AUTOMATED SEARCH OF FEASIBLE SMALL HYDROPOWER PLANTS SITES

This section includes only brief introduction to the methodology of economical hydropower potential estimation developed by the authors. The detailed methodology description will be presented after the verification of results of automated sites search.

The algorithm of entire process of prospective hydropower plants siting is shown on Fig. 6.

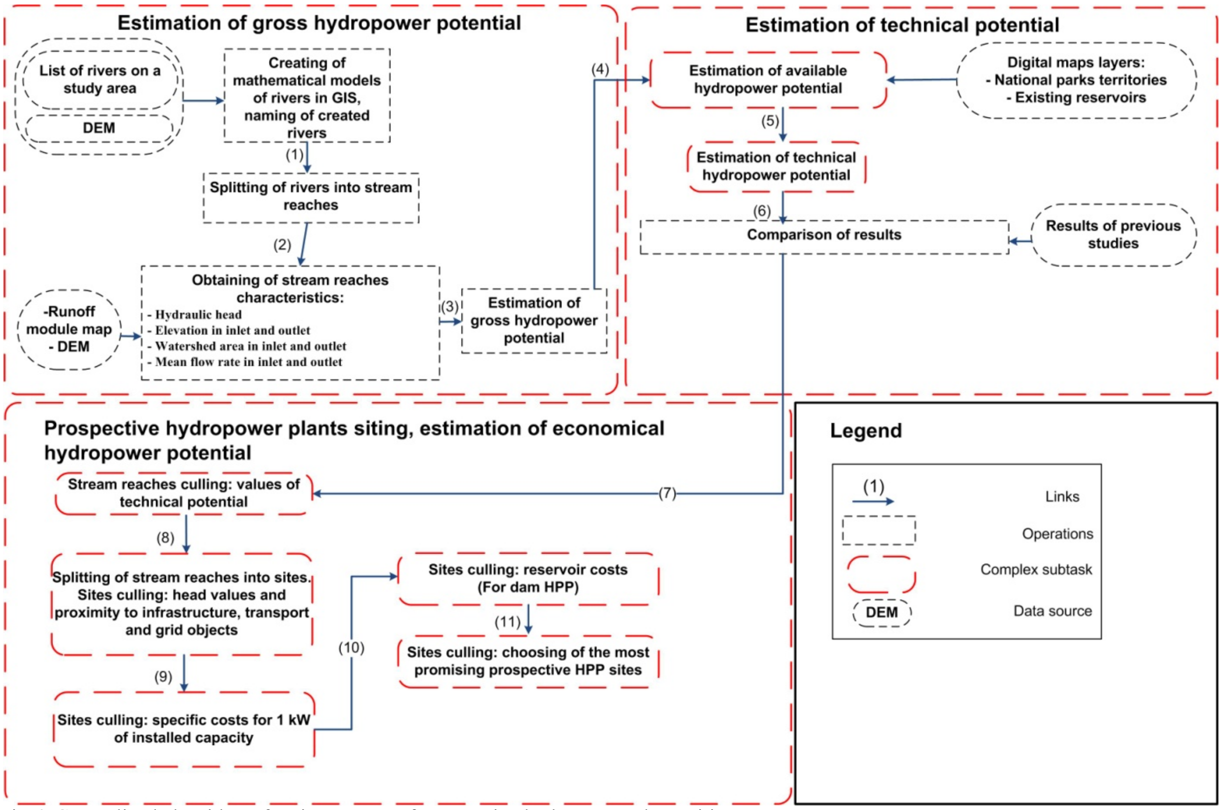


Fig.6. Generalized algorithm of entire process of prospective hydropower plants siting

To identify locations for prospective sites, first, stream reaches with low values of technical hydropower potential should be excluded.

After that, every remaining stream reach should be split into sites, and basic technical characteristics (installed capacity, discharge and head) of sites should be calculated.

Algorithm for small hydropower plants siting provides the way to identify suitable locations for dam HPPs and diversion HPPs. In case of dam HPP siting, at every site a list of HPP variants with different installed capacity should be analyzed. For each variant, the HPP head might be obtained using equation:

$$H = \frac{N}{8Q} \tag{6}$$

Where:

H – HPP head, m;

N – installed capacity, kW;

Q – HPP discharge, m3/s.

In case of diversion HPP, a penstock should be drawn from every site to every site inside the current stream reach. Elevation difference between inlet and outlet of penstock is the head of HPP, so, the installed capacity can be calculated using (6).

After obtaining basic HPP technical characteristics, a list of criteria can be used to exclude sites not matching the criteria:

- If obtained value of HPP head and discharge does not match the range of head and discharge values for HPP equipment, this site should be excluded.
- Proximity to infrastructure, transport and power grid objects affects site suitability. If site is located too far from settlements, roads, power grid, etc., this site should be excluded.
- Specific costs for 1 kW of installed capacity is the next criteria.
- For dam HPP, reservoir can be delineated. Using spatial intersection of reservoir GIS-layer and layers such as agricultural lands, roads, forests and other flooded objects, reservoir creating costs can be calculated, having statistics of reservoir costs for relative sites. If these costs exceed 30% of entire HPP investments, this site should be excluded.
- Remaining sites after all culling stages should be analyzed to identify the most promising sites. On this step, economic calculations should be performed. Rough estimations of costs of construction for each site can be obtained having the estimation of volumes of

dam, length of diversion scheme, costs of units and other equipment. These estimations at the prefeasibility stage of the study are fulfilled only for the purpose of searching feasible sites according to preferable topographical and hydrological conditions. Geotechnical conditions should also be taken into account, but at this stage authors only exclude territories with unsuitable geotechnical conditions for hydropower development. After that, all the sites are treated as equal according to geotechnical conditions. According to obtained technical-and-economic indexes, sites can be filtered to find most feasible ones. The final selection of sites can be performed based on multi-criteria analysis to identify the most promising sites.

Figures showing the results of the main steps are shown on Fig.7 (example of dam small hydropower plants siting).

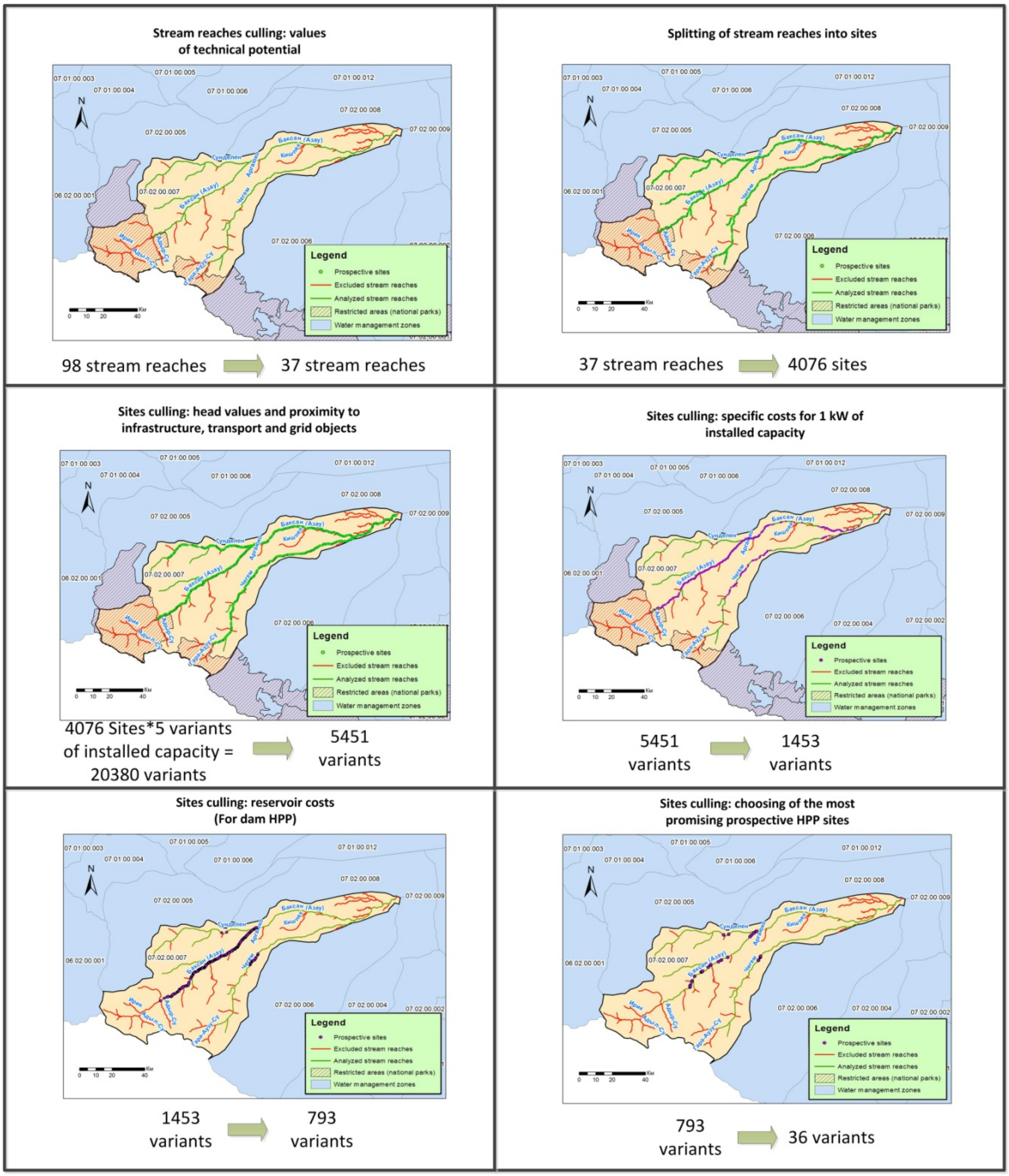


Fig. 7. Results of the main steps of small hydropower plants siting

VI CONCLUSION

Authors have developed and tested methodological approach and GIS-tools for automated hydropower potential estimation. Created GIS-based tools and applications were used for calculation and re-assessment of the hydropower potential in Russia. Verification of obtained results proved their reliability. Currently verification performed for about 300 pour points and 100 gauge stations.

Assessment of hydropower potential can be performed not only for water management areas, but also for administrative regions. Process of calculating hydropower potential is largely automated, so this allows calculating hydropower potential on large areas in a relatively short time. The proposed methodology allowed to execute automated hydropower potential estimation for the territory of Russia. Russian rivers gross hydropower capacity and gross hydropower potential were estimated as 350 GW and 3,07*103 TWh respectively.

Generalized algorithm for identifying prospective hydropower sites is presented in the paper. Figures presenting the results of main steps of the algorithm are shown. Detailed algorithm with criteria used for each factor while comparing the sites will be presented in additional paper, after methodology of feasible sites search is verified and the results are compared with the previous studies.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 51-55

Study on the influencing factors and strategies of sorted collection of urban refuse in China

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Abstract. **Although the sorted collection of urban refuse in China started later than that in developed countries, it has been sustained 14 years since the implementation of pilot project of waste sorting. However, the waste sorting among cities is still making slow progress and beset with difficulties in China. With a review of the actual situation of waste sorting in China, this article firstly introduced the urban refuse sorted way in China, and then analysed the influencing factors of the sorted collection of urban refuse. At last, we put forward some strategies and suggestions for dealing with the prominent challenges of the sorted collection of urban refuse in China.**

Keywords: **Urban refuse, Sorted collection, Influencing factors, Strategy.**

I INTRODUCTION

Waste sorting refers to put the same or similar quality waste together. According to designated time and type, the waste is placed to designated site and then collected by garbage truck, or put into waste recovery system. In developed countries (such as Japan and Germany), waste sorting management has entered a mature stage, while the implementation of waste sorting in China began relatively late and makes slow progress. In 2000, eight cities, such as, Beijing, Shanghai, Guangzhou, Shenzhen, Hangzhou, Nanjing, Xiamen and Guilin, were designated as pilot cities for sorted collection of urban refuse. However, in the past 14 years, the implementation of waste classification in these cities was not going well and still in the process of continuous exploration and research. How to effectively promote this people livelihood project? First and foremost, we should find the real cause of the slow development of the sorted collection of urban refuse. Only after knowing the cause, we can take appropriate measures to promote the stable development of the classification and collection of urban refuse.

II THE CLASSIFICATION OF THE URBAN REFUSE IN CHINA

Different countries have their own ways of classifying urban refuse according to national conditions. For example, Korea classified urban refuse into four kinds: recyclable waste, food waste, large waste and general household waste. In Germany, the urban refuse is divided into four categories: light-weight packing waste (yellow bin), biological waste (brown bin), paper waste (blue bin) and other waste (gray bin).

The urban refuse in China was classified into six sorts by recommended standard: recyclable waste, large-size waste, compostable waste, combustible waste, hazardous waste and other waste. But due to the limitations of waste collection/transportation and terminal disposal facilities, there are hardly any cities can sort urban refuse in more detailed and precise way. Most cities classified urban refuse into merely recyclable waste and other waste. Only a few pilot cities or areas classified urban refuse into recyclable waste, kitchen waste, hazardous waste, other waste and so on. Table 1 showed the present situation of waste

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.631

sorting and disposal in the four pilot cities in China [1,2,3].

TABLE 1
THE GENERAL SITUATION OF URBAN REFUSE SORTING IN PILOT CITIES

City	Beijing	Shanghai	Guangzhou	Shenzhen
Urban Refuse Output in 2014	18400 t/d	22000 t/d	18000 t/d	14500 t/d
Starting Time of Piloting	1996	1995	1998	1998
Categories	·Recyclable waste ·Kitchen waste ·Other waste	·Recyclable waste ·Wet waste ·Hazardous waste ·Dry waste	·Recyclable waste ·Kitchen waste ·Hazardous waste ·Other waste	·Recyclable waste ·Hazardous waste ·Other waste
Components (and their proportion) of Urban Refuse	Kitchen waste:53.61 %; Plastics:15.84 %; Paper:13.22%; Glass:1.29 %; Dust:1.93%; Textiles:1.04 %; Metal:1.08%; Other:11.99 %	Kitchen waste:31 %; Packaging:23 %; Plastic bag:18 %;Paper:12 %; Glass:9%;Harmful and electronic waste:7 %	Organic waste:65 %; Plastics:8.5 %; Glass:4 %;Paper:2.5 %; Other:20 %	Kitchen waste:47.16 %; Paper:8.5 %; Plastics:10.73 %; Glass:2.53 %; Metal:1.32 %; Textiles:3.57 %; Dust:21 %; Other:5.19 %
General Situation of Urban Refuse Sorting	There have been more than 3,000 residential area that implemented urban refuse sorting management. An initial urban waste disposal system was formed, which involves source separation, sorted collection, sorted transportation and sorted disposal of urban refuse.	At present, urban refuse sorting covers the number of residents about 2,450,000 households, more than 7,000 units. 2,000 electronic waste recycling points were built.	All 128 subdistricts and 36 towns in Guangzhou started waste sorting disposal. There are over 30% communities having started substantive waste sorting out of the 1400 communities that have launched the publicity. Standardized waste collecting stations cover more than 90 % communities.	In 2013, there are 527 units (communities) participated in the "Construction of Model Unit in Waste Reduction and Sorting". 261 residential communities and more than 230,000 households took part.
Terminal Disposal Mode and Disposal Capability	At present, there are 37 urban refuse disposal facilities (9 transfer stations, 4 incineration plants,16 sanitary landfills,6 composting plants, 2 kitchen waste treatment plants), and the disposal capacity is 22000t/d.	At present, there are 6 waste disposal facilities (3 incineration plants,2 sanitary landfills,1 resource utilization center), and the disposal capacity is 18042t/d.	At present, there are 4 waste disposal facilities (2 incineration plants,2 sanitary landfills), and the disposal capacity is 14000t/d.	At present, there are 10 waste disposal facilities (7 incineration plants,3 sanitary landfills), and the disposal capacity is 11000t/d.
Rate of NonHazardous Disposal	99.1 %	91.4 %	92 %	98.3 %

III THE INFLUENCING FACTORS OF URBAN REFUSE SORTING IN CHINA

Laws and regulations on urban refuse sorting are imperfect, and implement difficulty

There have been enacted many laws and regulations on environmental protection, but the relevant laws, regulations and detailed rules for the sorting and classification of urban refuse, have still been under research or in pilot phase and without any substantial breakthrough. If there are no relevant laws and regulations as the legal basis and supporting for the implementation of waster sorting, it cannot be enforced steadily and successfully.

Furthermore, sorting waste was without a unified standard and differed in relevant policies and local regulations of different regions. In such a large country with strong population mobility as China, the people livelihood project of waste sorting would not be promoted well if there is no a unified waste classification standard [2,4].

No system was builted for sorted collection/transportation and disposal of urban refuse

At present, the facilities for separating urban refuse in China are far from being perfect. There is no clear distinction of waste source specified in dustbins or trash cans in most regions. In some regions, although source-separating dustbins and trash cans have been equipped in many places, e.g., both sides of the roads, residential quarters, enterprise, and public institutions, only two slots of recyclable waste and other waste are given on the dustbins. Which cannot meet the requirement of further sorting of waste. The current urban refuse compression and transportation machinery equipment is hardly with the function of classified compression and transportation. So the two separated kinds (recyclable waste and other waste was separated in the collection) would mix together again in transportation. Sorted disposal is the ultimate purpose of sorted collection and transportation. But in most regions of China, the urban refuse was final disposaled by traditional ways, such as sanitary landfill, composting or incineration for electricity generation. There are only a few waste sorting and recycling factories and comprehensive utilization treatment plants. Such facts will eventually lead to meaningless waste classification. There are close correlations the source separation and sorted collection of urban refuse, sorted transportation, and the final sorted disposal. No system was built for sorted collection and transportation and disposal of urban refuse is one of the main causes of the difficulties in waste sorting [4, 5,6].

Unclear management responsibility and insufficient fund of urban refuse sorting

Waste management in China involves a number of sections at current stage. Waste of residential quarters was collected by environmental sanitation section of the sub-district. Waste of enterprise and public institution was collected and disposed by their own. Waste in the dustbins on the roads was collected by local Urban Management Bureau. Hazardous waste and expired drugs was dealted with by environmental protection administration and Food and Drug Administration, respectively. The management results in a chaotic situation of waste dispose. Waste sorting would not become effective and successful naturally. In addition, at present in China, the main emphasis of urban waste management is on terminal disposal and with less attention to the initial sorting of waste sources and sorted transportation. Moreover, the charge system for urban waste management has not been carried out in most cities in China, it is still aomost depending on fiscal investment, which incurs a financial overload and less money put into the sorting of waste, thus affects the input and update of the facilities used for sorting, transporting and disposing urban refuse [2,6,7].

Citizens with low environmental awareness, insufficient knowledge of waste sorting, low degree of participation

In China, as the urbanization accelerates, population mobility between urban and rural areas and among regions also becomes faster, which makes a considerable difference of environmental awareness among citizens. Some people with low environmental awareness discards trash at will, not to mention sorting the rubbish. Citizens with a relatively high environmental awareness would just discard rubbish into dustbins or trash cans without any distinguishing. There are even some people mix hazardous waste as waste battery and modulator tube with general domestic refuse. The publicity of waste classification by the relevant departments of the government or public organization is also insufficient, so that the citizens merely know relevant concepts of waste sorting but lack of the knowledge of urban refuse classification method. Naturally, waste sorting has not become a joint action [8,9,10].

IV STRATEGIES FOR THE SORTED COLLECTION OF URBAN REFUSE IN CHINA

To establish sound and easy-facilitate laws, regulations and policies on urban refuse sorting

Waste sorting needs to be guided and normalized by a series of laws, regulations and policies. What can be done can be summarized as follows: formulate mandatory laws and relevant supporting regulations on the sorting of urban refuse, develop sound management methods for the sorting of urban refuse, supervision and examining system of sub-district office and communities for the sorting, to introduce relevant policies paying equal attention to sorting, transportation and disposal of urban refuse, to establish rewards and penalties system concerning the sorting of urban refuse and urban refuse charge system, to elaborate the classification standards and detailed rules for hazardous waste. Through these laws, regulations and policies, a scientific, implement and nationwide-applicable legal system on the sorted collection of urban refuse can be constructed. And detailed enforcement rules for waste sorting should be elaborated gradually, and unified classification standards and methods should be specified. Such unified laws and regulations are easy to advocate and convenient for administration. So no matter where you are in China, you only need to know one unified classification policy [11].

To strengthen the construction and accomplish of the facilities for sorting, transporting and disposing urban refuse

The purpose of waste sorting is sorted transportation, and the purpose of sorted transportation is sorted disposal. So the ultimate goal of waste sorting is sorted disposal. Currently, the sorting facilities in most regions of China merely make the distinction between recyclable waste and other waste, while there is few specified subdivision of waste compression and transportation facilities. The terminal disposal is mainly conducted in three ways, such as sanitary landfill, composting and incineration for electricity generation. Therefore, it is necessary to update the present facilities used for sorting the waste, and also the technological research and development of facilities. So the new facilities can be put into application as soon as possible. Additionally, the sorted disposal of urban refuse needs government support. With a lower requirement for access, entrepreneurs would take an active part in sorted collection and disposal of waste, making the sorting and disposal of urban refuse reach a large scale, thus gradually improve the virtuous circle of the sorted collection and disposal of urban waste [5].

To make a sound management and supervision system of urban waste, and to promote the waste charge system

Concerning the chaotic situation of urban waste sorting and management, it can solve this problem by choosing a department which has more power and influence, a high level of administration, and stable financial source to be in charge of the urban refuse sorting. Which can unified dispatch and manage other different departments. Concerning the emphasis on terminal disposal, administrative department ought to ensure the management balance among all the sorted collection, sorted transportation and sorted disposal, rather than a highlight on a particular part. Less attention to any part(s) would affect the whole management system. Besides, the waste disposal charge system should be carried out, which can ease the fiscal burden of urban refuse disposal, and also enhance the participation of citizens into the sorted collection of urban refuse [11].

To enhance the publicity and advocacy of urban refuse sorting, and to gradually raise citizens' environmental awareness

Firstly, publicity of waste sorting requires a combination of school education and social education. Knowledge of waste sorting shall be given to students of different levels, from primary school to college, and the relevant knowledge reserve would be increased gradually. So citizens have good habit of waste sorting from early age. Meanwhile, the neighborhood committee publicize the knowledge of waste sorting in the community according to different ages and education levels. Secondly, the publicity function of news media should be highlighted. Print media, radio and television, and new media can all be employed to publicize the knowledge of environmental protection and waste sorting. A long-term publicity will exert a subtle influence on people, and they can naturally understand waste sorting knowledge. Last but not least, it is not be ignored the NGOs and environmental protection volunteers, who are more familiar with relevant waste sorting knowledge and ways of publicity. The governmental departments might print brochures or pamphlets on waste sorting and offer to these organizations, to guide the residents into the waste sorting work more actively [3,12,13].

V CONCLUSIONS

The sorted collection of urban refuse is the inevitable requirement and prerequisite of the “minimization” “harmlessness” and “recycling” process of waste. Which is also the irresistible trend of urban refuse disposal. In order to well realize the sorting of urban refuse, it not only need to establish sound laws, regulations and policies on waste sorting, but also to insist a long-term extensive publicity through various channels, and to consolidate the management and supervision system of urban refuse sorting. More importantly, the route by which waste goes from source separation to final disposal should be made unimpeded. It is necessary to establish a virtuous cycle of sorted collection, sorted transportation and sorted disposal of urban refuse system, so that the goal of transforming sorted urban refuse into resources can be achieved.

VI ACKNOWLEDGMENTS

This research was supported by the project of the development subject leader in HeFei university (2014dtr02), and the project of key discipline in HeFei university(2014xk01)

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 56-59

Challenges in the transition to the Education for Sustainable Development paradigm in higher vocational education in Russia

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Abstract. **The paper focuses on the transition to the education for sustainable development (ESD) paradigm in Russian university education, defining the variety and scope of problems to be solved. A comparative study of the progress in various educational and research fields is presented. The prospects for further solutions are considered.**

Keywords: **Architectural education, curriculum changes, ecological issues, ESD paradigm.**

I INTRODUCTION

Last year marked the end of the UN Decade of Education for Sustainable Development (ESD) which concluded at an international UNESCO conference in Nagoya, Japan, from the 10th to 12th November 2014. The conclusions were summarised in a declaration adopted at the conference [1]. This declaration also reiterated the urgency of questions of ESD in the modern world, and called for the inclusion of ESD issues in the list of priority aims for the period beyond 2015.

The development of ESD in the Russian Federation has its own distinctive features [2]. One of them is mainly linguistic, since the essence of the principle of sustainable development is not precisely conveyed in the established Russian translation of the term. 'Ustoychivoe razvitie' solely brings to mind characteristics of a stable process of development [3], whereas in the English term, the dominant idea is of a self-sustaining process, rationally balanced to avoid harmful distortions in any direction. Moreover, it fails to recall another fundamental factor to be found in all manifestos and key documents concerning sustainable development, an orientation towards the future generations who will inherit the world in which we now live.

This comprehensive understanding of sustainable development was formulated as early as 1987 in a UN paper on the environment and development. The emphasis then was on future generations and a concern for their existence, which is easily lost sight of amid the hasty and intensive concentration on the needs of the current generation. Sustainable development may be defined in this way: a strategy of satisfying the demands of the current generation without jeopardising the capacity of future generations to meet their own needs.

Amongst the most important tasks for adherents to the concept of sustainable development the conservation of natural resources necessary for the existence and harmonious development of all peoples (including the conservation of the diversity of these resources and the fairness of their distribution) is primary, along with the preservation of historical, anthropological and cultural (in the broadest terms) heritage and the diversity, development and accumulated spiritual richness and values of mankind over the years of its existence.

Concern over the legacy which will remain for our successors is easily justified with reference to history; the loss of both natural and cultural resources have been constant companions to human development over the ages (see for example [4]). Over time the scale of this loss has reached catastrophic proportions. The twentieth century was characterised not only as a time of exponential population growth, but also of the rapid development of manufacturing and consumption and of globalisation in many other areas of life. Simultaneously, in this epoch of industrialisation the disparity in the pace and character of development in the separate aspects of such growth became more apparent. The clash of technological breakthroughs

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.256

and revolutions lead to man-made ecological crises and severe economic instability, which in their turn provoked social unrest and political fallout.

It became clear that in order to counter the extreme dissonances of development, all of these aspects needed to be somehow harmonised and resolved. The necessity became apparent of re-directing the process of development of modern society along a course which guarded against the risk of arrest, delay or even regress due to crisis or collapse in any one of its aspects. In this way the concept of sustainability, so vital to modern society, was formed.

One of the first (chronologically) aspects of the sustainable development of humanity to emerge concerned the catastrophic condition and development dynamic of ecology, and this may be considered the precursor to the emergence of all paradigms of sustainable development. The UN gathered in 1992 for the Conference on Environment and Development (UNCED), at which two important policy documents were adopted: “Rio Declaration on Environment and Development” and “Agenda 21”, in which the basic contours of the concept of sustainable development were set out at a global scale, and a programme for action established.

II RESEARCH METHODS

The fundamental and general principles of sustainable development need to be expressed in concrete terms if they are to be realised in practical daily life and if urgent ecological priorities are to be addressed, such as slowing the rate of deterioration and reducing the level of pollution of the environment [5]. These general aims may become yet more defined when we turn to tasks such as the development of alternative sources of energy [6], the utilisation of industrial and other solid waste or by-products [7], the development of new ecologically sound technologies, the conservation of natural resources, the improvement of urban land use and transport networks, etc.

It is obvious that, one way or another, this problematic should be at the heart of the scientific research and design activity of the universities. It should be noted that these scientific areas were addressed in the research work of many of the departments of Samara State University of Architecture and Civil Engineering (SSUACE) in connection with other technological and social requirements, long before the concept ‘sustainable development’ appeared. For example, the school of hydro-electrical energy, which is one of the oldest within the walls of the University and has significant accumulated scientific and practical experience, was founded in response to the need for cheaper electrical energy during the industrialisation of the Middle Volga region [8]. This Hydro-technical Institute, as it was then called, was created for research and training specialists in that specific field, but gradually developed into other fields of education and research and today has become a multi-disciplinary university. The approach towards study shifted with the winds of the age.

Hydro-energy, which was once considered of critical importance purely from an economic and technological standpoint, was one of the most significant links in the development of ecological thought, and became the starting point for the development of the theory and practice of renewable sources of energy [8] and the solution of other urgent problems in environment conservation, which were able to make a substantial contribution in such global sustainable development movements as the conservation of resources, the limitation of human impact on the environment [9], preservation of biodiversity and the fight against climate change. The hydro-electrical energy research school has produced several dissertations on the solution of ecological issues (see for example [9]-[12]), and has received patents for a whole series of inventions ([13]-[16]).

In a similar way, other departments of the University are increasingly directing their research activities in accordance with the spirit of the sustainable development paradigm towards the harmonisation of industrial-technological, economic, cultural and historical factors in the development of the country and the regions and the preservation of cultural historical, national and regional identities.

However, the significance of the universities in the investigation of particular issues of sustainable development is not limited to academic research activity. The philosophy of sustainable development prioritises attention on the next generation. Special significance is given to the task of not only conserving the world in all its diversity and functional opportunities, but in educating people to continue this task and seek out ways to further improve these processes. For this reason the recently concluded UN Decade was devoted not only to the actual tasks of sustainable development but also to education in this area. The role of higher education institutions in the promotion of the ideas of sustainable development was particularly highlighted: it was a consistent theme in all of the conferences, seminars and similar events of the Decade.

The need to activate educational technology was reflected in the Nagoya Declaration, which outlines priorities such as youth education (raising the awareness of their responsibility globally and towards the next generations), training of teaching staff for the promotion of the ideas of sustainable development and support for local communities and regional centres.

III RESULTS AND DISCUSSION

Considering that educational and research activities in almost every discipline at SSUACE are being drawn into the orbit of the modern concept of sustainable development (industrial-technological, economic, ecological, social etc.), the University has great potential in the development and realisation of methodologies for education in the area of sustainable development. A certain degree of experience in the promotion of principles of education for sustainable development has been accumulated thanks to the fact that the university is host to the Samara Regional Centre of Expertise in Education for Sustainable Development (RCE Samara), which was the first of its kind to be established in Russia. The Centre was founded in 2007 with the official recognition and partnership of the UN University. Along with the centre at Nizhny Novgorod State University of Architecture and Civil Engineering (NNSUACE), it is part of a worldwide network of similar organisations. Owing to the partnership of the two Russian centres, SSUACE and NNSUACE obtained a TEMPUS grant for the development of a Master's programme in innovative project management: "Managers for the Future", the underlying principles of which are education for sustainable development.

Academic disciplines connected with the general and detailed principles of sustainable development are being included in the teaching process in universities in all countries signatory to the Bologna Process (for example in 50% of higher education institutions in Scandinavia, 96% in the UK and Sweden) [16]. An interesting case in point is the research and practical application of the philosophy of sustainable development in the education of aspiring architects [17]. The issue of the responsibility of architects and town-planners in the transformation of our planet was raised at a high level at the UN Department of Economic and Social Affairs in 2011. Two basic approaches to education for sustainable development were defined: general and professional. The evaluation of perspectives for the development of the professional approach showed that a decisive factor would be the development of leaders who were ecologically and socially responsible and concerned with ecological and social issues. The leading role of the schools of architecture and town-planning in the formation of a sustainable architectural environment was underlined [18].

The process of introducing the technology of sustainable development into architectural education is growing on different continents. In 2011 four European universities from Spain, The Netherlands, Portugal and the Czech Republic formed a partnership under the International Initiative for a Sustainable Built Environment (iiSBE) to devise the International Masters on Sustainable Building (IMoSB), which was proposed to the European Commission [19].

The teaching of students in the Faculty of Architecture in SSUACE is in accordance with national educational standards and substantially meets them. An extensive revision of course programmes and teaching methodology is being undertaken in the context of sustainable development, with greater attention being given to ecological and social questions. Part of the lecture course in Ecology for Architecture at Bachelor's level is given over to the concept of sustainable development, and many urgent issues in environment conservation are addressed within the frameworks "Individual – society" and "Society – natural environment".

The ability to take into consideration local ecological and social factors is an important step towards professional competency. Both issues are examined from two positions: on the one hand the localisation and neutralisation of negative phenomena, and on the other, the encouragement and widening of positive trends. This theoretical course helps future architects to apply their knowledge in their coursework and final projects. Attention is particularly given to conservation of resources, considering how architectural and urban planning solutions can be developed which minimise negative effects on the ecosystem, and support the relative ecological balance.

Social issues are touched upon with the aid of teaching technologies, and students are expected to take account of particular conditions such as demographics, the economic status of potential clients and the necessity to adopt a tolerant approach [20].

The most interesting design ideas are reflected in the subjects of coursework and final diploma projects which go beyond the bounds of traditional design, for example: "Techno-park in a disused mine", "Residential building designed to 'green' standards", "Redevelopment of former industrial zones", "Shelter for the homeless", "Tolerant space" and others. In addition, one of the most effective means of provoking students to consider ideas of sustainable development is to encourage participation in related competitions, festivals and olympiads.

The University's architecture faculty is currently developing an integrated methodology which brings together both fundamental and inter-disciplinary (ecological and sociological) programmes. This approach facilitates the main pedagogical task – the formation of general cultural and professional competency in aspiring architects, based on the integration and optimal balance of scientific knowledge in different fields.

IV CONCLUSION

There is significant potential for the continued development and application of the principles of education for sustainable development in the modern world. UNESCO has called for concrete investment in the realisation of the global action programme, and interested parties in 80 countries have responded, taking upon themselves the duties in the above-cited declaration [1].

V ACKNOWLEDGMENTS

The authors would like to express their gratitude to S. C. Buss (MA Cantab, DipArch, ARB) for assistance in producing the English version of the text and valuable advice on the issues addressed.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 60-63

Satellite Technologies in Monitoring of Ecosystems

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Abstract. **The article provides a description of modern geodetic devices, which are used to solve several problems connected with environmental and hydraulic engineering. In particular, a non-conventional method of area measurement for ecosystems monitoring, which involves the usage of satellite navigation devices, is considered.**

Nowadays electronic tachymeters, digital levelling instruments, laser scanning systems and satellite systems are widely used for implementation of geodetic engineering works. In full extent it could be also applied to different environmental and hydraulic engineering problems solution.

The satellite navigators, especially with GPS+GLONASS system support, are the promising alternative to handle different planimetric tasks, particularly, water surface and drainage area measurement.

The paper presents an analysis of the results of research carried out in 2012-2014 years and comparison of them with the new field data. Moreover the obtained results are compared with the theoretical values of quadrates' areas and the dependence of the relative accuracy versus land plot area is built.

Based on a practical research, the accuracy of the method is being estimated. The analysis of different measuring conditions and factors, regarding their effect on accuracy, is made.

The suitable areas, where the method could be used, are mentioned. Particularly, the possibility of water surface and drainage area measuring is examined with the usage of previous theoretical base.

Keywords: **monitoring, engineering geodesy, satellite navigator, area measurement, GPS and GLONASS systems, measuring accuracy, water surface area, drainage area, ecosystems.**

I INTRODUCTION

To start with, geodetic works are the most important part of complex of tasks involving exploration, design, construction, exploitation and monitoring of different buildings and structures. The works are executed with accordance to a united schedule for certain building site, which also depends on time of civil and erection, fitter's and specific works. The costs and quality of construction, as well as engineering object maintenance conditions are mostly defined by geodetic works [1].

Nowadays electronic tachymeters, digital levelling instruments, laser scanning systems and satellite systems are widely used for implementation of geodetic engineering works. In full extent it could be also applied to different environmental and hydraulic engineering problems solution [2] – [4].

Electronic tachymeters and laser scanning systems are used in research of wind and wave weathering of water banks, areal and linear land-surveying and solution of other tasks [5]. For example, such devices can be used to determine the volume of heaps of different quick materials. Areas of land plots and water objects can also be determined by electronic tachymeters. Electronic tachymeters and levelling instruments are widely used in supervising of structures being built or operated, particularly to spot their subsidence.

II RESULTS AND DISCUSSION

The process of monitoring of fill dam, which was being erected in Ust-Luga trading sea port on soft foundation soils, is described in research [6]. The objects of monitoring were the hydraulic structures included in first stage of erection of dock frontage of condensed hydrocarbonic gas overloading complex.

The method of dam subsidence measurement consisted in levelling of control marks and comparison of the results of measurements in order to spot the deformation of structure or foundation soil [7].

The following calibrated geodetic devices were used for measurements:

- Digital levelling instrument Leica Sprinter 100m with bar-coded surveyor's pole GSS 111;
- Electronic tachymeter Pentax R 325NX with components.

As a result of geodetic works on approach embankment several features of the above-mentioned devices were determined [8], [9].

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.237

Electronic levelling instrument Leica Sprinter 100m has the following advantages:

- impossibility of errors connected with human factor while reading and writing the measurement results;
- high speed of levelling caused by freedom from necessity for reading with the usage of both black and red sides of surveyor's pole;
- high accuracy of levelling (in precision mode up to 10-4 m);
- simplified device installation on the spot due to built-in compensator.

The disadvantages of the device are mainly connected with difficulties in measurement in certain conditions, such as:

- insufficient visibility (atmospheric pollution: dust, fog, hoarfrost etc.);
- temperature contrast (thin ice mound on the surveyor's pole);
- impact of sun rays into the lens of the device;
- windy weather;
- intensive operation of heavy building machines during the measurement process, which causes increased vibration and device automatic turning-off.

Some of the features of electronic tachymeter Pentax R-325 NX are:

- reflectionless mode availability, which allows to measure distances up to 200 m without a reflector pole;
- precision of angle measurements is 5";
- double-axis compensator.

In general, the advantages and disadvantages of the above-mentioned device are the same as of electronic levelling instrument.

Despite the mentioned disadvantages, such geodetic equipment allowed to execute the measuring process with required accuracy.

Recently the research concerning the availability of the usage of geodetic satellite systems in route levelling was performed on the Water resources and hydrotechnical engineering department (Saint-Petersburg State Polytechnical University). The comparison of the results acquired by different levelling devices (in particular, optical levelling devices, electronic digital levelling instruments and satellite systems) was established [10]. The result of the research indicates, that satellite navigation devices do not provide the required accuracy. Modern geodetic satellite receivers, however, practically have the same level of presicion as optical and electronic digital levelling instruments. Moreover, satellite receivers' accuracy is superior to the optical and digital devices in case of strong altitude difference of the measured route. This is demonstrated by the fact that surveyor's poles needed for differential levelling have a restricted length, while the satellite receiver does not require a pole. Therefore the usage of geodetic satellite receivers while levelling open-landscape routes in some cases could be the most effective method.

Another field of application of satellite technologies covers the problems connected with land plot area determination, as well as water surface and drainage area measuring.

In some cases such tasks can be accomplished with the usage of electronic tachymeters [11], [12]. For instance, in the research [12] the data concerning the measuring of lake water surface using an electronic tachymeter Pentax W-825NX is presented. Even though the result of the measurement was of high accuracy, it was mentioned, that the measuring process can be interrupted by the variety of external factors. For example, all points of the measured contour must be directly visible from the station (the spot where tachymeter stands), but dense vegetation or buildings could lessen the visibility. In addition to that, the process can be affected by weather conditions.

During the studies [13] – [15], the problem of determination of land plot and water surface areas with the usage of satellite navigators was being solved.

According to work [13], four quadrates with common vertex were divided on location, with their sides 10×10, 20×20, 40×40 и 80×80 meters. Each quadrate was repeatedly bypassed with satellite navigator Garmin GPSMAP 78S. In the process, the values of areas and perimeters were determined and recorded by a program installed on the device. Apart from that, the geographical coordinates of the quadrates' vertexes were fixed. Than, with the usage of this data and computer programs Photomod Geocalculator 4.2.490, Autocad 2008 и Gepath 1.4.4a, areas and perimeters of the polygons were additionally determined.

The diagrams of the relative accuracy as function of land plot size were built as a result of comparison of obtained practical results with the theoretical quadrate area and perimeter values. In addition, the trend line was built with the usage of logarithmic approximation.

Based on the analysis of the result, the following conclusion was made:

- When the land plot size reaches the value of 7 hectares, the usage of GPS navigator allows to obtain the result with same presicion as if an electronic tachymeter was used. In view of GPS navigator all-weather operation posibility, its capability of working without a free vision of measured polygon and reasonable price, the obtained result indicates, that it is efficient to use such device to solve some planimetric tasks. For instance, such tasks can include drainage area or agricultural land area measurement. Another advantages of GPS navigation device are pocket size and weight, simplicity of use and long time of autonomous work without battery recharge.

- The method of determination of areas and perimeters with the usage of fixed coordinates and computer programs (conversion of geographical coordinates into the rectangular ones) do not have the advantages over immediate measurement (bypassing the area), furthermore, the additional error is inserted. However, in some cases, when determination of certain location of polygon is required, the coordinates' fixation is necessary.

The aim of the research [14] was to specify the relation between the accuracy of area measurement and land plot size (quadrate areas were increased by 3.5 times in comparison to former researches). This time GPS-navigator GPSMAP 78S and GPS+GLONASS navigator Garmin eTrex 30 were used. In addition, the aim was to indicate, which system has better accuracy and reliability.

To accomplish the task, three quadrates were divided on location with their sides 50×50, 100×100 and 150×150 meters, which also had one common vertex (Fig. 1). Each quadrate was repeatedly bypassed separately with navigators Garmin GPSMAP 78S and Garmin eTrex 30. The areas of the quadrates were determined with the usage of special programs installed on the devices. In addition to that, without a preliminary laying and in extreme conditions (darkness, rainy weather, high trees and buildings), the following areas were measured: rectangular woodlands with their areas 52460 m^2 and 163590 m^2 (the areas were additionally determined with the usage of satellite maps on www.yandex.ru) and two curvilinear lakes in Sosnovka park in Saint-Petersburg.

The obtained results were compared with the theoretical values of quadrates' areas and the dependence of the relative accuracy versus land plot area was built. As a result, trend lines were obtained for each system with the usage of methods of mathematical statistics (Fig. 2).

As a result of the diagram analysis and general supervision, the following conclusion was made:

- The relative error decreases on greater areas, but not as fast as was assigned in former research [13]. The accuracy of GPS navigator measurement can be compared with precision of electronic tachymeter if the measured area is larger than 15 hectares.
- Navigator supporting GPS+GLONASS system provides higher accuracy in comparison with navigator using only GPS system. Moreover, if the measured area is initially unknown, combined GPS+GLONASS system provides greater reliability (less rude errors during the measurement) and smaller quantity of bypasses is required.
- The relative error was not increased due to the extreme measuring conditions in case of GPS+GLONASS system, what confirms its reliability. The results, obtained during the measurement of the areas without preliminary laying, support the dependence achieved on the divided quadrates.

In work [15] navigator Garmin eTrex 30 with GPS+GLONASS system was used for testing the above-mentioned method while measuring a curvilinear area, in particular, Chornoye lake in Gatchina and its drainage area (Fig. 3).

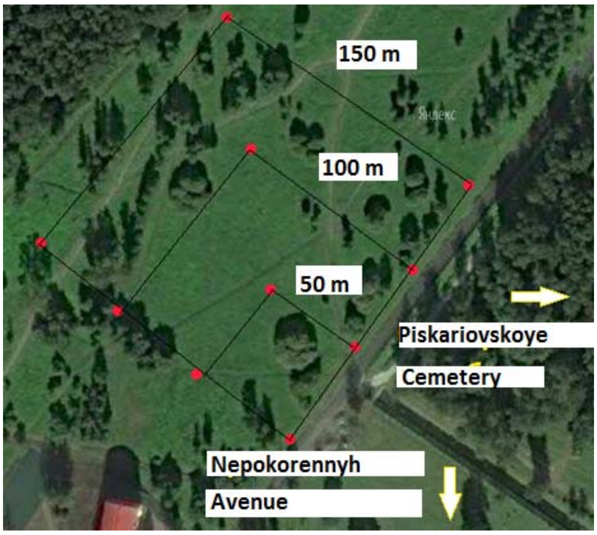

Fig. 1. Layout of quadrates

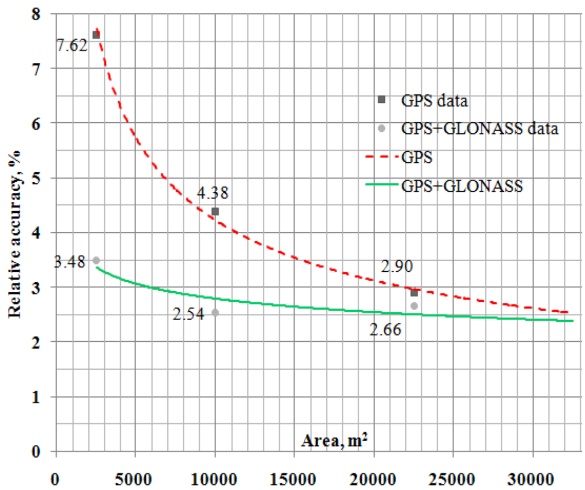

Fig. 2. Trend lines for the research [14]

To sum up, the following conclusions were made:

- When the curvilinear land plot size reaches the value of 10 hectares (Fig. 3), it is possible to obtain the results as accurate as if the graphical method was used, namely 1 % [15].
- The absolute accuracy of coordinate determination is more or less constant — approximately 3 meters in case of at least 10 satellites being within the navigator range [16]. In addition, in case of GPS+GLONASS system, the absolute accuracy faintly depends on measurement conditions and on dense vegetation presence around the water object in particular.

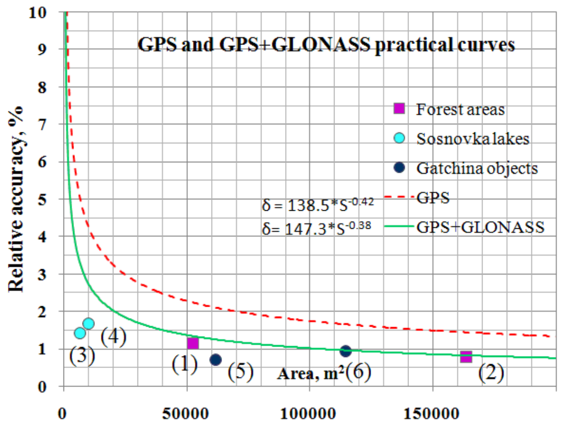

Fig. 3. Practical curves (trend lines) and real objects: 1, 2 – forest areas; 3, 4 – Sosnovka lakes; 5 – Chornoye lake; 6 – drainage area

III CONCLUSION

Taking everything into account, the satellite navigators, especially with GPS+GLONASS system support, are the promising alternative to handle different planimetric tasks, particularly, water surface and drainage area measurement in monitoring of ecosystems.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10^{th} International Scientific and Practical Conference. Volume II, 64-70

Difference in the treatment effectiveness of woodworking wastewater between polyaluminium chloride-based coagulants

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Abstract. **In the work, a comparative study of the efficiency of coagulation of a model solution, simulating woodworking wastewater, with the known composition of polyaluminium chloride (PAC) with aluminium sulphate and a new PAC-based composite coagulant was carried out. It has been found that, in comparison with the known composition, the developed composite coagulant makes it possible to enhance the efficiency of the wastewater treatment and to decrease the content of residual aluminium therein, which enables the return of the treated water in the technological cycle. The enhancement of the coagulation ability of the developed composite coagulant relative to the known composition of PAC with aluminium sulphate is governed by the formation, in the $AlCl_3$/PAC system, of polynuclear Al-complexes with a high-molecular structure. This is testified by the results of the comparative study of those coagulants by the Ferron and ion mass spectroscopy methods.**

Keywords: **coagulation, composite coagulants, polyaluminium chloride, wood hydrothermal treatment, model wastewater, hemicelluloses and lignin containing pollutants.**

I INTRODUCTION

The qualitative and quantitative treatment of woodworking wastewater makes it possible to return the purified water into the technological cycle, which is important from both economic and ecological viewpoints. It is known that aluminium salts – aluminium sulphate and aluminium chloride, and polyaluminium chloride have found wide application as a coagulant [1, 2].

According to Chernoberezhsky [3, 4], aluminium sulphate, at a content of no more than 150 mg/L in wastewater, quantitatively removes lignin in acidic media with a pH of 4.5-5.0. In its turn, aluminium chloride is most effective at pH 6.0 and the dosage 100-110 mg/L [5, 6]. It should be mentioned that the decrease of the wastewater temperature from 22˚C to 2˚C has an adverse effect on the coagulation ability of aluminium salts, namely, the optimum dosage of aluminium sulphate and chloride as well as the optimum coagulation time increase several times [7].

It is known [8, 9] that polyaluminium chloride (PAC) is a more efficient coagulant than aluminium sulphate and chloride. It has been found [10] that, for 91% of the decrease in COD of the pulp industry wastewater, the required dosages of aluminium sulphate and PAC are 1000 mg/L and 500 mg/L, respectively. It is shown [11] that, for treating the pulp industry wastewater with a high pollution load (COD 7000 mg/L), the optimum value of pH is 4.0, but the required dosages of aluminium chloride and PAC grow up to 5000 mg/L and 2400 mg/L, respectively. It has been established [12] that the optimum pH for PAC and aluminium chloride is equal to 6.0. However, at this value of pH, the concentration of organic substances in the treated wastewaters, representing water-soluble complexes with aluminium ions, is higher for chloride aluminium than for PAC. This is the reason for the enhanced content of residual aluminium in wastewater. As shown in the studies on the coagulation of wastewater [13, 14], polluted with compounds of wood origin, the optimum dosage of PAC does not exceed 100 mg/L. At the same time, according to our results [15, 16], PAC as a coagulant is characterized by a weaker ability to purify woodworking wastewater than the high molecular polyethylenimine.

To enhance the efficiency of the coagulation ability, PAC are used in compositions with different chemical reagents, for example, calcium oxide and chloride [17, 18], iron oxides or halogenides [19, 20], natural bischofite [21, 22], silicic acid and iron [23]. The use of PAC with a cation copolymer of acrylamide and

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.250

dimethylaminoethylmethacrylate [24], with a cation flocculate based on polyacrylamide, is also known [25]. There are also a range of methods for effective treatment of wastewaters, including their stage-by-stage treatment, firstly, with aluminium sulphate and then with polyaluminium chloride [26, 27]. However, such a mode is complicated from the technological viewpoint due to the multistageness of the coagulation process.

The aim of the present work was to compare the efficiency of the coagulation ability of the known composite coagulant and the PAC-based coagulant developed by us. The main criteria of efficiency were the residual concentration of pollutants, the concentration of residual aluminium in wastewater, and the colour degree of wastewater after its treatment in a temperature range of 14-40^oC.

II MATERIALS AND METHODS

In the study, polyaluminium chloride Polypacs-30 (basicity ~ 80%, mass fraction of Al_2O_3 ~35%) was used. For comparison purposes, the new composite coagulant developed by us [28], representing a complex compound of PAC and aluminium chloride, and the known coagulant, incorporating PAC and aluminium sulphate [29], were used. The mass ratio of the reagents in the new coagulant varied from 1/1 to 10/1 ($PAC/AlCl_3$), while the mass ratio of $Al_2(SO_4)_3$ and PAC varied in the range of 2.7/1-0.5/1 ($PAC/Al_2(SO_4)_3$). The applied dosage of coagulants varied from 50 to 150 mg/L. As aluminium salts, $AlCl_3·H_2O$ and $Al_2(SO_4)_3·16H_2O$ were used.

The developed and known aluminium coagulants have been described by the traditional Ferron method [30] and by electrospray ionization (ESI) mass spectrometry [31]. Al (III) reacts with a Ferron reagent to form an Al-Ferron complex at pH 5.0, λ_{max} = 370 nm. A Genesys(TM)10 spectrophotometer was used to measure the Al-Ferron kinetics. The absorbance at 370 nm was recorded from 30 s to 7200 s. Therefore, based on detecting the mass to charge ratio (*m/z*) of complexes, the ESI-MS measurement proved to be a good method for aluminium speciation. To investigate aluminium hydrolysis of the coagulant at pH 6.0, the coagulant was diluted to a concentration of $1.5·10^{-4}$ mol L^{-1}. The ESI mass spectra were recorded with a micromass hybrid quadrupole time of a flight mass spectrometer (GCMS-QP2010) equipped with an electrospray ion source. The solutions were introduced into the spectrometer at a flow rate of 10 μL min^{-1}. The instrumental conditions were as follows: capillary voltage 3500 V, sample cone voltage 70 V, source temperature 120˚C, cone gas (N_2) flow rate 300 L h^{-1}, and mass range 60-600.

The wastewater of a woodworking enterprise was simulated with a model solution, obtained by way of hydrolysis of birch sawdust according to [14]. The mass ratio between the sawdust and the liquid phase was 1:50. Hydrolysis was carried out at a temperature of 90˚C during 6 h 20 min, from which, within 40-50 min, the required temperature was reached; the cooking process at 90˚C proceeded for 4 h and then the system cooled during 1.5 h. To obtain model wastewater, the obtained solution was filtered for removal of fine-disperse particles. The physical parameters of the model solution are listed in Table 1.

TABLE 1

Characteristics of the model wastewater

Parameters	Value
Hemicelluloses, lignin and wood extractive substances (HLES)	1400 mg L^{-1}
Lignin-originated substances (LSV)	280 mg L^{-1}
Chemical Oxygen Demand (COD)	1285 mgO L^{-1}
Colour	746 mg L^{-1} Pt^{-1}
Total Organic Compounds (TOC)	732 mg L^{-1}
pH	9.02
Kinematic Viscosity	3.81 mPa s^{-1}

The elemental and functional composition of the dry matter of the model solution is presented in Table 2.

TABLE 2

Elemental and functional composition of the dried solid from the model wastewater

C, %	37.70
H, %	4.70
O, %	57.16
S, %	0.14
N, %	0.30
OCH_3, %	2.29
CO, %	1.15
OH, %	10.15

A study of the component composition [32] showed that the dry matter of the model solution consisted of 75-80% of hemicellulose compounds (HCC), which were isolated from the model solution by ethyl alcohol according to the known procedure [33]. The content of the formed Klason lignin in the residue formed did not exceed 10%.

The coagulation process was carried out by way of mixing the model solution and the solution of the composite coagulant at a ratio of 1:1. The composite coagulant solution was introduced into the model solution, at a constant mixing with a rate of 100 r.p.m. After 1-min stirring, a certain amount of HCl was introduced into the system so that to reach the required pH value (4.0-9.0). After reaching the pH, stirring was continued at a rate of 200 r.p.m. during 1 min, and then at a rate of 40 r.p.m. during 2 min.

Experiments were conducted in the temperature range of 14-40^{o}C. Coagulation at low temperature was carried out by way of mixing the model solution and the solution of the composite coagulant with a temperature of 14(±1)°C, which was reached by way of cooling the solution in a thermostat (MLW U7^{c}) using tap water. Similarly, the lowered temperature was maintained during 2 h of the coagulation process. For the coagulation at a temperature of 40°C, the model solution, pre-heated up to 60 (±1)°C, and a solution of the composite coagulant with a temperature of 20 (±1)°C were used. As a result, the coagulation temperature was 40 (±1)˚C, which was maintained in the coagulation process by way of using a Julabo thermostat.

The efficiency of the coagulation was defined after 2 h of the system's settling and filtration. UV/Vis spectrophotometer Genesys 10UV was used to measure the optical density of the effluent at wavelengths of 490 nm and 280 nm. These wavelengths correspond to the different chemical composition of wastewater: 490 nm corresponds to the removal of HLES and 280 nm is related to the removal of lignin compounds, which are usually present in the wastewater. Colour (LVS EN ISO 7887:1994), COD (LVS EN ISO 6060:1989), TOC (LVS EN ISO 1484:2000) and residual aluminium (GOST 18165-89) were determined according to standard methods

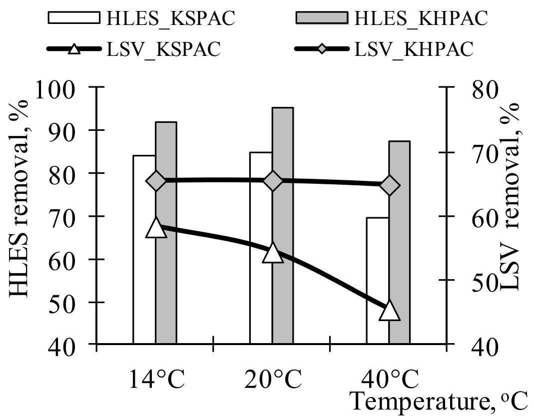
Coagulation efficiency was determined, comparing the initial parameters of the model solution with the parameters obtained for the filtrate after coagulation, using the following formula:

$$removal,\% = \left[\frac{(C_i - C_f)}{C_i} \right] * 100,$$

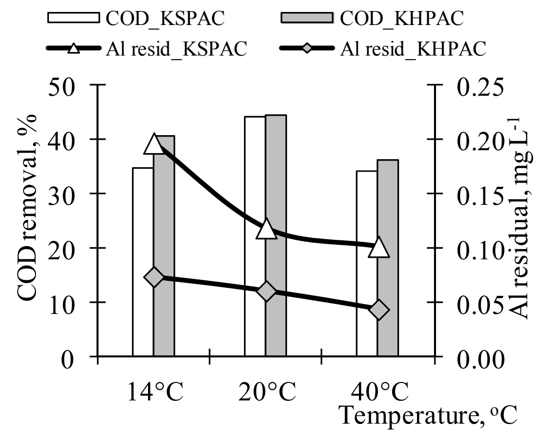
where C_i and C_f are the initial and final concentrations of HLES, LSV, COD and the colour.

III RESULTS AND DISCUSSION

At first, the effect of temperature on the efficiency of HLES coagulation with the new and known composition coagulants was studied. Fig. 1 (*a*, *b*) shows the results of the comparison of the treatment effectiveness of the model solution at pH 6.0 and the application dosage of composite coagulants equal to 100 mg/L at different treatment temperatures.



a)



b)

Fig. 1. HLES and LSV removal (a), COD removal and residual aluminium (b) of the model wastewater after coagulation using 100 mg L^{-1} composite coagulants at pH 6.0 depending on temperature.

The obtained results show that the new composite coagulant $AlCl_3$/PAC, at the components' mass ratio of 1/1, is characterized by a higher degree of purification of the model solution from HLC and LC in the whole temperature range. The highest efficiency of the model solution is reached upon the use of $AlCl_3$/PAC with a ratio of 1:1 at a temperature of 20^{o}C; in this case, the removal of HLC and LC is 95.3% and 65.6%, respectively. COD and colour decrease by 44.4% and 88.0%, respectively, and the residual concentration of aluminium is 0.061 mg/L. A comparison of the quality of treating the model solution using $AlCl_3$/PAC with a ratio of 1:1 relative to $Al_2(SO_4)_3$/PAC of the composition 2.7/1 shows that, at a temperature of 14^{o}C, the removal of HLC and LC increases by 8% and 7%, respectively, while that of COD decreases by 6%; in this case, the content of residual aluminium in the model solution falls 2.5-fold. At a temperature of 20^{o}C, the removal of HLC and LC increases by 11% and 10%, respectively, but the decline in COD grows by 2%. In this case, the content of residual aluminium in the treated model solution decreases twice. With increasing temperature up to 40°C in the model solution, treated with the new composite coagulant, the increment in the removal of HLC, LC and COD grows up to 18%, 21% and 4%, respectively, while the content of the residual aluminium decreases 2.3-fold, in comparison with the solution treated with the known coagulant.

Since the coagulation process is rather sensitive to decreased temperatures, it was of interest to compare the coagulation efficiency of the composite coagulants at temperatures below 20°C. Table 2 lists the results of the treatment of the model solution depending on the medium pH at a temperature of 14˚C and the dosage of the applied coagulants 100 mg/L.

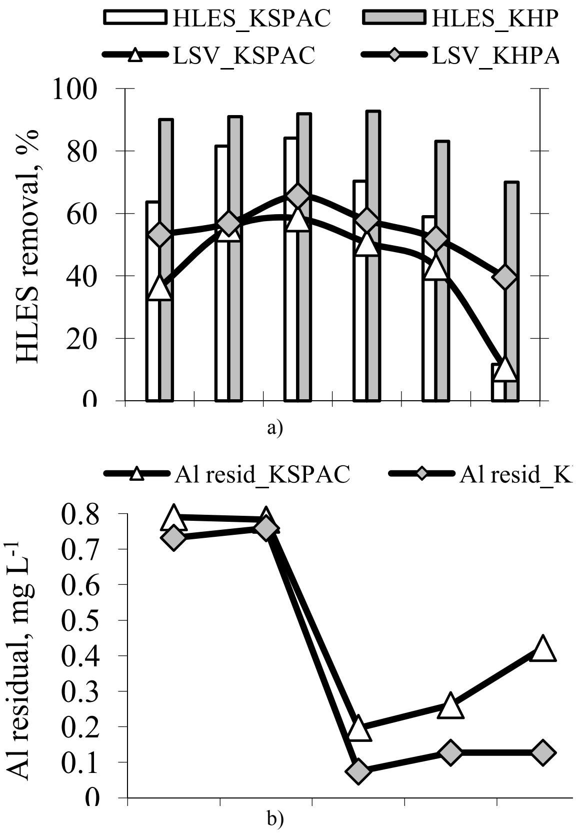


Fig. 2. HLES and LSV removal (a) and residual aluminium of the treated model wastewater (b) after coagulation using 100 mg L^{-1} composite coagulants at a temperature of 14°C depending on pH.

The obtained results show that the new composite coagulant is characterized by a higher degree of purification of the model solution from HLC and LC, in comparison with the new coagulant, in the whole pH range. The maximum effectiveness of treatment is in the pH range of 5.0-7.0. At the same time, the elevated value of the residual concentration of aluminium in the model solution (0.074-0.127 mg/L) at pH 5.0 after its treatment is not desirable from the viewpoint of the return of the treated water in the technological cycle. Therefore, the recommended pH values for purifying wastewaters from HLC and LC at lowered temperatures vary in the range of 6.0-7.0. At one and the same application dosage, the enhancement in the coagulation pH from 5 to 6 increases the removal of HLC and LC up to 8% and 7%, respectively; in this case the content of residual aluminium in the model solution decreases down to 2.5 times. The further increase in the pH value up to 7.0 increases the removal of HLC and LC by 22% and 7%, respectively, while the content of residual aluminium in the model solution decreases twice, in comparison with the same indices at pH 5. It should be mentioned that the developed composite coagulant demonstrates also the incomparably high coagulation efficiency in comparison with the known coagulant at pH values of 4.0 and 8.0. In weak acidic medium, the content of the model solution, using $AlCl_3$/PAC with the ratio of 1/1, is more than 3-fold lower, compared with the case of $Al_2(SO_4)_3$/PAC with the ratio of 2.7/1. However, both the acidic and alkaline values of pH can have an adverse effect on the quality of the technological water.

The results of the study of the dosage of the composite coagulants on the treatment effectiveness of the model solution at pH 6.0 and a temperature of 14˚C are shown in Figure 3.

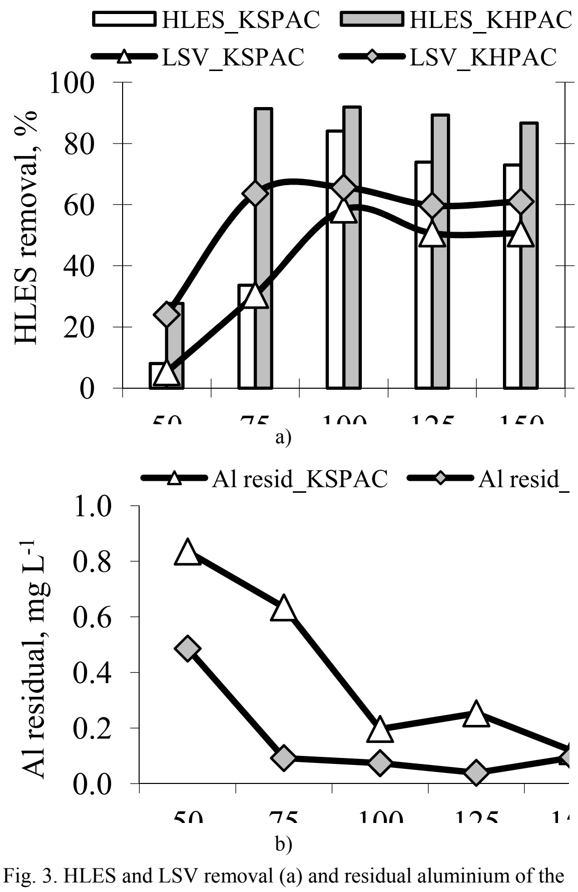


Fig. 3. HLES and LSV removal (a) and residual aluminium of the treated model wastewater (b) after coagulation using composite coagulants at a temperature of 14°C and pH 6.0 depending on the dosage.

A comparative analysis of the obtained results shows that, in the whole range of dosages, the new composite coagulant $AlCl_3$/PAC with the ratio of 1/1 demonstrates a higher degree of purification of the model solution from HLC and LC than the composite coagulant $Al_2(SO_4)_3$/PAC with the ratio of 2.7/1. In this case, the model solution is characterized by a much lower concentration of the residual aluminium after coagulation. The best results are reached in the dosage range of 75-125 mg/L. The efficiency of the removal of HLC, LC and COD, on the average, reaches 91%, 65% and 47%, respectively; colour – 90%, and residual concentration of aluminium – 0.04-0.09 mg/L. A comparison of the quality of the treatment of the model solution using the known coagulant at the application dosage of 75 mg/L has shown that the increase in the removal of HLC and LSV is 58% and 33%, respectively, while the content of residual aluminium in the model solution declines 8-fold. At the application dosage of 125 mg/L, the increase in the removal of HLC and LSV is 15% and 9%, respectively, while the content of residual aluminium declines 6.5-fold. A similar regularity is retained also upon the treatment of the model solution at pH 7.0. It is found that the model solution, after applying the new composition coagulant $AlCl_3$/PAC at the mass ratio of the components 1:1, pH 6.0 and the application dosage 100 mg/L, is characterized by the following indices: HLC – 33 mg/L, COD – 367 mg/L, colour – 60 mg/L Pt, TOC – 123 mg/L, residual aluminium – 0.061 mg/L.

We have found that the increase in the coagulation ability of the composite coagulant relative to the known coagulant is governed by the formation of polynuclear Al-complexes, having mainly the polymer and high-molecular structure in the $AlCl_3$/PAC system. This is confirmed by the results of the comparative study of the composite coagulants by the Ferron and ion mass-spectroscopy methods. The first method is based on the kinetics of the interaction of monomer, polymer and high polymer forms of aluminium with the Ferron reactive [30]. According to the obtained results listed in Table 3, the amount of the Al-containing polynuclear complexes, having a polymer and high polymer form, in the developed coagulant is greater than that in both the initial PAC and the $Al_2(SO_4)_3$/PAC system.

TABLE 3

Contents of aluminium species in solutions of PAC-based coagulants

Coagulant	Al_a, %	Al_b, %	Al_c, %
PAC	16.6	66.6	16.8
KSPAC	16.4	67.2	16.4
KHPAC	10.3	72.0	17.1

The second method of comparison is based on the qualitative analysis of the forms of the products of hydrolysis of composite coagulants by the ion mass-spectroscopy on a GCMS-QP2010 device (Shimadzu, Japan) [34]. The analysis of the aluminium forms was performed by the characteristic peaks with the intensity no less than 20%. The obtained spectra of PAC and composite coagulants are given in Fig. 4.

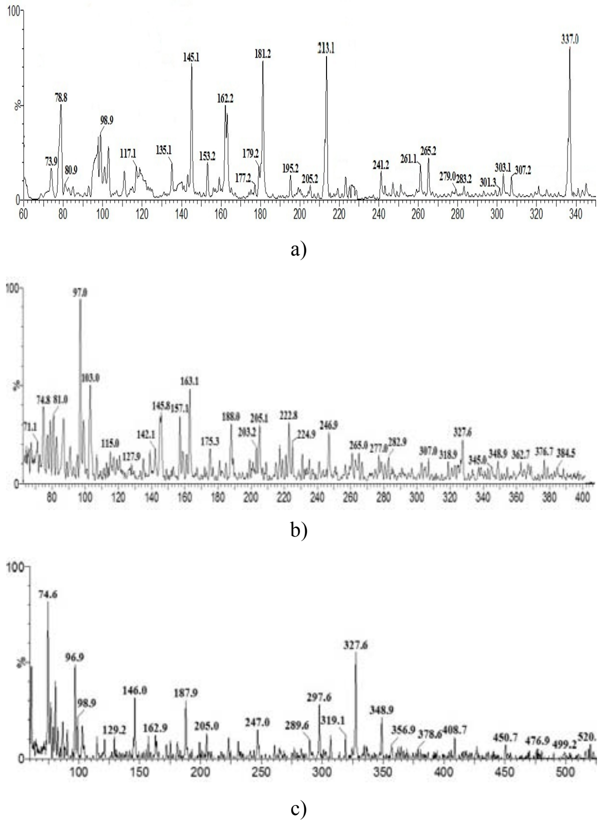


Fig. 4. ESI-MS spectra of the solutions of PAC (a), KSPAC (b) and KHPAC (c).

The PAC spectrum (Fig. 4, a) is characterize by signals of the monomeric forms of aluminium at 78.8 and 98.9 *m/z*, and trimeric forms $[Al_3O_4(H_2O)_{0-5}]^+$ at 145.1, 162.2, 181.2 *m/z*. In turn, the intensive peaks at 231.1 and 337.0 *m/z* correspond to the high molecular forms $[Al_{13}O_{18}(H_2O)_{0-2,4}]^{3+}$ and $[Al_{13}O_{18}(OH)(H_2O)_{0-4}]^{2+}$, respectively. The composite coagulant $Al_2(SO_4)_3$/PAC (Fig. 1(b)), is characterized by signals of monomeric $[Al(OH)_2(H_2O)_{1-2}]^+$ - 97.0 *m/z,* dimeric $[Al_2O_2(OH)(H_2O)_{0-4}]^+$ - 103.0, 157.1 *m/z*, trimeric $[Al_3O_4(H_2O)_{0-5}]^+$ - 145.8, 163.1 *m/z*, tetrameric $[Al_4O_5(OH)(H_2O)_{1-5}]^+$ - 188.0, 205.1, 222.8 *m/z* and pentameric $[Al_5O_7]^+$ - 246.9 *m/z* forms of aluminium. The less intensive peak at 327.6 *m/z* is characterized by the presence of the high polymer form of aluminium $[Al_{13}O_{18}(OH)(H_2O)_{0-4}]^{2+}$. In turn, for the developed composite coagulant $AlCl_3$/PAC (Fig. 4(c)), besides the presence of the above-mentioned monomeric and polymeric forms of aluminium, the presence of the high molecular forms of the type $[Al_{12}O_{17}]^{2+}$ - 297.6 *m/z*, $[Al_{13}O_{18}(OH)(H_2O)_{0\text{-}4}]^{2+}$ - 327.6 *m/z* and $[Al_{14}O_{20}(H_2O)_{0\text{-}1}]^{2+}$ - 348.9 *m/z* is pronounced. The presence of peaks in the range of 400-550 *m/z,* which is characteristic for the high polymer forms of aluminium with 9, 10 and 16 atoms of aluminium in the structure, is observed [30, 34]. According to the present results, the composite coagulant $AlCl_3$/PAC is characterized by great amount and variety of the high polymer forms of aluminium.

IV CONCLUSION

The results of the treatment of the model solution, simulating woodworking wastewater, show that the use of the new composite coagulant based on chloride polyaluminium enables a considerable enhancement of the degree of treatment of the model solution from hemicelluloses and lignin compounds, in comparison with the new composite coagulant. The developed composite coagulant is efficient at both low and elevated temperatures, and is characterized by a minimum residual concentration of aluminium, which makes it possible to return the treated wastewater into the technological cycle.

V ACKNOWLEDGMENTS

The authors are grateful to the Ministry of Education and Science of the Republic of Latvia for the financial support of the National Research Programme.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 71-75

Trends of the culinary herbs diversity research and their use in green plantations

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***Abstract.* In recent times, due to the globalization the fashion of plant cultivation has been changing as well; imported, decorative acclimatized culinary herbs have been penetrating, therefore, new tasks to integrate them into the traditional plantations have been arising.**

The main aim of the paper is to select culinary herbs for the design solutions having different purpose and adapted to different environmental conditions, to reveal the possibilities to use the best properties of these plants, to help the persons interested in the use of culinary herbs to decide on the proper plant selection, to provide recommendations on the combination and composition possibilities of these plants.

The authors of the article have analyzed and evaluated the research carried out in Lithuania related to the issues of culinary herb cultivation. In the Institute of Horticulture Lithuanian Research Centre for Agriculture and Forestry 24 species of culinary herbs are cultivated. By analyzing the culinary herbs cultivation technologies, plant bio ecology and morphology as well as priority propagation techniques have been evaluated; decorative properties of herbs and the possibility of their use in green plantations have been assessed.

***Keywords:* globalization, culinary herbs, bio ecology, plantations.**

I INTRODUCTION

A person gets to know his surroundings through the senses: sight, smell, taste, hearing and touch. There are more than 1000 species of plants, the parts of which are used as spices, in the world. About 100 species of culinary herbs are cultivated in Lithuania. In XI–XIII centuries Europeans started using lavender, rosemary, thyme, etc. as culinary spices [1].

The first data about the Renaissance garden plants was found in Lithuania in 1542-1547 in the description of Radvilos palace garden in Vilnius. Besides local trees and fruit trees, decorative, culinary plants such as hyssop, rosemary, lavender are mentioned.

In the pre-war Lithuania there was no a single house or a homestead without a flower garden. It was the centerpiece of the entire homestead. Flower gardens were created for the beauty of the flowers, for different rites, as well as medicines and spices. An absinth was always grown under the windows, because its smell scared flies, thus, when leaving open windows they did not fly inside. Every homestead was decorated by peonies; according to the elders they drove away the fear. Lithuanians could not do without lavender, it was perfect for scenting bed and the clothes, seasoning meat and it was believed to bring happiness. They were dried and carried to the bath, their smell perfectly relaxed after a hard day. Wormwood was cultivated for medical purposes, they were used for stomach ailments. [6].

Mint, spearmint, lemon balm, thyme, basil, oregano, hyssop, sage, Santa (catnip – *Nepeta* L.) were cultivated in gardens. Gardens could not do without „cibuliukų“ (onions), „tribulkų“ (chives – *Allium schoenoprasum* L.) [2]. Medicinal herbs such as fleabane (*Inula* L.), absinth (*Artemisia absinthium* L.) were cultivated not only in the garden, but also in other parts of the homestead. The flower beds were established under the windows to produce nice smell, mostly L-shaped in the southern and eastern side, over the entire house side, in the rear side of the house [5].

During the last years there has been an increasing tendency to promote, propagate the use of herbs in

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.278

the green plantations of homesteads, country tourism homesteads or other territories, although their versatile benefits on a human being have long been recognized. Culinary herbs descriptions are presented K.K, Vilkonis works [8].

Culinary herbs are not widely grown in flower beds, because most of them are not as good looking and decorative as imported plants. However, for smaller homesteads, in order to have splendid flower gardens, and at the same time a few culinary herbs after combining them, we can have decorative combinations.

The growing demand for non-traditional, culinary, aromatic, medicinal plants encourages investigating new plant species and their application possibilities. In Lithuania culinary herbs are not widely cultivated although many of them grow well in the natural environment conditions.

In the culinary herbs collection of the Institute of Horticulture of Lithuanian Research Centre for Agriculture and Forestry long-term phenological observations of culinary herbs - plant growth, development and adaptation have been carried out. The best harvesting time of raw material and yield is identified. Studies on the quality of the raw material are performed [3]. Valuable selection of individuals, formation of populations are carried out. During individual selection and after the studies on economical value, in 1999 the smoked coriander breeding line No. 20 was given the name of the strain 'Raslė', in 2005 the chives breeding line No. 028 was given the name of the strain 'Aliai' [4].

Possibilities for culinary herbs adaptation in green plantations were little studied. When growing herbs for green plantations, it is essential to select perspective herb species and varieties for cultivation in Lithuania.

The aim of the research is to investigate and evaluate morphological and bio-ecological characteristics of over ground parts of culinary herbs cultivated in Lithuanian local soils conditions, their cultivation and application in green plantations.

II MATERIALS AND METHODS

The studies were performed at the Institute of Horticulture LRCAF in the test field of crop rotation in 2013–2014. The soil - sandy on light loamy calcaric shallow luvisol (*Idg8-k / Calc*(*ar - Epihypogleyc Luvisols – LVg-p-w-cc*) (Buivydaitė et al., 2001). Plant preceding crop – black fallow land. 26 species of perennial aromatic herbs were cultivated. In 2013 seedlings were planted in 70 cm spacing rows and 30 cm between plants on flat surface in the second decade of May. Accounting field area – 9,6 m². Test versions were repeated three times. Observations of plant height, flowering time and duration were carried out.

Growing of herbaceous plants in green plantations, their combinations with perennial flowers and decorative shrubs were studied in Kauno kolegija in 2012-2013.

Sixteen different species of perennial culinary herbs of different growth were selected for the investigation: *Inula helenium* L., *Artemisia dracunculus* L., *Agastache foeniculum* L., *Hyssopus officinalis* L , *Nepeta cataria* L., *Satureja montana* L., *Thymus serpyllum* L., *Origanum vulgare* L., *Mentha x piperita* L., *Monarda didyma* L., *Melissa officinalis* L., *Lavandula angusitifolia, Salvia officinalis* L., *Allium nutans* L., *Allium ursinum* L.

Culinary herbs were cultivated following the garden plants growing technology approved in the Institute of Horticulture Lithuanian Research Centre for Agriculture and Forestry.

During every year of research in the group of perennial and annual culinary herbs species seasonal development phases were recorded once a week. The beginning of a plant vegetation and flowering time were evaluated. Biometric measurements were carried out once every vegetation during massive flowering time of plants. During the years of investigations the average air temperature during the growing season of perennial plants was lower than the average. There was enough precipitation for plants to grow. The height, flowering time and the application of culinary herbs in green plantations were assessed following the methodology prepared by Jonas Vaidelys (2005) in the publication „Methodology of ornamental herbaceous plant phenological observations, biometric measurements and the assortment f formation“ [7]:

Plant height was measured during the flowering time of a plant from the ground to the highest point. It is evaluated in centimeters, providing data about plants their height can be decoded. Florists grade the height of flowers in 20 cm intervals. The following height categories of flowers can be distinguished:

0 – 20 cm – carpet dwarf;
21 – 41 cm – carpet tall;
42 – 60 cm – average height;
61 – 80 cm – semi-tall;
81 – 100 cm – tall;
101 and more – very tall.

Flowering duration is assessed the following way:

1-5 days;
6-10 days;
11-20 days;
21-30 days;
31-50 days;
51 and more days.

Assessment of the application possibilities

The following plant application positions can be distinguished: for beds (rabates), edges (boarders), raised beds, parterres, groups, single growing (solitaires), flower boxes, vases, growing in pots, balconies, hedges, cemeteries, water pools, water pool coastlines, rockery, and picking.

The following applications are distinguished: very limited application possibilities (1–3 application positions), limited application possibilities (4 – 6 application positions), medium application possibilities (7 – 9 application positions), broad application possibilities (10 – 12 application positions), and very broad application possibilities (13 – 15 application positions).

III RESULTS AND DISCUSSION

Table 1 presents morphological and bio ecological characteristics of culinary herbs.

TABLE 1.
MORPHOLOGICAL AND BIO ECOLOGICAL CHARACTERISTICS OF CULINARY HERBS (BABTAI, 2013–2014)

The botanical name of the plant	Aboveground part of the plant		Beginning of flowering time, month., days.	Massive flowering, month., days	Duration of flowering, days
	Height, cm	Diameter, cm			
Allium nutans L.	51,5	69,8	07 14	07 25	30
Allium schoenoprasum L.	54,8	57,6	06 05	06 22	33
Allium angulosum L.	53,5	59,3	06 18	07 04	37
Allium ursinum L.	48,4	55,5	05 14	05 26	27
Inula helenium L.	195,7	89,1	07 08	07 20	56
Artemisia abrotanum L.	137,6	86,2	08 17	09 03	44
Artemisia absinthium L.	153,5	104,3	08 06	08 28	47
Sanquisorba officinalis L.	62,2	61,5	06 26	07 09	33
Geum urbanum L.	42,7	48,9	06 04	06 26	45
Hyssopus officinalis L.	65,6	67,8	06 21	07 15	52
Salvia officinalis L.	62,3	67,4	06 12	06 29	35
Melissa officinalis L.	77,4	84,2	07 23	08 18	46
Origanum vulgare L.	72,7	61,5	06 17	07 02	40
Thymus vulgare L.	23,5	38,6	06 04	06 26	30
Thymus serpyllum L.	31,3	54,2	06 20	07 08	42
Satureja montana L.	37,8	52,7	07 10	08 04	57
Nepeta pannonica L.	38,6	41,4	05 26	06 14	74
Marrubium vulgare L.	56,4	68,5	06 18	07 11	65
Mentha piperita L.	53,8	58,4	07 13	08 01	52
Mentha spicata L.	66,7	55,2	06 26	07 21	58
Agastache foeniculum L.	72,5	65,8	06 14	07 19	64
Salvia sclarea L.	93,3	78,2	06 27	07 19	47
Monarda didyma L.	46,8	63,2	06 29	07 19	63
Nepeta cataria L.var. *citriodora* Becker	88,6	79,5	07 04	07 26	40
Lavandula angustifolia L.	50,4	49,6	06 20	07 09	46
Hierochoe odorata L.	51,8	41,7	05 16	06 18	52

Out of the investigated culinary herbs the most widely studied were the plants of Labiatae (*Lamiaceae*) family – 16 species.

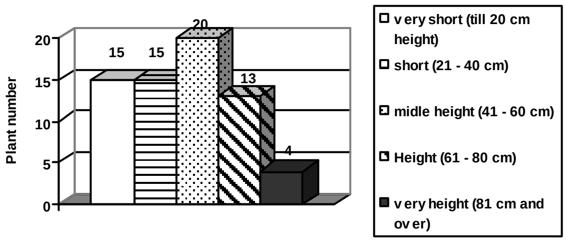

Fig. 1. The height of culinary herbs

The majority of plants are of medium height - 20 species: *Allium schoenoprasum* L., *Artemisia absinthium* L., *Lavandula angustifolia* L. etc. The least number of plants are very high herbs – 4 species: *Inula helenium* L., *Artemisia abrotanum* L. etc. (Figure 1).

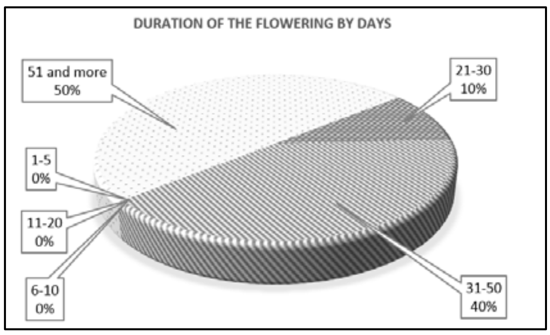

Fig. 2. Herbs distribution by flowering time

The longest flowering time of studied plants is 51 days and more, this makes 50 percent of all investigated plants (Figure 2). This feature of culinary herbs is positive and it provides excellent possibilities to use these plants in green plantations.

TABLE 2.

THE USE OF CULINARY HERBS IN GREEN PLANTATIONS

No	The botanical name of the plant	Beds	Edges	Raised beds	Parterres	Groups	Balconies	Flowering lawns	Coastlines of water pools	Rockeries	Picking	Pots	Cemeteries
1.	*Inula helenium* L.			x		x			x		x		
2.	*Artemisia dracunculus* L.					x		x					
3.	*Agastache foeniculum* L.	x		x		x		x			x	x	
4.	*Hyssopus officinalis* L.					x		x					
5.	*Nepeta cataria* L.					x		x					
6.	*Satureja montana* L.		x				x			x		x	
7.	*Thymus serpyllum* L.		x					x		x		x	
8.	*Thymus citriodoru* L.		x				x			x		x	x
9.	*Origanum vulgare* L.		x			x		x		x	x	x	
10.	*Mentha x piperita* L.					x							
11.	*Monarda didyma* L.					x		x			x	x	
12.	*Melissa officinalis* L.					x							
13.	*Lavandula angusitifolia* L.	x	x	x	x		x	x		x	x	x	
14.	*Salvia officinalis* L.			x		x		x			x	x	
15.	*Allium nutans* L.		x							x			
16.	*Allium ursinum* L.					x		x		x			

The most culinary herbs used in green plantations are used for groups - 12 species, flowering lawns - 10 species, pots – 8 species and rockeries – 7 species (Table 2).

The highest number of investigated culinary plant species (8) has limited application possibilities in green plantations (Pr 4-6), and 7 species – very limited application (Pr 1-3) (Figure 3).

Lavandula angusitifolia L. has the biggest possibilities for the application in green plantations (9). 8 investigated plant species have medium possibilities for the application in green plantations, and 7 species - very limited application possibilities. It can be stated that possibilities for culinary herb application are much more limited than those of cultural decorative plants (Figure 4).

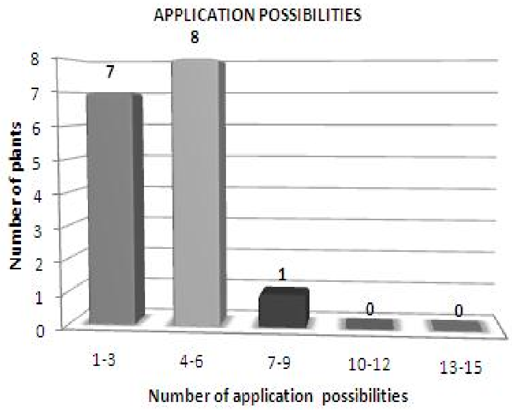

Fig. 3 Number of application possibilities

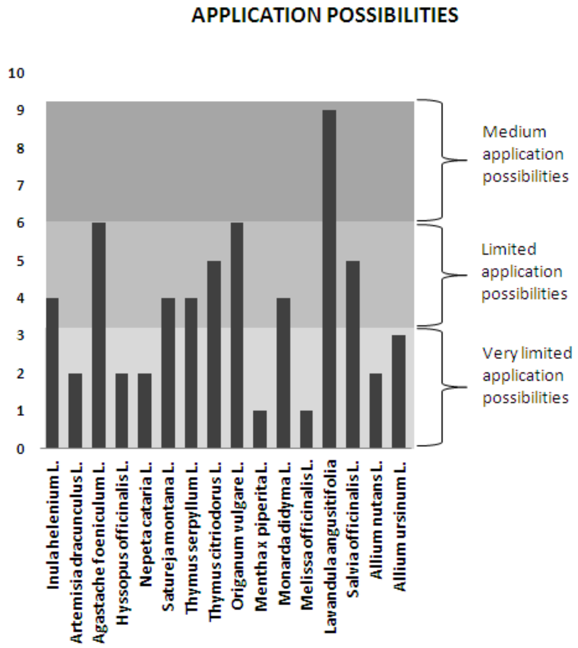

Fig 4. Possibilities for culinary herbs application in green plantations

Using the investigated species of culinary herbs 2 examples of flowerbeds designs (A and B) have been created (Figure 5).

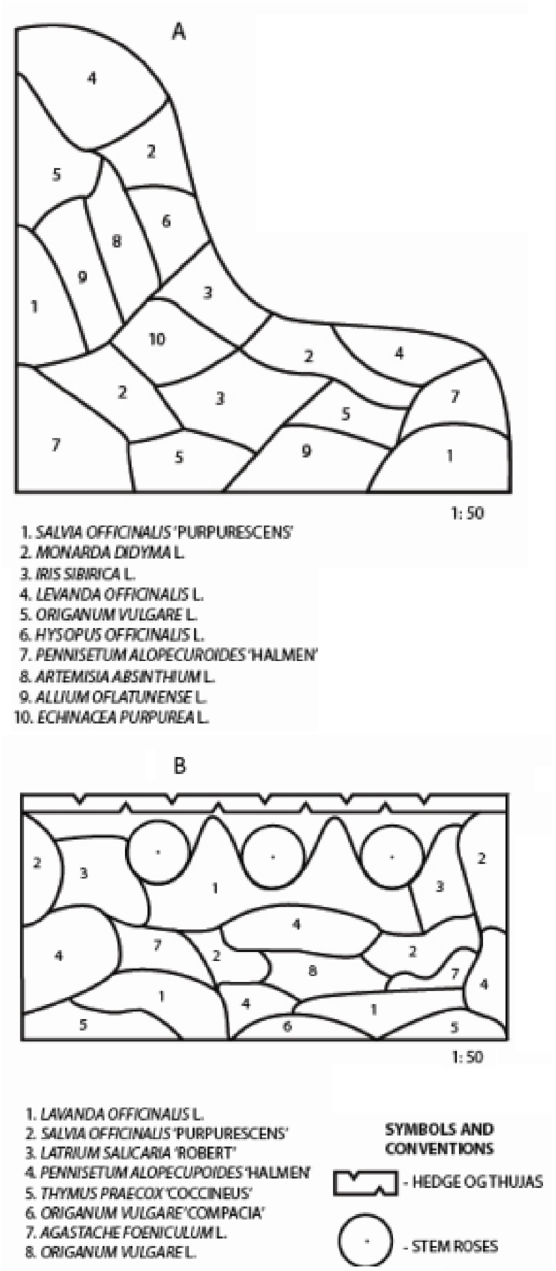

Fig 5. Designs of flower gardens of culinary herbs (A, B)

IV CONCLUSION

The analysis of bioecological-morphological characteristics of studied culinary plants indicates that majority of plants (20 species) are of medium height: Allium schoenoprasum L., Artemisia absinthium L., Lavandula angustifolia L. etc. The smallest number of plants (4 species) includes very tall culinary herbs: Inula helenium L., Artemisia abrotanum L. etc.

The duration of flowering time of 50 percent of all studied plants is 51 day and longer, therefore, this feature opens the possibilities to use these plants in green plantations.

The majority of investigated plants have limited application possibilities in green plantations (8), mostly 4 or 6 application positions. The biggest application possibilities (9) are possessed by Lavandula angusitifolia L. Therefore, it is possible to conclude that the application possibilities for culinary herbs are much lower than for cultural decorative plants.

Two examples of flowerbeds including culinary herbs recommended for green plantations have been designed because nowadays it is very popular to cultivate aromatic spices in living environment.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 76-81

Pyrolysis of wild cyanophyta from Chaohu lake for bio-oil

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Abstract. **To solve the environmental problems caused by the algae, pyrolysis experiment was studied to produce bio-oil with the wild cyanophyta from Chaohu lake for the first time. The results showed that the suitable temperature, carrier gas flow rate, and the smaller particle size were better for liquid products generation, the liquid (bio-oil) yield obtained maximum (66 %) at temperature of 450 ^{o}C, carried gas flow rate of 50 mL/min and particle size of less than 0.25 mm. The main ingredients of liquid product from cyanophyta pyrolysis consisted of hydrocarbons, nitrogenous compounds, acids and other organic compounds (such as alcohols, phenols esters and non-identified materials). Acid content was the highest and greatly affected by temperature. The content of hydrocarbons was about 15%.**

Keywords: **cyanophyta, pyrolysis, bio-oil, Chaohu lake.**

I INTRODUCTION

Chaohu lake is the main water resources and scenic spot in Hefei city of China, however, cyanophyta frequently occurred in August and September every year caused serious water pollution problem of eutrophication [1]. The previous research showed that the amount of cyanophyta (the dry biomass) was 5×10^5 t ~ 7×10^5 t every year [2]. There were no thorough methods to resolve the problem, the traditional interception and refloatation was the effective and emergency method [3]. A mass of wild cyanophyta by interception and refloatation able to be recycle very few, they were usually open piled up or landfill. Nonetheless, cyanophyta decay produced odor and poison, these polluted the air and surface water or even underground water, caused secondary pollution [4]. So it is urgently to properly resolve the refloatation of cyanophyta.

As we all know, biomass can accomplish thermal decomposition in a very short time under the condition of anaerobic or less oxygen, and then the yield rapidly condensed, the reaction process is biomass pyrolysis. It can reduce the secondary pyrolysis chance of the initial pysolysis products, and increase the yield of liquid products. The biomass pyrolysis can convert the abandoned biomass into the pyrolysis oil, which could use as chemical raw materials or alternative energy sources for fossil fuels. The process is simple, and easy to realize, it could achieve the biomass energy conservation and waste recycling use. So it's necessary to develop the biomass pyrolysis [5-10].

There were lots of researches on the algae for bio-oil by the pyrolysis process, but most of the algae was artificial cultivation. This study used the wild cyanophyta from Chaohu lake as raw material for bio-oil by the pyrolysis process for the first time. The influence of temperature, carrier gas flow rate, and particle size for cyanophyta pyrolysis were investigated, and the composition of pyrolysis liquid was analyzed. The research could provide technical and theoretical basis for the wild cyanophyta treatment and application of pyrolysis liquid.

II MATERIALS AND METHODS

Materials

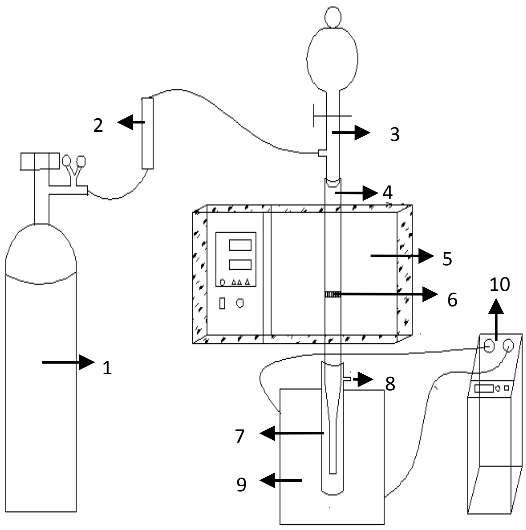
The analytical grade of methyl alcohol, ethanol, sodium hydroxide, and the chromatographical grade of n-hexane were purchased from Sinopharm chemical reagent Co. Ltd., China. The secure without

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.630

pyridine of Karl Fischer reagent was obtained from Shanghai Xin Zhong chemical science Co. Ltd., China.

The cyanophyta was refloated from the Caohu lake, then it was treated by dehydration, drying, crushing, and sieving. Afterward, it was stored in a dry vacuum oven for further investigate. The cyanophyta powder properties showed in Table 1.



Experimental device and procedure

Fig. 1 Schematic diagram of pyrolysis device

(1 nitrogen cylinder, 2 flow meter, 3 feed tube, 4 reaction tube, 5 vertical tube furnace, 6 quartz pads layer, 7 collection tube, 9 non-condensable outlet, 10 circulating cooling system)

The pyrolytic device schematic diagram was shown in Fig. 1, it constituted by three units of feedstock, reaction, and product collection. The unit of feedstock was comprised by pear type glass tube, the unit of reaction made of vertical tube furnace (OTF-1200X-S-V7) and quartz tube, the unit of product collection was consisted of oil collecting tube and circulating cooling system.

A mount of cyanophyta powder was sent to the feedstock, at the same time, a stream of pure nitrogen added to keep the anaerobic environment. When the vertical tube furnace reached the target temperature, turned on the reaction unit and the temperature was maintained for 10 min. The bio-oil collected by the collection tube from the circulating cooling system (0 ^{o}C).

Analytical methods

Elemental analysis was analysed by vario SL cube (Elementar, German). The composition was analysed by Clarus SQ8 GC-MS, the chromatographic column was Elite-5MS (50 m*0.25 mm*0.25 um), temperature of the injection port was set at 250 ^{o}C, the column kept at 50 ^{o}C for 2 min, then raised the temperature to 300 ^{o}C with heating rate of 10 ^{o}C/min and kept the temperature for 10 min. The carrier gas was helium, with the flow rate 1.0 mL/min, and split ratio 20:1. The GC transmission line temperature was 280 ^{o}C, ion source temperature was 230 ^{o}C, the scan quality range was 33 to 450, solvent delay was 2.8 min.

TABLE 1
PROPERTIES ANALYSIS OF THE CYANOPHYTA POWDER

Industry analysis (%)				Elemental analysis (%)				Main ingredients (%)		
Water content	Ash	Volatile matter	Fixed carbon	C	H	O	N	Crude protein	Crude fat	Crude polysaccharide
4.76	10.75	69.52	14.97	46.68	7.36	38.95	7.02	43.88	6.44	7.46

III RESULTS AND DISCUSSION

Effect of temperature on the pyrolysis product distribution of cyanophyta

Temperature is an important influencing factor in the biomass pyrolysis process, it can affect product yield and composition [11]. The product distribution of cyanophyta pyrolysis affected by temperature was showed in Fig. 2. When the temperature was raised, the change trend of liquid yield was increased first and then decreased. When the temperature between 300 to 450 ^{o}C, the liquid yield increased continuously, reached the maximum value at the 450 ^{o}C and then decreased slowly. The solid yield was decreased and the gas yield showed an increasing trend with increasing temperature. The reasons were analyzed as follows: thermal decomposition of cyanophyta can break chemical bonds with smaller bond energy and produced less volatile substances under the low temperature. Therefore, the pyrolysis liquid and gas yield were low. The pyrolysis reaction was occurred acutely at high temperature, so the temperature continuously raised, the pyrolysis reacted sufficiently and produced more volatile material, accordingly, the liquid and gas yield increased, the yield of solid declined [12]. But when the temperature increased further, the volatile substance produced by secondary pyrolysis of bio-oil in higher temperature, bio-oil was translated to small molecule non condensable gas, so the liquid yield decreased.

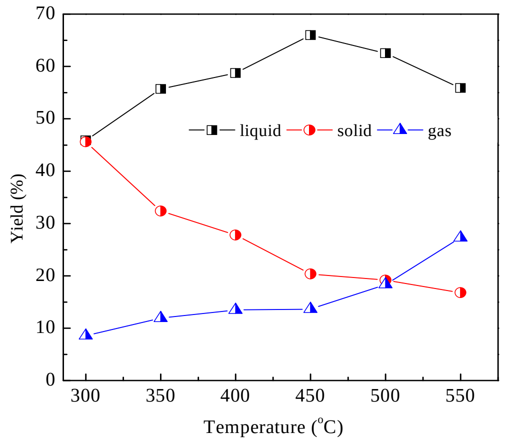


Fig. 2 Effect of temperature for cyanophyta pyrolysis

Effect of carrier gas flow rate for cyanophyta pyrolysis

The influence of carrier gas flow rate on the distribution of the pyrolysis products of cyanobacteria was exhibited in Fig. 3. It was observed that the temperature was maintained constant at 450 °C, when the carrier gas flow rate was lower than 30 mL/min, the liquid yield significantly increased with the enhance of flow rate. The liquid yield reached the maximum at flow rate of 50 mL/min, the liquid yield gradually decreased with the continue improve of flow rate, because of the lower carrier gas flow rate can prolong the retention time of volatile substances in the reactor and increase the possibility of secondary pyrolysis. Specifically, when the carrier gas flow rate was too high (e. g, more than 50 mL/min), the volatile was taken out of collecting pipe by the carrier gas rather than completely condensed, which reduced liquid yield. In addition, many cold gas carried by the high flow rate of carrier gas can reduce the temperature of reaction.

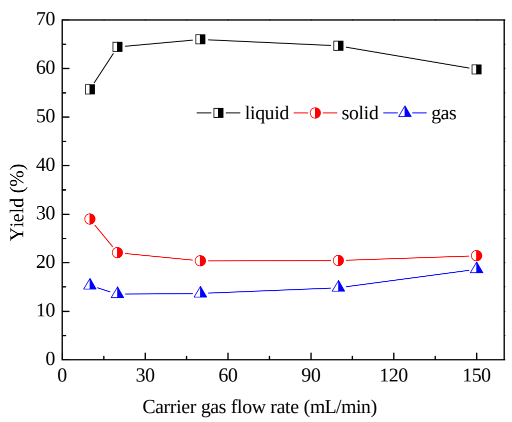


Fig. 3 Effect of carrier gas flow rate for cyanophyta pyrolysis

Effect of particle size of raw materials for cyanophyta pyrolysis

Raw material particle diameter was also an important factor affecting biomass pyrolysis [13]. Fig. 4 showed the influence of particle diameter on the cyanophyta pyrolysis product distribution. When the gradual increased of raw material particle diameter, liquid yield decreased, solid yield raised steadily, gas yield declined slightly. Due to the smaller particle diameter may be more beneficial to heat transfer, the raw material particles can rapidly reach the specified temperature of pyrolysis reaction. Furthermore, pyrolysis of volatile substances precipitation rate was speed among the smaller particles that reducing the possibility of the secondary pyrolysis reaction and improving the liquid yield. On the contrary, when the larger diameter of the particle was heated, the heating rate of the center of the particle was relatively slower than the surface. Based on this fact, the center of the particle was easy to generate carbon at lower pyrolysis temperature, so the higher solid yield.

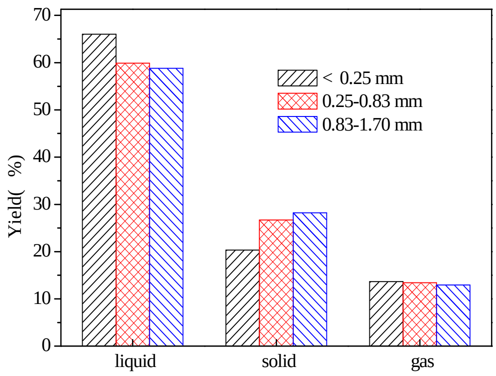


Fig. 4 Effect of particle size of raw materials for cyanophyta pyrolysis

Cyanophyta pyrolysis liquid analysis

Cyanophyta pyrolysis liquid was analyzed and exhibited in Table 2, the results showed that the moisture content was about 28.31 %, which was higher than the raw material, because of the process of pyrolysis produced by the combining of hydrogen and oxygen. It had a much greater density than light and heavy fuel, which was determined to be 1.16 g/cm^3. In addition, the pyrolysis liquid was very corrosive due to the high acidity (129.31 mg KOH/g). The calorific value of pyrolysis liquid (25.4 MJ/kg) was lower than that of bio-oil and gasoline, which may be related with the high moisture content.

TABLE 2
PROPERTIES OF LIQUID PRODUCED FROM CYANOPHYTA PYROLYSIS

category	fator	reuslt
React condition	temperature	500 °C
	carrier gas flow rate	50 mL/min
	raw material particle size	less than 0.25 mm
Chemical element	C	47.12 %
	H	9.31 %
	O	35.14 %
	N	8.44 %
Characteristics	moisture content	28.31 %
	density	1.16 g/cm^3
	acidity	129.31 mgKOH/g
	calorific value	25.4 MJ/kg

The main component of algae pyrolysate was investigated with the application of the GC-MS. The total ion chromatogram was showed in Fig. 5, the main content was demonstrated in Table 3.

TABLE 3
THE MAIN CONTENT IDENTIFIED BY GC-MS

No.	Retention time (min)	Compound	CAS#	Chemical formula	Area (%)
1	16.18	heptadecane	629-78-7	$C_{17}H_{36}$	11.95
2	17.24	octodecane	593-45-3	$C_{18}H_{38}$	3.46
3	17.62	phytol	102608-53-7	$C_{20}H_{40}O$	7.93
4	18.05	phytol	102608-53-7	$C_{20}H_{40}O$	4.05
5	18.99	palmitic acid	57-10-3	$C_{16}H_{32}O_2$	29.10
6	20.26	Phytosterol	150-86-7	$C_{20}H_{40}O$	4.77
7	20.66	oleic acid	112-80-1	$C_{18}H_{34}O_2$	4.65
8	20.81	stearic acid	57-11-4	$C_{18}H_{36}O_2$	6.01
9	20.95	hexadecanamide	629-54-9	$C_{16}H_{33}NO$	6.28
10	22.46	oleamide	301-02-0	$C_{18}H_{35}NO$	4.72
11	22.67	Octadecannamide	124-26-5	$C_{18}H_{37}NO$	3.93

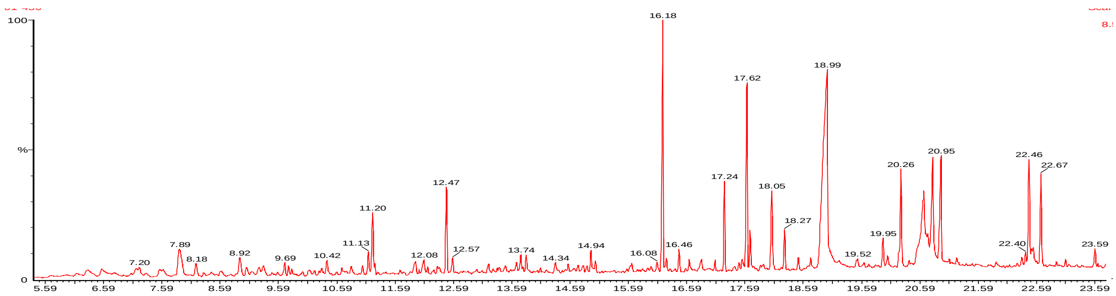


Fig. 5 Total ion chromatogram of product from cyanophyta pyrolysis liquid

From the analysis result in Table 3, it was obvious that the pyrolysis liquid composition was complex and the content of component was significantly different to each other. Some compounds had the higher content in the range of retention time 16～23 min, such as the peak area of palmitic acid, heptadecane and phytol were 29.10 %, 11.95 % and 7.93 %, respectively. All the detected components can be divided into four categories, for example, hydrocarbons, nitrogen-containing compounds, acids and other organic matter (such as alcohols, phenols, esters and so on).

The distribution of these four components at different reaction temperature was different. As showed in Fig. 6, whatever the temperature considered, the content of acids (including palmitic acid, oleic acid, stearic acid, etc.) were the highest. However, the percent of acids were reduced when the temperature was higher. The highest content of acids were mainly due to the high levels of ash of algae raw materials, which contained the alkali metals (such as sodium, potassium, etc) had catalytic effect on biomass pyrolysis process and produced large amounts of acids [14]. The pyrolysis liquid with high content of acidic substances was corrosive and instability, so it will adverse to long-term stable operation of the engine. The important issue of bio-oil preparation and refining was how to reduce the content of acids. The two common methods were the raw ash pyrolysis and pyrolysis liquid catalytic esterification.

There lative content of nitrogen-containing was increased from 12.02 % to 24.92 % as the temperature raised from 300 ^oC to 450 ^oC. It was increased significantly can be attribute to the breakage of C=N bond in the molecular structure of compound caused by high temperature. With respect to nitrogen-containing of cyanophyta pyrolysis liquid, this was mainly from the pyrolysis of peptide and amino acid of protein. Carbonyl compounds, indole, nitrile and other nitrogen-containing substances [15] were produced from many processes of the pyrolysis of amino acid, such as intramolecular elimination reaction of CO_2, stern depolymerization, etc.

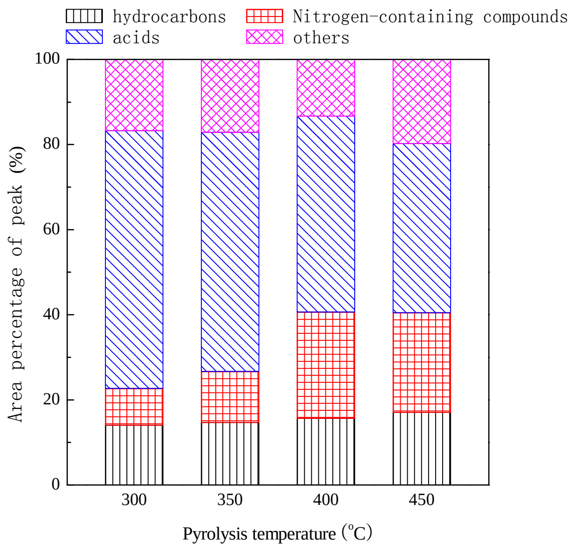


Fig. 6 The distribution of four components at different reaction temperature

Hydrocarbons mainly contained alkyl radical from the fracture of aliphatic groups of cyanophyta. It also included normal alkane and alkenes generated from these alkyl radical gain and loss of hydrogen free radical [15].The content of the hydrocarbons were about 15%, and less affected by the temperature, which was importance to instead of fossil fuels by refining the oil from the cyanophyta pyrolysis.

The other organics contained alcohols, esters, phenols and amount of an unknown substance. The alcohols were mainly refers to the phytol, which were lipophilic long-chain fatty alcohol as the main pyrolysis products of chlorophyll. The main esters were palmitic acid and stearic acid methyl ester, which were gained esterification of alcohol and acid in the process of pyrolysis storage rather than the direct product [15].

IV CONCLUSIONS

The main findings of this study can be summarized as follows:

(1) With the increasing temperature, cyanophyta pyrolysate liquid yield was increased at the early stage and then decreased, the solid yield reduced gradually, and the gas production rate was raised gradually. With the the increasing carrier gas flow rate, cyanophyta pyrolysis liquid yield was also increased firstly and then reduced, just change trend was relatively small. Additionally, the smaller the particle size of cyanophyta was more conducive to the formation of liquid products. In this experiment, cyanophyta pyrolysis liquid (bio-oil) yield was as high as 66 % when temperature was 450 ^oC, carrier gas flow rate was 50 mL/min, and the particle size was less than 0.25 mm.

(2) The main component of cyanophyta pyrolysis liquid was explored with the application of the GC-MS. Results showed that the mainly composed of hydrocarbons, nitrogen-containing compounds, acids and other organic matter (such as phenols, alcohols, esters and other substances). Furthermore, the hydrocarbon was about 15 %, which was little affected by temperature and helpful for cyanophyta pyrolysate. However, the ratio of acids and nitrogen-containing compounds of cyanophyta pyrolysis liquid were strongly influenced by temperature. The content of acids gradually reduced with the increasing temperature, while the high temperature was beneficial to production of nitrogen-containing compounds.

V ACKNOWLEDGMENTS

This research was supported by the project of the development subject leader in HeFei university (2014dtr02), and the project of key discipline in HeFei university (2014xk01)

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 82-84

Sensitivity of the coupled model of the White Sea dynamics and biochemistry

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Abstract. **The JASMINE model based on the prof. N.G. Iakovlev's model of the Arctic Ocean (FEMAO) is the software complex for simulating hydrodynamics and thermal dynamics of a sea; we use the White Sea as an example and also have tried to model other seas. JASMINE allows coupling with special purpose blocks, such as data assimilation or simulation of the sea ecosystem. For that we chose the mature BFM model of pelagic sea biochemistry. An important question is sensitivity of the model with respect to the outer forcing, such as synoptic data (air temperature and pressure, cloud cover, precipitation, wind), boundary values on liquid boundaries, river run-off, initial distributions of the tracers. The White Sea is a convenient model region for such investigation because of dominating tides; thus boundary values become important, while initial distribution is expected not to influence on the results in the long run, at least. The biochemical system also depends on the boundary conditions strongly, and also reacts on the forcing variations. We describe the response of the sea subsystems to different variations of forcing, show what values are crucial and what is not important.**

Keywords: **ecosystem simulation, modelling, thermohydrodynamics, the White Sea.**

I INTRODUCTION

Interest to northern seas, especially those of the Arctic region, has been constantly increasing. Numerical and computer simulation, including high-performance computing, become more and more important [1, 2]. However, there is still a lack of models that describe a sea as a complex system, taking into account three-dimensional currents, dynamics of thermohaline fields, sea ice, etc. Existing projects, e.g., NEMO [3], are not all open-source and cannot, usually, be easily adapted for a given sea.

The FEMAO model by prof. N.G. Iakovlev [4], developed for the Arctic Ocean, has been used for simulation of the White Sea [5, 6]. Its sea ice block is very advanced. Ice is described as an ensemble of flakes with thickness distribution. Flakes form a two-dimensional continuum.

Using this model as a hydrodynamical core, we develop the software complex JASMINE [7] for simulation of a sea. It has modular structure and can include modules for describing dynamics of ecological system, data assimilation, and other purposes.

II THE WHITE SEA

We use the White Sea as the test sea for verification of the model. The White Sea is rather well studied (see e.g. [8] and references therein) and is important for the Russian Federation. It is convenient for testing numerical models, being semi-closed: it has the single liquid boundary with the Barents Sea. Besides, tidal motion dominates in the sea; this reduces (and almost eliminates) the problem of initial distribution of hydrodynamical fields. Existing data bases concerning the White Sea, open internet resources (e.g., [9]), and new atlases [10] allow comparing model results with both measurements and results obtained by other models. However, the complex can model other seas and oceans: we tried to simulate the Arctic Ocean (geophysical and biochemical fields) and obtained reasonable results.

As for the existing models of the White Sea, we must mention the joint three-dimensional numerical model of hydrodynamics, thermal dynamics, and ecological system of the White Sea developed by I.A.Neelov and O.P. Savchuk [11], operational model by E.V. Semenov [12], and the model by M.V.Luneva [13].

III BIOCHEMICAL BLOCK

The pelagic ecosystem block uses the Italian BFM model [14-15]. It describes interaction and evolution of more than fifty tracers (such as concentrations of nutrients, carbon, nitrogen, phosphorus, etc., in different groups of plankton or bacteria, dissolved matter, etc). Physical model supplies water temperature and salinity, light, and other physical factors; besides, it provides transport of the tracers, their sinking, and describe processes on liquid boundaries and in river mouths. Ecological model is

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.245

able to influence back on the hydrodynamics via water transparency. It is important that three-dimensional transport of a tracer field is time-consuming, so using multiprocessor high-performance hardware is necessary: calculation of ecological dynamics in different grid nodes and transport of different tracers are independent and can be performed in parallel. Acceleration of calculation on computer clusters of Karelian Research Centre [16] and Institute of Numerical Mathematics [17] compared to the modern PC was as high as 300 times. Using this block, we are able to simulate not only physical state of a sea, but also evolution of its ecological system.

The data assimilation block is based on the open source EnKF (Ensemble Kalman Filter) library [18]. Using this technique also demands multiprocessor computers: an ensemble of processes implement the same numerical model with differing factors, using some measurements for correcting the ensemble members.

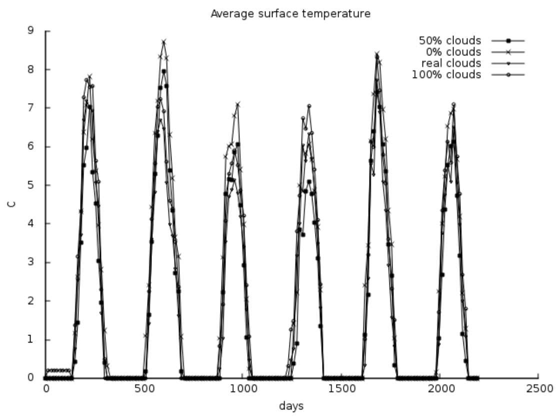

Fig. 1. Average surface temperature of the White Sea depending on clouds, %

It can be used for restoring missed boundary values using observations (possibly elsewhere), but it demands much computing power.

IV PROBLEM OF BOUNDARY VALUES

Boundary values of biochemical and geophysical scalar fields on liquid boundaries and in river mouths are extremely important. Results of modeling depends significantly on the boundary values, so high number of quantities and relatively low amount of data is a serious problem. Simulating the World Ocean to avoid liquid boundaries seems too expensive. However, the developed computer model is able to be adjusted to different seas, so that various seas of the region, including the White Sea, can be simulated at once.

V SENSITIVITY PROBLEM

In context of discussions about global warming, it seems interesting to look how a model sea would react on increase or decrease of global temperature.

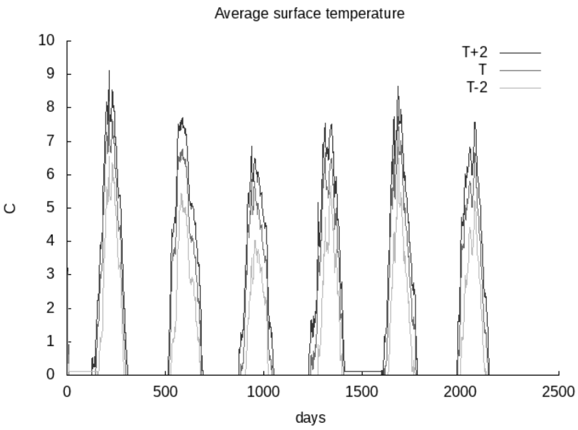

Fig. 2. Average surface temperature (T is water temperature (°C))

The model forcing includes air temperature and temperature of water at liquid boundaries. We tried to use JASMINE to see reaction of the model of the White Sea on changes of these temperatures. In particular, we compared average water temperature and some biochemical tracers for different scenarios of temperature change in the long run. Given air and boundary temperatures were increased or decreased on 1°C or 2°C.

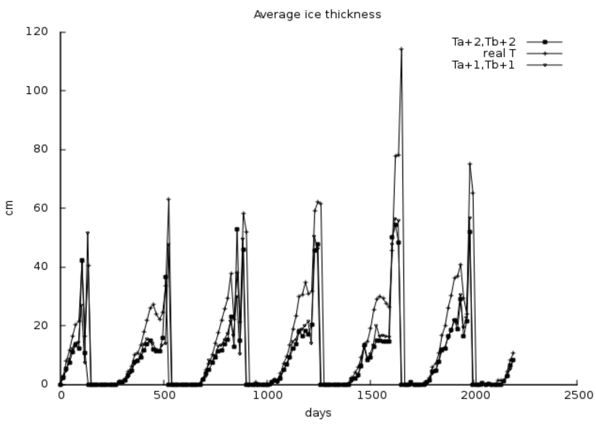

Fig. 3. Average ice thickness (Ta is air temperature (°C), Tb is boundary temperature (°C))

Also we changed the cloud cover, comparing real clouds with clear sky, 100% clouds, and 50% clouds. Fig. 1 shows how the surface water temperature reacts on the clouds. Note that both clear sky and 100% clouds produce warmer water compared to the real cloud cover.

As for air and boundary water temperature variations, the general conclusion is that the sea is rather stable with respect to these perturbations: all fields change, though not drastically. Fig. 2 shows surface water temperature for three cases: real conditions, both temperatures 2°C higher than real ones, and 2°C lower.

Ice thickness reacts strongly on temperature decrease on the liquid boundaries; the reason is that this temperature is (during winter time) low itself, so its decrease results in constant ice formation. Fig. 3 and 4 illustrate this: in fig. 3 we see average ice thickness for real conditions, warm air (+2°C) with water 1°C or 2°C warmer. Fig. 4 shows only influence of the air temperature: ice thickness hardly changes.

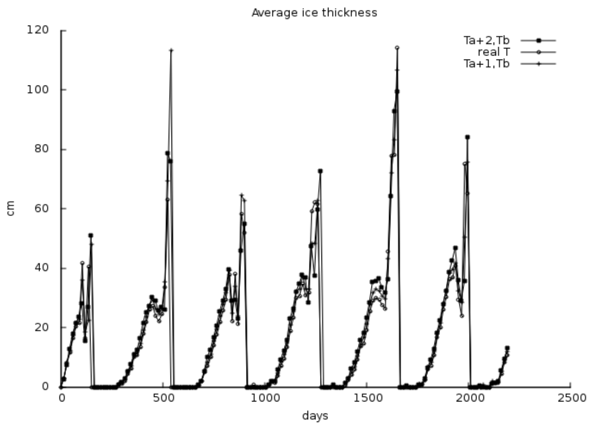

Fig. 4. Average ice thickness (Ta is air temperature (°C); Tb is boundary temperature (°C))

As for biochemical tracers, they change even less (see e.g. fig. 5, where oxygen near the surface is compared for the warm, cold, and normal year). The reason is that the highest concentration of plankton organisms is under the surface (5 m deep or more): there temperature changes are lower.

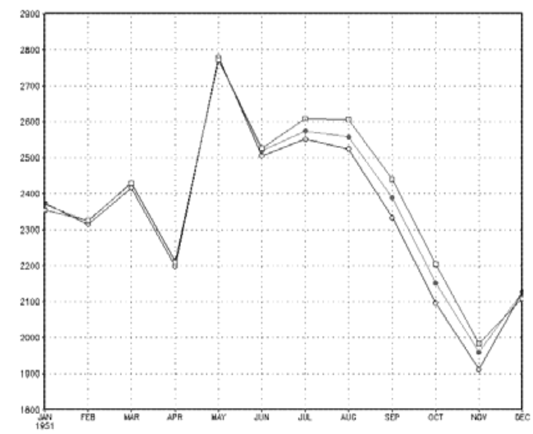

Fig. 5. Average oxygen (respectively downwards: warm, normal, cold year

Preliminary results indicate that distribution of nitrogen, phosphorus, silicon tends to reasonable fields; however, there are still significant problems connected with the lack of nutrient data for simulations on the liquid boundaries.

Also the model sea shows stability with respect to perturbations of the forcing and we believe that this reflects stability of real seas.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 85-90

Review-based Emergy Analysis of Energy Production

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Abstract. **The role of power and thermal energy is impossible to overestimate in development of both state economy sector and everyday life of households. Importance is connected with use of resources, economical feasibility and effect to climate changes. The optimization of energy production allows to promote development of sustainable society. The most popular and efficient technologies for generation of power and thermal energy are cogeneration plants (CHP). Traditional evaluation methodologies of energy production systems are based on analysis of energy and mass balances as well as on cost analysis. It is not enough for assessment of complete sustainability of system. Necessary environmental impact assessment of energy production is possible to implement by use of emergy analysis. Definition of emergy includes one type of energy, which is used directly or indirectly to produce materials, provide services and finances. Emergy dimension is emjoules (seJ.). Paper presents case study of emergy analysis of different operation modes of one cogeneration plant.**

Keywords: **Emergy analysis, cogeneration, sustainability.**

I INTRODUCTION

Traditionally, for the purposes of analysis of energy production systems, the energy, mass flow and economic analysis methods are applied; however, nowadays, as the topic of sustainable system development is on the rise, the analysis must also integrate environmental impact assessment methods. Emergy analysis, which is being successfully applied for the analysis of energy production systems, could be given as an example of such an integral assessment method [1, 2]. Emergy is defined as the available solar energy that has previously been directly or indirectly used to make a product or provide a service [3]. The unit of emergy is the emjoule (sej) and it represents the energy incorporated in a product or service. Emergy time units sej/s or sej/yr are called emergy flow or empower. Compared to energy analysis, emergy analysis is more versatile and has wider boundaries. It addresses not only energy and material flows, but also information, services, finance, labor, as well as changes to the environment caused by the production process. Assessment is expressed in a single energy unit – the sej. One could say that emergy analysis is ecology-driven, if compared to energy analysis, which is human-focused. Actually, emergy is a means to determine the amount of work contributed by the biosphere for a company to produce a particular product. Accordingly, emergy analysis is a way to describe a company in the long run and within a wider space (biosphere), i.e. to assess its sustainability [4]. Company sustainability is difficult to assess and quite often it is reasonably judged by presuming that the more renewable energy a company uses, the more sustainable it is. It is increasingly forgotten that fossil fuels are being consumed in order to extract, transport and process renewable resources, which is why it is necessary to analyze the entire energy production chain and determine the net energy gain. The damage caused to the environment as a result of using these resources should also be taken into account.

Net energy gain is energy contained within the resource (taking into account the environmental impact, labor costs, consumption of materials, etc.) minus fossil fuel energy consumed. As a result of such a net energy gain assessment, it may turn out that fossil fuels are more sustainable when compared to the use of renewable resources [5].

In energy production, the environment is used in various ways [6]:

- it provides energy resources;
- it absorbs emissions;
- it provides cooling for various processes by means of water or air;
- it provides oxygen for combustion processes.

The aforementioned 'services' put a burden on the environment and shall be assessed to determine the sustainability of energy production. The concept of environmental loading is based on the opinion that when using an environmental service, it is not available to another user. The environment has a certain service accumulation capacity that regenerates

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.629

if the load does not exceed the permissible values. Exceeding the permissible environmental loads kicks off an irreversible degradation process within the local environment. It is clear that the sustainability assessment of the energy production process must include the analysis of net energy gain, environmental loading and production emissions, which enter the environment.

Emergy analysis is based on the principles of thermo-dynamics, system theory, system ecology [6]:

- it serves as a link between the system economic and ecological assessments, allowing their objective comparison thanks to a single assessment;
- by using specific indicators, it determines the environmental impact of the system and processes;
- it studies how renewable the resources used are. This is determined by the amount of work required by the ecosystem for the resources to regenerate;
- it evaluates the quality of flows in terms of quantity, which is particularly important for flows that do not have market monetary value;
- it determines the emergy per monetary unit and labour unit;
- it studies the amount of environmental services required to ensure the functioning of the system and processes;
- compared to other methods (life-cycle analysis, exergy analysis, entropy analysis), it provides more complete and quantitative information for making environment-related decisions; emergy analysis covers the entire system, instead of just individual parts or processes.

It has been noted that emergy analysis has a significant deficiency, namely, the necessity of solar energy conversion data for a wide range of services and products. Database accuracy and completeness influence the results of emergy analysis.

II EMERGY ANALYSIS METHODOLOGY AND INDICATORS

In energy analysis various forms of energy can be expressed as coal, oil or another given fuel, and these can be compared. This is, however, impossible as regards the materials, services or labour necessary for the energy production process. Yet, each of the input quantities required in the energy production process has its own energy value, which has been consumed in the production or in ensuring economic resources created by the production process, and this value should be taken into account in assessing the energy production process. When using emergy calculations, the aforementioned input values can be calculated in comparable units – sej/J; sej/€; sej/kg, etc. and with their help it is possible to determine the total emergy necessary for the production process. An overall chart of the production system and the symbols used in emergy analysis are presented in Figure 1. The chart shows the input resources required for the process and the obtained product output, as well as the flow interaction within the process.

In the chart, by means of the larger square, the local system has been isolated from the biosphere; the smaller square represents the production process. The flows that cross the boundaries of the production process are used for the calculations. The production process uses two environmental resources:

- R – renewable natural resources, which in turn are divided into two groups:
  - renewable R1, which include solar energy, wind energy and rain;
  - renewable R2, which are related to local ecosystem-provided resources such as renewable energy resources (biomass), as well as water and air in process-cooling equipment. Air is also used in combustion processes.
- N – non-renewable natural resources, including coal, gas, oil products or groundwater if used faster than its regeneration rate.

Input F contains economy-ensured services related with the development and operation of the production process, services, technical equipment, remuneration, etc. Total Y emergy is attributed to the process end product (output) and is labeled Y. The production by-product (pollutant) flow is labeled with W, and it penetrates the environment. Using the examined flows, the following indicators are defined for each production process (company):

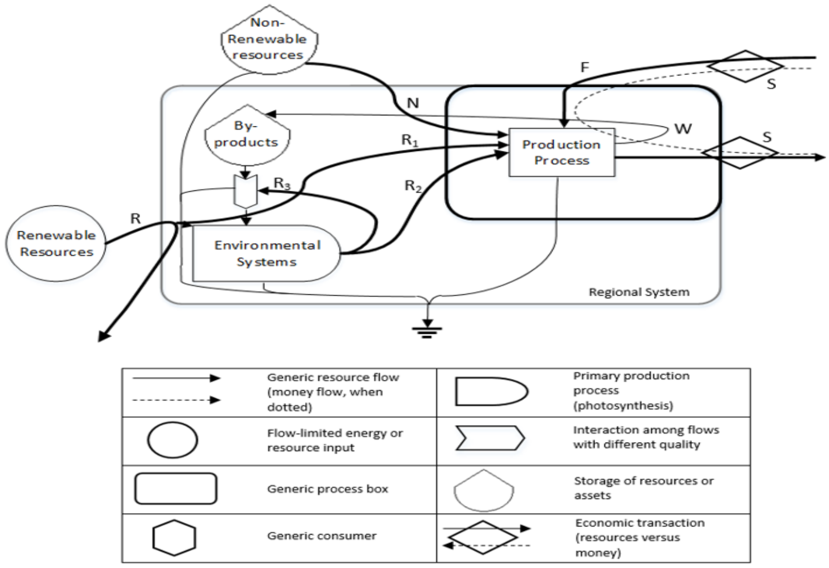

Fig. 1. Overall system chart and symbols used

1. Emergy yield ratio (EYR). The emergy yield ratio describes the benefit of various production processes to the general public. The bigger the share of local renewable (R) and non-renewable resources (N) per unit of external (F) investment, the bigger the EYR value and the more the facility is focused on local resources. The indicator does not evaluate whether or not the resources are renewable or non-renewable; it determines whether the emergy is of local (Y) origin or imported from outside (F) [7, 8].

$$EYR = \frac{Y}{F} = \frac{F + R + N}{F} \qquad (1)$$

2. Environmental loading ratio (ELR). The use of environmental services to ensure the production process is defined by the environmental loading ratio. If the indicator is high, it means the production is significantly affecting the environment and that it uses mainly emergy from non-renewable resources. It also means that there is substantial use of economy-provided resources F. If the emergy yield ratio (EYR) is increasing due to intensive use of renewable resources, the environmental loading ratio decreases and the level of production environmental loading is low. In turn, if the EYR is increasing because the amount of external (economy) services is growing, then the environmental loading ratio (ELR) will also increase and the production process will exert a greater load on the environment [9, 10].

$$ELR = \frac{F + N}{R} \qquad (2)$$

3. Emergy sustainability index (ESI). The emergy sustainability index is a ratio between the emergy yield ratio (EYR) and the environmental loading ratio (ELR). It is recommended to achieve a higher emergy yield ratio (EYR) with less environmental loading. For the production process to be sustainable, the emergy sustainability index (ESI) value must be above 1. Should the ESI value fall below 1, this means that the production process,
product or economy is not sustainable in the long term [4].

$$ESI = \frac{EYR}{ELR} \qquad (3)$$

4. Empower density (ED). Emergy density (ED) describes the intensity of an activity (process, product, economy) and allows the comparison of activities.

$$ED = \frac{F + R + N}{unit(J; kg; etc).time} \qquad (4)$$

5. Renewable share (R) in percentages. Renewable share in percentages R defines the share of renewable resources in the production of the final product. Processes with a higher percentage are more sustainable since they are using more renewable resources.

$$R = \frac{100.R}{F + R + N} \qquad (5)$$

6. Emergy investment ratio (EIR). The emergy investment ratio describes the economy-developed investment F in the production process that uses local renewable resources (R) and non-renewable resources (N). The ratio compares the input (R, N) required for the process with the input from the process environment F. A high EIR value indicates a significant contribution from the economy in ensuring the production process, and it is also subject to changes in the economy. A low EIR value means that the production process is beneficial for the economy and confirms the existence of an investment-friendly environment. It is observed that with the reduction of the use of non-renewable resources N, the EIR value moves towards the environmental loading ratio (ELR) value.

$$EIR = \frac{F}{R+N} \tag{6}$$

7. The unit emergy value (UEV) is used for the emergy calculations of processes, which is expressed as follows [11]:

$$UEV_i = \frac{S}{F_i} \tag{7}$$

where

S - annual emergy of the process (sej/yr);

F_i - i: annual flow of the particular resource (g/yr, m3/yr, J/yr, etc.).

The unit emergy value (UEV) is a conversion factor used to determine the emergy of any service or product, and its value is determined by analysis or taken from data provided in the literature. Where the UEV is attributed to the resource mass flow, it is often called the specific emergy and its measurement unit is sej/g. In turn, if the resource flow is expressed in energy units, then the UEV is called transformity and its measurement unit is sej/J [12].

The chart in Figure 1 is used to develop a detailed chart of production process flows, which is used as a basis for process emergy calculations.

Uncertainty in emergy analysis is significantly affected by two [13]. The first is the insufficient and inaccurate unit emergy value (UEV) data available in the literature, which primarily deals with industrial products and transport systems and demonstrates mainly generic or approximate indicators..

The next source of uncertainty is the inaccurate inventory of a process and the incomplete assessment of process input. For instance, emissions from the production process exert a load on the environment, which must be assessed. This requires information on the condition of the region's ecosystem, which in turn requires a separate study and assessment.

When carrying out emergy calculations and using data from unit emergy value (UEV) literature, it is important to carefully follow the data origins and the chain of calculations in order to avoid the double inclusion of emergy. One potential option is to use data on the total impact of the biosphere, excluding the impact of individual chain sections.

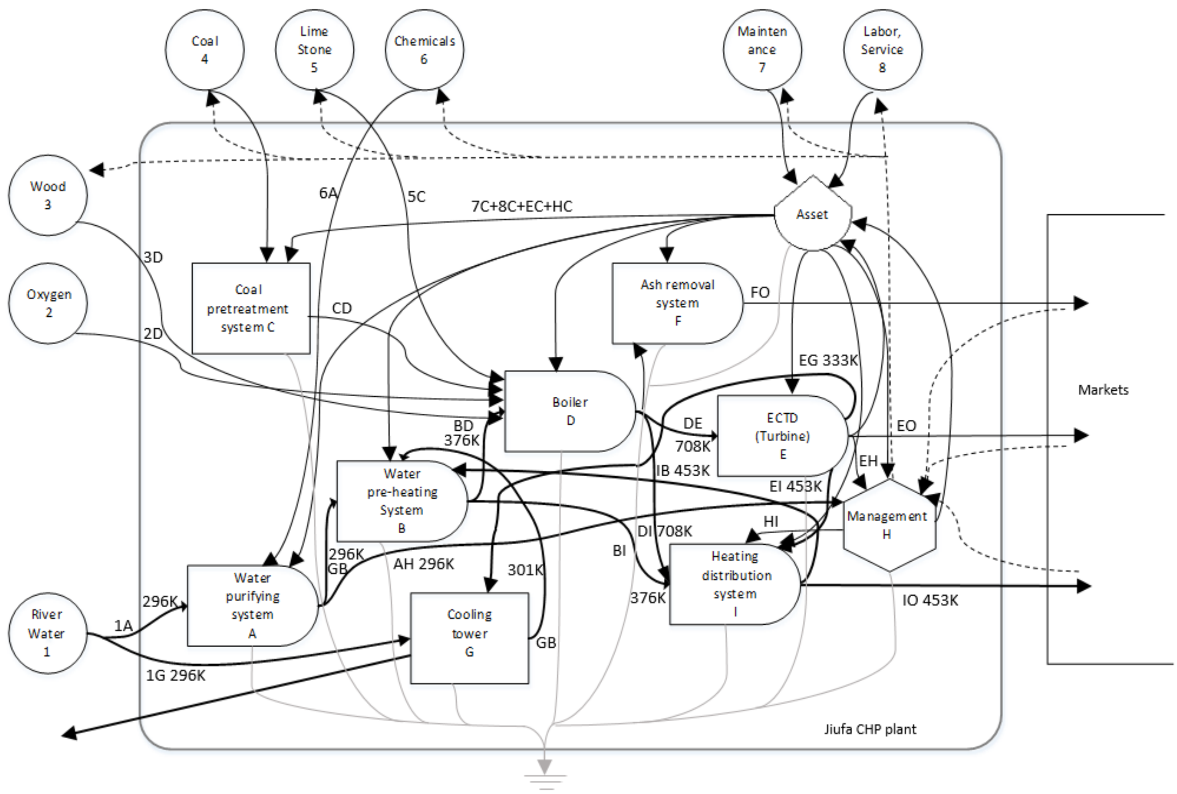

Fig. 2. Co-generation plant energy flow chart with input and output data [14]

III EXAMPLE OF EMERGY ANALYSIS FOR THE PRODUCTION OF CO-GENERATION ENERGY

Energy production processes and technologies differ both in terms of input (different energy resources, water source) and output (heat or electricity generated). In order to achieve a more complete analysis result, a co-generation plant generating both energy types was selected. Emergy analysis of co-generation plants and comparison with coal and biomass uses [14, 15].

The case study for emergy analysis of cogeneration plant (CHP) data is implemented by use of data published in paper [14]. Emergy calculations are done for three different operation modes of cogeneration plant fuelled by coal.

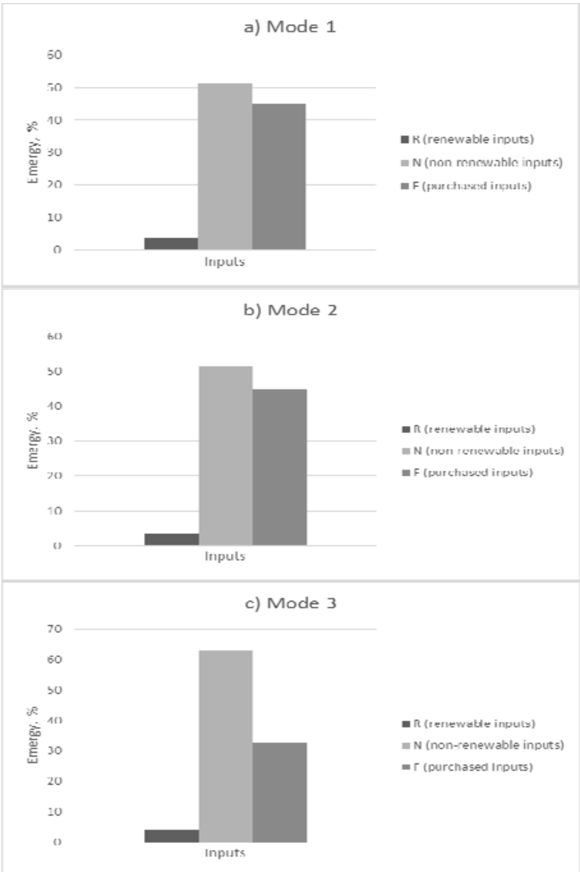

Fig.3. Emergy shares for resources of CHP

Results of cost benefit analysis of three operation modes are presented in Figure 4.

Mode 1 presents the operation of cogeneration plant in the case when steam produced by the boiler is used for power generation and only some part of thermal energy production (other part is cooled in cooling tower of CHP). It means no possibility to use all potential thermal energy because of lack of heat load.

Mode 2 presents the integration of cogeneration plant in regional energy supply system and increase of heat load of CHP. It allows to use steam energy completely without application of the cooling tower. Power load changes are not observed.

Mode 3 presents the operation of cogeneration plant with installed power and heat energy capacity without use of the cooling tower.

The results of emergy and economic analysis of three operation modes of the cogeneration plant fuelled by coal are presented in figures below. Comparison of three operation alternatives show that emergy of renewable resources input is similar in all three operation modes. Different is situation with emergy of non-renewable resources: in the Mode 1 and Mode 2 emergy is similar and it is increasing in Mode 3. Emergy of purchased inputs is lower in the third operation mode.

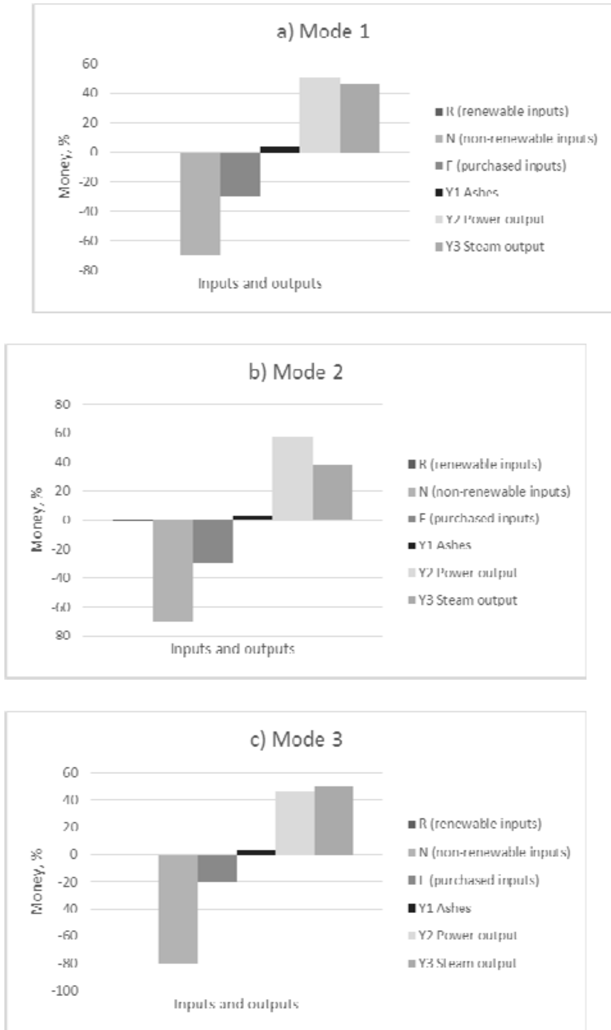

Fig. 4. Economical evaluation of three operation modes

Graphical illustration of economical cost benefit analysis is presented for three CHP operation alternative solutions (see Figure 4). Income from energy and ashes sold are taking place above horizontal axes (positive value). Costs of fuel, water, materials etc. in this case are placed under x axes as negative value. Presentation of costs and benefits in percentage allow to compare shares of renewable and non-renewable resources as well as produced energy in economical balance of cogeneration plant in case of three different operational modes.

A similar procedure applies to the emergy analysis of not only power generation, but also of energy resource extraction. For example, the emergy analysis for bioethanol and biodiesel production processes, as well as power generation using household waste or landfill biogas, has been examined in the study by [16].

IV CONCLUSIONS

Emergy analysis is the analysis of the sustainability of energy production, allowing to determine the amount of work to be performed by the biosphere in the production of energy. Although currently the literature primarily provides emergy assessment for energy production, it is the future analysis tool for the assessment of the impact of a given product on the biosphere.

V ACKNOWLEDGMENT

The work has been supported by the National Research Program 'Energy efficient and low-carbon solutions for a secure, sustainable and climate variability reducing energy supply (LATENERGI)'.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 91-95

Analysis of Heavy Metal Content in the Dry Matter of Different Energy Crops

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Abstract. **The study shows results of research on heavy metal concentration in the biomass of common reed, hemp and reed canary grass. Research of common reed was performed in winter from 2010 until 2012 in 11 natural and artificial water bodies of Latvia. Samples of hemp and reed canary grass collected in the spring of 2009 and 2010 were analysed.**

Analysis of the collected samples of common reed allowed detecting heavy metal content (Cd, Pb, Cu, Ni, Fe) in the biomass. Studies of samples of hemp and reed canary grass revealed that Cd and Pb were present in the biomass. Basing on these results, suitability of the plant biomass for energy production was analyzed.

Heavy metal content in the common reed biomass complies with the requirements of solid biofuel. Common reed from all the reed beds of Latgale region can be collected in one place and used for the production of fuel. Removal of common reed would help to reduce the concentration of heavy metals in natural waters and sediment of the reed beds.

The content of heavy metals in the samples of hemp and reed canary grass was periodically analysed. It was found out that in some of the research samples the amount of heavy metals exceeded the maximum acceptable concentrations for fuel.

Keywords: **common reed, heavy metals, solid biofuels, reed beds.**

I INTRODUCTION

Common reed (*Phragmites australis* (Cav.) *Trin. = Ph. communis Trin. = Arundo phragmites L*) is a perennial plant of the cereal grass family, and it is one of the most widely spread plants worldwide [1; 2]. The common reed can be used for energy production [3; 4].

Common reed, similarly to other plants in different growth stages actively absorbs nutriments from water, which helps to reduce environmental pollution [5; 6; 7]. Artificial common reed plantations are useful for effluent water treatment and purification. [8; 9; 10; 11; 12]. Common reed absorbs heavy metals well. [13; 14; 15; 16; 17]. Heavy metals are very dangerous for natural ecosystems. One of the methods used for removal of heavy metals from natural waters is phytoremediation, i.e. the use of plants to remove heavy metals from water bodies [18; 19; 20]. The common reed is suitable for removal of heavy metals, therefore its harvesting would help the purification of water bodies from heavy metals. One of the aims of the research is to establish the amount of heavy metals that can be removed from water bodies, by cutting the common reed above the ice in winter. On the other hand, it is not known if the heavy metal content in the common reed does not exceed the maximum allowed concentration (MAC) for biofuel. Similarly to the common reed that removes heavy metals from water bodies and sediments, hemp and reed canary grass take up heavy metals from the soil. Thus, the biomass of these plants can contain heavy metals, therefore it is necessary to examine this issue.

The content of heavy metals in the biomass used for fuel production is limited by various standards. Suitability of reed biomass has been evaluated according to the German standard DIN 5173 and EC standard prEN 14961 – 3 that specify the maximum acceptable concentrations (MAC) of heavy metals in solid biofuel.

II MATERIALS AND METHODS

In order to inspect the areas of common read, in each of the investigated lakes four reed stands were chosen that visually corresponded to the characteristic

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.242

parameters of the average reeds found in the specific water body. For each stand two sampling plots were investigated. About 1kg of the common reed biomass was taken from each sampling plot, and it was used for determination of the parameters in laboratory conditions. However, previous research has shown that the stalks and leaves of common reed have different capacities of accumulation of heavy metals [21].

In this research the stalks and leaves of common reed were not separated because harvesting of common reed for the production of biofuel and separating would be complicated and energy capacious, which would increase the cost of the common reed processing. The samples of common reed collected from the 8 sampling plots in each lake were combined to form an average sample. The reeds were chopped up, and for the laboratory research 1kg was taken of the average sample.

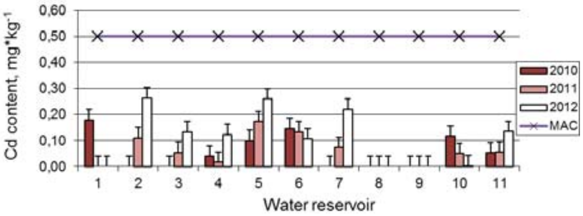
Reed canary grass (RCG) varieties 'Marathon' and 'Bamse' were cultivated in sod-podzolic loamy soil (the organic content of the soil – 5.2%, pH KCl – 5.8, P_2O_5 – 20 mg·kg^{-1}, and K_2O – 90 mg kg^{-1} of the soil) in the Agricultural Science Centre of Latgale. The area of plots was 16 m^2, the location of the plots was randomized. The RCG was sown after a bare fallow. Before sowing a complex fertilizer was applied N:P:K – 5:10:25 – 400 kg*ha^{-1}. The RCG varieties 'Marathon' and 'Bamse' were sown in April 2009 and 2010. The local hemp 'Pūriņi' (*Cannabis sativa* L.) is an annual crop from the *Cannabinaceae* family which has been cultivated in Latvia for more than 200 years. Hemp trials (varieties 'Pūriņi' and 'Bialobrzeskie') were on the sod gleisoil soil (organic matter content 35 – 38 g kg^{-1}, pH KCI 7.0 – 7.3, available plant phosphorus content – 83 – 145 mg kg^{-1} P_2O_5, changes in the potassium content – 65 – 118 mg kg^{-1} K_2O). The samples for the laboratory research were gathered in April 2009 and 2010.

To establish the heavy metal content in the biomass samples, mineralization was undertaken by using the following methodology: biomass samples were reduced to fragments <150 µm by using a mill, and then producing a sample of 1.5 g. Then 15 ml concentration HNO_3 was added, and the sample was heated to 95 ^{0}C temperature over a period of 2 hours. The cooled sample was strained through a filter, which had been previously washed with 0.5% HNO_3, and diluted with deionized water up to 65 ml.

The metal content in the solution was determined by optical plasma emission spectrometer Perkin Elmer Optima 2100 DV. The data procured were recalculated for mg*kg^{-1} dry matter.

III RESULTS AND DISCUSSION

Amount of Cd in the reed biomass was relatively small and varied within limits of 0 – 0.28 mg*kg^{-1}, which was below MAC in all the lakes under research (see Figure 1). Cd content in forestry production waste is 0.1 – 0.2 mg*kg^{-1} [22] which indicates that the Cd content is similar in reed biomass and fire wood. The Cd substance output from reeds comprised 0 – 0.20 mg*m^{-2}*year^{-1}, which was higher than from reeds in sewage treatment plants [21], where it consisted of 0.014 – 0.038 mg*m^{-2}*year^{-1}, which shows that Cd absorption in reed stalks depends on its content in water and sediment.



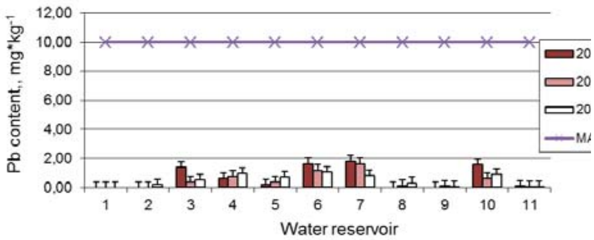
1-Lubanas lake, 2-Kvapanu ponds, 3-Idenas ponds, 4-Luknas lake, 5-Cirisa lake, 6-Sivera lake, '7-Rusonas lake, 8-Feimanu lake, 9-Raznas lake, 10- Cirmas lake, 11-L.Ludzas lake.

Fig. 1. Cd content average values in winter for the reed biomass harvested above ice level in the lakes of Latgale

In all the researched water reservoirs, Cd content in reed biomass significantly changed according to the harvesting year, which shows a high Cd compound mobility in natural waters that has been described in another research [23; 24]. In Feimanu and Raznas lakes no traces of Cd have been found in the reed biomass for years of research, in Lubanas lake Cd was found in 2010 in the reed biomass, but not in 2011 or 2012. In Kvapanu and Idenas ponds no Cd was found in the research samples of reed biomass in 2010, but was found in 2011 and 2012. In another lakes Cd was found in various concentrations every year, which shows a high Cd compound mobility in natural waters. Cd content was different in the reeds harvested from different lakes, although it did not exceed the MAC, as a result one can assume that the reeds from different lakes can be mixed together as a fuel.

Cd in the hemp samples was not found in any of the years of investigation, thus it can be deduced, that, in terms of Cd content, the hemp biomass is suitable for biofuel production. In the samples of 2010, in the reed canary grass Cd was established for both researched varieties, which comprised 1.85 mg* kg $^{-1}$ for the variety "Marathon" dry mass and 1.18 mg *kg^{-1} for the variety "Bamse", which exceeded MAC (0.5 mg * $^{-1}$ kg) However, in the samples of 2009 Cd compounds were not observed. Such variation in Cd presence indicates to a high degree of Cd mobility. Cd content can cause problems of compliance with quality standards when using reed canary grass as biofuel.

Pb content in the dry matter of reed biomass varied within the limits of 0 – 1.81 mg*kg^{-1} and in none of the researched lakes it exceeded MAC. Pb content in forestry production waste is 2 – 5mg mg*kg^{-1}, [22] which makes one conclude that the Pb content in the reed biomass is lower than in the forestry production waste. In this research, Pb in the reed substance was 0 – 1.27 mg*m^{-2}*year^{-1}, which varied over a wider range than for reeds that are used for sewage treatment [21] where the substance value for Pb is 0.36 – 0.44 mg*m^{-2}*year^{1}. In all the researched water reservoirs, except for Lukna and Cirisa lakes, the Pb content in the reed biomass changed significantly according to the harvesting year. In Lubanas lake, Pb has not been detected in the read biomass in any of the years (Fig. 2).



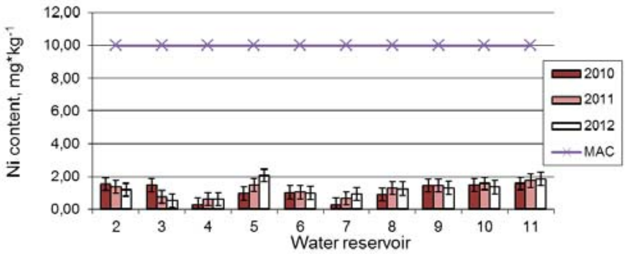
1-Lubanas lake, 2-Kvapanu ponds, 3-Idenas ponds, 4-Luknas lake, 5-Cirisa lake, 6-Sivera lake, 7- Rusonas lake, 8-Feimanu lake, 9-Raznas lake, 10-Cirmas lake,11-L.Ludzas lake.

Fig. 2. Pb content average values for the reed biomass harvested above ice in the lakes of Latgale

The Pb content varied significantly among the reeds of different lakes, even though it did not exceed the MAC in the researched lakes, and therefore is can be assumed that the harvested reeds can be mixed together and used as fuel.

Pb content in hemp biomass was established while studying both samples of 2009. Pb content for the variety "Puriņi" comprised 14.97 mg *kg^{-1} of the dry mass, but for the variety "Bialobrzeskie" 11.23 mg *kg^{-1} of the dry mass, which exceeds the MAC for biofuel (10mg *kg $^{-1}$). In 2010 Pb was not established in the samples taken.

In the reed canary grass samples of 2009 Pb was not established, however in 2010 the level of Pb – for the variety "Marathon" 35.4 mg *kg^{-1} in the dry mass, but for the variety "Bamse" 22.1 mg *kg $^{-1}$in the dry mass. The different Pb concentrations in different years can be explained by the influence of climatic conditions. A higher Pb concentration in hemp and reed canary grass could cause problems with conformity to standards. The heavy metal content and influencing factors in hemp and reed canary grass need to be researched further, in order to clarify the causes of their formation in the biomass. Ni content in the reed biomass varied within limits of 0.29 – 2.06 mg*kg^{-1}, in all the research water reservoirs it was about five times lower than the MAC. Ni content in forestry production waste was 0.5 mg*kg^{-1} [22] which indicates that the Ni content in the reed biomass is on average three times greater than the Ni content for fire wood, although it does not exceed the MAC. The output of reed Ni substance was 0.2 – 1.44 mg*m^{-2}*year^{-1}, which varied within a wider range, than for reeds used in sewage treatment plants [21] where the Ni substance output was 0.57 – 0.91 mg*m^{-2}*year^{-1}, Ni compounds were found in all the analyzed samples. In Lubanas lake, Idenas ponds and Cirisa lake significant differences were detected in the reed biomass for Ni content in the samples taken in different years. In the other researched lakes, Ni content in the reed biomass did not change significantly depending on the harvesting year (Fig. 3).



1-Lubanas lake, 2-Kvapanu ponds, 3-Idenas ponds, 4-Luknas lake, 5-Cirisa lake, 6-Sivera lake, 7-Rusonas lake, 8-Feimanu lake, 9-Raznas lake, 10-Cirmas lake, 11-L.Ludzas lake.

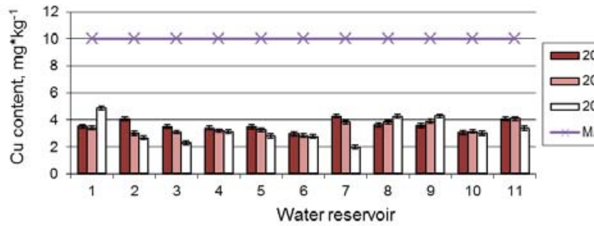
Fig. 3. Ni content average values in winter in the reed biomass harvested above ice in the lakes of Latgale

Ni content varies among the reeds harvested in different lakes, however in none of the researched lakes it did not exceed the MAC, therefore one can assume, that the reeds collected from various lakes can be mixed together and used for fuel.

Cu content in the reed biomass varied within the limits of 2 – 5 mg*kg^{-1} which comprised up to 50% of the MAC biomass fuel. Cu content in forestry production waste amounts to about 2 mg*kg^{-1} [22] which indicates that the reed biomass contains on average 1.5 times more Cu than the forestry production waste however it is still within the MAC limits. The reed plant Cu substance output was 1.4 – 3.5 mg*kg^{-1}*year^{-1} which is about two times less than the amount established in the reed biomass of sewage treatment plants [21].

The ability of reeds to absorb Cu from natural water bodies and sediments depends on the Cu compound concentration in them. By harvesting 1ha of reeds from the water it is possible to remove 138 – 148g Cu. The Cu substance output in another research [14] where reed stalks were harvested was 570 g for 1ha, which shows that reed stalks have a good capacity of absorption of Cu, which confirms the findings of the previous research [24].

Cu compounds were noted in all the analyzed samples. In terms of Cu content in Lukna, Sivers and Cirma lakes there were no significant differences between the samples taken over different years, in the other lakes the Cu content varied in the reed biomass according to the harvesting year, which shows high Cu mobility in natural waters, although in none of the research samples did the Cu content exceed the MAC (Fig. 4).

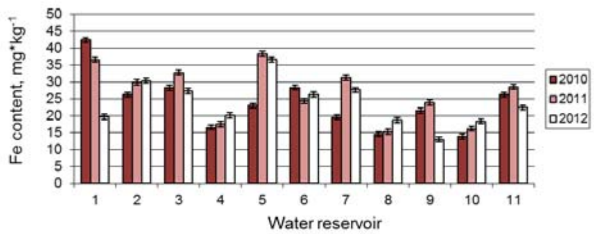


1-Lubanas lake, 2-Kvapanu ponds, 3-Idenas ponds, 4-Luknas lake, 5-Cirisa lake, 6-Sivera lake, 7-Rusonas lake, 8-Feimanu lake, 9-Raznas lake, 10-Cirmas lake,11-L.Ludzas lake.

Fig. 4. Cu average content in winter in the reed biomass harvested in the lakes of Latgale

Cu content was different in the reeds harvested from different lakes, although it did not exceed MAC in any of the researched lakes, which allows concluding that the reeds extracted from various lakes can be mixed together and used as fuel.

Fe compounds were detected in all the analyzed samples. Fe content in reed biomass varied within limits of 12.9 – 42.4 mg*kg^{-1} (Fig. 5), Fe concentration is not limited by analyzed standards.



1-Lubanas lake, 2-Kvapanu ponds, 3-Idenas ponds, 4-Luknas lake, 5-Cirisa lake, 6-Sivera lake, 7-Rusonas lake, 8-Feimanu lake, 9-Raznas lake, 10-Cirmas lake,11-L.Ludzas lake.

Fig. 5. Fe average content in winter in the reed biomass harvested in lakes of Latgale

The Fe substance output from reeds amounted to 3.7 – 12.1 mg*m^{-2}*year^{-1}, and this result was higher than results provided by another elements. Fe absorption in reed stalks depends on its concentration in water and sediment.

IV CONCLUSION

Heavy metals were found in all the common reed samples, in all the researched years. The content of heavy metals essentially changes depending on the harvesting year, which shows a high degree of heavy metal mobility in nature.

The analyzed heavy metal content in the common reed biomass corresponds to the requirements of solid biofuel. The common reed can be collected from all the water bodies of Latgale region in one location and used for the production of biofuel. Harvesting of the common reed would reduce the content of heavy metals in the natural water and water body sediments.

While studying the hemp biomass, it was established that Pb content exceeded MAC in 2 samples, which can cause problems related to compliance of biofuel with the set standards.

While studying the reed canary grass biomass, it was established that Pb exceeded MAC in 2 samples, and that the amount of Cd exceeded MAC in 2 samples as well, which can produce problems related to compliance of biofuel with the set standards. The problem can be solved by producing composite biofuels from various types of biomass.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 96-98

Genetic diversity of two perch *Perca fluviatilis* populations of the Latgale region

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Abstract. **Molecular markers based on retrotransposons possibility of integration into genomes of many organisms are commonly used for genetic analysis of different species. The aim of this study was to test the possibility of use those markers in perch and detect the genetic diversity of populations of two lakes of the Latgale region of Latvia: Cirišs and Sventes. The distance between the lakes is nearly 60 km, they belong to the same Daugava River basin but are different from the ecological point of view. Forty-two blood samples of *Perca fluviatilis* were collected altogether. Extracted DNA was analyzed using inter-PBS amplification technique with specifically selected retrotransposon-based primers and agarose gel electrophoresis. Data of genetic diversity of lakes were calculated by POPGENE and NTSYS software. In total, 127 loci were found in two populations, 81 of them were polymorphic. In spite of the rather small distance between lakes Cirišs and Sventes, several differences in genetic variation of populations of two lakes were found. For example, the number of polymorphic loci in samples from Lake Sventes was 61, but only 47 from Lake Cirišs. A unique allele was found in Lake Sventes. Genetic similarity and distance between populations of lakes Cirišs and Sventes was 0.9288 and 0.0739, respectively. The results proved that molecular markers based on retrotransposons PBS regions can be very useful to test the genetic diversity of fish populations.**

Keywords: **iPBS, *Perca fluviatilis*, perch, retrotransposon-based molecular markers.**

I INTRODUCTION

Molecular markers based on retrotransposons integration into genome are universal, informative and rather easy for analysis, therefore they become very popular for investigation of the genetic diversity of many organisms. There are a lot of publications about genetic particularities of populations of some animals, plants and yeasts using retrotransposon-based molecular markers like REMAP (Retrotransposon-Microsatellite Amplified Polymorphism), SSAP (Sequence Specific Amplified Polymorphism), RBIP (Retrotransposon-based Insertion Polymorphism), and IRAP (Inter Retrotransposon Amplified Polymorphism) [1]-[6] but only limited information is available about retrotransposon-based markers in fish.

Molecular markers give an opportunity to compare genetic particularities of different populations which usually are not revealed by phenotypic characteristics. Possible genetic differences could be related with the history of populations and with differences of ecological conditions of their locations. From this point of view, it is interesting to compare populations of two lakes, Cirišs and Sventes, located in the Latgale region of Latvia [7]. Although the distance between the lakes is only about 60 km and both lakes belong to the same Daugava River basin, the environmental conditions of these lakes are different. Lake Sventes is one of top ten deepest lakes in Latvia, the average depth throughout the area of the lake is 7.8 m, but in some places it reaches even 38 meters. In opposite, Lake Cirišs is not so deep: the maximum depth of Lake Cirišs is approximately 10 meters. Total areas of lakes Sventes and Cirišs are 7 348 and 6 306 km^2, respectively. Lake Sventes contains as many as 7 species of fish, however in Lake Cirišs more than 10 fish species were found. The goal of this study was to look for the possibility of using IRAP method for genetic analysis of perch *Perca fluviatilis* and compare the genetic diversity of perch populations of both the above mentioned Latgale lakes.

II MATERIALS AND METHODS

In 2011, fish blood samples were collected from the two lakes of the Latgale region of Latvia (Figure 1), altogether 42 samples: 22 from specimens of Lake Cirišs and 20 – from specimens of Lake Sventes. DNA from blood samples was extracted using Fermentas Genomic DNA Purification Kit. DNA extraction method was based on the Fermentas (ThermoScientific) protocol (thermoscientificbio.com/ fermentas/). Extracted DNA was electrophoresed for quality testing on a 1.7% agarose gel at 80 V for two hours. For most appropriate primers screening for IRAP analysis of *Perca fluviatilis* universal retrotransposon-based primers were applied [1]. Primers sequences selected for the investigation were: 2080 — CAGACGGCGCCA, 2081 — GCAACGGCGCCA, 2239 —

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.280

ACCTAGGCTCGGATGCCA [4]. PCR reaction consisted of 32 cycles. The first cycle at 95 °C for 3 min, 30 cycles at 95 °C for 30 s, at 50 °C for 40 s, at 68 °C for 1 min, and the last cycle at 72 °C for 10 min. Total mix volume was 25 µl. Amplified fragments were electrophoresed on 1.7% agarose gel for 15 hours at 50 V and stained with ethidium bromide, then documented with Transiluminators UViTEC STX 20M (Uvitec Limited, UK) and Digital photosystem MultiDOC DJ-HD (Cleaver, UK). Genetic characteristics of populations were calculated by Popgene and NTSYSpc 2.1 software. Principal coordinates analysis or Classical Multidimensional Scaling was calculated and matrix plot based on genetic distance matrices was generated using DCENTER and EIGEN.

Fig. 1. Fish samples collection spots in the Latgale region of Latvia.

III RESULTS AND DISCUSSION

Forty-two samples were analyzed using the IRAP method with three specific retrotransposon-based primers: 2080, 2081, and 2239. The selected primers showed good applicability for analysis of perch genetic polymorphisms: 50 loci were revealed by the primer 2080, 42 loci – by primer 2081, and 35 loci – by primer 2239 (Figure 2). In total, 127 loci were found in the two populations using the IRAP method, 81 of them were polymorphic (64%). The number of polymorphic loci in the population of Lake Cirišs was 47 (37%), in the population of Lake Sventes almost half of loci – 61 (48%) were polymorphic. A unique allele *2080_18* was found in three specimens from 20 of Lake Sventes (Fig. 2).

Genetic similarity between *Perca fluviatilis* populations of the lakes Sventes and Cirišs was 0.9261, accordingly genetic distance between them was 0.0768. By using different types of markers small genetic differences between perch populations were also detected in Switzerland, Poland, and Italy lakes. Nei`s genetic distances between 27 allozymes from 136 fish specimens of four Swiss lakes (Lake Constance, Lake Zürich, Lake Geneva, and Lake Maggiore) was small (0–0.003), despite that these lakes belong to different drainage systems [8]. For analysis of the genetic diversity of perch from Central Poland differences in sequences in cytochrome b gene and *D-loop* region of mitochondrial DNA were used. Data showed that nucleotide divergence based on haplotype frequencies varied in the range of 0–0.128 and nucleotide diversity within populations from reservoirs with different size, ecological parameters and even age of construction also were low: 0.003–0.02 [9]. Sequencing and RFLP (Restriction Fragment Length Polymorphism) method was used to find genetic diversity in mitochondrial DNA of five different perch species from Italy, however, only five different haplotypes were found [10].

All specimens from both populations of two lakes of Latgale region could be grouped into two clearly different clusters (Figure 3). Specimens from Sventes population were situated more diverse, which can be explained by a higher number of polymorphic loci in comparison with Cirišs population (61 and 47, respectively).

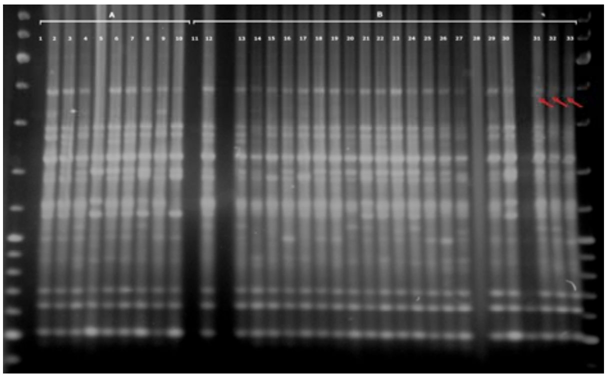

Fig. 2. Agarose gels after PCR amplification with primer 2080. (A) 2-10, specimens of Lake Cirišs; (B) 12–33, specimens of lake Sventes; 1 and 11 – the negative controls. The unique allele *2080_18* in three specimens is marked with the red arrows.

IV CONCLUSION

The IRAP method like other retrotransposon-based molecular marker systems could be very useful for analysis of genetic diversity of many organisms, including perch *Perca fluviatilis*. Specimens from the lakes Sventes and Cirišs of the Latgale region form two different clusters according to the IRAP molecular markers. Comparison our results with results of others studies across the Europe lead to conclusion that genetic differences are not related to geographical distances but probably depend on some ecological characteristics. Investigations of the influence of the ecological factors on the genetic diversity of perch populations including other Latvian lakes are in progress.

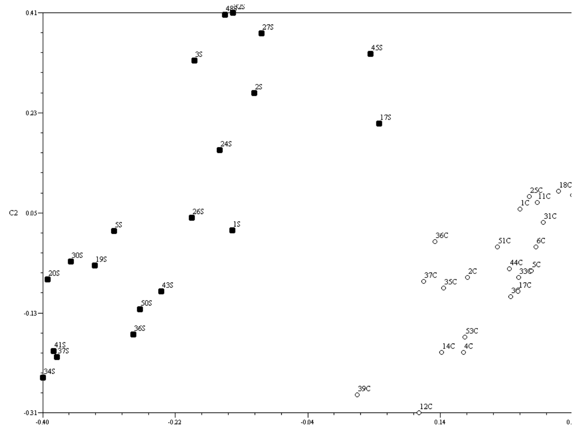

FIG. 3. PRINCIPAL COORDINATES ANALYSIS OF TWO POPULATIONS OF *PERCA FLUVIATILIS* FROM TWO LAKES OF LATGALE REGION OF LATVIA WAS BASED ON GENETIC DISTANCE MATRICES AND WAS GENERATED USING DCENTER AND EIGEN FUNCTIONS OF NTSYS SOFTWARE. SPECIMENS OF SVENTES POPULATION WERE MARKED WITH BLACK SQUARES, SPECIMENS OF CIRIŠS POPULATION – WITH WHITE CIRCLES.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 99-102

Research of dumps at construction sites in the urban area

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Abstract. **The article deals with the problems of the construction waste formed in the course of demolition and construction of buildings in the city. The author presents results of the survey made at construction sites located on the territory of Samara, gives the analysis of the construction waste composition and considers options for the use of the construction waste as a secondary resource in the manufacture of building materials.**

Keywords: **construction waste, environmental pollution, urban development, recycling.**

I INTRODUCTION

The urban environment is constantly evolving and being transformed. The changes are expressed not only in the reconstruction of buildings, but also in the demolition of obsolete structures and construction of new ones. Construction and demolition are always accompanied by the formation of large amounts of waste. Depending on the type of demolition or construction different kinds of waste are formed: broken concrete, crushed brick, wood waste, etc. Usually the formed waste is temporarily stored directly at construction sites and as it is accumulated it is removed for processing or to specialized dump sites.

Construction waste has a negative environmental impact both during demolition and during accumulation at the areas of temporary storage. With time under the action of wind and rain there is a gradual destruction of waste and its spread over the construction site and the adjacent area [1].

II MATERIALS AND METHODS

In 2014 a group of students of the Samara State University of Architecture and Civil Engineering under the guidance of the author examined the existing construction sites in Samara. The location inspection paid special attention to compliance of construction sites with the sanitary requirements and determination of waste composition. The following types of waste were distinguished: broken concrete products, crushed brick, and scraps of metal, wood waste, plastics, glass, paper and paperboard.

As many as 12 construction sites have been examined [2-4]. All sites were located in close proximity to residential areas in the central part of the city. Figure 1 shows the scheme of one of the construction sites.

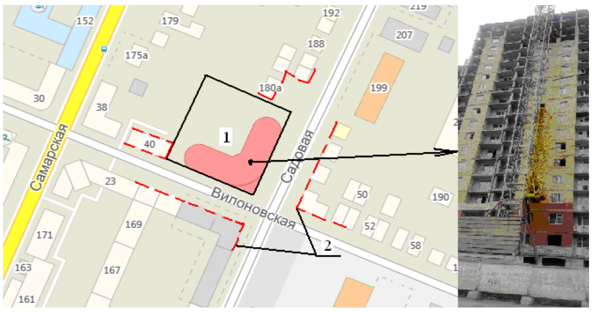

Fig. 1. The scheme of construction site №1: 1 – the construction site, 2 – borders of a residential area

TABLE 1. Characteristics of construction sites

№	Construction site location	Building type	A number of floors	Distance from the residential area, m	Type of the adjacent residential area
1	Vilonovskaya St./Sadovaya St.	Monolithic reinforced concrete	28-34	10	private
2	Sadovaya St.	Monolithic reinforced concrete	9	10	private
3	Leninskaya St.	Monolithic reinforced concrete	17	15	private
4	Polevaya St./ Leninakaya St.	Monolithic reinforced concrete	17	30	high rise
5	Petlevaya St.	Monolithic reinforced concrete	24	35	private
6	Vrubelya St.	Frame, administra-tive	2	86	high rise
7	Solnechnaya St.	Panel	19-24	100	high rise
8	5th Proseka	Panel	18	25	high rise
9	5thproseka	Panel	19	40	high rise
10	5thproseka	Brick	9	95	high rise
11	5thproseka	Panel	25	90	high rise
12	5thproseka	Brick	17	25	high rise

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.244

Characteristics of construction sites are given in Table 1. The location inspection was carried out twice: in spring and autumn. The time interval between surveys was at least 4 months.

The first stage of the studies showed the absence at almost all construction sites specially equipped places for temporary storage of waste. The waste was placed in spontaneously formed open dump sites and represented chaotically piled and mixed waste. Besides, all dump sites were found to be compact, i. e. they occupied a small area at the construction site and had an average height of about 1 – 1,5 m.Then the wastes composition of a dump site was defined. The wastes were sorted according to their main elements and a ratio of their volume shares to the whole of the dump site was calculated.

The composition of the dump site showed that the main components of the construction waste in the examined dump sites (fig.2) were as follows: broken concrete, wood waste, scraps of metal and polymers.

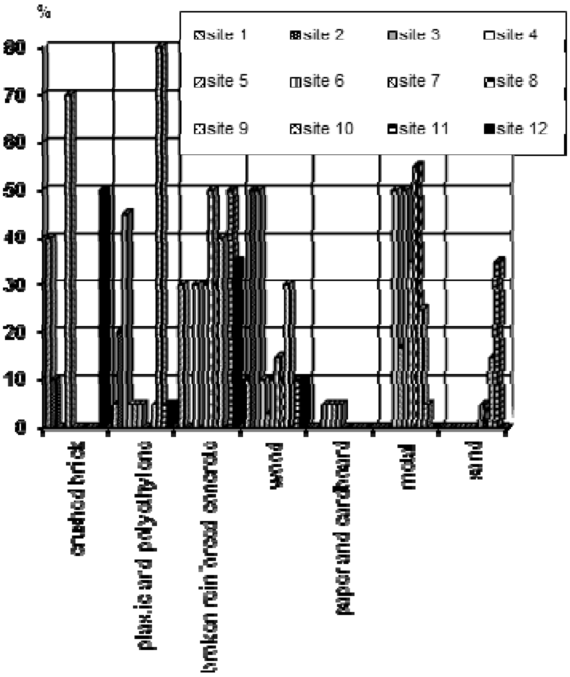

Figure 2. The composition of construction waste dump sites

At construction site №5 the maximum amount of waste (about 70%) was crushed brick. It was explained by the basic material used in the construction of a building at this site. At construction site №10 the maximum waste components were polymers (80%), as the construction company had completed the main stage of the building construction and went to work on the interior decoration, which was accompanied by the formation of a large number of plastic containers.

The most rare components were rags in the amount of 15% (bags for loose materials) found at the dump site of site №1, paper waste and paperboard in the amount not exceeding 5% of the total volume of the construction waste (dump sites №3 – 6) and a roofing felt waste in the amount of 15% (construction site №2).

In October- November 2014 the same construction sites were examined once again. Analysis of the obtained data showed that no construction waste was available at 60% of all urban building sites, which was associated primarily with the transition of those companies to the final stage of construction, i.e. layout and landscaping. The period of time of temporary dump sites was about one year.

The remaining 40% of the sites had territories without significant changes, i.e. open construction waste dump sites had not been removed (fig.3). At two sites there had been a slight increase in waste; at one of them to the list of previously defined waste the foam plastic was added.

III RESULTS AND DISCUSSION

During prolonged storage the construction waste begins to undergo qualitative changes. For example, the concrete and reinforced concrete can have a gradual destruction of the weak surface layer under the adverse effects of rain and surface runoffs formed on-site which causes the accumulation of all kinds of smaller particles (including the concrete aggregate) and concrete dust on the soil surface. Bricks are also subjected to gradual destruction and crumbing. In the case of a long stay of the metal waste in the aquatic environment (in the rain, in the lower parts where puddles form) corrosion processes occur. Prolonged storage of wood, cardboard and paper waste in dump sites can lead to putrefactive processes.

In addition, the close location of the residential area, particularly the private sector, to the construction site and the lack of control over the state of the site and timely removal of waste, lead, as a rule, to the transformation of the construction waste dump site into a mixed one due to the ingress of solid waste from construction workers and the surrounding residential area [5-8].

To reduce the negative impact of the construction waste on the environment a variety of ways have been developed, e. g. [9-15]. These methods allow minimizing the impact of the construction work both during dismantling obsolete buildings and during erecting new facilities. Implementation of various additional devices for environmental protection and the implementation of environmental protection measures will reduce the likelihood of soluble pollutants and dust particles in the surface layers of the soil, reduce the area of contamination by fine particles and soluble contaminants of surface flows, prevent the spread of fragments of animal waste, as well as keep the ground water and adjacent water bodies clear of polluted runoffs.

A larger amount of construction waste is normally disposed of at specialized dump sites. As this takes place, valuable components that can be used as secondary resources are lost [16-17]. The experience of foreign and some domestic enterprises shows that the processing and use of waste can save a considerable part of natural resources and make it possible to gain an additional profit. Construction wastes are ones of the most common wastes that are used in the construction process and in the process of manufacturing building materials.

For example, the metal waste is processed in areas of the country from 35% to 70%, however, the metal waste formed at the construction site is almost completely disposed of at specialized dump sites. Given that the dump site metal waste ranges from 5% to 55% in the volume and the average volume of the construction waste dump site ranges about 10 m3, we can say that when the bulk density of the lump scrap is 2,5 - 3,5 t/m^{3}and the cost of scrap is 12 rubles per kilogram it is possible to get income in the amount of up to 200 000 rubles without any pre- processing.

The most common way of wood waste recycling is the processing and production of chipboards and fireboards. It can also be used directly at the construction site when installing a formwork system. Crushed brick despite its lower strength in comparison with concrete is often used when laying roads and aligning surfaces. It is used as filling when establishing drainage systems, as well as an aggregate in concrete products.

The broken concrete and reinforced concrete products accounting for from 30% to 50% in the surveyed dump sites after preliminary sorting, separation of metal and crushing are used when laying temporary roads, in preparation for the construction of permanent roads, as an aggregate in the process of production of new concrete products and so on [18-20]. To improve the efficiency and increase the use of construction waste as secondary resources it is necessary to conduct a preliminary sorting of waste formed in-situ, i.e. directly on the site.

One of the possible cases for the concrete and reinforced concrete waste use is using it during the construction and reconstruction of environmental and hydraulic structures [21-23]. Since such constructions usually involve temporary or permanent contacts with water bodies, the waste used in them must undergo a thorough pre-sorting and checking for harmful pollutants.

Figure 3. The view of the construction waste dump site (dump site 2)

The use of the broken concrete and reinforced concrete will reduce the amount of primary raw materials for construction, reduce the amount of waste recycled at dump sites making them long-lived and cut the negative impact on the environment.

IV CONCLUSIONS

1. During in-situ survey of Samara construction sites building wastes dumps were found out.The life time of these dumps is limited by the terms of construction works and can last from 1 to 7 years so it is hardly possible for them to get mature and grow into brownfields. On completion of construction the dumps are liquidated and the wastes are transported to landfills. According to the results of these examinations weight shares of their components were determined. Broken brick, timber, broken concrete and reinforced concrete as well as metals constitute a major part of it.

2. It is recommended that construction wastes be used as secondary resources in the construction work and manufacture of building materials.Some ways of

secondary use of wastes applied nowadays in Russia and other countries are considered. It is also proposed to apply them to repair or reconstruct environmental facilities and construct flood-control dams. Such use allows not only saving the amounts of natural resources used in construction but also it leads to reduction of the wastes taken out to landfills.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 103-106

Impact of Microbiological Fertilizer Baikal EM-1 on Onion Growth in Greenhouse Conditions

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Abstract. **The microbiological fertilizer Baikal EM-1 contains lactic acid bacteria, photosynthetic bacteria, nitrogen fixing bacteria, *Saccharomyces* yeasts and microbial cultivation media. The aim of the present study was to evaluate the impact of it on onion grown in controlled greenhouse conditions.**

In summer 2014 two trials with this product were carried out on onions in greenhouse conditions. Before planting onion bulbs were soaked in water with added fertilizer and growth substrate was watered with the fertilizer according to the instructions of manufacturer. During the vegetation period plants were watered with the fertilizer several times. Identical treatment was performed with water in the control plots. Different treatment schemes and growth substrates (neutralized peat and substrate for vegetables) were used in both trials. The main difference of the used substrates was in the content of mineral nutrients that was higher in the substrate for vegetables. In the second trial additional fertilization with ammonium nitrate was applied three times during the vegetation period. At the end of the trials the yield of onion leaves was estimated, as well as the length of leaves and their chlorophyll content was measured.

At the first trial the obtained yield of onion leaves was increased by 6.4 % and in the second by 8.2 % due to treatment with Baikal EM-1 but these differences were not statistically significant in comparison to the control plots. In general, the fertilizer increased all other measured parameters as well, including average length of leaves by 4.6 % and 1.3 %, the chlorophyll content by 5.0 % and 1.5 %, in the first and second trial respectively, and percentage of onions developing leaves increased by 13.2 % in the second trial. Only the last parameter showed statistically significant differences in comparison to the control. Additionally the growth of the onion was more even in the control treatment. In conclusion, the microbiological fertilizer Baikal EM-1 gave positive impact on onions in greenhouse conditions.

Keywords: **chlorophyll content, microbiological fertilizer, onions, yield.**

I INTRODUCTION

Microorganisms and their populations in soil and rhizosphere are important players for plant nutrition and health. Beneficial soil microorganisms are responsible for soil born disease suppressiveness [1]. Various soils contain diverse microbial populations. The most important for nitrogen nutrition are nitrogen fixing bacteria, nitrifiers and denitrifiers [2].

Several studies have shown positive impact of the microbiological fertilizer Baikal EM-1on plants. This fertilizer contains among nitrogen fixing bacteria also lactic acid bacteria, photosynthetic bacteria, *Saccharomyces* yeasts and microbial cultivation media. Lactic acid bacteria have been isolated from rhizosphere of fruit trees [3]. Application of photosynthetic bacteria has increased grain yield of rice plants [4] and has shown potential for biocomposting [5]. Baikal EM-1, containing broad spectrum of microorganisms, has reduced the inhibition of photosystem II activity of tree seedlings in the conditions of salt stress [6]. In field conditions Baikal EM-1 (1 and 2 %) has increased yield of maize by 1.85 and 2.65 t h^{-1}, respectively, chlorophyll content in leaves of maize [7] and yield of sugarbeet [8]. A bio-fertilizer, containing *Lactobacillus casei, Lactobacillus lactis, Rhodopseudomonas palustris, Saccharomyces cerevisiae*, has improved yield of tomato in greenhouse conditions by 13 and 19 % if used in soil or foliar application [9]. Since scientific information about the microbiological fertilizer Baikal EM-1 is limited, the aim of the present study was to evaluate the impact of it on onion grown in controlled greenhouse conditions.

II MATERIALS AND METHODS

In summer 2014 two trials with Baikal EM-1 (EM Technology, Russia) were conducted on onion (*Allium cepa* L.), cultivar ‘Stuttgarter Riesen’ (distributed by Latvijas Skirnes Seklas Ltd, Latvia) in greenhouse conditions in Kekava region (Latvia).

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.273

Before planting onion bulbs were soaked in water with the added fertilizer (0.1 %) and growth substrate was treated with the fertilizer (1 %) according to the instructions of the manufacturer. During the vegetation period plants were watered with the fertilizer several times. Identical treatment was performed with water in the control plots. Different treatment schemes and growth substrates (neutralized peat and substrate for vegetables) were used in the trials (Table 1). The main difference of the used substrates was in the content of phosphorus that was two times higher in the substrate for vegetables. In the second trial additional fertilization was performed three times during the vegetation period with ammonium nitrate (Agrochema Latvia Ltd, content: total nitrogen 34.4 %; ammonium N-NH_4 17.2 %; nitrates N-NO_3 17.2 %) and malt extract was added to the fertilizer solution as suggested by the Baikal EM-1 manufacturer in order to activate the microorganisms present in the preparation. The trials were carried out in greenhouse conditions, and onions were planted in eight plastic boxes per treatment. Boxes were regularly watered manually.

In the first trial all onions were able to develop leaves but in the second trial the sprouting capacity was reduced and therefore the number of onions developing leaves was counted at the end of the trial.

At every treatment and assessment, the average air temperature and air humidity in the greenhouse was measured.

Fig. 1. Sorting of onion in groups depending from the length of the leaves in the second trial.

At the end of the trials, at four- to five-leaf stage, the yield of onion leaves per box was estimated (fresh weight), as well as the average length of leaves and their chlorophyll content was measured (five measurements per box) using a hand-held chlorophyll meter SPAD-502 (Konica-Minolta, Japan). At the end of the second trial all onions from each box were sorted in groups depending from the length of the leaves (Fig. 1) and respective number of onion and weight of each group (0-10 cm, 11-20 cm, 21-30 cm, 31-40 cm, 41-50 cm, 51-60 cm, 61-70 cm) was estimated.

Significance of differences between means was determined by the t-test at the α = 0.05 level with *Excel* (Microsoft, USA). Significance was evaluated at $p < 0.05$ level.

TABLE I

TREATMENT SCHEMES

Process	First trial	Second trial
Size of plastic boxes, m^2	0.24	0.10
Substrate treatment two weeks before planting with 1 % Baikal EM-1 solution	yes	no
Soaking of onion bulbs before planting in 0.1 % Baikal EM-1 solution	20 min	12 h
Planting , 1500/m^2	07.05.2014.	25.07.2014.
Spraying with 0.001 % Baikal EM-1 solution	one time	none
Watering with 0.001 % Baikal EM-1 solution	two times	three times
Addition of malt extract (0.001 %) to Baikal EM-1 solution	no	in all treatments
Fertilizing with ammonium nitrate, 10 g m^{-2}	no	three times with 7-8 day interval
Harvest	02.06.2014.	28.08.2014.
Substrate and its content	Neutralized peat „Kasvuturvas", Estonian Peat Products Ltd., Estonia Added nutrients, g mg l^{-1}: Nitrogen (NH_4 and NO_3) – 120.00 Phosphorus (P_2O_3) 140.00 Potassium – (K_2O) 240.00	Substrate for vegetables „Terra Vita", SAS "MNPP PHART", Russia. Content, mg l^{-1}: Nitrogen (NH_4 and NO_3) 150.00 Phosphorus (P_2O_5) 270.00 Potassium (K_2O) 300.00.

III RESULTS AND DISCUSSION

In the first trial the average length of onion leaves at the harvest in the control was 34.94 ± 3.25 cm. The average length of onion leaves in the treatment was 36.55 ± 2.09 cm. The difference was 4.61 % but it was statistically not significant ($t_{Stat} = 1.17 < t_{Critical\ two\text{-}tail} = 2.15$). At the first trial the obtained yield of onion leaves per box of the control was 585 ± 67.40 g that corresponds to 24.4 t ha^{-1}. The obtained onion yield in the treatment was 622.5 ± 83.79 g per box (0.24 m^2) that corresponds to 25.9 t ha^{-1}. The difference was 6.41 % but it was statistically not significant (t_{Stat} = 0.99 < $t_{Critical\ two\text{-}tail}$ = 2.15). The average chlorophyll content of onion leaves in the control was 17.08 ± 1.61 SPAD units. The average chlorophyll content of onion leaves in the treatment was 17.92 ± 1.82 SPAD units that was increased by 4.92 % in comparison to the control. This difference was statistically not significant (t_{Stat} = 0.97 $t_{Critical\ two\text{-}tail}$ = 2.15).

In the first trial all onions were able to develop leaves but in the second trial only 70.83 ± 12.36 % of bulbs developed leaves in the control but 84.00 ± 2.89 % bulbs developed leaves in the treatment. The difference was 13.17 % and it was statistically significant (p = 0.02; t_{Stat} = 2.93 > $t_{Critical\ two\text{-}tail}$ = 2.31).

In the first trial at the harvest the average length of the onion leaves in the control was 40.88 ± 3.70 cm. The average length of the onion leaves in the treatment was 41.41 ± 3.91 cm. The difference was 1.31 % but it was statistically not significant (t_{Stat} = 0.28 < $t_{Critical\ two\text{-}tail}$ = 2.15).

At the second trial the obtained yield of onion leaves per box of the control was 438.13 ± 44.60 g that corresponds to 43.8 t ha^{-1}. The obtained onion yield in the treatment was 474.00 ± 33.81 g per box (0.1 m^2) that corresponds to 47.4 t ha^{-1}. The difference was 8.19 % but it was statistically not significant (t_{Stat} = 1.81 < $t_{Critical\ two\text{-}tail}$ = 2.15).

The average chlorophyll content of onion leaves in the control was 25.80 ± 0.91 SPAD units. The average chlorophyll content of onion leaves in the treatment was 26.18 ± 1.18 SPAD units. The difference was 1.47 % but it was statistically not significant (t_{Stat} = 0.32 < $t_{Critical\ two\text{-}tail}$ = 2.15).

The average chlorophyll content was statistically significantly higher in the second trial in the control (p < 0.001; t_{Stat} = 8.65 > $t_{Critical\ two\text{-}tail}$ = 2.15) as well as in the treatment (p < 0.001; t_{Stat} = 7.77 > $t_{Critical\ two\text{-}tail}$ = 2.15) in comparison to the first trial. Differences between trials can be explained by the higher level of nitrogen in the substrate used for the second trial and additional fertilization with ammonium nitrate. However the detected level of the chlorophyll has to be considered low in comparison to other investigations were onion has been grown on organic soils and the chlorophyll content was estimated with the same method. For example, in the study of Westerveld et al. [9] the chlorophyll content of yellow cooking onion cultivar 'Hamlet' leaves at five-leaf stage varied from 46.9 to 56.2 SPAD units on organic soil in field conditions depending from the amount of nitrogen rate in the fertilization (0 – 200 kg ha^{-1}) and year of the trial. Such differences can be explained by different growth conditions (greenhouse *vs*. field) and different cultivars.

The average yield of fresh onion leaves was statistically significantly higher in the second trial in the control (p < 0.001; t_{Stat} = 2.76 > $t_{Critical\ two\text{-}tail}$ = 2.15) as well as in the treatment (p < 0.001; t_{Stat} = 2.79 > $t_{Critical\ two\text{-}tail}$ = 2.15) in comparison to the first trial. This can be explained by a higher amount of mineral nutrients in the substrate used in the second trial. Increased fresh weight of onion leaves followed by higher potassium and phosphorus concentrations, for example, has been reported in other investigations as well [11,12].

Sorting of onion in groups depending from the length of the leaves has shown that in the treatment higher biomass was obtained in the length groups up to 50 cm, especially in the length group 31-40 cm (Table 2) where this difference was statistically significant in comparison to the control (p = 0.01, t_{Stat} = 3.00 > $t_{Critical\ two\text{-}tail}$ = 2.15). In the length groups 51-60 cm and 61-70 cm the highest biomass was observed in the control, especially in the length group 51-60 cm, where the difference in comparison to treatment was statistically significant (p = 0.01, t_{Stat} = 2.78 > $t_{Critical\ two\text{-}tail}$ = 2.15).

Number of onion in the control boxes was higher in the smallest (0-20 cm) and largest length groups (51-70 cm) but in the treatment number of onion was higher in the length categories from 21 to 50 cm (Table 2) that is more suitable for the production quality.

Plant growth-promoting soil microorganisms improve plant nutrition and growth characteristics through various processes including nitrogen fixation, breakdown of organic substances, solubilization of minerals, release of chelating compounds and biologically active molecules such as phytohormones, vitamins and enzymes, and, as a result, improve the nutrient uptake by plant root system [13]. In the present study the tested fertilizer significantly increased the sprouting capacity of onion, slightly increased the length of the onion leaves, the fresh weight, the chlorophyll content, and the growth evenness. The growth period of the onion was remarkably shorter than in other studies where crops with longer vegetation period were used, such as tree seedlings, maize, sugarbeet and tomatoes [6,7,8,9]. Probably the time period in the present study was too short for the beneficial microorganisms of the fertilizer Baikal EM-1 to multiply up to effective level and to give the maximal potential.

IV CONCLUSIONS

Although the level of mineral nutrients caused significant impact on the yield of onion leaves (fresh weight), as well as the average length of leaves and their chlorophyll content, the added fertilizer has shown positive impact of these parameters if comparing the control plots with treatment plots. Additionally Baikal EM-1 showed plant growth stimulating activity in the second trial when the sprouting capacity of onions was reduced. The percentage of onions developing leaves was increased by 13.2 % in comparison to the control plots, and the length of the onion leaves was more even that is suitable for the production quality aspects.

TABLE 2
ONION FRESH MASS AND NUMBER OF PLANTS IN EVERY LENGTH GROUP

Measured parameter	0-10 cm	11-20 cm	21-30 cm	31-40 cm	41-50 cm	51-60 cm	61-70 cm
Fresh mass (g) (± S.D.) in the control	0.75±0.46	6.13±2.47	20.75±5.18	91.75±33.38	196.75±30.87	109.63±29.26	12.38±15.95
Fresh mass (g) (± S.D.) in the treatment	0.88±0.35	6.38±3.46	26.75±9.97	141.50±32.91	225.75±56.70	67.38±31.37	5.38±11.70
Number of plants (± S.D.) in the control	2.38±2.07	7.00±2.45	13.63±3.02	28.63±10.50	37.75±9.38	14.13±3.40	1.25±1.58
Number of plants (± S.D.) in the treatment	2.50±1.85	6.50±2.33	16.00±5.58	42.25±8.97	44.25±10.94	9.88±3.83	0.75±1.75

V ACKNOWLEDGEMENTS

We are very thankful to EM Technologies for providing the fertilizer used in the study.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 107-111

Influence of SiO_2 nanoparticles on relative fluorescence of plant cells

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Abstract. **Nanoparticles (nano-scale particles (NSPs)) are defined as particles with dimensions less than 100 nm. SiO_2 nanoparticles are one of the most widely common nanoparticles in the environment, particularly in urban areas. The sources of SiO_2 nanoparticles are very different, including natural nanoparticles, anthropogenic and engineered nanoparticles. The SiO_2 nanoparticles could be considered a source of different pollution effects on leaving organisms. Nevertheless, knowledge of the mechanisms, through which the SiO_2 nanoparticles affect cells, is incomplete. The aim of the research was to elaborate a method to determine changes in relative fluorescence of both somatic and immature gametic plant cells in presence of SiO_2 nanoparticles. Relative cell fluorescence was measured with BD FACSJazz® cell sorter using 488 nm exciting laser light. Mean cell fluorescence was determined for samples of purified cell suspension. Gates of different size and shape were preliminary tested to find those with the lowest CV. Cell plots were created by BS FACS Software 1.0.0.650. The densest part of the plot was gated using oval-shaped gate. The gate included 95-99% of all cells. A logarithmic scale in arbitrary fluorescence units was applied to determine cell relative fluorescence. More than 10 000 cells were gated and analysed from each sample. Somatic cell culture from callus culture initiated from leaves of flax (*Linum usitatissimum*) was obtained. The relative fluorescence of the somatic cells had large distribution, since the cells differ by many parameters (size, shape, metabolism etc.). Immature pollen cells (one-nucleus stage) as best for SiO_2 nanoparticles influence investigation were found. The influence of SiO_2 nanoparticles on several plant species (*Cyclamen persicum, Tilia cordata, Hordeum vulgare* and *Triticum aestivum*) immature pollen cells were investigated. A significant increase in relative cell fluorescence was observed for all mentioned plant species cells after incubation in SiO_2 nanoparticles suspension. It was found that cell relative fluorescence was dependent on cultivation duration in SiO_2 nanoparticles suspension.**

Keywords: **plant cell fluorescence; flow cytometry; SiO_2 nanoparticles; urban ecology.**

I INTRODUCTION

Nanoparticles (nano-scale particles, NSPs) are defined as particles with dimensions less than 100 nm. Silica or silicon dioxide (SiO_2) nanoparticles, including natural, anthropogenic and engineered nanoparticles, are one of the most widely common nanoparticles in the environment, particularly in urban areas [1]-[7]. They could be considered a source of different pollution effects on leaving organisms, nevertheless, knowledge of the mechanisms through which nanoparticles affect cells is incomplete. The major importance has the understanding of biological mechanisms through which nanoparticles affect cells [8]. SiO_2 nanoparticles were described as non-toxic, environment-friendly and safe for use in nanocomposites consisting of organic polymers. However, there is still evidence that amorphous SiO_2 nanoparticles could be hazardous [9], [10]. Silica also has an important role in plant tolerance to environmental stresses und plant photosynthesis [11], [12].

Flow cytometry methods (FCM) in the last 20 years is widely used method for investigation of different plant cell parameters, including cell oxidative stress [13]-[15]. FCM has several advantages − on the base of changes of cell relative fluorescence it is possible to analyse more than 20 parameters of each cell, large number of cells can be evaluated in a very short time, the results are statistically significant and represent the all studded population. All this make the method an excellent investigation tool in many areas [16]-[18]. The aim of the research was to elaborate a method to determine relative fluorescence of both somatic and immature gametic plant cells in presence of SiO_2 nanoparticles.

II MATERIALS AND METHODS

A. Plant Material

The plant cells from different genus five genetically distant species – lime trees (*Tillia cordata),* cyclamen *(Cyclamen persicum),* wheat *(Triticum aestivum),* barley *(Hordeum vulgare)* and flax *(Linum*

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.281

usitatissimum) were used in the research. The lime trees (three years old), cyclamen, wheat and barley were grown in greenhouse. Flax calli culture was obtained using an earlier elaborated method [19], [20].

B. Cell Culture Preparation

The cell cultures of immature microspores of lime trees, cyclamen, wheat and barley, as well as flax somatic cell culture preparation was done using modified methods of cells culture establishment [21]. The optimal stage of microspores for each plant species were determine by light microscope (magnification x10^3) [22]. The buds, spikes and calli were collected and put in the Waring Blender 8011 and grind in 0.3 M solution of D-mannitol. The samples were grinded in the mode Nr. 2 up to five times each during 20 seconds till visually homogeneous suspension. The samples were filtered through mesh (50 µm) three times then the acquired liquid was collected into several 45 ml centrifuge plastic tubes. The samples were centrifuged (Eppendorf Centrifuge 5810R) for 15 min at 4 °C, 900 rpm. After centrifugation the liquid phase was decant, but the sediment (cells) was diluted with 45 ml 0.3 M D-mannitol solution and centrifuged one more time for 15 min at 4 °C, 900 rpm. 1 ml of cell sediment contained about 600 000 cells [21]. The liquid phase was poured off and 1 ml of cell sediment was suspended in 4 ml liquid MS medium [23] and mixed. The cell culture quality was determined by light microscope (magnification x10^3).

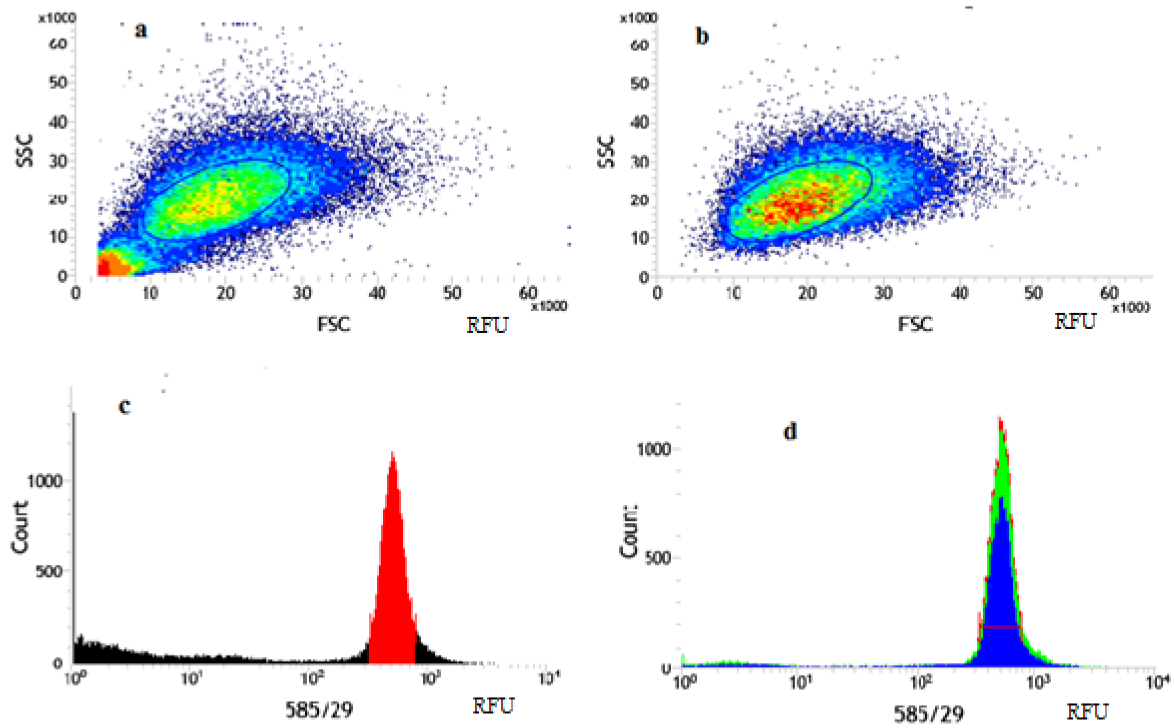

Fig. 1. Flow cytometer analysis of cyclamen *(Cyclamen persicum)* cells: a – oval shape gating of control cells sample; b – oval shape gating for cells cultivated in SiO_2 suspension (1 mg/ml) for 1 hour; c – the relative fluorescence units (RFU) in logarithmic scale for control cells; d – the relative fluorescence units (RFU) in logarithmic scale for cells cultivated in SiO_2 suspension (1 mg/ml) for 1 hour.

C. Evaluation of SiO_2 Nanoparticles Influence

A suspension of SiO_2 nanoparticles was prepared by silicon dioxide (SiO_2) nanoparticles (Sigma – Aldrich inc., size 10-20 nm, purity 99.5%) dilution in distilled water in proportion 1 mg per 1 ml. After dilution the suspension flask was placed into Bandelin® RK-31 ultrasonic bath (frequency 35 kHz, effective US power 40 W) for 30 min for sonification to separate possible nanoparticle conglomerates. Immature pollen cells of cyclamens were used as a model object for elaboration of flow cytometry method. The cells were incubated in MS medium without and in presence of SiO_2 nanoparticles for 1, 2, 3 and 4 hours at 17 °C temperature in speed shaking regime. The concentrations of SiO_2 NSP in media were 0.5, 1.0 or 1.5 mg/ml (0.5 ml, 1 ml or 1.5 ml of SiO_2 NSP suspension was added to 10 ml of cell suspension). After incubation the suspension was filtered through a flow cytometry-pass filter (mesh 40 µm).

For the establishing of relative fluorescence of plant cells of different species immature pollen cells of lime trees (*Tillia cordata),* cyclamen *(Cyclamen persicum),* wheat *(Triticum aestivum) and* barley *(Hordeum vulgare), as well as* somatic cells of flax *(Linum usitatissimum)* calli were used. After cell incubation at temperature 22 °C without and in presence of 1 mg/ml SiO_2 nanoparticles in speed shaking regime for 1 and 3 hours the suspension was filtered through a flow cytometry-pass filter (mesh 40 µm).

D. The Device and the Software for the Research

To test relative fluorescence of plant cells BD FACSJazz® cell sorter (BD Biosciences, USA) with flow cytometer function with a 100 µm nozzle was used; phosphate-buffered saline (BD Pharmingen^{TM} PBS, BD Biosciences, USA) was applied as a sheath fluid.

Sphero^{TM} rainbow calibration particles (3.0–3.4 µm, BD Biosciences, USA) in phosphate buffered saline (PBS) were used for flow cytometer calibration. The calibration was considered successful if the coefficient of variance (CV) of relative fluorescence of the rainbow calibration particles was not exceed 3%. The cytometer settings were: trigger level 1418, trigger detector FSC, scope channel 1 and scope channel 2 585/29, PMT; power voltages PMT1 – 25.73 (FSC), PMT2 – 25.01 (SSC), PMT3 – 43.16 (log 530/40), PMT1 – 41.99 (log 585/29) were used. The method was based on changes of relative self-fluorescence intensity of cells after excitation with 488 nm Coherent Sapphire Solid State (blue) laser. The light emission was measured at 585/29 nm. The information of mean fluorescence intensity from the purified cell suspension samples was recorded. Preliminarily, multiple gate sizes and shapes were tested to find the one with the lowest CV. Using flow cytometer BS FACS Software 1.0.0.650 cells plot was created to determine the densest part that was later gated using oval-shaped gate (Fig. 1). Gate included from 95 to 99% of all target cells. A logarithmic fluorescence scale in arbitrary fluorescence units was used to determine relative fluorescence units (RFU) of cells. 3 x 10^3 gated cells were analysed from each sample.

For statistical analysis of results the *p*-value obtained through TDIST function (MS Excel) was used; *p*-value is a tool to test the null hypotheses in certain level of significance. The significance threshold chosen for the research was p=0.05 (5%).

III RESULTS AND DISCUSSION

Influence of nanoparticles on plant cells depends on particles properties and concentration, evaluated plant cells type und physiological state [24], [25]. Great importance has also the cells wall structure, including the cells wall pores diameter, as well permeability of cell wall pores complex [29]. The SiO_2 nanoparticles with diameters of 10-20 nm used in this investigation were regarded as biologically active [26], [27].

The relative fluorescence of cyclamen immature pollen cells depended on cultivation temperature and time (Fig. 2 and Fig. 3). After cell incubation in SiO_2 nanoparticles suspension with concentrations 0.5, 1.0 and 1.5 mg/ml in 17 °C temperature (Fig. 2) a significant difference from control cells (cultivated without SiO_2 nanoparticles) was found only for the cells cultivated during 1 h in media with 1.5 mg/ml SiO_2 nanoparticles.

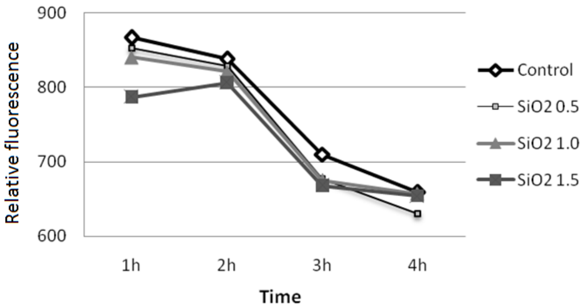

Fig. 2. The relative fluorescence of cyclamen immature pollen cells after incubation in suspension of SiO_2 nanoparticles with 0.5, 1.0 and 1.5 mg/ml concentrations after 1, 2, 3 and 4 hours of incubation (the cultivation temperature was 17 °C).

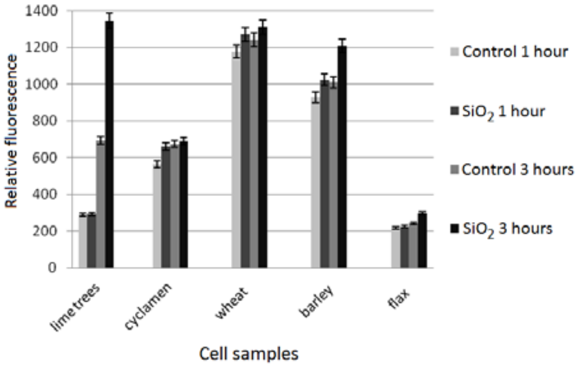

Fig. 3. The relative fluorescence of lime trees (*Tillia cordata),* cyclamen *(Cyclamen persicum),* wheat *(Triticum aestivum),* barley *(Hordeum vulgare)* immature pollen cells and flax *(Linum usitatissimum)* callus somatic cells after incubation at room temperature (+22 °C) without and in presence of 1 mg/ml SiO_2 nanoparticles.

After 3 h of cultivation extreme reduction of relative fluorescence were observed for all cultivated cell samples. It might be because of decrease of activity of cell metabolic processes in 17 °C temperature. After cell cultivation in 22 °C temperature in presence of SiO_2 nanoparticles extension of cell relative fluorescence was observed (Fig. 3). This could be due to the fact that increase of cultivation temperature for 5 degrees increases the cell metabolic activity. The enhancing of cell relative fluorescence, depending of the species, was related with the changes of different cell parameters such as fluorescence of fluorescent pigments, proteins, including histones, fluorescent proteins in the chloroplast, and cell life process products such as peroxidase [28].

The influence of SiO_2 nanoparticles on plant cells is still in discussion: in some investigations [13], [15], [24], [27] SiO_2 nanoparticles were found to be toxic, but in the other studies [12] it was found that SiO_2 nanoparticles has been successfully used as fertiliser. However, it should be noted that authors do not indicated the size of used SiO_2 nanoparticles, but it is also known that in cell reaction on presence of nanoparticles is significant the type, size and concentration of SiO_2 nanoparticles [11], [24], [25]. All investigated cells after cultivation in 22 °C temperature in presence of SiO_2 nanoparticles showed increase of relative fluorescence for 1 and for 3 hours (Fig. 3). The changes of cell relative fluorescence depending of plant species were observed: the highest changes (from 695 relative fluorescence units (RFU) of control cells to 1345 RFU of cells cultivated in SiO_2 nanoparticles suspension) were detected for lime trees immature pollen cells after cultivation for 3 h in presence of SiO_2 nanoparticles, the lowest relative fluorescence changes were detected for somatic cells obtained from callus culture initiated from leaves of flax (*Linum usitatissimum)*. It ranged from 216 RFU (1 h cultivation, control cell sample) to 298 RFU (3 h cultivation in suspension of SiO_2 nanoparticles). The somatic flax cells fluorescence had large distribution, since the cells differed by many parameters (size, shape, metabolism etc.) and were problematic for gating. In turn, the immature cells (one-nucleus stage) had very small difference in shape and size and were more useful (the cell pool was clear for gating, Fig. 1) to establish changes in cell relative fluorescence after influence of SiO_2 nanoparticles.

IV CONCLUSIONS

The significant increase in relative cell fluorescence was observed after incubation in SiO_2 nanoparticles suspension for several plant species – immature pollen cells of lime trees (*Tillia cordata),* cyclamen *(Cyclamen persicum),* wheat *(Triticum aestivum),* barley *(Hordeum vulgare)* and somatic cells of flax *(Linum usitatissimum)*. Relative cell fluorescence was dependent on cultivation duration in SiO_2 nanoparticles suspension. The influence of temperature on cell fluorescence was observed after cell incubation in SiO_2 nanoparticles suspension. The immature (one nucleus stage) pollen cells of all evaluated species were found to be appropriate for investigation of influence of SiO_2 nanoparticles on plant cells.

V ACKNOWLEDGEMENTS

The study was financially supported by the European Social Fund, the project No. 2013/0060/1DP/1.1.1.2.0/13/APIA/VIAA/041.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 112-115

Floodwater storage capacity of the Middle Daugava floodplain

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Abstract. **This study highlights the flood risk prevention services provided by the Middle Daugava river-floodplain system located downstream from Daugavpils City. Today, it acts as a principal storage area for floodwaters of the Daugava River during the spring floods, therefore diminishing the risk of flooding and related costs for urban municipalities like Jēkabpils and Pļaviņas located further downstream. Statistical analysis of hydrological data records of the Daugava River at Daugavpils and Jēkabpils during the top-10 flood events in 20th century are performed in order to quantify the largest daily discharge deficits between these two hydrological posts as well as to calculate the amount of floodwaters that could be intercepted by the entire floodplain area. The highest daily discharge deficit (2230 m^3 s^{-1}) is used to calculate additional water level heights for Jēkabpils town if the floodplain did not intercept the floodwaters at all. Therefore, reduction of annual flood risk level provided by the existing river-floodplain system of the Middle Daugava River could be assessed from hydrological perspective as well as from the Ecosystem Services Concept point of view.**

Keywords: **Daugava River, Ecosystem Services Concept, flod risk prevention, floodplain storage capacity.**

I INTRODUCTION

The river-floodplain system of the Middle Daugava is located in South-East Latvia, within the East-Latvian Lowland, downstream from Daugavpils City (Fig. 1). In this stretch, the Daugava's valley is shallow and wide, with broad segments of floodplains located on its both sides behind natural levees [2]. Its hydrological regime is still unaffected by the large-scale hydro-engineering projects and modifications. During the spring floods, this river-floodplain system acts as principal storage area for the floodwaters of the Daugava River that are intercepted and stored there for several weeks [4].

Usually, this floodplain area is inundated from late March till mid-May [1], depending on the peak flood discharge of the Daugava River at Daugavpils and the amount of discharge produced by snowmelt and rainfall in local drainage network.

The floodwater storage capacity of the Middle Daugava river-floodplain system has been assessed for the first within the scope of National Research Program "KALME" in 2007 [4]. According to digital elevation model of this area created by geomatic methods, the floodwater storage capacity of the Middle Daugava river-floodplain system exceeds 0.31 km^3 at mean floodwater level. In addition, it is capable to intercept at least 4.06 10^7 m^3 of the Daugava's floodwaters per day as estimated for the record spring floods in April-May, 1931 [4].

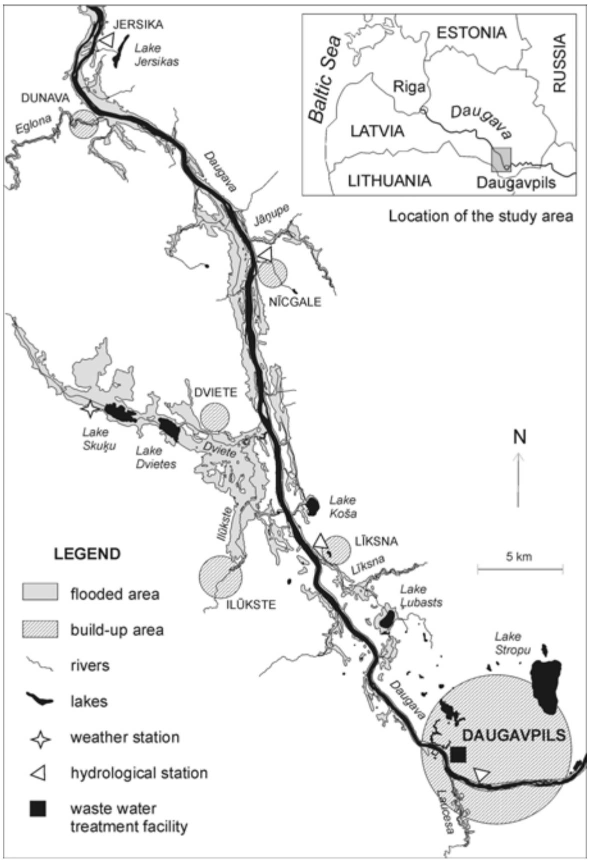

Fig. 1. The river-floodplain system of the Middle Daugava between Daugavpils and Jersika

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.251

These estimations are based on an assumption that negative differences between the daily discharge values (i.e. the discharge deficits) stated between the Daugavpils and Jēkabpils hydrological posts indicate the effect of floodwater detention (interception) by the floodplain area at the beginning of its filling phase [4].

Therefore, reduction of annual flood risk level provided by the river-floodplain system of the Middle Daugava could be assessed from hydrological perspective as well as from the Ecosystem Services Concept point of view [3].

Until now, the effect of the floodwater detention by the Middle Daugava's river-floodplain system has been assessed for the above mentioned record spring floods in 1931 only. Similar cases, when the daily discharge values were much lower at Jēkabpils than at Daugavpils could be detected for other years too [4].

The aim of this study is to assess the maximum floodwater storage capacity of this river-floodplain system during the floods based on the analysis of hydrological data records of the Top-10 flood events of the 20th century. This study is aimed also to highlight the flood risk reduction services provided by the existing river-floodplain system of the Middle Daugava for Jēkabpils municipality located further downstream.

II METHODS

For this study, the top-10 spring flood events of the 20th century were selected by taking into account the peak flood discharges of the Daugava River at Daugavpils [12]. The recorded daily discharge values at Daugavpils and Jēkabpils were obtained for the selected years from the historic annual publications of hydrological observations on Latvia's rivers and lakes [6-11]. For those years when the discharge records at Jēkabpils were missing, their values were obtained from the stage-discharge relationship curve constructed for the record floods in 1931 (Fig. 2).

Differences in the daily discharge values between both hydrological posts were calculated for each date in March, April and May directly as well as by taking into account a delay in 24 hours which is needed for the floodwaters to travel approximately 100 km long distance between these two hydrological posts [2]. Negative differences (the discharge deficits) were attributed to the floodwater detention effect by the floodplain and used for further analysis. To assess the maximum floodwater storage capacity of the river-floodplain system of the Middle Daugava between Daugavpils and Jēkabpils during its filling phase, the daily discharge deficit values were summed-up. Finally, additional increase of the floodwater level at Jēkabpils was assessed for the highest amount of daily discharge intercepted by the floodplain by means of the stage-discharge relationship curve (Fig. 2).

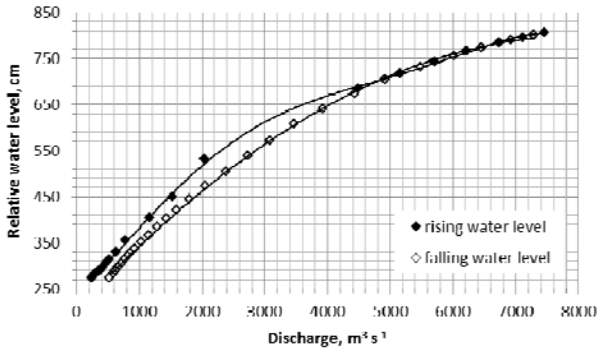

Fig. 2. Stage-discharge relationship curve for the Daugava River at Jēkabpils during the record spring floods in 1931

III RESULTS AND DISCUSSION

During the entire history of regular hydrological observations on the Daugava River at Daugavpils, there were 14 significant flood events when the peak flood discharge reached and/or exceeded 4000 $m^3 s^{-1}$ (Fig. 3). The top-10 floods of the 20th century are those observed in 1922, 1924, 1929, 1931, 1941, 1951, 1953, 1956, 1958, and 1962, respectively.

When the daily discharge values at Daugavpils and Jēkabpils are compared to each other, significant negative differences could be detected for the first days of the water level rise phase (Table 1). However, the daily discharge values recorded at Jēkabpils were also compared to those recorded at Daugavpils a day before due to the above mentioned delay period (24 hours) for the passage of the floodwaters from Daugavpils to Jēkabpils. In result, the recalculated discharge deficits are much lower but, nevertheless, quite impressive (Table 1).

Comparison of the recalculated discharge deficits at different years shows that the magnitude of the floods is not the single most important factor that determines the amount of floodwaters that is intercepted by the Middle Daugava's floodplain on a single day.

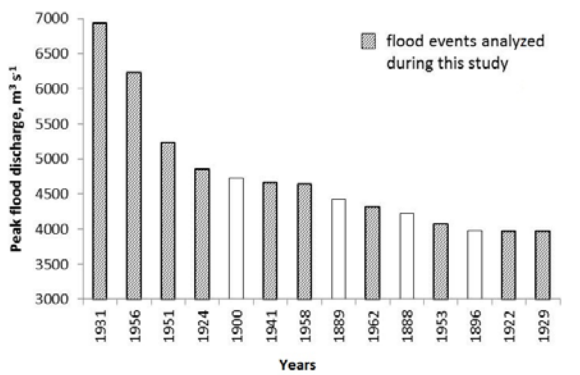

Fig. 3. The largest flood events on the Daugava River at Daugavpils since 1881. (The analyzed flood events are presented in descending order according to their peak discharges. White bars represent other major flood events that were not analyzed during this study. Their discharges are presented here for comparison only)

TABLE 1

DISCHARGE DEFICITS FOR THE MIDDLE DAUGAVA RIVER BETWEEN DAUGAVPILS AND JĒKABPILS HYDROLOGICAL POSTS DURING THE TOP-10 SPRING FOOD EVENTS OF THE 20TH CENTURY

Year	The peak flood discharge at Daugavpils, $m^3 s^{-1}$	Largest daily discharge deficits when no time delay is applied, $m^3 s^{-1}$	Largest daily discharge deficits when the 24-hours delay period is applied, $m^3 s^{-1}$
1931	6930	-1550	-470
1956	6230	-2560	-800
1951	5230	-630	-290
1924	4850	-2270	-2230
1941	4660	-1410	-800
1958	4640	-720	-450
1962	4320	-610	-360
1953	4070	-140	-240
1922	3970	+ 880 (no deficit recorded)	+ 740 (no deficit recorded)
1929	3970	-139	-51

For example, the record-high spring floods in 1931 has relatively low discharge deficit value (470 $m^3 s^{-1}$), while in 1924 it exceeds 2200 $m^3 s^{-1}$ at much lower peak discharge (Table 1). Such differences could be explained by several factors.

The first driving factor is progression of the snowmelt front across the Daugava's basin at spring. The snowmelt that produces annual floodwaters usually starts in the lower (western) part of the Daugava's basin, and its front moves to the upper (eastern) part of the basin a few days/weeks later. Therefore, local drainage area along the Middle Daugava produces its own minor flood pulse at first, which however moves away quickly, in a matter of days. Under such circumstances, the major flood pulse from the Upper Daugava meets almost no resistance from local drainage network when it reaches the Middle Daugava's floodplain area at Daugavpils. Therefore, under 'normal' snowmelt front progression scenarios (i.e. from West to East) the floodplain area of the Middle Daugava has maximum storage capacity. In addition, floodwater detention by the floodplain is significantly enhanced by formation of the ice jams within the Daugava's channel at Līksna village, Glaudānu Island and other sites [14]. During the extreme ice jams, the floodplain area of the Middle Daugava transports up to 70 % of total floodwater discharge [5].

In contrast, the most significant flood events in 1931 and 1956 were produced by unusual snowmelt scenarios - the snowmelt started simultaneously within the entire drainage basin of the Daugava River. In addition, the amount of snow that accumulated during winter season was exceptional (up to 200 and 250 %, respectively) [13]. Simultaneous melting of the snow cover within the entire drainage basin produced also large local flood pulses which prevented massive intrusion of the Daugava's floodwaters into the floodplain area. Therefore, the maximum discharge deficits in 1931 and 1956 were much lower than that recorded for April 1924.

Therefore, the largest floodwater detention effect of the Middle Daugava floodplain could be observed in those years when hydrological role of locally generated snowmelt runoff is less important.

In this pilot-study, the largest daily discharge deficit (2230 $m^3 s^{-1}$ or 1.96 10^8 m^3 per day) was detected for April 4, 1924. The sum of negative differences over a five days period (April 3-7, 1924) reached 6.18 10^8 m^3 or 0.62 km^3 (Fig. 4). It is comparable to the floodwater storage capacity at mean floodwater level (0.31 km^3) estimated from digital elevation model [4]. Obviously, the floodwater storage capacity of the entire Middle Daugava's floodplain area is much larger at record high floods.

The discharge deficit in 2230 $m^3 s^{-1}$ means also reduction of the floodwater level stage at Jēkabpils by 1-3 m (Fig. 2.). In other words, if the floodplain did not intercept the floodwaters at all, there would be about 1-3 meters higher water level during the floods depending on the peak flood discharge characteristics.

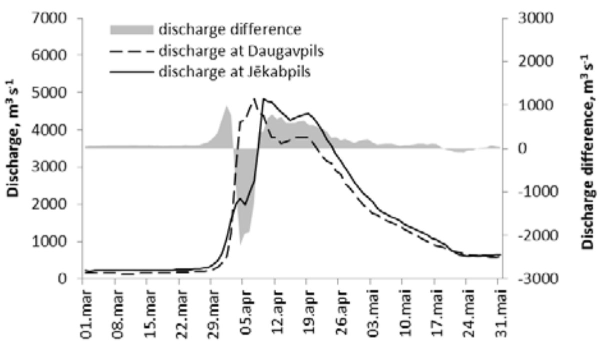

Fig. 4. Daily discharges of the Daugava River at Daugavpils and Jēkabpils and their differences during the spring floods in 1924 [6]. The differences in discharges are calculated by taking into account the 24 hours delay period

Furthermore, the maximum floodwater capacity of the Middle Daugava's floodplain (i.e. 0.62 km^3) significantly exceeds total water storage capacity of the Pļaviņu reservoir (0.51 km^3) – the largest artificial reservoir in Latvia that is used for electricity generation. Thus, the natural floodplain area located between Daugavpils and Jēkabpils cities has much larger regulating effect on the discharge characteristics of the Daugava River during the floods than that generated by operation of the Pļaviņu hydroelectric power station's dam at Aizkraukle.

These two facts clearly indicate that the flood risk prevention services provided by this natural lowland river-floodplain system in South-East Latvia are of regional as well as of national importance in the context of the Ecosystem Services Concept [3] as well as the European Union's Floods Directive.

In fact, the above mentioned maximum floodwater capacity for this river-floodplain system was rather underestimated. Even the largest daily discharge deficits obtained during the historic hydrological data analysis and comparison are masked by additional runoffs generated by several small tributaries (Dubna, Laucesa, Līksna, Berezovka, etc.). Evaporation from the floodplain's water surface should be also taken into account. Therefore, it is right to assume that, under favorable conditions, the maximum amount of floodwaters that could be intercepted by the entire floodplain area of the Middle Daugava River between Daugavpils and Jēkabpils certainly exceeds those 0.6 km^3 stated for the spring floods in 1024.

IV CONCLUSIONS

Under favorable conditions, the Middle Daugava's floodplain area located between Daugavpils and Jēkabpils cities is capable to absorb at least 2230 m^3 of floodwaters per second, and accumulate more than 0.2 km^3 of them on a single day during the filling phase of the spring floods. The maximum floodwater storage capacity of the Middle Daugava's floodplain exceeds 0.6 km^3, therefore generating strong regulating effect on the Daugava's discharge characteristics.

For towns that are located further downstream it provides significant flood risk reduction service, especially for Jēkabpils municipality. Because of this service, the highest floodwater levels could be reduced by 1-3 meters depending on the peak flood discharge therefore also reducing possible costs related to the flooding effects and flood risk prevention measures at Jēkabpils.

V ACKNOWLEDGEMENTS

The authors would like to cordially thank Dr. Elga Apsīte (University of Latvia) and Ing. Rūdolfs Gruberts (Joint-Stock Company "Ceļuprojekts") for their help to obtain the necessary hydrological data records.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 116-119

Using the lichen *Parmelia sulcata* Taylor in the urban environment monitoring

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Abstract. **The article presents the results of the long-term research of the lichen species population in urban environment. The tolerant species *Parmelia sulcata* Taylor was chosen as an indicator of urban conditions. The study was conducted in different parts of the city of Pskov (Russia) varying in degree of air pollution. The analyses of species' urban habitats, substrate diversity, thalli location in relation to the points of the compass, abundance and projective cover are discussed. Attention is also focused on the morphological parameters of the lichen's thalli (thalli size, presence or absence of apothecia, vegetative propagules, thalli color and presence of necro spots on the lichen individuals etc.) in different environmental conditions. Received data will serve as a base for monitoring *Parmelia sulcata* population change continuously.**

Keywords: **tolerant lichen species, *Parmelia sulcata*, urban environment, population state.**

I INTRODUCTION

Parmelia sulcata Taylor is one of the most common species of lichens with cosmopolitan distribution [3].

Parmelia sulcata is considered to be one of the lichen species tolerant to the effects of atmospheric pollutants in the city environment [7], [12], [13], [14], and along with other species it is used as an indicator of environment conditions, e.g. [12], [14]. However, in the city of Pskov, where large industrial enterprises are absent, but the amount of motor transport annually increases [10], there has been a tendency of *Parmelia sulcata* population size reduction in recent years.

The aim of this work was to study the population state of the lichen *Parmelia sulcata* in the city of Pskov.

II MATERIALS AND METHODS

Parmelia sulcata was studied in 9 green areas, located in 5 districts of Pskov city (Fig. 1).

All selected areas were located in different part of the city and were under different anthropogenic pressure.

The present study was conducted during the field seasons in 2004-2012. In every stand, the tree trunks were examined. The presence of *Parmelia sulcata* was recorded up to a 3 m height all around the tree. The total number of investigated stems, number of stems with the thalli of *Parmelia sulcata*, and the number of detected thalli are presented in Table I.

Fig. 1. Studied areas in Pskov city: 1 – Parks in the city center (*1* – Detskiy park, *2* – Kutuzov park, *3* – "Botanical garden", *4* – "Letniy garden", *5* – Finskiy park); 2 – Zapskov'e (plantings along Truda street); 3 – Zavelich'e-1 (*1* – planting around the regional hospital, *2* – plantings around military hospital, *3* – Mirozhskiy dendropark); 4 – Zavelich'e-2 (planting around the city hospital); 5 – public garden near the railway station

TABLE I

NUMBER OF INVESTIGATED TREES AND LICHEN THALLI

City district	Number of trees	Number of tree trunks with thalli of *Parmelia sulcata*	Number of thalli
Center of the city	1587	484	747
Zapskov'e	386	64	234
Zavelich'e-1	131	73	243
Zavelich'e-2	59	30	69
Near the railway station	807	122	186

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.282

For every phorophyte species belonging was identified, tree diameter at breast height (cm) was measured, type of bark was defined according to V. Peciar [9].

For every sample of *Parmelia sulcata* the exposure, height, thallus size, the color of thallus, the presence (or absence) of reproductive organs, and the presence of necro spots were recorded.

III RESULTS AND DISCUSSION

In total *Parmelia sulcata* was discovered on the bark of 13 tree and shrub species (Table II).

However, it more frequent settled on the trunks of broad-leaved species, in particular on the bark of lime, which is dominant in urban green areas.

TABLE II

DISTRIBUTION OF *PARMELIA SULCATA* BY TREE SPECIES (IN %)

Green areas / Tree species	Parks in the city center					Zapskov'e	Zavelich'e-1			Zavelich'e-2	
	Detskyi park	Kutuzov park	"Botanical garden"	"Letniy garden"	Finskiy park	Plantings along Truda street	Planting around the regional hospital	Plantings round the military hospital	Mirozhskiy dendropark	Planting around the city hospital	Public garden near the railway station
Acer platanoides L.	10.3	4.6	1.5	26.2		6.3	32.4	5.2	35.0	23.3	1.1
Tilia cordata L.	82.1	81.4	81.5	69.7	72.7	87.5	32.4			46.7	85.0
Quercus robur L.	4.7	14.0	4.5		1.8	4.7	5.8			6.7	0.5
species of *Populus*				1.4	1.8		2.9	94.8	10.0		4.8
Fraxinus excelsior L.			8.1	2.1			17.6		55.0	3.3	
Aesculus hippocastanum L.	1.8		1.5				2.9				1.6
Betula pendula Roth					23.6	1.6					6.4
Sorbus aucuparia L.							5.8			3.3	0.5
Ulmus glabra Huds.	0.9			0.7							
Malus domestica Borkh.										3.3	
Crataegus sanguinea Pall.										13.3	
Corylus avellana L.			1.5								
Padus avium Mill.			0.7								

Tree age and age-related parameters of the tree (size of trunk) influence the lichen species composition and distribution of lichen thalli on the phorophytes, e. g. [5]. In our study, tree size was assessed by measuring the stem diameter at breast height. The measurement data of the surveyed trees are presented in Table III.

TABLE III

CHARACTERISTICS OF TREES WITH *PARMELIA SULCATA*, RECORDED IN DIFFERENT CITY DISTRICTS

City district	Tree diameter at breast height, cm		
	mean	min.	max.
Center of the city	35.4	10	120
Zapskov'e	31.2	10	50
Zavelich'e-1	38.1	10	210
Zavelich'e-2	27.4	12	60
Near the railway station	41.5	19	64
Mean	34.7	10	210

The analysis of habitat preference showed that in the city of Pskov *Parmelia sulcata* occurred on phorophytes with different trunk diameter (from 10 to 210 cm). However, it is mainly found on trees with the average stem diameter (34.7 cm).

In the literature, there is information about the vertical distribution patterns of lichens on the trunk of phrophytes [1]. Some species of epiphytic lichens settle on the base (butt) of the stem, while others climb up the trunk to a height of several meters, and others prefer habitats on the branches in the tree crown. Distribution of *Parmelia sulcata* thalli on the tree stems presented in Table IV.

TABLE IV

DISTRIBUTION OF *PARMELIA SULCATA* BY PHOROPHYTES: HEIGHT

City district	Altitude, cm			Number of lichen thalli, %	
	mean	min.	max.	under 60 cm	above 60 cm
Parks in the center of the city	129.7	10	300	5.5	94.5
Zapskov'e	118.8	15	230	14.1	85.9
Zavelich'e-1	135.1	25	200	15.1	84.9
Zavelich'e-2	172.9	80	200	0	100.0
Near the railway station	175.0	150	200	0	100.0

In the Pskov green areas the vast majority of *Parmelia sulcata* thalli were found on stems above 60 cm in height. Up to 15% thalli may occupy the lower part of the stem (from the base to 60 cm). However, the annual treatment of the tree trunks with whitewash (protection from insect pests), leads to the disappearance of lichen thalli on the entire treated surface of the stem. In this case, mean height of thalli occurrence on the trunk increases (Table IV).

For different epiphytic lichen species physical properties of tree bark, in particular, parameters of the surface, are the determinants for settlement [1], [11]. Typically, for many tree species growth of stem leads the changes in the physical properties of the bark. It becomes more rough and cracked, the depth of cracks increases with age, creating more opportunities for lichens to settle and secure.

In the city of Pskov *Parmelia sulcata* grows on tree trunks with 3 different structural types of bark (in accordance with the V. Peciar [7]): 1. bark with deep cracks; 2. relatively thin bark with swallow cracks; 3. smooth bark, or in older trunks with shallow cracks (Table V).

TABLE V

DISTRIBUTION OF *PARMELIA SULCATA* BY PHOROPHYTES: TYPE OF BARK (IN %)

City district	Type of bark		
	1	2	3
Center of the city	34.5	58.2	7.6
Zapskov'e	76	9	15
Zavelich'e-1	46	49	5
Zavelich'e-2	64	29	7
Near the railway station	93	7	0
Mean	62.6	30.4	7.0

In the environment of Pskov city, studied species prefers the first type of bark (with deep cracks). At the same time, in the parks of the central part of the city the majority of thalli was found on the bark of the second type (58.2%). Apparently, for the main park-forming species (linden, maple, ash) the types of bark correspond to the age stages of the phorophytes.

It is very widely believed that lichens prefer to settle on the northern side of the trunk, but A. V. Dombrovskaya [2] considered, that in most cases lichens settle either evenly (on any side of trunk), or on the leeward side. In our case the distribution of *Parmelia sulcata* thalli occurrence was not highly skewed (Table VI).

TABLE VI

DISTRIBUTION OF *PARMELIA SULCATA* BY PHOROPHYTES: EXPOSURE (IN %)

City districts	Exposure			
	North	East	South	West
Parks in the center of the city	41.4	25	18.8	14.8
Zapskov'e	44	25	7	24
Zavelich'e-1	31.7	27	21.3	20.3
Zavelich'e-2	35	20	23	22
Near the railway station	36.5	28	15.6	19.8
Mean	37.7	25	17	20.2

According to our data, *Parmelia sulcata* was found on all four exposures, preferring northern one.

Various factors of the urban environment effect on the physiological processes in lichen thallus, changing the speed of growth and morphological parameters. *Parmelia sulcata* thalli size in the studied green zones are shown in Table VII.

TABLE VII

PARMELIA SULCATA THALLI SIZE (IN CM^2)

City district	Thalli size, cm^2		
	Mean	Min.	Max.
Center of the city	12.5	0.2	400
Zapskov'e	16.6	0.1	140
Zavelich'e-1	6.5	0.15	51
Zavelich'e-2	14.5	0.25	84

In general, reduction in the average size of lichen thalli is observed in different parts of the city. If we compare the data obtained with the average parameters specified in the literature (25-225 cm^2) [3], it becomes evident, that these changes are significant.

Reducing the size of lichen thalli with increasing atmospheric pollution noted by many authors [1], [4]. A 4 times decrease in the size of lichens thalli in comparison with conventionally clear territory was shown by the investigations in Ekaterinburg [8].

The reproductive potential of the species is considered to be one more criterion of the environment impact assessment. In our study presence or absence of soredia on *Parmelia sulcata* thalli was recorded (Table VIII).

In the majority of the surveyed stands a high percentage of thalli with soredia (up 75.4%) was recorded. Some authors suggest that, for many lichen species increase in soredia production associates with protection from the harmful effects by sulfur dioxide on the thallus, as well as promotes the reproduction and expansion to new habitats in the urban environment [6]. Others [8], on the contrary, observed a decrease in the soredia generation for *Hypogymnia physodes* and *Parmelia sulcata* with increasing of anthropogenic pressure.

TABLE VIII

NUMBER OF *PARMELIA SULCATA* THALLI WITH SOREDIA

City district	Number of thalli recorded	Number of thalli with soredia	
Center of the city	747	463	62.0%
Zapskov'e	234	-	-
Zavelich'e-1	243	147	60.5%
Zavelich'e-2	69	52	75.4%
Near the railway station	186	106	57.0%
Mean			63.7%

To determine the absolute age of lichens is difficult, but there is a direct correlation between development and age: the larger the thallus, the more his calendar age is. Therefore, in our study all *Parmelia sulcata* thalli were assigned to three groups:

1) up to 2.5 cm^2 – young samples;
2) from 2.5 to 25 cm^2 – middle-aged;
3) from 25 cm^2 – old.

The diagram (Fig. 2) shows the age structure of the investigated population.

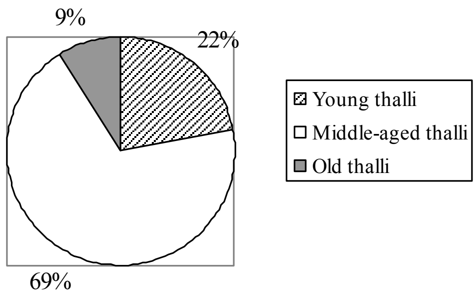

Fig. 2. Age structure of the *Parmelia sulcata* population

The population of *Parmelia sulcata* in the city of Pskov is mature, with the dominance of middle age generative thalli (69%).

Air pollution in the cities leads to a change in the color of the upper surface of the thalli and emergence of necro spots on them. In case of our study, the change of normally grey upper surface to rose and further brown color was recorded.

The quality of the thalli of different age groups is presented on the diagram on a Fig. 3.

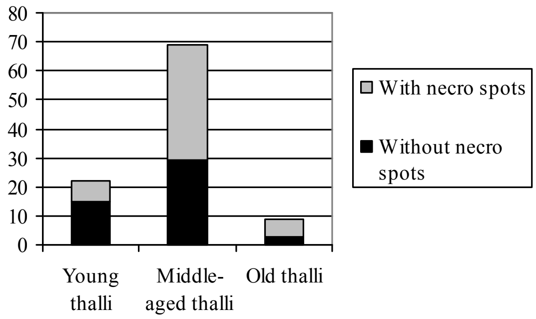

Fig. 3. Quality of different age groups thalli

In all surveyed areas in the city lichen thalli with necrosis were found in all age groups. Probably, changes in the color of thalli related to the degree of pollution, induced by traffic, the intensity of which increases in the city annually.

IV CONCLUSIONS

Tolerant lichen species *Parmelia sulcata* in the city of Pskov is in a state of depression. There is tendency of lichen thalli size reducing, high soredia production and emergence of necro spots on *Parmelia sulcata* thalli, that appeared as a response to the city air pollution.

The data obtained can become the basis for the long-term monitoring of *Parmelia sulcata* population in the city of Pskov. Further study of species biology and its ability to adapt to the urban environment is planned.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 120-123

Investigation of hemp *(Cannabis sativa L.)* crop weediness

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Abstract. **The investigation of hemp crop weediness was carried out at the Upytė Experimental Station of the Lithuanian Research Centre for Agriculture and Forestry in 2014. Bi-factorial trial was carried out: Factor A – variety (A1 – USO 31; A2 – Bialobrzeskie); Factor B – sowing rate (B1 – 45 kg ha^{-1}; B2 – 70 kg ha^{-1}). Data showed that seed rate had a significant influence on crop density at full hemp emergence as well as at harvesting time. Rainy vegetation period was favourable not only for hemp growing, but for weeds as well. Crop density (resulted by seed rate) had a significant influence on crop weediness – significantly more weeds (in average 166 plants m^{-2}) were found in the plots with seed rate of 45 kg ha^{-1}, consequently at lower crop density, and under 140 weed plants m^{-2} were found in the plots with seed rate of 70 kg ha^{-1}, consequently at higher crop density. Hemp crop weediness at harvesting time was much lower than that at the beginning of vegetation; reduction of weediness over the vegetation period was close to 87-90 percent.**

Keywords: ***Cannabis sativa*** **L., crop density, seed rate, variety, weediness.**

I INTRODUCTION

Hemp (*Cannabis sativa* L.) is a plant having an ability to grow quite rapidly in some its ontogenesis periods. The rapid growth period starts from the appearance of the 6th set of leaves (BBCH stage 1012) [1], [2]. Weeds become stressing when hemp plants begin to overshadow them, and this suppressing lasts for the all rest vegetation period as hemp is quite tall plant. In central and southeaster Europe, where hemp is sown for fibre, hemp crop height could be 1.5–3.0 meters while in our previous trials in Lthuania the medium height of 2.78 m (for cultivar Beniko) was fixed [3].

Hemp produces a higher amount of biomass due to its higher growth rate (0.5 m month^{-1}) and it is rich in leafage. These characteristics make hemp dominant over the weeds [4], [5].

Hemp's ability to suppress weeds during its vegetative period could be expressed under few conditions. Firstly, hemp plants must thrive well for what they need a sufficient supply of water and nutrients, good soil structure, avoiding soil compression and excessive moisture. Grown in poor soil hemp has no chance to fight against weeds. Secondly, weed suppression can be executed only at relatively high crop densities. We tried to find information about what is "relatively high crop density" for hemp. The marginal seed rate is considered to be close to 40 kg ha^{-1}: if hemp is sown with lesser seed rate, the crop is unable to expand sufficiently, and weeds have a greater chance for surviving [1]. A seed rate of 30 kg ha^{-1} as suitable for hemp seed production is also mentioned [6], [7].

A normal crop density is considered 200-300 plants per square meter which shades out the weeds, leaving the fields weed-free at harvest for the next crop [8]. Experiments in the Netherlands demonstrated that hemp crops effectively suppressed weeds and that no herbicides were needed, except in the cases where plant densities were very low (10 or 30 plants per m^2) [9].

In the trials in Australia, weed suppression was clearly affected by plant population as plant populations of 100 plants m^{-2} resulted in significantly greater weed biomass than did higher plant densities [7].

In Manitoba, the field choice, pre-sowing tillage, soil temperature, shallow sowing are main factors help ensuring that the hemp stand will emerge quickly and uniformly to gain advantage over the weeds [10].

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.272

Some authors also report that this crop requires no herbicides during vegetation time (in sufficient crop density) [1], [11], [12], [13], [14]. Firstly, weeds are destroyed by soil preparation in autumn and spring, and then overgrown by rapidly growing hemp plants. Exceptional could be hemp growing cases with wide (0.2-0.5 m) inter-row spaces (for seed purposes) where weed problem at the beginning could be solved by mechanical methods – using hoes or harrows [1].

Because of weed suppressing ability, hemp can be a prosperous proceeding crop for many crops, even for flax, as it is leaving clean and loose soil. Hemp can be grown with aim to reduce soil weediness as hemp plants are suppressing as annual as well as some perennial weeds [15], [16].

Some references point out that hemp supresses weeds so well that they rarely mature. So this weeds control carries over to all following crop, and it is why this plant is so interesting to organic farmers [1], [11].

The allelopathic potential of hemp is also mentioned [17].

The studying of crop weediness of few hemp varieties sown at different seed rates was the main task of our research presented here.

II MATERIALS AND METHODS

The investigation on hemp crop weediness was carried out at the Upytė Experimental Station of the Lithuanian Research Centre for Agriculture and Forestry in 2014. The soil – an Eutri-Endohypogleyic Cambisol, CMg-n-w-eu [18]. The $pH_{KC}l$ level was 6.8 (potentiometrically), humus concentration – 2.23% (by Hereus apparatus), content of available phosphorus (P_2O_5) in the soil plough layer was 116 mg kg^{-1}, the content of available potassium (K_2O) – 85 mg kg^{-1} (determined in A-L extraction). Hemp followed winter wheat in the field rotation. Before sowing, complex fertilizers N9-P25-K25 (200 kg ha^{-1}) have been applied.

Bi-factorial trial was carried out: Factor A – variety (A1 – USO 31; A2 – Bialobrzeskie); Factor B – sowing rate (B1 – 45 kg ha^{-1}; B2 – 70 kg ha^{-1}). Both of selected varieties are monoecious,

Hemp was sown on 7^{th} of May in 15 cm inter-row spacing by single-row sowing machine. The size of trial plots was $2 \times 5 = 10$ m^2, the size of record plots – $2 \times 4 = 8$ m^2 (trial was sown in tree replications). Randomised plot design was used. At both sides of the trial the protective plots of the same size as record plots were sown.

Hemp crop weediness (as well as crop density) was assessed after full crop emergence and at hemp harvest time. For this purpose 4 microplots of 0.25 × 0.25 m were marked in each trial plot after full crop emergence. Hemp was harvested when the first matured seed appeared (26^{th} of August), and counting of weeds was done at the same time. The weeds for air-dry weight were picked up at hemp harvest and evaluated when weeds in the laboratory became air-dry.

For statistical data evaluation the statistical software developed in the Lithuanian Institute of Agriculture was used, ANOVA method applied [19].

Mean air temperature and amount of precipitation were assessed during hemp growing period (Table 1).

Hemp germinated approximately in two weeks after sowing. It was warm and rainy in the middle of May (the amount of precipitation was twice more than the long-term average for second ten-day period of May). June was slightly cooler that long-term average but abundant in precipitation. It was warm in July and August, but the amount of precipitation was again huge, and even oversupply as the water for some time was flooding some surfaces on the trial field. Hemp and weeds were thriving over the vegetation period.

TABLE 1.

MEAN WEATHER TEMPERATURE AND PRECIPITATION DURING HEMP GROWING PERIOD

Upytė, 2014

Month	Ten-day period	Mean weather temperature, ºC		Rainfall, mm	
		2014	Long-term average	2014	Long-term average
May	I	8.2	11.0	23.5	16.0
	II	13.8	12.6	34.0	16.0
	III	16.8	13.5	7.5	18.0
	Aver./total	**12.9**	**12.4**	**65.0**	**50.0**
June	I	17.0	14.4	12.0	22.0
	II	13.2	15.3	27.0	23.0
	III	12.6	16.2	71.0	24.0
	Aver./total	**14.3**	**15.3**	**110.0**	**69.0**
July	I	19.0	17.2	49.5	25.0
	II	18.8	18.0	20.0	25.0
	III	21.9	18.0	23.0	26.0
	Aver./total	**19.9**	**17.7**	**92.5**	**76.0**
August	I	22.4	17.2	58.0	28.0
	II	17.0	16.1	35.5	29.0
	III	13.2	15.0	79.5	28.0
	Aver./total	**17.4**	**16.1**	**173.0**	**85.0**

III RESULTS AND DISCUSSION

One of the investigated factors (Factor B, seed rate) could influence crop density, and, perhaps, crop weediness, thus the evaluated data of crop density are discussed also. The data of investigation show, that Factor B, seed rate, had a significant influence on crop density right after full emergence (Table 2). The mean crop density was 137 plants m^{-2} at seed rate of 45 kg ha^{-1}, and significantly higher – 216 plants m^{-2} – at seed rate of 70 kg ha^{-1}.

Also some significant interaction of tested factors was found – crop density was significantly higher when sowing hemp of both varieties at seed rate of 70 kg ha^{-1}, than that when sowing at 45 kg ha^{-1}.

The same significant differences have been found at hemp harvest time (Table 3).

TABLE 2.

CROP DENSITY (PLANTS M^{-2}) AFTER FULL HEMP EMERGENCE

UPYTĖ, 2014

Variety (Factor A)	Seed rate (Factor B)		Mean for Factor A
	45 kg ha^{-1}	70 kg ha^{-1}	
USO 31	121.7	223.3*	172.5
Bialobrzeskie	152.0	209.3*	180.7
Mean for Factor B	136.8*	216.3*	-
R_{05} (variety) = 14.64 R_{05} (seed rate) = 14.64 R_{05} (variety x seed rate) = 25.36			

* – significant at 0.05 probability level;

TABLE 3.

CROP DENSITY (PLANTS M^{-2}) AT HEMP AT HARVEST

UPYTĖ, 2014

Variety (Factor A)	Seed rate (Factor B)		Mean for Factor A
	45 kg ha^{-1}	70 kg ha^{-1}	
USO 31	104.7	195.0*	149.8
Bialobrzeskie	130.3	179.7*	155.0
Mean for Factor B	117.5*	187.3*	-
R_{05} (variety) = 17.23 R_{05} (seed rate) = 17.23 R_{05} (variety x seed rate) = 29.85			

* – significant at 0.05 probability level;

Weed number counted in trial plots at full hemp emergence varied from 140 to 166 plants m^{-2}. Significantly more weeds (in average 166 plants m^{-2}) were found in the plots with seed rate of 45 kg ha^{-1}, and consequently lower crop density, and under 140 weed plants m^{-2} were found in the plots with seed rate of 70 kg ha^{-1}, and consequently higher crop density (Table 4). Variety, as a Factor, didn't have any influence on crop weediness at full crop emergence.

TABLE 4.

CROP WEEDINESS (PLANTS M^{-2}) AT FULL HEMP EMERGENCE

UPYTĖ, 2014

Variety (Factor A)	Seed rate (Factor B)		Mean for Factor A
	45 kg ha^{-1}	70 kg ha^{-1}	
USO 31	167.3	141.3	154.3
Bialobrzeskie	165.3	138.3	151.8
Mean for Factor B	166.3*	139.8*	-
R_{05} (variety) = 12.28 R_{05} (seed rate) = 12.28 R_{05} (variety x seed rate) = 21.27			

* – significant at 0.05 probability level;

Hemp crop weediness at harvesting time was much lower than that at the beginning of vegetation (Tables 5 and 4), but still abundant (12-23 plants m^{-2}). Similar amount was found at harvest in previous our investigations [20]. Perhaps, rainy period was favourable not only for hemp growing, but for weeds as well.

TABLE 5.

CROP WEEDINESS (PLANTS M^{-2}) AT HEMP HARVEST

UPYTĖ, 2014

Variety (Factor A)	Seed rate (Factor B)		Mean for Factor A
	45 kg ha^{-1}	70 kg ha^{-1}	
USO 31	23.3	12.0	17.7
Bialobrzeskie	18.7	14.0	16.3
Mean for Factor B	21.0	13.0	-
R_{05} (variety) = 6.94 R_{05} (seed rate) = 6.94 R_{05} (variety x seed rate) = 12.02			

Again more weeds were in the plots with lower seed rate, but the differences were not significant.

Reduction of hemp crop weediness during vegetation period was emphatic – in average 136 weed plants m^{-2}. The tendency is visible that reduction of crop weediness was higher (145 weed plants m^{-2}) in thinner crop and smaller (127 weed plants m^{-2}) – in denser crop (Table 6).

TABLE 6.

REDUCTION OF HEMP CROP WEEDINESS (PLANTS M^{-2}) SINCE FULL GERMINATION UNTIL HARVEST

UPYTĖ, 2014

Variety (Factor A)	Seed rate (Factor B)		Mean for Factor A
	45 kg ha^{-1}	70 kg ha^{-1}	
USO 31	144,0	129,3	136,7
Bialobrzeskie	146,7	124,3	135,5
Mean for Factor B	145,3	126,8	-
R_{05} (variety) = 16.59 R_{05} (seed rate) = 16.59 R_{05} (variety x seed rate) = 28,74			

The reduction of hemp crop weediness in ratio (in percent) to previous crop weediness (since full hemp emergence to harvest) was also calculated. It was rather similar in all plots (close to 87-90 percent) and nether seed rate (crop density) nor variety did not show influence on it (Table 7).

TABLE 7.

REDUCTION OF HEMP CROP WEEDINESS (%) SINCE FULL GERMINATION UNTIL HARVEST

UPYTĖ, 2014

Variety (Factor A)	Seed rate (Factor B)		Mean for Factor A
	45 kg ha^{-1}	70 kg ha^{-1}	
USO 31	85.8	91.5	88.6
Bialobrzeskie	88.3	89.8	89.0
Mean for Factor B	87.0	90.6	-
R_{05} (variety) = 4.89 R_{05} (seed rate) = 4.89 R_{05} (variety x seed rate) = 13.56			

Air-dry weight of weeds was significantly lower (4.5 g m^{-2}) in the plots of variety Bialobrzeskie sown at seed rate of 70 kg ha^{-1}. Data presented in Table 8 show clear tendency that air-dry weight of weeds was rather lower in the plots sown by higher seed rate (Table 8).

TABLE 8.

THE AIR-DRY WEEDS' WEIGHT (G M^{-2})

UPYTĖ, 2014

Variety (Factor A)	Seed rate (Factor B)		Mean for Factor A
	45 kg ha^{-1}	70 kg ha^{-1}	
USO 31	23.3	8.8	16.1
Bialobrzeskie	11.9	4.5*	8.2
Mean for Factor B	17.6	6.7	-
R_{05} (variety) = 5.77 R_{05} (seed rate) = 5.77 R_{05} (variety x seed rate) = 10.00			

* – significant at 0.05 probability level;

IV CONCLUSION

Seed rate had a significant influence on crop density at full hemp emergence as well as at harvesting time. Rainy vegetation period was favourable not only for hemp growing, but for weeds as well. Crop density (as a result of seed rate) had a significant influence on crop weediness – significantly more weeds (in average 166 plants m^{-2}) were found in the plots with seed rate of 45 kg ha^{-1}, and consequently lower crop density, and under 140 weed plants m^{-2} were found in the plots with seed rate of 70 kg ha^{-1}, and consequently higher crop density. Hemp crop weediness at harvesting time was much lower than that at the beginning of vegetation; reduction of weediness over the vegetation period was close to 87-90 percent.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 124-127

The toxicity of Lake Onego sediments in connection with the natural and anthropogenic factors influence

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Abstract. **The toxicity of the sediments detected in the northern bays of Lake Onego is determined by anthropogenic factors (pulp-and-paper industry and communal waste waters). Besides the toxic bottom sediments were observed in the central deep part of Lake Onego, which is connected to the geotectonic features of the area.**

Keywords: **lake Onego, bottom sediments, bioassay, anthropogenic influence.**

I INTRODUCTION

Lake Onego (the northwestern part of Russia, Karelia) is one of the largest freshwater reservoirs with a great storage of high quality water – 295 km^3 [1]. Lake Onego provides a strategic reserve of drinking water and requires special principles and methods of monitoring and protection.

At present time, the ecosystem of Lake Onego for most of its water area (in central deep parts) retains natural status, which is characterized as oligotrophic. Nevertheless, the northern bays of this lake now undergoing major changes associated with eutrophication. The main sources of pollution of the lake are situated on the banks of the northern bays. They are associated with the industrial towns Petrozavodsk, Kondopoga, and Medvezhyegorsk (Fig. 1).

Also, Lake Onego is influenced by trout farms which tend to grow nowadays. Now in Karelia annual production of trout is about 12,000 tons (70% of the total amount in Russia), of which 5300 tons are produced in Lake Onego [2]. Thus, the regular monitoring of Lake Onego is required.

According to the modern principles of biomonitoring, hydrobiological indicators are of high priority for assessment of aquatic ecosystems [3; 4]. Bioassay of water and sediment is one of the main elements of biomonitoring. Methods of sediments bioassay have been developed relatively recently [5; 6]. Their approbation is necessary for the conditions of Lake Onego.

The purpose of the report is to present the results of bioassay of bottom sediments of Lake Onego and to consider the reasons for their toxicity..

II MATERIALS AND METHODS

The field campaign on Lake Onego was carried out on the research vessel "Ecolog" in August, 2014. Samples of sediment were collected at 47 stations with depths of 4.5-104 m (Fig. 1). The upper surface (3 cm) layer of silts was selected for bioassay. According to methodology [7], aqueous extract was obtained from samples of sediment and then was tested.

Planktonic crustacean *Ceriodaphnia affinis* Lillijeborg was used as a test-organism. The biotest with using of *Ceriodaphnia affinis* (Cladocera) was adapted for the purposes of environmental monitoring about 15 years ago [8]. The species *Ceriodaphnia affinis* is the best test for express evaluation of the aqueous extract sediment toxicity [6; 9]. This species was used to evaluate the bottom toxicity of the large water bodies of the northwestern part of Russia [10].

The duration of the bioassay experiments was 5 days. All experiments were carried out at a water temperature of 19.5-21° C. The experiments were in duplicate. Five examples of crustaceans were placed in each vessel. Two kinds of water were used as a control: ground water (pH = 8.02), used for the cultivation of crustacean *Ceriodaphnia affinis*, and water from the central area of Lake Onego (pH = 7.54), used for the preparation of extracts from sediments. The survival of the crustaceans in the

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.246

control was 100%. In total 1050 examples of crustaceans were used in the experiments, including 110 examples in the control experiments.

In sediments the total sulfur content was determined by spectrophotometric method [11]. The amount of sodium lignosulfonates in sediment samples was determined by spectrophotometric method by reacting with nitric acid [12]. Organic carbon content was determined by method of Turin [13]. The amount of total nitrogen content and total phosphorus was determined by spectrophotometric method [14]. The amount of all components was calculated in percent of dry weight of sediment.

III RESULTS AND DISCUSSION

According to results of bioassay of aqueous extracts two different toxicity groups of sediments were determined. The majority of sediment samples (29 of 47, i.e. 61%) were non-toxic. On the Figure 1 the stations with non-toxic sediments are shown by dots.

The distribution of stations with different toxic sediments is presented in Fig. 1 (these stations are shown by stars). The most toxicity sediment were found in the different part of Lake Onego (Table 1). Six samples of toxic sediments (stations 6, 7, 8, 9, 10, 11) were found in the northern polluted bays. Three stations with toxic sediments (7, 8, 9) were situated in Kondopozhskaya Bay, where the main source of pollution of Lake Onego (Kondopozhskiy pulp-and-paper mill) is situated. The reasons of toxicity of sediments in the Kondopozhskaya Bay are associated with the large concentration of sodium lignosulfonate (the main component of pulp-and-paper mill wastewaters). Its content in sediments (% of dry weight) ranged 0,030-0,059. In the other samples of sediments sodium lignosulfonate was not found. Besides high concentrations of total sulfur, organic matter (organic carbon), nitrogen, phosphorus were found in the sediments of Kondopozhskaya Bay (Table 2). All these figures reflect the impact of pulp-and-paper mill, which has discharged their sewage into the Kondopozhskaya Bay for more than 80 years.

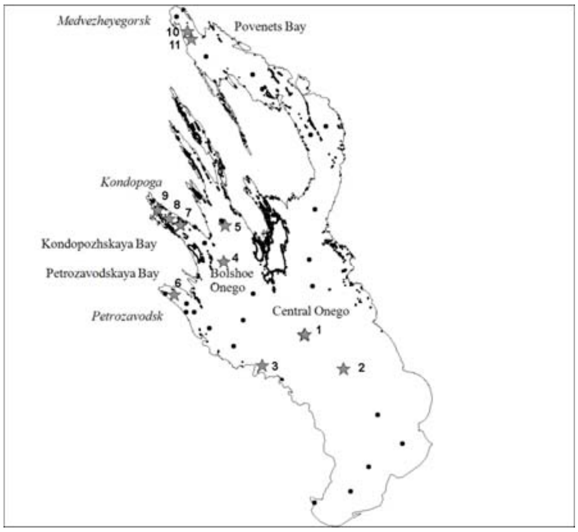

Fig. 1. The Lake Onego. Stars - toxicity of bottom sediments (survival-rate 0-30%); dots - not toxicity of bottom sediments (survival-rate 80-100%).

TABLE I

The survival rate of *Ceriodaphnia affinis* in the aqueous extract of the most toxic bottom sediments in Lake Onego

Part of Lake	Number of station*	Limits of survival-rate, %
Kondopozhskaya Bay	7, 8, 9	0–20
Petrozavodskaya Bay	6	0
Povenets Bay	10, 11	0–60
Bolshoe Onego	4, 5	0–40
Central Onego	1, 2, 3	0–40

Note: * Number of station – see Fig. 1.

TABLE II

Parameteres of the chemical composition of sediments of Lake Onego,% of dry weight

Part of Lake	Statistical parameteres	organic carbon	total sulfur	total phosphorus	total nitrogen
Kondopozhskaya Bay	Average	4,85	0,31	0,24	0,49
	Min	1,59	0,15	0,17	0,29
	max	14,66	0,58	0,35	1,06
Petrozavodskaya Bay	Average	1,67	0,14	0,15	0,23
	Min	0,54	0,08	0,06	0,17
	max	2,68	0,17	0,22	0,28
Povenets Bay	Average	4,01	0,12	0,16	0,20
	Min	0,31	0,10	0,11	0,18
	max	7,35	0,13	0,20	0,24
Bolshoe Onego	Average	1,92	0,15	0,26	0,30
	Min	0,91	0,11	0,13	0,10
	max	4,07	0,18	0,43	0,46
Central Onego	Average	3,88	0,16	0,19	0,28
	Min	2,31	0,13	0,14	0,20
	max	5,50	0,18	0,25	0,35

Increased concentration of sulfur in the sediments of the Kondopozhskaya Bay is associated with the sewage of a pulp-and-paper mill. The sulfur compounds, which are used in the wood pulping process reacts with lignin substances and form sodium lignosulfonate, which is deposited and accumulated in the sediments. It leads to an increase of the sulfur content in sediments. It can be assumed that the toxicity of sediments is connected with the pollutants that have been accumulated in sediments of Kondopozhskaya Bay.

Toxic samples of sediments were also observed in the Petrozavodskaya bay. This station (number 6) is deep (depth of 26.7 m) and is located opposite the harbor of Petrozavodsk. The area accumulates pollutants coming from the territory of the city of Petrozavodsk which determines the toxicity of the sediments. Toxic sediments were also found in the upper part of the Povenets Bay (stations 10, 11) that reflects the impact of wastewaters from the city of Medvezhyegorsk.

The toxic sediments from the central deep parts of Lake Onego (Bolshoe Onego and Central Onego, stations 1, 2, 3, 4, 5) are of the greatest interest (Fig. 1). These are the most deep areas (depth of 40-100 m). The reason of toxicity of the sediments from these areas comes from the increased concentrations of trace elements, which enter the sediment as a result of subaqueous discharge. Lake Onego, like other deep lakes of Karelia, located in the zone of tectonic faults [15]. According the data [16] in deep-water areas of Lake Onego (Bolshoe Onego) anomalous distribution of chemical parameters (CO_2, trace elements, pH) and conductivity were found in the upper bottom layer. The conductivity reached up to 140 mkS/cm in the pore water. In areas of subaqueous discharge geochemical anomalies were detected. Here, the differentiation of trace elements (Zn, Ni, Cd, Cu, Pb) and their accumulation in the solid phase and pore waters in the surface layer of sediment were observed. The concentrations of trace elements reached toxic levels for water organisms: copper – up to 130 mkg/l; cadmium – 15 mkg/l; lead – 20 mkg/l; nickel – 30 mkg/l; zinc – 1 mg/l.

Based on the bioassay data, we assume the existence of toxic factor of natural origin, which is related to the accumulation of toxic trace elements in zones of tectonic faults in the central parts of Lake Onego.

New data on the toxicity of sediments in the central parts of Lake Onego are of importance in developing lake monitoring in terms of macrozoobenthos. Heavy metals (Zn, Ni, Cd, Cu, Pb) which enter the sediment in subaqueous discharge may adversely affect the benthic organisms, namely, to limit their number in the deep area in Lake Onego. This assumption is confirmed by observational data on abundance and biomass of benthic organisms which are the lowest in the deep part of Lake Onego [17].

IV CONCLUSIONS

The results of bioassay of sediments show that the most bottom areas of Lake Onego are characterized by non-toxic sediments at present time. The toxic sediments were found in Kondopozhskaya Bay, polluted by wastewater of pulp-and-paper mill, as well as in the Petrozavodskaya Bay and in the Povenets Bay which are anthropogenically affected. The hypothesis on the existence of a toxic factor of natural origin which is related to the accumulation of toxic trace elements in zones of tectonic faults in the central part of Lake Onego is proposed. The data obtained should be taken into account in biomonitoring of Lake Onego.

The study has been financially supported by the Russian Science Foundation (#14-17-00766).

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 128-132

Social life cycle assessment of biomethane production and distribution in Latvia

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Abstract. **A social life cycle assessment is proposed for the evaluation of the social potential impact in regard to the production and use of biomethane derived from biomass (algae and manure) in Latvia. The Multi-Criteria Analysis (MCA) is used to evaluate the social performances, which have been selected based on literature, statistics and legislation data. Seven alternatives are evaluated by experts and the best alternative is figured out.**

Keywords: **biomethane, multi-criteria analysis, social impacts, social life cycle assessment.**

I INTRODUCTION

Biomethane production from algae and manure raw materials and its use in motor transport or energy production is an alternative to the use of fossil fuel. Life Cycle Assessment has shown in several studies the beneficial effect of the biomethane production pathway from an environmental point of view [1]; toward an overall sustainability perspective the social aspects represents a key issue and the Social Life Cycle Assessment (hereafter – S-LCA) a proper methodology for a wider analysis of the system. S-LCA is a technique that aims to assess the potential impact of a specific product of service toward an holistic approach, basically a cradle-to-grave approach that considers the extraction of raw materials till turning into waste [2]. Traditionally life cycle perspective is conducted for the evaluation of environmental impacts, but nowadays the attention is addressed to the social dimension, which sometimes is more difficult for a quantitative final evaluation.

Several studies and methodologies assessing the social performances have been already conducted. In 2009 the United Nations Environmental Programme (UNEP) proposed specific guidelines and methodological sheets for conducting the S-LCA process [2], [3]. Macombe et al. [4] pointed out an important research aiming to improve the methodological and empirical basis of the S-LCA at various levels of decision-making.

Dzene et al. [5] proposed a study based on a multi-criteria analysis for the evaluation of biogas use under different hypothetical scenarios for the Latvian conditions. However, only one potential social criterion was proposed in the study and thus included within the comparison, mostly due to the difficulty to collect quantitative information in regard to the social aspects.

The aim of this paper is to evaluate the possibilities of biomethane use in different applications in Latvia, highlighting the application in the area of transport.

II MATERIALS AND METHODS

A. Goal and scope definition

According to [2], the first step for the evaluation of social impact under S-LCA perspective is to highlight and identify stakeholder groups, that can be identify in terms of:

- Local community,
- Society,
- Workers,
- Consumers,
- Value chain actors.

Specific indicators within the inventory should be associated to each stakeholder group, which are assessed, taking into account information about product, or process under analysis as well as background information, which describes the situation in the state. The result of the S-LCA is strongly dependent on the geography of manufacturing and distribution of the analyzed product or system, and is also taking into consideration the non-homogeneity of welfare of nowadays world.

Looking toward the opportunity to use novel feedstock for biomethane production, marine macro algae represent an important perspective in this direction. This aspect is topical for Latvia if we consider the high level of eutrophication of the Baltic Sea that thus tent to increase the amount of growing algae biomass. Due to the difficulties to harvest marine macro algae during the winter time the co-

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.628

digestion with manure would represent a viable opportunity.

At the moment, there is no algae use for biomethane production implemented any biogas plant in Latvia, for this reason the proposed analysis is provided based on the information collected from the literature sources, legislative acts, statistical reports and reports about other similar experiences contextualized the situation of Latvia.

To evaluate the biomethane implementation from the social welfare point of view, the process is divided into the principle unit processes (or stages) that may have an impact on different social groups:

- Supply of a raw material (algae, manure),
- Raw material treatment into biomethane,
- Biomethane storage and distribution,
- Efficient usage of a digestate as a by-product of the process.

The considered stages also define the system boundary, in which the assessment is carried out. The inventory analysis is structured, being based on the distribution of processes and stakeholder groups.

According to [4], the role of the functional unit should be clarified from a LCA perspective and harmonized with the S-LCA scheme, but not always this is possible.

In fact with reference to the UNEP/SETAC (2009) methodology the S-LCA should embraced the assessment of the potential social impact through the correct selection and the analysis of social indicators. This must be in connection to the typical holistic approach of the LCA methods that involves the definition of the functional unit and system boundaries, and the final impact assessment.

The selection of the indicators is thus the crucial and key issues of the S-LCA, most of the time because are referenced to qualitative and subjective evaluations, but also because site specific information often lacking of specific information or are related to time spending analysis (such as questionnaire, face-to-face meeting with experts and/or local companies, etc..).

The “non-physical” aspects related to the information to be collected is one bottle-neck of the S-LCA method mostly if we are considering that then the social aspects must be related to a functional unit that foresees allocation and aggregation of multi-input and output unit processes toward the whole life cycle.

From a preliminary literature review it has been noticed that not many focused studies have been performed on the application of S-LCA methodology to the biomethane context (and thus connected to the fertilizer as well), but several theoretical argument have been discuss within the scientific arena [15].

Nevertheless if one is looking toward the use of the results as support tool for final decision for specific decisional scenarios the solely S-LCA should be not enough to match this question.

B. Inventory analysis: background information

According to [6], in the 4th quarter of year 2014 the level of unemployed inhabitants in Latvia reached the percentage of 33.5%, which means a third of the social group within the age range of 15-74 years. The net migration rate has been negative since 1991, and in 2013 it was 14 262 [7].

Biomethane production and infrastructure system establishment in practise may have an important impact respect the social situation mostly in connection with two issues:

- standard of living changes,
- social cohesion and stability [8].

Social cohesion is a characterization of a society, the main characteristics are the strengthening of the social relations, feeling of a common identity, trust among societal members, shared values, etc. [9].

Standard of living from an economic point of view characterizes a consumption level of a household or its income rate [8]. It is important to note that this factor has also a long-term impact such as the possibility to get education and healthcare [8]; education is one of the uppermost factors for further funding of social employment and healthcare directly affects inhabitants’ capacity for work and lifespan.

C. Inventory analysis: supply of raw materials, biomethane production, distribution and use of digestate

Stakeholders for all the process stages are local community, society and workers; biomethane storage and production also involve important effects on the value chain actors and thus can be selected as indicators for the multi-criteria analysis. Specifically the selected indicators are employment, standard of living, rational use of resources, environmental protection and security of energy supply. Moreover growth of economy, lack of competition with food crops for arable land, working conditions, fair competition etc would represent important and critical indicator to be further investigated.

For this specific case study it is suggested that manure would be delivered from the local rural areas, while for the collection of algae as feedstock two ways are proposed:

- Industrial cultivation,
- Collection of natural growing algae, i.e. the Baltic Sea.

One can consider the algae growing as a link and opportunity to raise the economic situation in a specific region thus increasing the interest of local community. The use of manure is a possibility for farmers and agricultural workers to get an additional income. According to the statistical data [10], 74K of inhabitants were employed in agriculture, forestry and fisheries in 2012. Total number of inhabitants in 2012 was 2 207 708 [11], which means that about 3% of inhabitants were engaged in these areas.

One of the advantages of algae use is the fact that there is no competition with food crops for arable lands [12, 13]. The same may be referred to manure, because it is a by-product of livestock farming not the primary end-product. Because of this, as well as of the reason that biofuel is not produced from such feedstock as corn or sugarcane, production of biomethane from algae and manure do not impact the food prices, as it is in the case of the first generation biofuels [12]. Food prices are one of the factors, which directly impact the social welfare.

As for biomethane production, plant installation can provide work places for the local community, wherewith also income and motivation not to cross the state border in the reason of employment. Amount and specificity of work places depend on the plant's production volume and level of automatization. The presence of work places is also a motive for rising generations to matriculate to specialized educational establishments and to acquire practically applicable knowledge and skills.

For storage and distribution of biomethane, a network of fuel filling stations is needed, in which biomethane would be storaged in a compressed form. This means that stations should be raised and maintained, which in both cases provides employment and welfare in the state.

Use of digestate is planned in 3 (three) types:

- In form of pellets for energy production,
- As a fertilizer in agriculture,
- As a building material.

In this case raw materials for other economic sectors are provided as a by-product of biomethane extraction; this fact raises the efficiency of use of the raw material and is connected with the welfare of the local community.

Use of digestate as an organic fertilizer is preferable for the local community, because it promotes the decrease of the concentration of nitrates in groundwater and drinking water; digestate is also preferable for the whole society, because consumers of crops, cultivated with the digestate as a fertilizer, may be located in distance from the agricultural territories.

Use of digestate in the form of pellets as a biofuel reduces the increase of carbon dioxide (CO_2) in the atmosphere and thereby prevents climate change caused by the global warming, and in such way positively influences the society's health.

One of examples for digestate use as a building material is the use of its dry fibers as a filling in plywood and similar materials. It may be considered as an economy of resources, which might be assessed positively from the point of view of local community and society.

D. Multi-criteria analysis

Macombe et al. [4] ascertained that multi-criteria decision analysis techniques can provide a methodological framework for the S-LCA.

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is applied for the assessment of social performances, by analogy on [5], [14].

Basic element of TOPSIS analysis is data matrix:

$$\begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccccc} x_1 & x_2 & \cdots & x_j & \cdots & x_n \end{array} \\ \begin{bmatrix} x_{11}^k & x_{12}^k & \cdots & x_{1j}^k & \cdots & x_{1n}^k \\ x_{21}^k & x_{22}^k & \cdots & x_{2j}^k & \cdots & x_{2n}^k \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ x_{i1}^k & x_{i2}^k & \cdots & x_{ij}^k & \cdots & x_{im}^k \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ x_{n1}^k & x_{n2}^k & \cdots & x_{nj}^k & \cdots & x_{nm}^k \end{bmatrix} \end{array} \tag{1}$$

Where $\{A_1, A_2, \ldots, A_i, .., A_m\}$ represent alternatives.

Seven scenarios with five criteria are evaluated by experts, where the scenarios ($A_1 ... A_7$)) are:

- Biogas to heat (A1),
- Biogas to heat and power (CHP) (A2),
- Biomethane with grid injection to heat (A3),
- Biomethane with grid injection to CHP (A4),
- Biomethane with grid injection to transport (A5),
- Biomethane directly to transport (A6),
- Natural gas (A_7),

And the criteria ($x_1 ... x_5$) or indicators, are social performances:

- Employment,
- Standard of living,
- Environmental protection,
- Rational use of resources,
- Security of energy supply.

The specific weights for all the criteria are regarded as equal. To make data comparable, the normalization of the values is carried out as in (2) and tabulated in a matrix.

$$b_i = \frac{x_i}{\sum_{i=1}^{7} x_i} \tag{2}$$

Normalized and weighted matrix is calculated:

$$v_{ij} = b_{ij} \cdot w_i \tag{3}$$

The determination of positive and negative ideal solution is done:

$$A^+ = \max_i w_j b_{ij} \tag{4}$$

$$A^{-} = \min_i w_j b_{ij} \tag{5}$$

Separation from Positive Ideal Solution (S^+) and Negative Ideal Solution (S^-) is calculated:

$$S^{+} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_{ij}^{+}\right)^2} \tag{6}$$

$$S^{-} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_{ij}^{-}\right)^2} \tag{7}$$

Relative closeness to the Ideal Solution:

$$C_i^* = \frac{s_i^+}{\left(s_i^+ - s_i^-\right)} \tag{8}$$

III RESULTS AND DISCUSSION

The normalised and weighted decision making matrix is given in Table 1, where A_1-A_7 are the scenarios, and A^+ (v_j^+) and A^- (v_j^-) are the maximum and minimum values, respectively.

TABLE I

NORMALISED AND WEIGHTED DECISION MAKING MATRIX

	Employment	Standard of living	Environmental protection	Rational use of resources	Security of energy supply	S^+	S^-	Rating
Criterion Weight	0.2	0.2	0.2	0.2	0.2	n/a	n/a	n/a
A_1	0.0697	0.0704	0.0742	0.0583	0.0786	0.0488	0.0778	0.6143
A_2	0.0766	0.0861	0.0865	0.0907	0.0846	0.0154	0.1071	0.8745
A_3	0.0766	0.0704	0.0680	0.0454	0.0725	0.0602	0.0721	0.5452
A_4	0.0836	0.0783	0.0865	0.0843	0.0786	0.0177	0.1021	0.8520
A_5	0.0836	0.0783	0.0865	0.0972	0.0846	0.0105	0.1113	0.9140
A_6	0.0906	0.0861	0.0804	0.0907	0.0846	0.0090	0.1104	0.9249
A_7	0.0348	0.0548	0.0309	0.0389	0.0302	0.1164	0.0000	0.0000
A^+ (v_j^+)	0.0906	0.0861	0.0865	0.0972	0.0846	0.0000	0.1164	n/a
A^- (v_j^-)	0.0348	0.0548	0.0309	0.0389	0.0302	0.1164	0.0000	n/a

Rating, or relative closeness to the Ideal Solution, is shown in Fig.1:

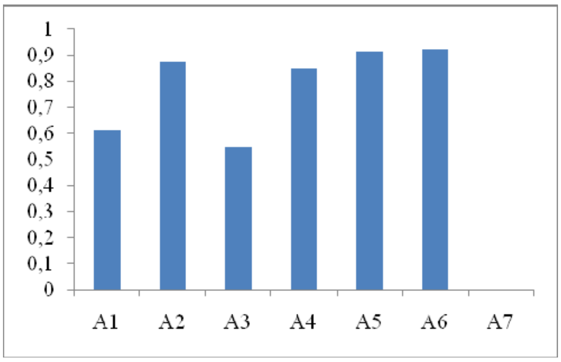

Fig.1. Rating (relative closeness to the Ideal Solution) for the evaluated scenarios

According to Fig.1, A_6 (biomethane directly to transport) has the closest to the Ideal Solution value, which is 0.9249. A_5, biomethane with grid injection to transport, has value 0.9140 and is the second of the best alternatives.

Comparing to other alternatives, natural gas is evaluated as unacceptable variant, and its rating is 0.0000.

A_6 scenario has maximum values for such indicators as employment, standard of living and security of energy supply. For the environmental protection maximal value has A_4 scenario (biomethane with grid injection to combined heat and power), and for rational use of resources – A_5 (biomethane with grid injection to transport).

IV CONCLUSIONS

Main social performances for the infrastructure of biomethane production, distribution and use in Latvia are analysed and multi-criteria analysis for corresponding alternatives is carried out. Social life cycle assessment is done according to the international guidelines of UNEP [2].

Biomethane use is evaluated as applicable for Latvian conditions, being based on the social considerations. Employment, standard of living and rational use of local resources, as well as environmental protection and security of energy supply are the main social performances, whose positive effect on the society is approved.

The result of multi-criteria analysis shows that biomethane injection directly to transport is the most appropriate alternative from the offered, and natural gas use is undesirable.

V ACKNOWLEDGEMENT

This work has been supported by the European Social Fund project “Involvement of Human Resources for Development of Integrated Renewable Energy Resources Energy Production System” (project No. 2013/0014/1DP/1.1.1.2.0/13/APIA/ VIAA/026).

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 133-136

The Importance of Geoheritage and Geo Top of the Charts in Environmental Studies

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Abstract. **scientifically the following categories are excluded: biodiversity, geoheritage, geodiversity, geo tops, nature objects and others. They are important from the scientific, aesthetic, tourism, cultural points of view. The aim of environment sciences has to be to analyse the categories exhaustively and to determine the conditions of protection.**

Keywords: **geoheritage, geodiversity, geo top, geosites.**

I INTRODUCTION

Quite often we read, hear and talk about the importance of saving biodiversity, about how environment pollution harms biodiversity, about how the growth of population requires growing more food sources and in this way the habitat areas – the home of biodiversity – are decreasing. But we rarely talk about the destruction of geological and geomorphologic objects because of the same reasons, especially because of agricultural development, construction. The mechanic erosion destroys the hills, deteriorates the soil. Contaminated ground water fastens the karst phenomena. Mining industry, large building move the ground surface, cause landslides, sometimes even earthquakes. New cultural layers destroy the surface that often can not even be recorded by scientists to preserve at least the graphic view of territory for the future research. For some time the world's geologists and geographers are trying to carry out as many scientific ground surface researches as possible, to present the results to the colleagues scientists, to the public and to the governments of their countries. But too little attention is paid to these spheres in the system of environmental sciences.

II RESEARCH METHODS

It is important to determine the priorities of research and protection. More than twenty years ago, scientists have made a distinction only one category - the geographical extremes. There are the largest, longest, deepest natural objects. Now scientists distinguish much more categories. For example geodiversity, geohertage, geosities and other. Firstly, we need to determine what the geodiversity is, what most important objects should be included into the geo tops and geoheritage lists and to determine the level of their protection.

"Geoheritage" is a generic but descriptive term applied to sites or areas of geologic features with significant scientific, educational, cultural, or aesthetic value. Scientifically and educationally significant geoheritage sites include those with textbook geologic features and landscapes, distinctive rock or mineral types, unique or unusual fossils, or other geologic characteristics that are significant to education and research. Culturally significant geoheritage sites are places where geologic features or landscapes played a role in cultural or historical events. Aesthetically significant geoheritage sites include landscapes that are visually appealing because of their geologic features or processes. Many geoheritage sites can be tourist destinations and provide local and regional economic benefits."(Geological Society of America). [1]

Geoheritage is similarly defined in the recommendations of Council of Europe (2004) – it is scientific, cultural, aesthetic, landscape, economic and generic value of natural geological objects that must be preserved to the future generations. Present experience shows that geoheritage can be used for recreation, educational tourism, education and training but the most important its value is scientific. [2]

Geoheritage sites (Geosites) serve the public interest. Such sites are critical to advancing knowledge about natural hazards, groundwater supply, soil processes, climate and environmental changes, evolution of life, mineral and energy supplies, and other aspects of the nature and history of Earth. Such sites have high potential for scientific studies, use as outdoor classrooms, enhancing public understanding of science, recreational use, and economic support to local communities. Geoheritage sites can be small but scientifically significant sites. Geoheritage sites can also be extensive areas with international recognition. Large or small, and regardless of ownership, many are

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.253

vulnerable to urbanization, infrastructure development, agriculture, over - use, or erosion. Conservation strategies appropriate to the type of site and nature of ownership are important to protect geoheritage sites from loss and maintain them for the long - term public interest. (Geological Society of America). [1]

World Heritage areas are also widely representative of geological and geomorphological phenomena, including:

- arid landforms;
- caves and karst;
- coasts, reefs and islands;
- ice fields and glaciers;
- fluvial, lacustrine and estuarine systems;
- mountain regions;
- tectonic, structural and stratigraphic features;
- volcanoes.

There are many geological sites around the world that are of international importance and we have a responsibility to conserve this geological heritage. [3]

III RESULTS AND DISCUSSION

While analysing and preserving biodiversity, geodiversity can not be forgotten because it is the guarantee of the habitats stability for the all living organisms and their living territory. Only if the geodiversity is large, it is possible to distinguish unique and reference objects of geoheritage.

Geodiversity can be described as the variety of elements of geology — the rocks, minerals, fossils and soils — and the natural landforms and processes that shape them throughout geological time. Best known are those rare and exceptional occurrences such as dinosaur footprints or mammoth tusks, but there are many more less exceptional, but equally important, pieces of the geological jigsaw puzzle. When pieced together, these give an insight into past climates, earlier environments and life on earth. Geodiversity also recognises the link between people, landscape and their culture. The recognition of the concept of geodiversity represents an opportunity for the geological sciences to raise their profile, and raise awareness of the importance of abiotic (physical rather than biological) parts of ecosystems. Geodiversity is the process of recognising and assessing the value of geological features, collections, sites, monuments, artworks, and landscapes and the application of practices for their care, maintenance and management for the long-term benefit of all. [3]

Geodiversity is extremely important. It describes the diversity within abiotic nature and gives it a name with which people can relate to the idea that it is important. Not only the geology but the records of the geomorphological processes that have created the landscape we see today on top of which the archaeology produced by our ancestors has barely scraped the surface. Without this diversity we would not be able to live on this planet. It describes the beginning of the Earth and life on the planet; the massive processes that have formed our continents and oceans; the minerals, rocks and fossils that hold out mineral wealth in the form of ore and fossil fuel resources; the climates the planet endures many of which we have learned to thrive in such as rivers, coastal environments, glaciation, deserts and finally the record of continual processes like weathering and formation of soils. [4]

An area of geodiversity encompasses:

- the interactive relationships between geology and other interests;
- sites or features where representative examples of the areas of geological deposits and features can be seen;
- the historical legacy of geological research within the area;
- sites and features currently used in interpreting earth science;
- the location and nature of past and present mineral workings;
- the influence of geology in shaping the built and man-made environment;
- materials collections and records, published literature and maps.

All geological features are potentially vulnerable. In addition to obvious threats posed by inappropriate site development and the infilling of quarries, geological sites are also threatened by the encroachment of vegetation, natural weathering and general deterioration, which with time, may damage or obliterate important geological features. [3]

At the global level a number of conservation programmes now recognise, or are beginning to recognise, that geodiversity is an important element in our natural heritage, must be managed effectively if we are to realistically manage biodiversity, and is a potentially important component of sustainable development strategies, particularly in the developing world.

Global programmes include the World Heritage Convention, the Global Geopark Network supported by UNESCO and the Convention on Biodiversity. These provide the basis for international recognition of natural heritage management, but draw upon local and regional actions to make them a reality.

Many global programmes can only be effective if they recognise the need for close involvement by local communities in heritage management programmes. Local community involvement can only happen if the people who live and work in an area understand and value the heritage with which they live and for which they have a responsibility. [3]

So, it is important for the scientists, the governments, the media, the education to disseminate the most comprehensive information about the natural objects in the people‘s living environment that are significant from the scientific, aesthetic and tourism point of views. It goes without saying that the private property has to be respected and if the individuals do not want to have tourist attraction object in their plot, they have a right not to let the tourist in but the scientific researches have to be admitted as public interest and must be allowed. The scientists and the government should arise people's feeling of pride and encourage them to preserve the protected natural object. Some of natural objects were considered sacred pagan times. Part of the springs so far used for food and health promotion. Some of Geo top describe in legends and mythological story. Following these Geo top research showed that the legend reminds reality. Environmental sciences must be encouraged and their research spheres must be extended as much as possible. All the possible natural objects – living and non-living – must be explored. Having set the unique natural objects, they must be explored as comprehensively as possible, described and all the possible preservation options must be identified.

These labels and boundaries provide convenient areas to deal and work with, but geodiversity can and should be recognised beyond these protected area boundaries. Concepts and techniques can be applied at local, regional and national scales and geodiversity management can be successfully carried out to effectively promote geodiversity management. In many countries worldwide, geodiversity and geoconservation is being recognised for its value and importance. [3]

The Global Geopark Network (GGN) supported by UNESCO was established in 2004 to conserve Earth's geological heritage, as well as to promote the sustainable research and development by the concerned communities. The GGN membership is formed by national geological parks, or geoparks — local areas focused on the protection of geological features and heritage.

The first members to the GGN were announced during the first International Conference on Geoparks in 2004. To date (January 2014) 100 geoparks from 30 countries are officially part of the GGN family. The European Geoparks Network (EGN), established in 2000, now consists of 49 Geoparks from 19 European Countries. Working together, the members co-operate to promote the protection of their geological heritage and to use that heritage to promote sustainable economic development in their respective regions. Of the 936 sites inscribed on the World Heritage List, 725 are cultural, 183 are natural and 28 are mixed sites. Only 20 are inscribed primarily because of their geological interest. [3]

In Lithuania UNESCO mostly protects the cultural objects. The Curonian Spit (Kuršių Nerija) is natural object partly protected by UNESCO. However, the most important international object to environmental sciences and all the geo sciences is Struves (Struvės) geodetic arch, the information about it is not spread widely.

One of the largest and most impressive attempt to analyse and determine the size and form of the Earth was the triangulation chain, made in 1816-1852. The Earth meridian's arch, which almost coincides with the edge of West and East Europe, stretched from the mouth of the Danube by the Black Sea to the Fuglenes (Norway) on the coast of the Arctic Ocean, i.e. from 45°20' to 70°40' of North Latitude. It crosses a few current states: Norway, Sweden, Finland, Estonia, Latvia, Lithuania, Belorussia, Ukraine and Moldavia. To calculate the arch's length and position, the measured fragments of triangulation nets in the above mentioned countries were used. When they were joined, the chain of 2820 km was obtained. The geographic latitudes difference between the edge points of this chain was 25°20'. At that time it was the most accurately measured and the longest arch of the meridian, its measurements results for entirely century were used to calculate and to specify the parameters of the Earth ellipsoid. [5]

The results of F.G.W.Struve‘s work were included in all the Earth ellipsoid parameters‘ calculations later made on the basis of the triangulation. This arch of the Earth meridian calculations has a huge scientific and cultural value. That is the reason why Finland Land Service and Finland Geodetic Institute in 1993 offered to include Struve (Struvės) geodetic arch into the UNESCO World Heritage List and to perpetuate the most important geodetic points of the meridian arch as the UNESCO World Heritage object.

The National Land Service by the Ministry of Agriculture and Vilnius Gediminas technical university‘s Geodetic Institute chose and offered to perpetuate 3 geodetic points of Struve (Struvės) meridian arch out of 18 in Lithuanian territory – in Meskonys (authentic used form Meschkanzi), in Paliepiukai (authentic used form Beresnaki) and in Gireisiai (authentic used form Karischki) (now they are points of national geodetic net). [5]

The experience in the sphere of international cooperation geological heritage (e.g. in the association of Europe geological heritage) preservation and in other spheres allows to state that Lithuania's geological peculiarity is the continental glaciers and warm periods change history that is preserved in the geological layers and the forms of relief. This history covers all the period of quaternary from the oldest ice-age to the retreat of the latest glacier. Such quaternary history, full of geological witnesses, can not be found in any of the neighbouring or northern countries. The other important aspect – is the history of the last ice-age, palaeogeography, the diversity of all the classical forms left in the relief of our region. Besides, the relief also underwent the ice-age processes. [2]

Geoheritage – is the remembrance of the Earth that must be saved to the new generations for Earth knowledge, scientific research that is constantly improving. It will never be too much of taking care of natural values, including geoheritage. It is a wide range of activities including the heritage value increasing, cleaning, public education and spread of information. There are 286 geological objects protected by state or municipalities in Lithuania. Beside the state protected geoheritage objects, there is one more geoheritage category – geo tops. They are scientifically and educationally (unique and reference) important geological, geomorphologic, hydrogeological objects and their groups – forms of relief, outcrop, boulders and their accumulations, high yield or increased mineralization ground water springheads, excavations, exposures and others. Very often they have huge aesthetic, tourist, archaeological, historical and cultural value. Most of them already have the status of nature heritage objects, the others are potentially claimed to be protected by the state. Part of the geo tops are in the private property or formed by human. [6]

For 20 years – since 1995 – geo tops are analysed and registered by Lithuania Geology Service by the Ministry of Environment. They are registered in the Geo tops subsystem of the State geology informative system. In this subsystem it is possible now to find information about 597 geological, geomorphologic, hydro geological and hydrographical natural heritage objects. They include 138 springs, 97 outcrop, 2 escarpment, 13 ravines, 54 huge hills, 15 grottos and suphosic cirques, 13 dunes, 1 cave, 12 eskers, 19 rocks, 175 boulders and 10 their exposures, 6 islands and peninsulas, 10 walls in the quarries, 11 sinkholes, 9 springy meadows, 12 continental dunes.

Geo tops are determined by carrying out state geological mapping, special scientific research, getting information from research organisations, individual nature explorers and promoters, and the directions of protected territories. [7]

Every state (municipality) has to „collect“ (register) its explored geocollection made up from geodiversity, geoheritage, geo tops and other reference and unique natural objects. This list will enable to know the available objects, research, protect them and be proud of them.

IV CONCLUSION

1. Geosites are analysed, the geo tops and geoheritage objects are distinguished, their scientific, aesthetic, tourism value is determined, the governments are offered to determine the mode of their preservation.
2. The Global Geopark Network supported by UNESCO and UNESCO protect the unique geoheritage objects and geoparks or geosites.
3. The state has to register its explored geocollection.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 137-140

A comparison of different charcoal production technology outputs

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Abstract. **Charcoal is a renewable material, with a long history of use as the predecessor of fossil fuels, now beginning to regain its place in the market, as the global society is fighting the Climate change. Charcoal along with bio-oils, and pyrolysis gas or syngas is obtained through thermo-chemical conversion of biomass. There are several different turns the charcoal production development has taken. The oldest charcoal production technologies are the batch-type kilns, they are associated with lower costs, and are widely used in the world, mainly in developing countries. A more recent introduction in charcoal production is the continuous operation retort where the biomass is conveyed through different process stages, heating and drying, carbonization, and cooling. This technology draws up high capital investments, but can reach a high level of automation. Apart from these technologies charcoal can be also obtained as a by-product in liquid and gaseous fuel production via pyrolysis and gasification of biomass. Each of the production methods can yield variant quality charcoal with properties distinguishing different charcoal applications. The charcoal use varies from a high capacity fuel to a sustainable soil amendment, adsorbent, source of carbon in chemical reactions, and many more. In this study an evaluation of the charcoal quality parameters, depending on the applied technology, is carried out. The analysed data includes information retrieved from previous studies, as well as an experimental investigation of real life production facility.**

Keywords: **pyrolysis, renewable resources, thermochemical conversion, quality parameters, heating value.**

I INTRODUCTION

Seeing the upcoming United Nations Climate Change Conference 2015, held in Paris, France, it is clear that increasingly harsh emission reduction and Climate Change mitigation means are going to be applied. The outcome of this Climate Policy event will cover all countries, and will be implemented starting from 2020. In the European Union are ongoing discussions on setting the emission reduction by 40% below 1990 level. [1]

A large focus for the emission control has been spared for the alternative energy resources, with a significant part of biomass as an energy resource. As biomass is a renewable material that participates in the active lifecycle of atmosphere carbon, it is assumed to be carbon neutral not like the fossil fuels.

Charcoal in the form of biochar is gaining an increasing attention as an attractive solution for trapping carbon dioxide in the ground. However, the use of charcoal as a substitute for fossil fuels in energy-intensive processes, and renewable biofuel should not be forgotten. A large share of the alternative energy sources can be useful in low temperature systems, as they provide low potential heat, for example waste heat from different industries, ground heat (retriever either by heat pumps or directly), some of the solar technologies etc. Direct biomass fuels on the other hand can provide higher potential energy, though not high enough for the most energy intensive industries. Charcoal is distinct from other wood fuels with its high heating capacity. Good quality charcoal can even exceed the heating capacity of fossil coal. The energy content of good quality charcoal ranges from 28 to 33 MJ/kg. In comparison to the flame temperature of maximum 850 °C reached by burning wood fuels, the temperature of burning charcoal can reach 2700 °C, withal burning without flame and smoke. [2] This makes it suitable for using in metal smelting and other energy intensive industries, which actually was the initial use of charcoal, and the prerequisite of the development of these industries.

II MATERIALS AND METHODS

The quality of charcoal as a fuel is described by several quality parameters. In this study the selected quality parameters are the moisture content, ash content, and the calorific value of the input and output material. The pyrolysis process is analysed in terms of the changes of these quality parameters due to the thermal conversion. In order to do that a literature study is performed to analyse the batch-type kiln

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.263

productions, but the continuous charcoal production retort has been subjected to a throughout process experimental evaluation. Samples are taken to characterize the feedstock as well as the output production, while registering the retort working temperatures. The samples are tested according to the following methods: Determination of moisture content LVS EN 14774-2:2010 [3], Determination of ash content LVS EN 14775:2010 [4], and Determination of calorific value LVS EN 14918:2010 [5].

The efficiency of conversion of firewood to charcoal is calculated from the overall firewood consumption, and the produced amount of charcoal in the industrial experiment period. The value is calculated for the input firewood at the average moisture content as specified in Table 1.

III RESULTS AND DISCUSSION

A. Batch-type Kilns

The largest share of the overall charcoal production in the world is produced in different types of batch kilns. The most ancient of which are the pit or mound turf kilns, then slightly upgraded to Casamance kilns by providing exhaust pipes for the pyrolysis gas. These are suitable for small yields, while brick kilns for a larger scale production. In the study by Sparrevik et al. [6] the efficiency of biomass conversion in a brick kiln is stated to be 34.5%. The paper by Bustamante-García et al. [7] states the calorific value in a beahive brick kiln from 25.2 to 33.9 MJ/kg for branches and cracked firewood. The variation depending on the material, as well as the material position in the kiln. In this study the Moisture content of the produced charcoal varied from 3.2 to 3.9%, and the ash content from 3.7 to 6.7%. In the same type kiln in a paper by Bailis et al. [8] the calorific value of Eucalyptus charcoal is 27.6 MJ/kg.

In a detailed study by Xiong et al. [9] in an experimental batch reactor cotton stalk and bamboo sawdust was pyrolysed. Char with a calorific value of 26 to 28 MJ/kg, and 29 to 32 MJ/kg respectively was yielded. The char yeald varied from 31.2 to 37.4% for cotton stalks, and from 31.2 to 37.4% for bamboo sawdust, while the ash amount in the char varied from 6 to 26% for cotton stalks, and 4 to 19% for bamboo sawdust. The variation was dependent on the pysolysis temperature, which was changed from 400 to 800 °C.

In the study by Harouna et al. [10] the pyrolysis of cotton stack in a metal kiln is analysed. The highest heating havlue of the cotton stalk is 19.1 MJ/kg, while for the derived charcoal 22.5 MJ/kg.

The main distinction of more advanced pyrolysis technologies from the traditional kilns is that the process heat is not provided by burning part of the input biomass material, but the process is sustained using the pyrolysis gas produced during the pyrolysis process itself. In this way higher process efficiency is obtained.

The first of the pyrolysis technologies that provided this option are so called Adam retorts. The charcoal yield in an Adam retort stated by Sparrevik et al. [6] is 30.4 to 33.9%.

B. Continuous Retort

Continuous production retorts are a relatively new technology for charcoal production. There is a gap of knowledge in the field of continuous pyrolysis process, thus an experimental research is commenced in this field. The use of this continuous retorts offer a shorter time span for generation of charcoal, higher process control, and a lower possibility of production loss. One of the main setbacks for the prevalence of this technology is the high capital costs.

The experimental evaluation and the field testing of the industrial Lambiotte SIFIC/CISR 2000 type continuous production retort shows a balanced process and a stable product quality.

The material and product quality is summarized in Table 1.

TABLE 1

CONTINUOUS PRODUCTION MATERIAL QUALITY*

Parameter	Units	Input - firewood	Output - charcoal
Moisture content	wt-%	12.3	3.4
Ash content	wt-%	1.0	2.8
Gross calorific value of dry mass (at constant pressure)	MJ/kg, d	18.7	32.8
Net calorific value as received (at constant pressure)	MJ/kg	16.1	31.2

* Analysis results applies only to the examined samples, since the biomass is an non-homogeneous material

The charcoal quality parameter values in Table 1 are given for an average of five separate loads. The input material is dried in a batch type chamber-dryer, aiming to lower the moisture content of the firewood below 20%. The output charcoal absorbs moisture from the atmosphere, so the moisture content of the production depends on the storage environment.

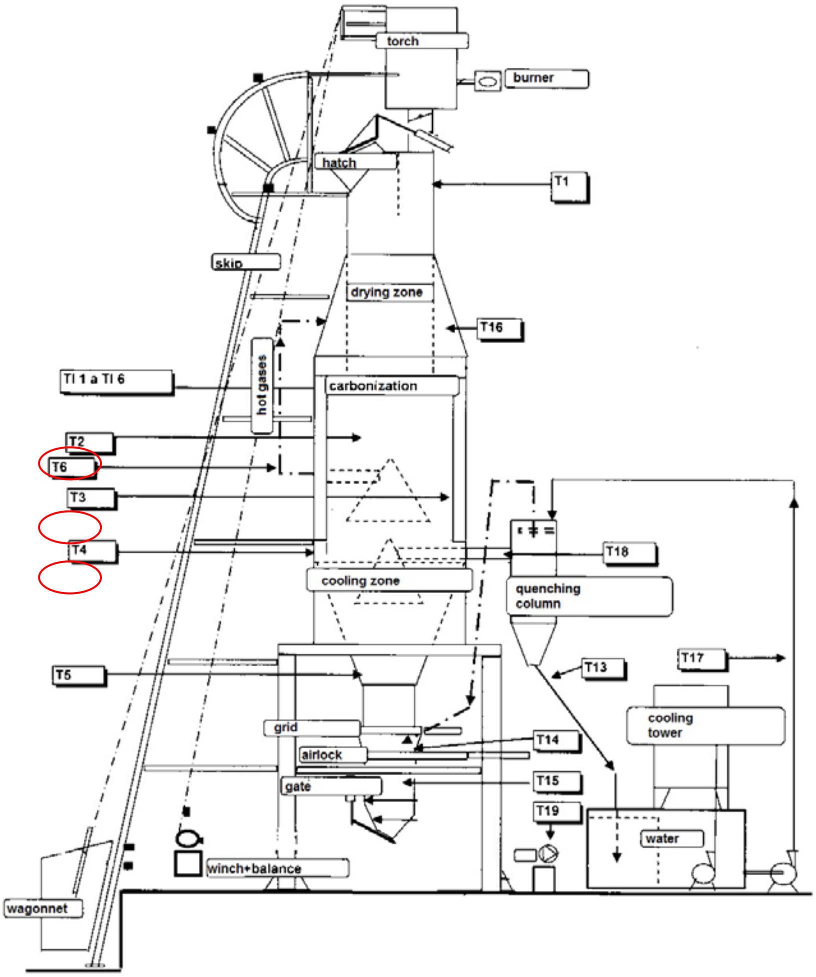

Fig. 1. Schematic representation of the Continuous pyrolysis process retort Lambiotte SIFIC/CISR 2000.

The Fig. 1 shows the schematic of the studied technology. The schematics show the main temperature control parameters (marked with a capital letter T) that are available at the technological process control.

The charcoal is produced in a stabilized mode, with the average carbonization temperature of 560 °C, varying from minimum of 529 °C to maximum of 591 °C (see Fig. 2).

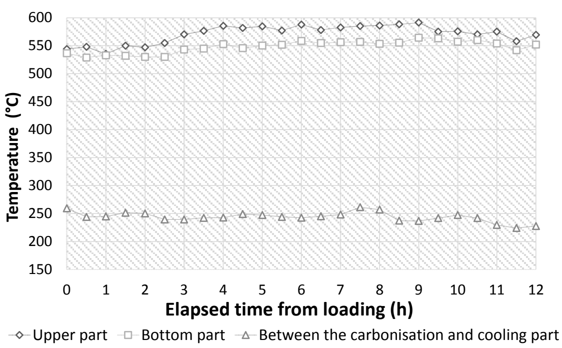

Fig. 2. Carbonisation process characteristic temperatures in a continuous pyrolysis process retort. In Fig.1 the Upper part temperature measurement point represented as T2, Bottom part as T3, and between the carbonisation and cooling part as T4

The conversion efficiency in terms of produced charcoal mass is discovered to be 62%. In other words one kg of charcoal is obtained from 1.6 kg of firewood (at 12.3% moisture content).

C. Charcoal as a By-product

If the pyrolysis process is aimed at a higher share of bio-oil or pyrolysis gas production, the produced charcoal amount and quality will be lowered. The pyrolysis of beech wood in a steel reactor was undergone in the study by Demirbas [11]. This study points out that while the bio-oils are produced the obtained char has a satisfying quality to be used as a biofuel. The obtained char has the highest heating value of 33.2 MJ/kg.

D. Hydrothermal Carbonization

Hydrothermal carbonization is a thermo-chemical process undergone in the presence of water at increased temperatures and pressure. The process produces a material in the form of a char-water-slurry, the char can be separated and dried. This method is suitable for biomass feedstock with a very high moisture content, such as sewage sludge. The energy content of the obtained chars at carbonization temperatures from 140 to 200 °C range from 21.5 to 23.3 MJ/kg, using sewage sludge as a feedstock. [12]

In the study by Álvarez-Murillo et al. [13] olive stones were used as the input biomass. The Hydrothermal carbonisation yealded a fuel with the highest heating value from 22.2 to 29.6 MJ/kg. This is a similar result as in the study mentioned previously. The main advantage for this method is the energy densification that otherwise would be spread in the body of the wet sludge, giving an oppurtunity to recover valuable energy.

In the study by Lench Nowicki and Maciej Markowski [14] pyrolysis of dried sewage sludge in a fixed-bed reactor is performed, and the obtained char has a heating value of 5.6 and 9.8 MJ/kg, with an ash content of 85.6 and 69.1 wt.%. The pyrolysis was performed at 1000 °C. Although the initial material characteristics used in the hydrothermal carbonisation experiments are not given, it could be inclined that for biomass with a very high moisture content as sewage sludge, hydrothermal carbonisation returns char with the calorific value suitable for using it as a fuel.

IV CONCLUSIONS

The produced charcoal quality is directly related to the material that is used as the feedstock. Nonetheless the selected pyrolysis technology also significantly influences the received product. In batch-type kilns a non-homogenous product quality can be suspected. The advantage of a continuous type pyrolysis retort from the experimental evaluation stands out the high mass convertion share of around 60% while that of above 30% for the traditional batch-type technologies. There is a lack of data to make concluding statements for the comparison of the obtained charcoal quality, as the used material has such a high influence. The experimental evaluation of the industrial production in a continuous retort reveals satisfying results in terms of the obtained charcoal quality. The densified energy in the charcoal makes it suitable for using as a substitute or an addition in a fuel mix for energy intensive manufacturing, such as metal smelting. However the increased ash content has to be reckoned when working with charcoal.

V ACKNOWLEDGEMENTS

The work has been supported by the National Research Program “Energy efficient and low-carbon solutions for a secure, sustainable and climate variability reducing energy supply (LATENERGI)”.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 141-147

GEOECOLOGICAL MARKETING OF TOURIST – RECREATIONAL ZONES OF CITIES TERRITORIES

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Abstract. **Now, practically in the all territory of the Russian Federation and, in particular, in it's Northwest federal region we can say about The Russian Renaissance with strongly pronounced elements of eclecticism. It's no coincidence, as the nature-innovative potential forces to think about investment many means on development of the real estate and tourist-recreational zones as a whole. Answering repeating questions, where are the most dangerous areas for an investment of means and for the business organization, in particular, in St.-Petersburg, even more often you are surprised to such questions, understanding that danger can proceed, first of all, from a geoecological situation on cities territories. We don't have reservations and/or divisions of administrative areas by a principle poor/rich and/or our and another's areas. You can feel genuine pride from comprehension of our deep tolerance. Means, it was possible to accept all the best, to learn to understand associates, to appreciate friendly relations, to live, without giving in to minute tendencies and the imposed stereotypes introduced by market relations.**

Keywords: **Sustainable development, Tourist-recreational territory, Environment assessment, allotment assignment, Tourism development, tourist-attractive, recreation infrastructure.**

I INTRODUCTION

From the point of view of the sustainable development the tourism is a profitable part of the budget of any country. The tourism development is a complex of common problems: allotment assignment and amenities, tourist product detection, distribution of human flows, the specialist education, organization of a transportation system and infrastructure, maintaining continuity of power supply, waste utilization, geoecological marketing of tourist-recreational zones of cities territory etc.

According to above-stated there are especially actual problems, bound up with:

- detection of tourist-attractive and safe places;
- detection of places for sporting objects development and building;
- environment assessment;
- infrastructure development;
- tourist and sport objects management.

II SUSTAINABLE DEVELOPMENT OF TERRITORIES OF RESORT, TOURISM AND SPORT FOR CITY REGIONS

Thus, it is necessary to create the integral tool for lowing man-hours for making concepts of terrain development in the recreational purposes, and also being a universal support instrument for detection location and designing of tourism and sports objects. Besides the tool tested in pilot area can be transferred in other countries for the purposes of the sustainable development. The given project is dedicated to the solution of these problems.

The purpose of the project is the creation of an integral geoinformation analytical complex with the applications as 3D interpretations for tourism and sports objects of the pilot urban. And also:

- making of a methodology of reasonable detection of terrains suitable for recreational activity;
- giving recommendations of their making and usage;
- making of specific land use scheme according to recreation kinds on the basis of environment analysis;
- real estate management and expertise and the sustainable development of territories with different requirements and technical-engineer capabilities (natural, anthropogenic, technogenic).

Direction of activity:

- Application of the decision support systems for sustainable development of territories
- Engineering of the renewable energy & water power for recreation territories
- Geoecological modeling and management of recreation infrastructure (tourism, sport, resort)
- Improvement of GIS of the recreation territory

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.267

- Databases
- Education programs for innovative engineering recreation territory use.

III BASIC REGULATIONS GEOECOLOGICAL ASPECTS OF TOURIST - RECREATIONAL ZONES

In case with fast development of tourism both sports and amateur the need for development tourist - recreational zones promptly increases. There are few officially accepted kinds of tourism: Foot, ski, mountain, water, bicycle, speleological, automobile, motor and ecological tourism.

At construction of objects of ecological, water, sports, speleological, extreme and other kinds of tourism, it is necessary to provide safe stay of sportsmen and having a rest, for this purpose it is necessary to consider geoecological aspects of built up territory.

Following geoecological aspects are considered:

- Nature management;
- Arrangement of a natural landscape.

The Nature management considers functionality using of built up territory, including quality estimation of an environment, limiting stability of development, geoecological risks estimation and liquidation of these risks in view of all requirements for preservation of stable geoecological safety in recreational zone all stages of its development.

Principles of maintenance of geoecological safety are based on Nature management and should be:

- based on use mainly natural resources;
- don’t putting damage to environment and don’t allowing the minimal damage which undermines ecological stability of environment;
- aimed to ecological formation and education, to format attitudes of equal partnership with the nature and territorial resources of development;

Considering geoecological aspects is necessary to analyze a system decision of requirements on territory using technological process, according to rational arrangement of a natural landscape.

Arrangement of a natural landscape is provided at information of an inhabitancy, availability of decisions, liquidity of development, considering seasonal prevalence and assimilability.

Formation tourist - recreational zones passes in two stages. One is carrying out the researches of geoecological marketing and concept statement of development is necessary. The second stage is planning of construction measures an infrastructure of the zones.

The future rates of urbanization and pollution of natural landscapes constantly increasing, therefore it is necessary to follow some factors to keep and provide favorable ecological development:

- The hotels, camping’s or shelters and huts where tourists stop should be located to save normal, ecologically steady development of a neighboring landscape.
- These hotels camping’s should be constructed of ecologically harmless materials and their inhabitants should not excessively spend energy and water, thus drains and emissions are cleared other waste are utilized;
- Should be provided transport availability and infrastructural security.

According to geoecological aspects of development tourist – recreation zones form the preservation of quality of an inhabitancy and as consequence a basis of health and safety of sportsmen and having a rest.

IV BASIC PRINCIPLES OF FORMATION OF TOURIST AND RECREATIONAL TERRITORIES

As for megalopolises and city agglomerations the analysis of town-planning development is kept, and for all settlements and development area to the comparative analysis is exposed:

- climatic conditions;
- territorial structure;
- demographic situation;
- master plans of development area;
- transport infrastructures of the territory.

The tourist - recreational territory is the territory having natural, historical, cultural potential for formation of requirement in a healthy lifestyle and preservation of a sustainable development through an ecological health and safety out of production, possessing the status of the protected and kept habitat, favorably influencing on the development of real estate.

So basic principles of formation of tourist-recreational territories of the historical cities both in Europe, and in Asia:

1. The existing landscape - ecological and historical - cultural frameworks are used as a basis of formation of structure of tourist and recreational zones.
2. Unprofitably used territories and real estate accustom as tourist and recreational zones and territories
3. The main priorities of specialization of tourist - recreational zones, scales of their liquidity and sequence of development are formalized.
4. Formation of system of tourist - recreational zones is conducted in the conditions of the existing and formed transport infrastructure.

Anyway the main attention at the present stage is more and more paid to identity of elements and details.

Before starting using this or that model of reconstruction - renovation revitalization of the development area it is necessary to carry out geoecological justification for formation of system of geoecological marketing of the tourist and recreational territory subsequently. Methods and the principles of reconstruction-renovation-revitalization will depend on it:

1. Existence of real estate objects of natural and cultural heritage.
2. Condition of rare and valuable architectural - planning and landscape - composite elements.
3. Valuable historical and religious environmental characteristics.
4. Unique real estate objects and monuments of architecture.
5. The protected wild types and natural landscapes, reserved zones.

V BASIC CONCEPTUAL PRINCIPLES OF GEOECOMARKETING

The ways of formalizations of geoecological marketing of tourist-recreational zones of development of cities territories which are based on conceptual bases of marketing and the theory of preservation of the environment in the conditions of a sustainable development of cities territories, are presented in a general view on fig. 1.

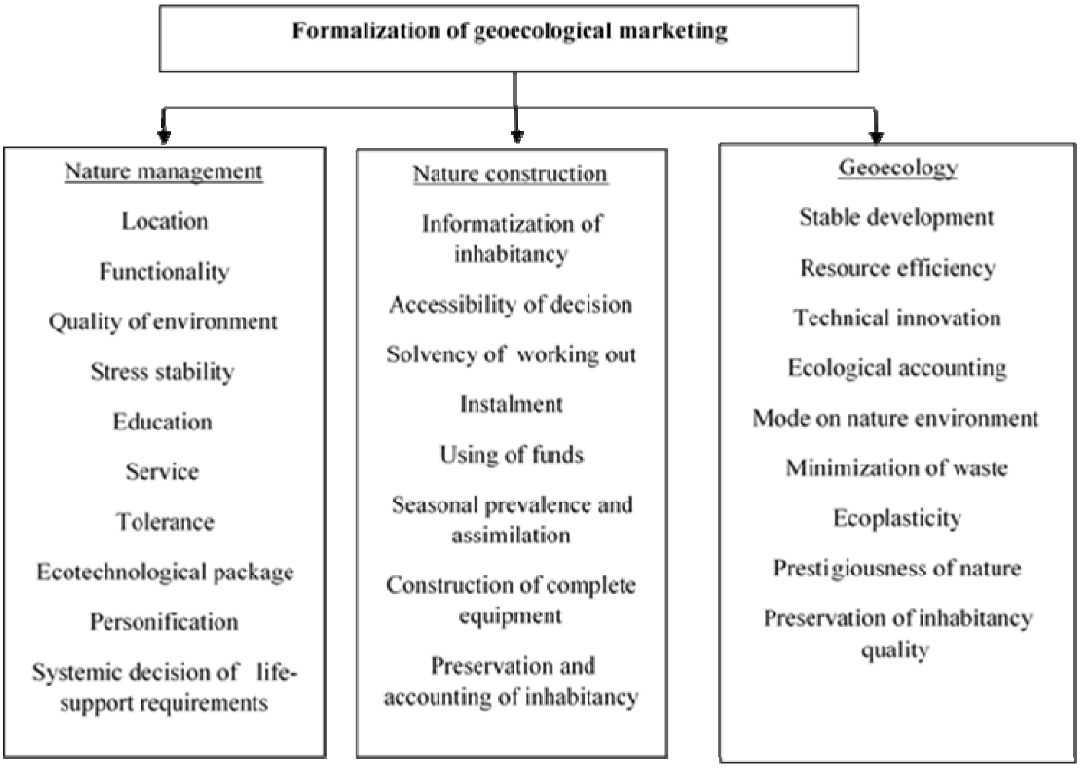

Fig.1 The ways for formalization of geoecological marketing of tourist-recreational zones of development of cities territories

Main principles of the modern concept of geoecological marketing of tourist-recreational zones of development of cities territories:

- Aiming at achievement of steady practical result of activity in borders of tourist - recreational zones.
- Orientation on long-term trouble-free and safe result of work of objects of rest and leisure.
- Use of unity and interrelation of strategy and tactics of activity of tourist-recreational zones. Primary is working out and study of decisions of the strategic geoecological problems connected with a long-term sustainable development of objects of the real estate and territories of development as a whole is primary, tactics of behavior of proprietors of objects of leisure and rest in the market is under construction on the basis of the developed strategy.
- Orientation of the fixed results of work to real conditions and quality of habitat providing desires and needs of the consumer, that is activity of objects of leisure and rest is directed on satisfaction social and spiritual needs of clients. Only being based on this principle, it is possible to count on successful activity.
- Orientation to innovations. For stable and long-term development of tourist-recreational zones of cities it is necessary to provide steady quality of an inhabitancy through constant technological innovations and resource efficiency, capable to answer inquiries of consumers of services of tourism and sports objects.

- System studying of the market of tourist branch and its conjuncture. Monitoring and market controlling has seasonal prevalence, a system and geoecological predisposition in all aspects. The timely and operative understanding of tendencies of change of a market situation and their account by strategy and tactics working out is a basis of an estimation, the analysis and the forecast of logistics of tourist streams and streams having a rest, influences of tourist-recreational zones on environment.
- Ecoplasticity and/or ecotolerance at aspiration to an object in view – increase of liquidity of the real estate of tourist-recreational zones of cities territories, reached by the permanent ecological account, information of an inhabitancy in the conditions of environment change.
- The system scientific approach to consideration and the decision of problems. In geoecological marketing are used scientifically well-founded methods of research and the analysis of geoecology and the marketing theory.
- Development of marketing thinking at all employees of objects of leisure and rest zones through training, the organization of service and working out individual ecotechnological packages.
- Establishment of partner relations on mutually advantageous conditions with accessory manufacturers for acceptance of system decisions under life-support requirements. The account of mutual interests promotes adjustment of close and long-term communications, gives the chance to all subjects of the market to realize the potential for maintenance of completeness of arrangement, preservation and the environment account.

Highly professional and qualified organization of service of marketing is necessary for realization of principles of geoecological marketing in work of each concrete company and in its structure of division on geoecomarketing.

VI THE LENINGRAD REGION DESCRIPTION

The chosen theme of research is relevant to the regions of the Northwestern Federal District because this district is the one of the most potential in Russia in organizing tourism and recreation activities. The District has all necessary resources for these activities: historical and cultural heritage, good geographical location, beautiful landscapes, labour forces and workforces development.

At the first stage of research the existing tourism infrastructure were investigated, including hotels, food service area, transport accessibility, the interest of Russian and foreign tourists in these facilities, the possibility of on-line booking and the major factors which are retarding development of incoming tourism. To achieve these goals the most promising directions of tourism development of the Northwestern District were considered – The Volga-Baltic waterway, places of pilgrimage and business tourism.

The Leningrad Region occupies a large area in the Northwest of Russia from the Gulf of Finland to Lake Onega (Fig. 2).

Figure 2. Diagrammatic layout of the Leningrad Region districts

The region is one of the most dynamically developing subjects of Russian Federation and consequently is attractive to many of the people. The developing tourism infrastructure, safety and proximity of Saint Petersburg attract tourists, as well as investors to region. The trends of development and monitoring of recreational zones of the Leningrad area are especially attractive in these conditions. The territory of the Leningrad region includes 350 places, attractable for the tourists. The table 1 demonstrates the recent state of infrastructure quality and the tourist load for 2004 in the Leningrad Region.

The table demonstrates that the greatest amounts of means of accommodation now have such municipal formations of the Leningrad Region, as Vyborg, Priozersk and Luga district. Gatchina and Lomonosov are objects of the most interest. There are residences of Russian tsars settle down in their territory.

Development of tourism infrastructures should be friendly for the nature and the people. It provides the geoecological analysis of territory of development. Also it necessary to consider recent and perspective design of engineering networks and communication, real-estate market and territories development, localization processes optimization.

Increase of population and economical growth of advanced countries entail step-up per capita off-hours, idle time of the social groups and the sociality that averages about 30% of day-time according to several calculations. Consequently, everybody will aim to realize his off-hours including recreational time (tourism, sport etc.). Therewith town, land, rural & industrial development decreases per capita potential recreational territories.

Thus, questions of acquisition of building land, architectural and landscape design, management and development of recent and future recreational areas, making new recreational resources become a very important (Fig. 3). Especially it is a vital question for heavily populated areas like the Leningrad Region.

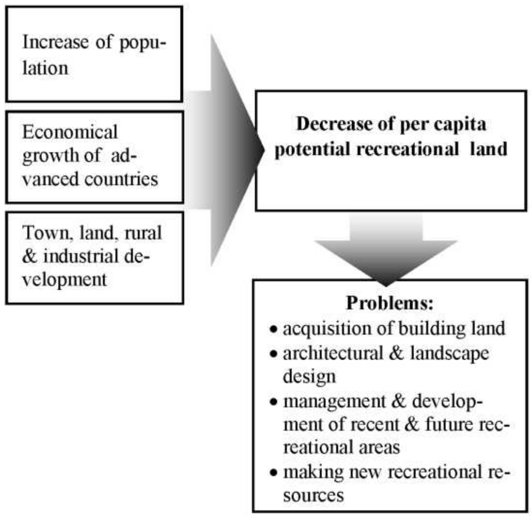

Figure 3. Effectiveness function of geoecological analysis within DSS

Organization, operating and developing of recreational zones of tourism and sports objects, and their interplay with residential, industrial, nature protection and other zones is necessary to conduct with allowance for many components:

- the schedules of the area perspective development;
- a geographic setting;
- climatic conditions;
- a level of development of an infrastructure and industry;
- location of the residential districts;
- density of population;
- availability of a cultural-historical value;
- traditions of the population and etc.

Besides many recreation kinds demand availability especial residing conditions: climatic (for example, seaside health resorts), landscape (for example, mounting skiing resorts), circumstance by resources (for example, hunting, fishery). The relevant factors are the transport accessibility, seasonal predilection and potential selectivity of the population on recreation kinds. Seasonal usage only of recreational objects is a great problem for developers and managers of this object in conditions of market economy. Thus, it is necessary to select season compossible recreation kinds with allowance for of psychological comfort and whenever possible by similar modes of operation. In this connection it is necessary to envisage a legible zoning of recreational territories with allowance for time of usage for rest (long-lived short-lived) and duration of work (year-round, seasonal), kinds of strain-relief crystallization, social and age composition of the people. The special attention should be given to a geoecological estimation of the territories, which is directional on definition of methods and means of the sustainable development of the recreational zones.

The information basis of GIS is electronic maps of a particular town or region. The map objects of a type (for instance, buildings, blocks, streets) are grouped into so-called information layers. The figure 4 demonstrates the key macrolayers of GIS-based DSS which are required for sustainable quality infrastructures and quantity management of tourism in the urbanized and nature area of the Leningrad Region. Every macrolayer presents a group of thematic layers of homogeneous objects. The landscape layer which is base of the system includes surface relief. The hydrological network contains natural and artificial surface and ground water bodies. Environmental conditions are a very important because they directly influent on type of recreational resource. The most of localities inside recreational areas are a recreational resource or a place of accommodation. Good quality of infrastructure and route networks is sine qua non for negotiability and boosts of the recreational areas. Well-working tourist and sport objects as well as routes are the goal of DSS.

VII CONCLUSION

Creation of modules of geoecological marketing for formation and arrangement of tourist-recreational zones of new generation of the globalized culture taking into account local color and natural conditions of landscape support of nature-climatic zoning of city territories is aimed at improvement and maintenance of innovative possibilities of operation of tourist-recreational zones of various qualitative and area characteristics, the dynamic and static loading, the determined and stochastic processes of operation of infrastructures. Developers and realtors should also know the characteristics of the territory around the object: its ecological indicators, traffic location, level of the infrastructure development etc.

1. Now the accounting of a water resource is defining at a geoecomarketing of development territories.
2. Absence of geoecomarketing doesn't allow to provide stability of development of tourism.
3. The account of geoecomarketing is necessary at formation of price estimations of territories of building of objects of tourism and sports.
4. Using of geoecomarketing – activity, service, product – forms the stable market with maintenance of seasonal geoecological safety.
5. Realization of geoecomarketing of leisure and rest territories raises target appeal of tourist branch.

Table 1. Number of collective accommodation objects of the Leningrad Region and its saturation points on 01.01.2005. (www.lentravel.ru, the information-statistical collection 2005. Tourism development of Leningrad region in 2000-2004 and the forecast for 2005. The statistical account and the analysis in tourism sphere of Leningrad region.)

Leningrad Region and districts	Total area of the region /district [km^2]	Total population [10^3 the inhabitants]	Collective means of accommodation (CMA)		Including					
			Number of objects	Seats of accommodation /Beds	Organisations of a hotel type		Sanatorium and resorts		Organisations of rest	
			(NO)	(SA/B)	NO	SA/B	NO	SA/B	NO	SA/B
Leningrad Region	**85,900**	**1659.90**	**432**	**44,422**	**66**	**3505**	**13**	**1442**	**353**	**39,475**
Volosovsky District	**2680.50**	**47.10**	**5**	**485**	**1**	**40**	**0**	**0**	**4**	**445**
Volkhov District	**5043.20**	**54.50**	**8**	**410**	**2**	**100**	**1**	**100**	**5**	**210**
Volkhov	**108.21**	**50.50**	**5**	**329**	**4**	**229**	**1**	**100**	**0**	**0**
Vyborg District	**7431.20**	**176.20**	**85**	**10,150**	**16**	**701**	**0**	**0**	**69**	**9449**
Gatchina			**5**	**267**	**3**	**177**	**2**	**90**	**0**	**0**
Gatchina District	**2864**	**114.70**	**17**	**2729**	**2**	**74**	**0**	**0**	**15**	**2655**
Lodeinopolsky District	**4911**	**39.80**	**19**	**721**	**3**	**198**	**0**	**0**	**16**	**523**
Luga District	**6025**	**86.70**	**41**	**7696**	**1**	**68**	**2**	**265**	**38**	**7363**
Podporozhsky District	**7705**	**38.90**	**7**	**195**	**2**	**58**	**0**	**0**	**5**	**137**
Priozersk District	**3597**	**38.90**	**109**	**10,029**	**4**	**126**	**1**	**350**	**104**	**9553**
Tikhvin District	**822**	**77.4**	**12**	**486**	**1**	**150**	**0**	**0**	**11**	**336**

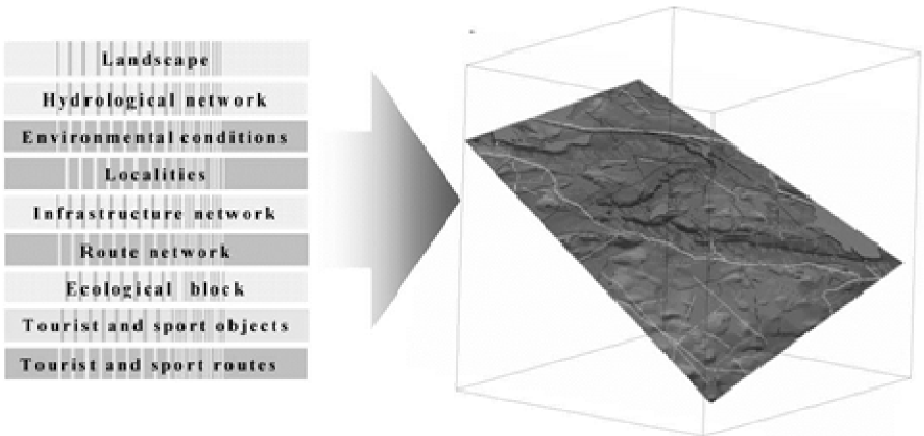

Figure 4. Thematic macrolayers of GIS - based DSS for sustainable quality infrastructures and quantity management of tourism in the urbanized and nature area.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 148-152

Creep gantry quay and accounting environment in its reconstruction

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Abstract. **Quay gantry type calculates in the technical literature in the form of a frame with hard rigel and rigid stopping up of piles. To account for long-term durability of the structures in the plastic clay soils in the existing scheme is additionally used the equation of state of a Newtonian viscous fluid. In its uses the coefficient of shear viscosity.**

The author used the proposed of the early engineering universal method of calculating berthing quays with respect to the thin walls, secured of anchor piles. In the design scheme not used lower secured racks, and counts up the stiffness characteristics of the soil, clarifying the nature of the work structures.

The author proposed a generalized mechanical model of compressible porous clay environment with the structural element. To account for the operation of facilities in the plastic clay soils in the proposed scheme uses a different equation of state of a Newtonian viscous fluid. It uses the ratio of the coefficient of viscosity in compression of porous soil (coefficient of Trutona).This allows us to consider how long-term strength and displacement of the structure in time.

Considers the issues of contamination and turbidity in the reconstruction of the gantry bulwark

Keywords: **pile quay, hard grillage, a generalized model of creeping soil, a compressible viscous fluid.**

I INTRODUCTION

The quays of St. Petersburg are of practical interest in the construction and reconstruction of the existing finishes of banks of rivers and canals in the form of a thin retaining wall with inclined anchor piles (gantry quay). It is during the construction does not require large volumes of earthworks that reduces harmful impact on the environment. This is especially valuable in dense areas of the city. The problem of providing long-term durability of thin retaining walls on deformable in time grounds received a special urgency. Such designs are widespread, but they are characterized by high sensitivity to deformation of soils.

Normative documentation on this type of embankment does not account for instant and long-term deformation characteristics of the Foundation soil. Clarification of the calculation municipal mooring quays gantry type and reduction of adverse environmental impact during construction is an important issue.

II PURPOSE OF THE WORK

Ensure long-term strength of the port hydraulic structures on deform in time basis, typical of St. Petersburg is of practical interest. Existing calculations of such structures using the hydrodynamic model of steady flow of a viscous incompressible fluid Navier-Stokes (N. N. Maslov, A. I. Budin, V. P. Karpov). This allowed them to assess the long-term strength of some types of port facilities. However, the above model describes the steady-state creep of slopes and slopes composed of clayey soils (N. M. Maslov, 1977). The operating experience of retaining walls of the creeping grounds showed that better fits the model of unsteady flow of a viscous compressible fluid. Since creep of the mooring is of a dying character in time.

The objective of this paper is to implement engineering method of calculation of wharfage waterworks on creeping of the ground. The porous foundation soil is describes by the model of a viscous compressible fluid, which. describing the decaying creep. Further dealt with environmental issues on the example of the reconstruction of the mooring quay in St. Petersburg.

III LITERATURE REVIEW

In the existing technical literature [1, 2, 3] and regulations [4, 5] each type of port hydraulic structures has its own method of calculation. Translation of manual calculation on the PC significantly reduced the computational complexity of the work, but not fully used large automation capabilities. Because, most of the methods of calculation based on the terms and assumptions used in the era before computers. This requires additional verification of the calculation results due to a wide

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.235

range of interval values of the original data, as well as in cases of the adoption of rigid sealing the bottom of the pile in the soil [6, 7, 8].

To simplify the understanding of the mechanism of interaction of structural elements with the soil and maximize the use of the computer by the author in 2002 was proposed universal engineering calculation method, which can be applied to any design of the mooring quay [9] and expanded in [10, 11].

Calculation of piled embankments grillage type has a significant number of works by Russian and foreign scientists. First N. M. Gersevanov was given general solution to the problem of calculation of pile grillage with the rigid rigel. He considering these structures as absolutely rigid frame with beams on elastic supports-stilts with hard of the sealing (1913). The work of recent years, , as a rule, use of the classical calculation scheme [12, 13]. Note the works of foreign scientists dedicated to the calculation of piled embankments grillage type [14 – 17].

Thin retaining wall, of anchored structures inclined piles, in the estimated attitude is a frame system with rigid beams and flexible racks. It is a special case of a design scheme N. M. Gersevanov. Departmental method of calculation is given in the work [18].

Work noted above describe the calculation of pile structures in soils do not possess of creep. They are used as a baseline, when the variable properties of the soil in time. Weak and clay foundation of soil have rheological properties. They exhibit properties of creep and relaxation. These soils are changing their stress-strain state in time. Rheological properties of soils were studied by S. S. Vyalov, Y. K. Zaretsky, G. A. Geniev, S. R. Meschyan, R. Reiner, Z. G. Ter-Stepanyan, V. A. Florin, L. Shukle, A. Bishop, K. Roscoe, A. Scepton and others.

N. N. Maslov (1968) used the model of a viscous liquid to account for the interaction of the retaining structures with creeping grounds. A. J. Budin taked into account the change in time of the reactive pressure of the foundation soil at a quay wall [13]. He used the model of steady flow of a viscous incompressible fluid for the description of the foundation soil. This solution is a particular case of changes in stress with time in a restrained retaining wall, excluding instant and long-term deformation characteristics of the foundation soil. A similar model for calculating thin quay wall was used Karpov V. M. (1977).

Review of current status of the problem shows that in the technical literature and in the regulations for the calculation of structures grillage type is used metod of N. M. Gersevanov. This scheme is used as basis in the calculation of buildings for long lasting durability. Creep of the foundation soil is described by the model of steady-state motion of a viscous incompressible fluid. Without deformation of this method in determining immediate and long-term strength distorts the design scheme of the building. This introduces some error in the determination of the forces in the elements of design and not gives the calculation for the second limit state.

IV THE SOLUTION OF THIS PROBLEM

Elasticity, plasticity is a characteristic property of solids, the viscosity of the liquid. Many real materials have both these properties. Viscous behavior of clayey soils is described by the following theories: the theory of linear viscoelastic deformation; the theory of hereditary creep; the creep theory; the kinetic theory of strength and creep of soils; mathematical models viscoplastic behavior of soils. All described creep theory allow to obtain a more or less satisfactory agreement with the test data. However, the choice of a particular theory in relation to the problems of soil mechanics is determined primarily by the requirements of the task.

Viscous behavior of clayey soils is described a generalized model of the behavior of creeping soil. Existing models of creeping soil in the port hydraulic engineering take into account the shear stress causing shear viscous steady flow. The author adopted the viscous porous medium. She resists compression under normal stresses. This model describes damped amounts creep in the shore facilities on clay foundation soil. Generalized model of creeping soil have structural element $S(I_1)$ environment and combines of models Kelvin - Voigt and Maxwell (Fig. 1a) [19]. The elastic properties of the bodies are indicated by the symbol N, and the viscous symbol N. (Fig.1a). Structural element of $S(I_1)$ depends on the ball tensor. It takes into account the change of the deformation modulus E and coefficient of viscosity ηc from the immersion depth of the wall. The viscous properties of the bodies designated by the model in the form of a cylinder filled with a viscous compressible porous medium, in which is immersed a perforated piston, and the speed dip is described by Newton's law.

$$\sigma = \eta_c \dot{\delta}, \tag{1}$$

where η_c – the coefficient of viscosity in compression (coefficient of Trutona); δ – speed compression (tension). (Fig.1a Graphs of creep and relaxation in relation to the clay-court basis of clay soils depending on the depth h is shown in Fig. 1b. The deformation of the viscoelastic body develops in time, but is damped (Fig. 1b, top). After unloading deformation is fully recovered in time. Wednesday shows the properties of relaxation (Fig. 1b, bottom). The relationship between normal stress and the longitudinal deformation is described by a variable E (Fig. 1c).

The analogy between the deformation diagrams for solids and viscous fluids allows the use of solutions of the elasticity theory and the theory of plasticity for tasks in a viscous fluid. These solutions are used by simply replacing the strain on its speed.

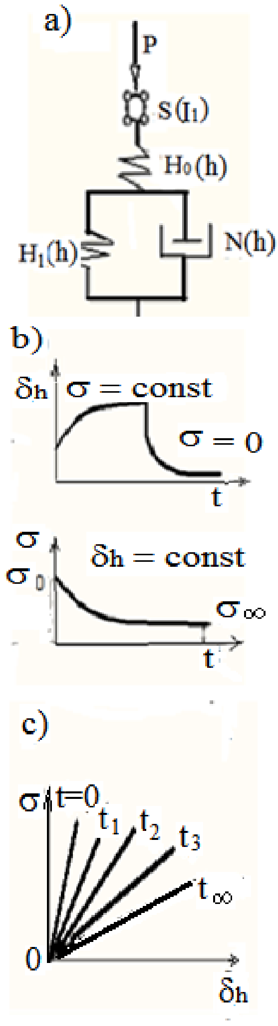

Fig. 1. a) Generalized mechanical model of compressible porous clay environment with the proposed structural element $S(I_1)$. b) Graphs of creep (top) and relaxation (bottom) with additional consideration h. c) The variable values of the deformation modulus of the soil over time.

Fig. 1. a) Mechanical model of a compressible porous clay environment. b) Graphs of creep (top) and relaxation (bottom). c) The variable values of the deformation modulus of the soil in time.

At constant characteristics E and η_c deformation of damped creep quay wall in time is:

$$\Delta_{п} = \Delta_0 + (\Delta_\infty - \Delta_0)\exp a(t/t_{п\,ст}), \qquad (2)$$

where $\Delta_0 = \Delta^* (h_0/h)^2$ – the initial deformation of the wall (Δ^* – limit displacement of the bottom wall with a minimum depth h_0 [20], h is the actual depth of the wall; $\Delta\infty = \Delta_\infty^*(h_0/h)^2$ – stable deformation of the wall. It is defined similarly to work [20], in view of the module of the compressive strain ($E\infty$; *a* – correction coefficient; t, $t_{п\,ст}$ – current and a finite time creep.

The period of damped creep (time delay deformations) is simply equal to:

$$t_{п\,ст} = \eta_c/E_\infty, \qquad (3)$$

where $\eta_c = 3\eta$ – linear coefficient of viscosity grip (friction force at compression of the area at unit velocity gradient), approximately is defined via the ratio of shear viscosity η; E_∞ – long module of the compressive strain are determined by the test stamps. $E\infty$ is approximately equal to:

$$E_\infty = (0{,}3\div 0{,}8)E, \qquad (4)$$

where of more importance to the solid clays, respectively less - of weak clays, intermediate values consistency are accepted by interpolation. Deformation properties of the coefficient similarly accepted due to the proportionality of the K_P and E.

Example. The initial mixture of top of wall height of 7m [18] of order Δ 0= 11 mm was obtained with the use of the solution [9]. Taking into account dependence (2) at *a* = 3.0 get Δ_∞ = 89,1 mm.

The nature of the curvature of a curve "a" is better described by a equation of the type:

$$\Delta t = \Delta_0 + \Delta_\infty(t/ t_{п\ ст})^{1/4}$$

Estimated value of the total displacement of faltering creep is 100,1 mm.

The offset of the top designs for the observation period for a period of 6 years (A. J. Budin, 1971) reached 94 mm. The starting offset in the application of external loads was only 17 mm

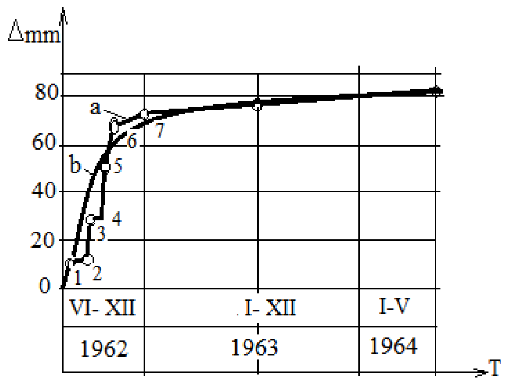

Fig. 2. The curves compare the cordon line mooring quay St. Petersburg river port. (a) Experimental broken curve corresponds to different degrees of loading of the wall. b) Calculated curve.

V ENVIRONMENTAL SAFETY DURING RECONSTRUCTION OF THE EMBANKMENT

The reconstruction of includes dredging described promenade. The amount of dredging was 10.5 thousand m^3 of soil on the area of 5200 m^2. When dredging and the dumping of excavated soil, calculation of zones of turbidity for the reservoir was carried out in accordance with the work of [21].

Assessment of contamination of soil. Before dredging was determined class of contamination of soils in accordance with the recommendations of the regional standard [22].

TABLE 1

POLLUTION SEIZED SOILS IN COMPARISON WITH THE PERMISSIBLE LEVELS

The name of the substance	Concentration, mg/kg	Target level, mg/kg	Maximum level (check level), mg/kg	Class pollution seized soils
Cadmium (Cd)	–	0.8	2	0 class
Chromium (Cr)	45	100	380	0 class
Copper (Cu)	60	35	35 (90)	II class
Lead (Pb)	52	85	530	0 class
Mercury (Hg)	0.25	0.30	0.5	0 class
Nickel (Ni)	42	35	35 (45)	II class
Zinc (Zn)	92	140	480	0 class
Arsenic (As)	—	29	55	0 class

The surface layer of bottom sediments is slightly contaminated (table 1). In accordance with the Regional norm [22] the soils in the area where dredging may be used without restriction for the blade into water bodies, education areas.

The calculation of turbidity during dredging. Spot turbidity during dredging is determined by the speed of sedimentation V_{oc} and the consumption of soil q, transformed into a balanced state [21]. Effective sedimentation rate of suspension is equal to:

$$V_{oc} = \frac{\sum_{i=1}^{n} V_{oci} \cdot p_i}{p} = 0{,}15 см/с$$

where n is the number of selected fractions of the soil size less than 0.1 mm; Voc - hydraulic coarseness of individual n-fractions of particles, cm/s (tab. 2); PI - weight content in the soil of the individual n-fractions of particles smaller than 0.1 mm fraction (table.); p is the total content by weight of soil particles smaller than 0.1 mm, in fractions of a unit.

The flow rate of the soil q, transformed into suspended state is equal to:

$$q = p \cdot k \cdot Q \cdot \gamma_T \cdot \frac{\gamma - \gamma_B}{\lambda_T - \gamma_B} = 0{,}0015 m/c$$

where p is the total content by weight of soil particles smaller than 0.1 mm fraction; k = 0.05 to the transition rate of the soil in suspension, in fractions of a unit; Q = 96 m^3/hour - performance technical means on the ground; γ = 1.7 t/m^3 volumetric weight of the soil in natural addition; γ_B= 1 t/m^3 volumetric weight of water, t/m^3;γ_T = 2.4 t/m^3 volumetric weight of soil particles, t/m^3.

TABLE 2

GRANULOMETRIC COMPOSITION OF SOILS DREDGING

The particle size, mm	Weight content, %	Hydraulic particle size of suspended solids Voc, cm/s
0.001	5.1	0.000059
0.005	10.2	0.00148
0.010	9.8	0.00593
0.015	8.2	0.0133
0.02	7.3	0.0235
0.03	7.2	0.0525
0.04	8.5	0.0923
0.05	6.2	0.1426
0.06	7.1	0.203
0.07	7.3	0.272
0.08	6.7	0.35
0.09	6.2	0.437
0.1	5.9	0.53

TABLE 3

POSSIBLE CONSEQUENCES OF EDUCATION SPOTS TURBIDITY DURING DREDGING

Seizures of soil, m^3	PDK suspended solids, mg/dm 3	Catego-ry logopo-lis	Area of the dull-making from the concentrati on was less than the PDK, m^2	Current of guy stains with a concentratio n less than the PDK, hour	Distance that the spot can go with the flow, km
18000	0.25	II	300000	6.1	8.8
18000	0.75	II	250000	5.5	7.9

Payment for environmental damage of suspended solids received in the waters during the period of dredging in volume 588,6m3 amounted 43947 rb. The calculation was performed Xia in accordance with the Order of Rostechnadzor from 05.04.2007 No. 204 and the resolution of the Government of the Russian Federation dated 12.06.2003, No. 344.

VI CONCLUSIONS

1. Pile quay gantry type calculates in the technical literature in the form of a frame with hard grillage and rigid restraint piles. To account for long-term durability of structures in the plastic clay soils in the existing scheme is additionally used the equation of state of a Newtonian viscous fluid. Idem uses the coefficient of shear viscosity. Model stationary viscous flow does not take account of the decaying creep in the shore facilities.
2. The author proposed a generalized mechanical model with a structural element, which allows to take into account creep and relaxation of the foundation soil due to the depth of immersion of the wall.

3. Calculation of the thin walls in the initial period of time used a job [9]. In a design model are introduced deformation characteristics of the soil, to clarify the nature of work facilities.
4. To account for the rheological properties, the author used the model of a compressible Newtonian viscous fluid. Idem was used a coefficient of the coefficient of viscosity in compression of discrete soil (coefficient of Trutona). This allows us to consider how long durability and damped displacement of the structure in
5. Considered are the issues of pollution and turbidity in the reconstruction of the gantry bulwark

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 153-157

Numerical simulation of urban berthing quays in a dense housing

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Abstract. **Calculation of pile quay gantry type as a frame with rigid crossbarand a rigid beam, is a special case of the decision method, presented by N. Gersevanov. This method was widely used in the technical literature and regulatory documents. Translation of manual calculation on the computer almost retained the existing design scheme.**
Practical implementation of the engineering universal method offered early to calculation of mooring embankments in relation to a thin wall, is given by anchored inclined piles. In the calculation scheme bottom sealing is not used, and entered stiffness characteristics of the soil, clarifying the nature of the work structure.
The obtained simplified solution determines the lateral pressure in the silo variable width. Engineering calculations showed that pressure is redistributed on the sheet pilling wall and the inclined piles from external soil pressure.
Comparative calculations, taking into account the deformation characteristics of the soil showed a significant impact on efforts in the elements of the embankment compared to method N. Gersevanov.

Keywords: **coefficients of subgrade resistance, lateral earth pressure, pressure in the conventional silo.**

I INTRODUCTION

The practical interest is the reconstruction of the existing urban waterfronts in St. Petersburg. Embankment in the form a gantry bolwerk (of a thin retaining wall with inclined anchor piles) is effective in condition of dense construction, since the construction does not require large amounts of earthwork.
Clarification of the calculation municipal mooring quays gantry type represents an actual task. Because departmental documentation on this quay does not account for the deformation characteristics of the soil.

II THE AIM OF THE WORK

In the current technical literature [1-3] and regulations [4, 5] each type of port hydraulic structure can be calculated in different ways. Transfer of manual calculation on the computers significantly reduced the complexity of computing work, but not completely used great opportunities for automation. In view of the most part of methods of calculation are based on provisions and assumptions, which were laid in the era of the lack of computers.

Calculation of mooring designs in software systems, using model of the continuous environment allowed to receive fuller picture of work of a construction in soil. However, the calculation of these structures in programs that use the model of a continuous medium, designed for structural materials, is not strict, as it gives an approximate picture of the behavior of pile foundations in discrete soil environments. Thus additional check of results of calculation, owing to the wide range of an interval of values of basic data, and also in cases of acceptance of rigid seal of a bottom of piles in soil [6-8] is required.
To simplify the understanding of the mechanism of interaction of structural elements with the ground in 2002 was offered a versatile engineering calculation method that can be applied to any design mooring quay [9] and with utilization in the work [10,11].

The purpose of the proposed work is the practical implementation of engineering universal method for computation of berthing type thin wall anchored inclined anchor piles. This is estimated adopted by the calculation scheme and the impact of the assumptions used in departmental norms and values effort in the construction.

III REVIEV OF THE LITERATURE

A significant amount of works of both the Russian, and foreign scientists is devoted to development of rational ways of static calculation of pile embankments of grillage type. For the first time N. Gersevanov gave the common decision of a problem of calculation of pile embankments with a rigid grillage, considering them as a frame with absolutely rigid crossbar on elastic support piles with rigid lower seal (1913). Having equated for unknown movements

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.236

of the lower side of a grillage (vertical, horizontal and its turn) N. Gersevanov received three initial equations of a method of deformations. Their decision allowed to pass from movements of a grillage to efforts in piles. These equations are usual conditions of the equation of balance of a rigid body.

Except an analytical way of the calculation developed by N. Gersevanov, the russian scientists B. Lozovsky, F. Dimentberg, V. Hristoforov proposed solutions of the same task by graphic methods. The works of the last years connected with calculation of pile grillages, as a rule, use the classical settlement scheme [12, 13].

We will note works of the foreign scientists, who devoted to calculation of pile embankments of grillage type [14 - 17].

Thin retaining wall, sloping piles anchored in respect of the settlement is a frame system with rigid and flexible bolt racks, representing a particular case of the solution proposed by N. Gersevanov [18].

The review of a current state of a problem shows that in technical literature and in normative documents for calculation of pile constructions of grillage type in frames with rigid fixing of the ends of the pile basis N. Gersevanov's decision is used. Thus purpose of depth of rigid seal of piles any or with use of a method of the elastic line doesn't answer the valid work of a construction. Estimating originality of a method of calculation of constructions of the rostverky type offered by N. Gersevanov, we will note that the deformation-free with respect to the interaction of pile foundation in the ground distorts the calculation scheme structures. It brings a certain error when determining efforts in design elements.

IV TASK SOLUTION

With regard to the retaining wall, sloping piles anchored consider a system of two beams with different strontium based and interconnected as a condition of joint deformation of structural elements and design of the whole.

The rigel – rigid beam, which is based on the elastic settling focused support, which is loaded as external loads and internal forces from the effects of pile foundation.

The pile basis – system of two beams racks of different rigidity which are rigidly fixed in a seal place in a crossbar, and in the lower part interacting with diverse soil of the basis. The pile basis perceives both external loadings, and the efforts from a crossbar influencing them.

In the settlement scheme the rack-mount frame with various rigidity of a crossbar and racks which can have various inclination is used. Thus unlike a classical method of the calculation used the rigid seal of a bottom of piles appointed randomly at a depth of 1-3 m or method of the elastic line, possibility of their elastic seal is connected with deformation characteristics of soil. Favorable impact of soil of inter pile space on work of an inclined pile which is ignored in a standard method of calculation is in addition considered.

Realization of the offered calculation was carried out in the program SCAD complex.

Initial loadings to calculation of a construction are given in fig. 3a. Lateral pressure upon the top elements of a gantry bulwark includes pressure on cap with a superstructure, a pile row and the sheet pilling.

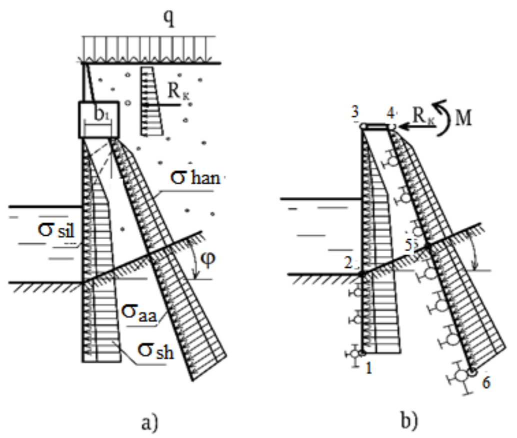

Fig. 1. a) Total plot of pressure of soil. b) Settlement scheme of a construction.

Soil pressure upon an inclined pile number (zone II) represents the sum of the lateral pressure upon the inclined screened plane designated σ_{aa} and pressure from loading of the soil hanging on piles σ_{han} (fig. 1a). Due to the small size of horizontal pressure from the hanging soil upon a rectangular pile, its influence we will consider in K_3 coefficient at determination of active pressure σ_{aa} on the inclined shielding plane of a pile row (Eq. 1).

$$\sigma_{aa} = K_3\,(q + \sum \gamma_i\, h_i)\lambda_{aa} \qquad (1)$$

where K_3 = 1.1 – 1.15 - the coefficient accounting of the hanging soil on a pile; q – the distributed payload; γ_i – the specific weight of soil; h_i – height of the considered point; λ_{aa} – coefficient of lateral pressure the shielding plane of an inclined pile row, $\alpha = 18^0\ 25^{II}$.

Soil pressure upon a sheet pilling wall (zone I) consists of soil pressure in this zone (a silo of variable width), σ_{sh} and the additional resultant pressure of a pile row σ_r taking into account the distributing ability of piles. Total plot of pressure of soil and settlement scheme of a construction are represented in Fig. 1.

Lateral pressure in a silo of variable width. Lateral pressure in a point 2 (Eq. 2), a certain straight line at an angle 45 ° – 0.5φ to a vertical from the beginning of the shielding plane of piles, is equal (Fig. 2a):

$$\sigma_{2\,sil} = \gamma_1\, h\lambda_a \tag{2}$$

Lateral pressure in a silo of variable width in points 3 (Eq.3) and 4 (Eq.4) is defined by the following reception (fig. 2), engineering in margin of safety. We assume that active pressure in a point 3 is defined by pressure of an incomplete prism of a collapse 1 3 11 10, and pressure in a point 4 respectively – a prism 1 4 5 8. Taking into account this circumstance lateral pressure 3 and 4 is equal in points (fig. 2, a).

$$\sigma_{3\,sil} = \gamma_2\, h_1\lambda_{a1} \tag{3}$$

$$\sigma_{4\,sil} = \gamma_2\, h_2\lambda_{a2} \tag{4}$$

In margin of safety on we consider basis soil coupling. In case it appears that σ_3 forces < σ_2 forces, value σ_3 forces is defined by the straight line passing through values σ_3 forces and σ_4 forces.

Lateral pressure upon the sheet pilling σ_{ton} represents the sum from conditional silage pressure σ_{sil} at forces in a zone I and additional pressure from the shielding pile row σ_{sh} (Eq. 5). The last is equal to a difference of external pressure σ_{aa} from a zone II and the return silage pressure upon the shielding inclined plane of soil σ_1 forces in a zone 1 taking into account coefficient of distribution of K_r (fig. 2, a).

At determination of additional pressure upon the sheet pilling σ_{sil} from the shielding pile row in departmental norms [18] the offer was used similar N. Smorodinsky's ideas (1937) about distribution of pressure upon the sheet pilling and a pile is proportional to their rigidity. Noted offer, progressive at the beginning of origin of calculations of pile designs, doesn't consider influence of distance of a pile row from a sheet pilling wall, and also cross section of piles and a step of a pile row along the line of a cordon. These factors have more essential impact on a sheet pilling wall and piles than the relation of their rigidity. The simplified decision on definition σ_{sh} by means of coefficient of distribution of K_r is

and many others

$$\sigma_{ton} = \sigma_{sil} + \sigma_{sh} \tag{5}$$

Pressure upon the sheet pilling from a zone 2 is taking into account influence of a step of piles through K_r (fig. 2).

$$\sigma_{sh} = K_r\,(\sigma_{aa} - \sigma^1_{sil}) \tag{6}$$

$$K_r = (b/n)(2l_1/l) \tag{7}$$

where n – a step of piles; $l_i = c_i$ tg φ – variable zone of partial distribution of resultant load behind piles of a sheet pilling wall (c_i – variable distance from a pile to the sheet pilling); $l = b + 2c_i\text{tg}\varphi$ – a variable zone of distribution of resultant load between site b piles of a sheet pilling wall; d – diameter of the shielding pile.

Deformation characteristics of soil. In practice of port design Fussa-Vinkler's model using the deformation characteristic of soil in the form of coefficients of subgrade resistance was spread at calculation of thin quays. The specified model repeatedly was exposed critics for not the account in it to distributive ability of soil. However, check of model of the continuous environment used in program complexes with data of natural researches showed that influence of distributive ability in relation to soil having discrete structure is overestimated.

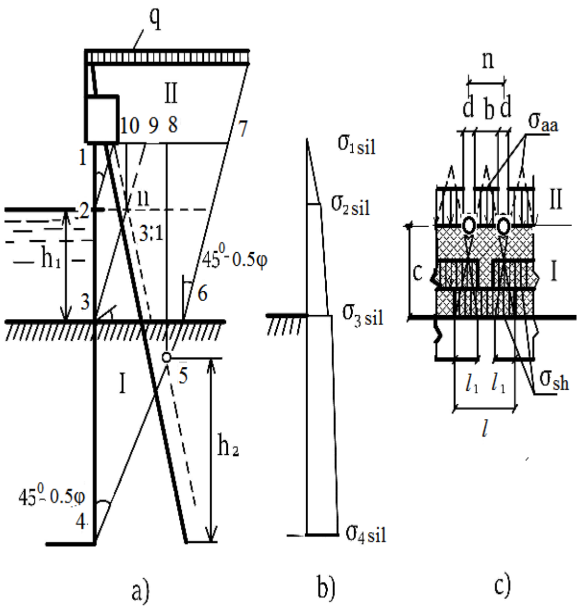

Figure 2. Settlement schemes to determination of lateral pressure in a zone I. a) The simplified scheme. b) The specified scheme defining intensity from a condition of the maximum plane of a collapse. c) Determination of pressure of a pile row upon the sheet pilling.

The solution of the differential equation of a bend of the beams leaning on the continuous (vinklerovsky) elastic basis on a method of local deformations, doesn't represent special difficulties, but contains four constant integration, which need to be defined from entry conditions.

First-hand experiences show that the coefficient of subgrade resistance for natural soil isn't a constant, and depends as on the size of specific pressure upon soil, and on the area of transfer of loading that it is necessary to consider at calculations.

The generalized methods of definition of deformations of soil consider both the general elastic, and local inelastic deformations of soil. From these methods we will note P. Pasternak's – V. Vlasov's method – the two-parameter elastic basis according to which the soil basis is characterized by coefficients of a subgrade resistance of compression and local elastic shift. The method of the structural restored by I. Cherkasov's – G. Klein's deformations, considering the general restored deformations (elastic and the adsorptive) and residual (structural). In the last method the restored deformations are accepted for linearly deformable and are characterized by the coefficient similar to coefficient of an elastic half-space.

The theory of calculation of the designs lying on the deformable basis with one and two coefficients of a subgrade resistance gained development in works, made by: A. Dinnik, P. Pasternak, M. Gersevanov, N. Zhukovsky, A. Krylov, A. Umansky, G. Dutov, V. Kiselyov, S. Golushkevich, B. Korolyov, N. Snitko, V. Vlasov, N. Leontyev Among foreign scientists were engaged in this task: H. Westergaard, H. Bufler, H., Lieb, G. Meier [20], Y. Cheung , O. Zienkiewicz [21], C. Desai, J. Christian [22], A. Ioannides etc.

Due to changes in the coefficient of a subgrade resistance on depth (for piles) and plan (for slabs) used the so-called coefficient of soil stiffness. With regard to the calculation of different types of mooring facilities are invited to use the stiffness coefficient of the base connecting the stiffness coefficient of soil elastic and limit states for the entire load cycle [23]. For practical use, it is piecewise linear values in each section of the structural element of the five intervals of the entire load.

Below is a comparison of the two calculations on the example of the type of quay gantry, built on the shores of the Neva River in St. Peterbrge [24].

Example. Basic data. Load on the surface of the filling q = 40 kN/sq.m. Free height of wall N=7 m, thickness of the sheet pilling is 30 cm, the section of anchor piles is 40x40 cm, a pile step n = 1.0 m, a bias of piles 3:1 (a=18 °25'), h_k=2.2 m, settlement width of a crossbar of b = 1.5 m.

TABLE 1
THE CALCULATION RESULTS PROMENADE TWO METHODS

Name	Classical method [18]	Universal method[1] [9]
Moment at the top sealing of the sheet pilling [kNm]	-0.0	-142.0
Moment at the top sealing of the pile [kNm]	-38	48
Moment in the span of the sheet pilling [kNm]	95	77
Moment in the span of the pile [kNm]	62.5	-138.8
Moment at the bottom sealing of the sheet pilling [kNm]	-92	-77
Moment at the bottom sealing of the pile [kNm]	-71	-
The longitudinal force in the vertical pile [kN]	-377	-273.0
The longitudinal force in the inclined pil [kN]	581	503
Horizontal displacement of the top [mm]	5.6	10.97

Settlement characteristics of soil of the basis: γ_{we} = 10 kN/m^3, φ = 20°, s = 0.015 MPa; backfill soil: γ = 18 kN/m^3, γ_{we} = 10 kN/m^3, φ = 30°. Module of elasticity of material of a design of $E_{Sh} = E_s = 2.1 \cdot 10^4$ MPa. Rigidity of the sheet pilling and piles on 1 m wall lengths: $E_{Sh}I_{Sh} = 4.7 \cdot 10^8$ KN · cm^2; $E_S I_S = 2.98$ 10^8 kN sm^2. Deformation characteristics for soil of a backfill and the basis in the form of horizontal and vertical coefficients of a subgrade resistance of soil of a backfill and basis for the sheet pilling and piles were accepted with use of normative documents [5]. The calculation results are shown in Tab. 1.

1. The calculation on the universal method was performed by student K. Kokoreva.

V ANALYSIS OF THE CALCULATION RESULTS

The comparison of calculation results by the two methods showed their incommensurability of individual values of the forces in the elements of the structure. This has arisen because of the different calculation schemes in the considered methods. So, based on [18] efforts are rigidly fixed to the frame arise from the active earth pressure on them and from turn the whole structure relative to the lower seal. In the calculation [9] hard sealing the bottom rack is not used, and the rotation of the whole structure starts to prevent the reactive pressure of the soil in disconnected space on the inclined pile. However, depending on the stiffness of the soil plot of bending moments in the pile can change the direction. Universal method that allows the variation of the values of the horizontal and vertical coefficients of subgrade resistance (without considering them in the filling) upwards to get more or less comparable amount of effort with departmental standards. However, in this case, the actual stiffness characteristics of the foundation soil will be distorted.

VI CONCLUSIONS

1. In the existing technical literature and normative documents each type of the port hydraulic engineering construction has the method of calculation. Calculation of the pile embankment of gantry type in the form of a frame with absolutely rigid crossbar on elastic support piles with rigid lower seal, represents a special case of the decision (deformation-free in soil) – Gersevanov's method. Transfer of manual calculation on the computer significantly reduced labor input of computing works, nevertheless the part of methods of calculation is based on provisions and assumptions which were put in the absence of the computer.
2. Practical realization of the engineering universal method offered early to calculation of mooring embankments in relation to a thin wall, anchored by inclined anchor piles is given**.** The calculation used the stiffness characteristics of the cross-beams, piles and soil, the latter are absent in the classical method.

3. The simplified solution of determination of lateral pressure in a silo of variable width is received.
4. Engineering reception of calculation of additional pressure upon a sheet pilling wall from pressure upon an inclined pile row is shown.
5. Comparative calculations promenade with various values of the stiffness characteristics of the soil interacting with the pile elements, showed their significant impacts on the classic design scheme of the building. In the case of flexible racks and dense sub-soil (without taking into account the stiffness of the soil) backfill settlement efforts more or less comparable with the method N. M. Gersevanov, which can be considered as a special case of the universal method. In other cases, efforts in the elements of the embankment on the universal method change up or down in comparison with the classical method of calculation.
6. During the construction of the gantry bulwark of rectangular reinforced concrete piles, it is recommended to limit its free height of up to seven meters, due to the emergence of a large bending moments and the longitudinal force in the inclined pile.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 158-167

Impact of the company's main budgeting objectives on the evaluation of importance of financial and non-financial indicators

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Abstract. **Financial planning forms a basis for the company's management and determines the company's objectives; the achievement of these objectives is measured using financial and non-financial indicators. The main budgeting objectives affect the importance of financial and non-financial indicators, thus, contributing to the achievement of the goals. The topicality of the research is determined by the fact that the financial and non-financial indicators have been examined by many authors; however, there exist problems regarding their practical application, since still there is no a consistent approach to the measurement and evaluation of both the financial and non-financial indicators. The study is based on the author's previous theoretical research on the application of financial and non-financial indicators in the evaluation of business performance; as a result, the author has established the sets of financial and non-financial indicators that were used in conducting the practical research.**

The aim of the current research is to determine the impact of the main company's budgeting objectives on the evaluation of importance of financial and non-financial indicators on the basis of the opinion survey of Latvian business persons and top-level employees. The Internet survey was used in the research, applying a random sampling method.

The research results indicate that the opinions in the groups of respondents regarding the main company's budgeting objectives differ, and the correlations exist among the main budgeting objectives. Comparison of the impact of the main budgeting objectives on the importance level of the financial and non-financial indicators shows that the possible impact is more significant regarding the importance of the financial rather than non-financial indicators.

Keywords: **budgeting objective, financial indicators, non-financial indicators, importance.**

I INTRODUCTION

To describe the results of the business activities, the term "performance" is used in the foreign research and academic literature Lebas considers that the performance is never objective, it is only a way of defining where one wants to go [16]. ''Performance'' is an interesting concept. ''Performance'' is not an objective reality out there somewhere waiting to be measured and evaluated. ''Performance'' is socially constructed reality [1]. Laitinen defines the performance as an ability of an object to produce results in a dimension determined a priori, in relation to a target. Thus it is necessary to have, first, an object whose performance is to be considered; second, a dimension in which one is interested; and, third, a set target for the result [15]. Folan supposes that the performance is governed by the following three priorities: (1) It is always made as per the deemed relevance of an entity to a particular environment (thus, we commonly assess a company on its impact, for example, in a particular market…); (2) It is always made with a relevant objective in mind (thus, we commonly assess a company as per some set future vision on what the company wants to achieve…); (3) It is always reduced to relevant, recognisable characteristics (thus, we commonly assess a company on competitive parameters, such as cost, quality, time, etc., and more harder-to-measure competitive priorities, such as flexibility, or sustainability, because they are relevant and recognisable etc.) [7].

One of the company's priorities is the achievement of the specific aim [7], [26], furthermore, the company is assessed according to its future goals, referring to the targets the company intends to achieve.

It could be concluded that the company's performance can be described as an ability of the company to represent itself to the outside, using the performance indicators that characterise activities and

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.270

achievements of the company in relation to its goals and thus creating an overall opinion about the company.

The analysis of the researches on the frameworks of the performance measurement [6], [7], [18], [21], [22], [24], indicates that the dimensions of the company's performance measurement include financial and non-financial indicators. Uyar believes that the performance measurement tools could be classified as *traditional* including financial measures and *new approaches* including non-financial measures along with financial ones [23]. The financial and non-financial indicators used in the researches on the evaluation of the company's performance reveal their diversity. In the evaluation of the companies' non-financial and/or financial performance, various number of the indicators have been used: 3 non-financial and 3 financial indicators [27], 11 non-financial and 5 financial indicators [5], 6 non-financial and 2 financial indicators [14], 9 non-financial indicators [3], 12 non-financial and 4 financial indicators [2], 5 non-financial and 5 financial indicators [20], 14 non-financial indicators [8], 23 non-financial and 8 financial indicators [19], 10 non-financial and 2 financial indicators [4], 12 financial indicators [25] etc. Lack of a united approach to the use of financial and non-financial indicators for evaluation of the company's financial and/or non-financial performance leads to the problem of their practical application. The author has carried out an assessment of the financial and non-financial indicators that are used in the evaluation of financial and non-financial performance of the companies, and as a result has established the sets of financial and non-financial indicators that are used in the practical research.

The researches on the companies' performance measurement using financial and non-financial indicators have not been carried out in Latvia; that defines timely character of the research topic.

The aim of the current research is to carry out the assessment of possible impact of the main company's budgeting objectives on the evaluation of significance of financial and non-financial indicators on the basis of the opinion survey of Latvian business persons and top-level employees.

In order to achieve the aim of the research, the following research objectives are defined:

- using the companies' survey results, to assess the impact of the companies' budgeting objectives on the evaluation of importance of the financial and non-financial indicators;
- to draw conclusions.

The object of the research: financial and non-financial indicators.

The methods of the research: information analysis and synthesis, method of constructive logics, data grouping and comparison method.

II MATERIALS AND METHODS

The current research is based on the theoretical studies by the author on the use of the financial and non-financial indicators in the evaluation of the business performance [12], [13] and continues the previous practical researches [10], [11]. To approbate the theoretical statements, the author has used the internet survey applying the random sampling method and has surveyed 208 Latvian companies in August and September 2012. The Latvian business persons and top-level employees of the Latvian companies, who are the users of the internal information making various operational and financial decisions, were surveyed: owners and top managers of the companies, heads of the structural units, heads and employees of financial departments. The aim of the survey was to establish the system of indicators for the evaluation of the business performance, which could be used by the managers to evaluate in an integrated way and to control efficiently the financial position of the company in the circumstances of the growing competition. The system of indicators would include both the set of specific financial indicators and non-financial indicators that would demonstrate the internal potential and future development possibilities of the company.

In the presentation of the study results, the opinions of the groups of respondents – owners, managers, heads of structural units, heads and staff of financial departments – are compared and assessed. The analysis of the research data was carried out considering four categories of enterprises: all enterprises (the total number of respondents), micro enterprises (1 - 9 employees), small enterprises (10-49 employees) and micro-small enterprises (1 - 49 employees), with the aim to identify possible differences regarding the small enterprises.

The assessment of the significance of the financial and non-financial indicators is based on the evaluation of importance of the financial and non-financial indicators in measurement of the business performance found in the companies' survey. In the survey, the five point Likert scale with a range from 1 ("Not important") to 5 ("Highly important") was used in the questions regarding the importance of financial and non-financial indicators in evaluation of the company's performance.

To establish a correlation among the groups of respondents and their replies, reciprocal correlations among the main budgeting objectives, as well as correlation between the main budgeting objectives and the importance of the financial and non-financial indicators, the Spearman's rank correlation coefficient method was used, as the respondents' responses being analysed are descriptions, and not precise values. Correlation between two questions has been considered, if the result has been statistically significant and the correlation coefficient $r>0.50$. If r is smaller, the correlation or relationship is weak or very weak. Considering r, it is possible to evaluate the strength of the relationship. Disregarding size of the sample, if $0 < |r| < 0.2$, a correlation is very weak, $0.2 \leq |r| < 0.50$ – correlation is weak, $0.50 \leq |r| < 0.70$ – correlation is moderate, $0.7 \leq |r| < 0.90$ – correlation is strong [9]. The result was considered to be statistically significant if $p < 0.05$ or $p < 5.00 \times 10^{-2}$ [17].

In order to examine whether the company's main budgeting objectives affect the importance of the factor groups of financial and non-financial indicators thus contributing to the achievement of the business goals, the regression analysis was conducted determining the impact (R^2) of each objective to the evaluation of the importance of the factor groups' indicators. The first, a linear regression was carried to identify the impact of the particular budgeting objectives (independent variable) to each factor group (dependent variable). Then, a multiple regression analysis was carried out to establish the overall impact of all company's main budgeting objectives on the factor groups. To verify the mode the importance of financial and non-financial indicators is affected by the company's main budgeting objectives thus fostering achievement of the business goals, the regression analysis was carried out determining an impact of each budgeting objective (R^2) on the assessment of importance of the financial and non-financial indicators. In view of the fact that the regression data is not intended to build the forecast models, only the possible impact (R^2) and the reliability of the regression model or impact (p) are specified in the research results, considering that the results are statistically reliable if $R^2 \geq 0{,}05$ and $p<0.05$.

The survey results are processed and analysed using SPSS and Excel programmes.

III RESULTS AND DISCUSSION

The survey respondents profile shows that, by the position in the company, most of the respondents (47.1%) are the owners of the companies (Table 1).

To identify the enterprise category (micro, small, medium enterprise or a large company), the average number of employees was used as a criterion. The respondents profile illustrates that according to the average number of employees the largest proportion is comprised by the companies with a number of employees from 1 to 9 (55.3%); according to the main business sector – wholesale and retail trade, repair of motor vehicles and motorcycles (24.5%), according to the year of founding – the companies that have been established from 1994 to 2000 (23.1%), and according to the companies' turnover during the last accounting year – the companies with the net turnover from 10 001 to 70 000 LVL (until 01.01.2014. 1 EUR = 0.702804 LVL) (30.3%).

TABLE 1.
PROFILE OF THE RESPONDENTS IN THE COMPANIES' SURVEY (%)

Position of respondents in the company, %	
Owners	47.1
General managers	24.5
Structural unit managers	4.3
Financial department managers	11.5
Staff of financial departments	12.5
Average number of employees in the company,%	
1 - 9 employees	55.3
10 - 49 employees	28.8
50 - 249 employees	14.4
More than 250 employees	1.4
Turnover in the last accounting year, %	
Less than 10,000 LVL	13.9
10,001 - 70,000 LVL	30.3
70,001 - 200,000 LVL	18.3
200,001 - 500,000 LVL	8.7
More than 500,000 LVL	28.8
Main business sector, %	
(A) Agriculture, forestry and fishing	10.1
(B) Mining and quarrying	5.8
(C) Manufacturing	15.9
(F) Construction	8.7
(G) Wholesale and retail trade; repair of motor vehicles and motorcycles	24.5
(S) Other services activities	14.9
(M) Professional, research and technical services	5.8
Others	14.4
Year of foundation, %	
Before 1991	10.1
1991 - 1993	21.6
1994 - 2000	23.1
2001 - 2007	18.8
2007 - 2010	16.8
After 2010	9.6

To sum up, the respondents have different positions in the companies; the companies represented are of different business sectors, different years of foundation, different average number of employees, and different volume of the net turnover. The author has carried out the statistical analysis and has concluded that there is a statistically reliable difference in all categories of enterprises, $p<0.05$ and with a probability of 95% it could be confirmed that the values used by the respondents of different groups to characterize companies significantly differ.

The establishing of sets of the financial and non-financial indicators included in the business efficiency evaluation of the companies is affected by the financial planning and controlling practices. The financial planning comprises a basis for the company's management and determines the objectives, achievements of which are measured using the financial and non-financial indicators. The respondents' views on what are the company's budgeting goals are summarized in Table 2, demonstrating variety of opinions.

Most of the respondents – company owners in all enterprise categories – consider that the main budgeting goal is *AR* (21.2%). General managers in all enterprise categories are of the same opinion on the main budgeting goals of the company – that is to be *IEP* (from 14.3% replies in the micro companies up to 20% in the small companies). Heads of structural units (15.8%) of all enterprises deem *IEB* to be the main budgeting objective. Views of the heads of structural units of micro-small and small companies are split among two budgeting objectives to be considered as the main - *IEB* and *IT* comprising 15.4%. Managers of financial departments have the biggest diversity of opinions in comparison with other groups of the respondents: they have named as much as six major budgeting objectives in all enterprise categories. Those are: *AR* (27.3%) in the category of all enterprises, *IEP* (20%) in the micro-small enterprises, and proportionally divided opinions in favour of *AR, IP, IEB* and *PD* (25%) in the small enterprises. The heads of financial departments of the micro enterprises identify *IP* and *ISS* as the main budgeting objectives (22.2%).

TABLE 2.
THE MAIN BUDGETING OBJECTIVES OF THE COMPANIES, %

The main budgeting objectives	Code	All companies					Micro-Small Enterprises					Small Enterprises					Micro Enterprises			
		1*	2*	3*	4*	5*	1*	2*	3*	4*	5*	1*	2*	3*	4*	5*	1*	2*	4*	5*
Assessment of the resources aiming at the rational and efficient utilization	AR	19.7	13.3	5.3	27.3	24.0	20.5	12.5	7.7	13.3	24.0	25.0	15.0	7.7	25.0	27.3	19.7	10.7	11.1	21.4
Increase of net turnover	IT	7.6	10.0	10.5	4.5	8.0	7.0	10.4	15.4	6.7	8.0	6.3	10.0	15.4	-	9.1	7.1	10.7	11.1	7.1
Increase of profits	IP	10.5	10.0	10.5	9.1	18.7	10.9	12.5	7.7	13.3	18.7	12.5	15.0	7.7	-	9.1	10.6	10.7	22.2	26.2
Increase of efficiency or profitability	IEP	8.6	16.7	5.3	13.6	4.0	8.9	16.7	7.7	20.0	4.0	12.5	20.0	7.7	25.0	-	8.3	14.3	-	7.1
Increase of utilization efficiency of equity capital and borrowed funds	IEB	1.9	6.7	15.8	-	10.7	2.0	4.2	15.4	-	10.7	6.3	-	15.4	-	18.2	1.2	7.1	11.1	4.8
Increase of customers satisfaction	ICS	11.5	10.0	10.5	9.1	-	10.9	6.3	7.7	13.3	-	12.5	-	7.7	25.0	-	10.6	10.7	-	-
Increase of market share	IMS	8.6	11.7	5.3	-	12.0	8.9	10.4	7.7	-	12.0	-	5.0	7.7	-	9.1	10.6	14.3	-	14.3
Increase of staff satisfaction	ISS	4.8	3.3	10.5	-	2.7	4.0	4.2	7.7	-	2.7	6.3	5.0	7.7	-	-	3.5	3.6	22.2	4.8
Improvement of products/ services quality	IQ	8.6	10.0	5.3	13.6	8.0	7.9	12.5	7.7	13.3	8.0	12.5	1.1	7.7	-	9.1	7.1	10.7	11.1	7.1
New products/ services development	PD	11.5	5.0	10.5	13.6	12.0	11.9	6.3	7.7	13.3	12.0	-	10.0	7.7	25.0	18.2	14.2	3.6	11.1	7.1
Improvement of reputation	IR	6.7	3.3	10.5	9.1	-	7.0	4.2	7.7	6.7	-	6.3	5.0	7.7	-	-	7.1	3.6	-	-

Designations: ** 1 - owner, 2 – general manager, 3 - head of structural unit, 4 – head of financial department, 5 – staff of financial department*

The conformity of opinions is observed among the staff of financial departments in all enterprise categories, except the micro-enterprises, determining *AR* as the main budgeting objective (25.1% in average); on its turn, the financial department staff of the micro enterprises deems the *IP* (26.2%) as the main budgeting goal. The author considers that the main budgeting objectives as named by the respondents, in general, corresponds with the time period, used by the companies to design financial plans for, usually, that is 1 (one) year (an annual budget). In addition, taking into account that approximately ¼ of the companies do not perform financial planning, it could have happened that part of the respondents have named just prospective budgeting goals of the company.

Summing up the opinions of the respondent groups, it could be concluded that the opinions of the different respondent groups on the main budgeting goals differ; hence, the views of the different groups of respondents on the compliance of the specific objectives with the main budgeting goal differ. There exists a moderate correlation |r=0.53| among the groups of respondents of the small companies and their replies regarding the compliance of the specific objective with the main budgeting goal PD. Furthermore, in accordance with the data, the lower is a position of the respondent in the company the more he/she considers the *PD* as the main budgeting goal. That indicates that the managers and the staff of financial departments, in contrary to the views of business owners and managers, consider this objective as one of the main budgeting goals.

An analysis of the correlation among the main budgeting goals leads the author to the conclusion that most of the objectives are interrelated, however, the correlation in the category of all enterprises and in the category of micro-small enterprises is very weak $0<|r|<0.2$ or weak $0.2\leq|r|<050$. There exists a moderate correlation |r=0.60| between two budgeting objectives – *ISS* and *IEB* referred to by the respondents of the micro enterprises. In the small enterprises, a few moderate correlations between the main budgeting goals could be found: a moderate correlation |r=0.64| between *PD* and *IMS*; a moderate correlation between *IR* and, consecutively, *IP* - |r=0.57|, *IEP* - |r=0.51|, *IMS* - |r=0.61|, *ISS* - |r=0.61|, and *IQ* - |r=0.61|.

The evaluation of the importance of the financial and non-financial indicators for the assessment of the company's business activities/performance provided by the respondents allows conducting the factor analysis of the financial and non-financial indicators establishing interconnections between the indicators. In the result of the analysis, three factor groups of financial indicators and two factor groups of non-financial indicators, considered by the respondents as important and affecting business performance, were established (Table 3).

TABLE 3.

RESULTS OF JOINT FACTOR ANALYSIS OF FINANCIAL AND NON-FINANCIAL INDICATORS IN THE CATEGORY "ALL ENTERPRISES"

Financial indicators						Non-financial indicators			
Labels and codes of factor groups									
Solvency and profitability / F-SP	Code	Efficiency of assets use and financial stability / F-ES	Code	Evaluation of investment possibilities F-I	Code	Role and influence of employees / NF-E	Code	Role and influence of consumers / NF-C	Code
Cash-flow report	F2	Net turnover	F1	Return on investments (ROI)	F14	Motivated employees	NF5	Level of consumers satisfaction	NF1
Current ratio	F3	Asset turnover, times	F4			Loyal employees	NF6	Increase of number of consumers	NF2
Debt-to-equity ratio	F9	Accounts receivable turnover (days/ times)	F5	EBIIMS (TD)A profitability	F15	The level of employees satisfaction	NF7	Consumers loyalty	NF3
Gross profitability	F10							Quality of the products / services	NF4
Return on assets (ROA)	F11	Inventory turnover (days/ times)	F6	DSCR (debt service coverage ratio)	F16	Development of new products / services	NF8		
Return on equity (ROE)	F12	Payables turnover (days/ times)	F7					Company reputation	NF10
Return on sales (ROS)	F13	Total debt ratio in the balance	F8			Training of employees	NF9	Market share	NF11

The results of the regression analysis between the financial/non-financial factor groups and the main budgeting objectives in accordance with the enterprise categories leads to the conclusion that a statistically reliable result in the micro-small companies exists between the budgeting goal *IEB* and the importance of the factor group *"Role and influence of employees" (NF-E).* The budgeting objective *IEB* affects a significance level of the *NF-E* factor group by 6%. Larger number of interrelated impact of the budgeting goals and the factor groups could be observed in the small and micro enterprises, hence, the author has summarised possible impact of the financial/ non-financial factor groups and the main budgeting goals in the small and micro enterprises in Table 4.

TABLE 4.

POSSIBLE IMPACT (R^2) BETWEEN THE FINANCIAL AND NON-FINANCIAL FACTOR GROUPS (DEPENDENT VARIABLE) AND THE MAIN BUDGETING OBJECTIVES (INDEPENDENT VARIABLE) IN THE SMALL AND MICRO ENTERPRISES (%).

Factor groups	Main budgeting objectives																					
	AR		IT		IP		IEP		IEB		ICS		IMS		ISS		IQ		PD		IR	
	Enterprise categories*																					
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
F-SP		5	9		19	5	8													5		5
F-ES		12							21			14	8									18
F-I	21				**22**			9				7	8						7		8	16
NF-E		5				14	15										**18**					
NF-C																	10					

*Designations:*1 – small enterprises, 2 – micro enterprises*

In the small enterprises, more significant possible influence is observed regarding four out of the eleven budgeting goals - *IP; IEP; IMS* and *IQ* that determine the importance of two out of the five factor groups in the achievement of these goals. The budgeting objective *IP* has the major impact on the *F-I* factor group and determines its importance by 22%. Higher potential effect could been observed with regard to the budgeting *IQ* objective*,* which impacts the *NF-E* factor group and determines its importance by 18%.

In the micro enterprises, higher potential influence is observed in respect of two out of the eleven budgeting goals – *AR* and *IR,* which determine the importance of three out of the five factor groups in the achievement of these goals. The highest impact these goals have on the *F-ES* factor group and, respectively, determine their importance by 12% and 18%.

The results of the multiple regression analysis between the financial and non-financial factor groups and the main budgeting goals in accordance with the enterprise categories lead to the conclusion that the importance of the *NF-E* factor group indicators in the micro-small companies is influenced by 13%, and only one variable – the budgeting objective *IEB*– is statistically significant. In the small and micro enterprises, a higher number of statistically significant variables, influencing the importance of the factor groups indicators, can be observed. Therefore, the author has compiled Table 5, summarizing possible impact between financial and non-financial factor groups and the main budgeting objectives in the small and micro companies, considering statistical reliability.

TABLE 5.

STATISTICAL RELIABILITY OF THE RESULTS OF THE MULTIPLE REGRESSION ANALYSIS OF THE FACTOR GROUPS OF FINANCIAL AND NON-FINANCIAL INDICATORS (DEPENDENT VARIABLE) AND THE MAIN BUDGETING OBJECTIVES (INDEPENDENT VARIABLE) IN THE SMALL AND MICRO ENTERPRISES

Factor groups	Main budgeting objectives																						**Possible impact (R^2)**	
	AR		IT		IP		IEP		IEB		ICS		IMS		ISS		IQ		PD		IR			
	Enterprise categories*																							
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
F-SP	√	√			√		√		√														0.37	0.17
F-ES			√	√	√				√			√		√	√				√			√	0.50	0.36
F-I	√		√		√		√		√		√		√		√		√		√		√		0.73	0.25
NF-E	√	√	√			√							√				√		√				0.58	0.29
NF-C				√	√	√	√	√	√	√	√			√	√		√				√		0.54	0.19

Designations: 1 – small enterprises, 2 – micro enterprises, √ - statistical significance*

The multiple regression analysis of the impact of the budgeting objectives in the small enterprises on the significance of the factor groups indicators points out (Table 5) that the importance of the *F-I* factor group indicators are determined by 73%, and all of the main budgeting objectives are statistically significant. The main budgeting goals influence the importance of the *NF-C* factor group indicators by 54%, and seven out of the eleven budgeting objectives *(IP, IEP, IEB, ICS, ISS, IQ, IR)* are considered to be statistically significant.

In the micro enterprises, in comparison with the small enterprises, the impact of the main budgeting objectives on the importance of the factor group indicators are essentially lower; the highest impact can be observed regarding the importance of the F-ES factor group indicators (36%), where four out of the eleven budgeting objectives *(IT, ICS, IMS, IR)* are significant.

Consistent with the results of the regression analysis of the particular financial indicators within the factor group and the main budgeting objectives in accordance with the enterprise category, it can be concluded that a statistically reliable result in the category of all enterprises exists between the budgeting objective *IEP* and the importance of the indicator *F3*. The budgeting objective *IEP* affects the importance level of the indicator *F3* by 6%. In the micro-small enterprises, the statistically significant result exists between the budgeting objective *AR* and the indicator *F15,* the influence is by 5%. In the small and micro enterprises, a higher number of interrelated effects between the budgeting objectives and the financial indicators can be observed, therefore, the author has compiled Table 6 to summarise the possible impact between the financial indicators and the main budgeting objectives in the small and micro enterprises.

In the small companies, a higher possible impact is observed regarding the budgeting objective *IP*, which determines the importance of eight out of the sixteen financial indicators in the achievement of this objective. The highest impact of this objective is on the indicator *F15* and determines its importance by 31%. In the small enterprises, the highest possible impact is observed as well regarding the objectives *IEB* and *IR,* which determine the importance of six out of the sixteen financial indicators in the achievement of this objective. The highest impact on the financial indicator F9 is determined by the budgeting objective *IEB,* affecting its importance by 31%. The budgeting objective *IR* affects the financial indicator *F11* and determines its importance by 19%.

In the micro enterprises, the highest potential impact is observed regarding the budgeting objective *IR,* which determines the importance of ten out of the sixteen financial indicators in the achievement of this objective. The highest impact of this objective is on the financial indicator *F4*, determining its importance by 29%. In the micro enterprises, higher possible impact is observed as well regarding the financial objective *AR,* which determines the importance of eight out of the sixteen financial indicators in the achievement of this objective. The highest impact of this objective is on the financial indicator F8, determining its importance by 12%.

TABLE 6.

POSSIBLE IMPACT (R^2) BETWEEN THE FINANCIAL INDICATORS (DEPENDENT VARIABLE) AND THE MAIN BUDGETING OBJECTIVES (INDEPENDENT VARIABLE) IN THE SMALL AND MICRO ENTERPRISES (%).

Factor groups	Code	Main budgeting objectives																					
		AR		IT		IP		IEP		IEB		ICS		IMS		ISS		IQ		PD		IR	
		Enterprise categories*																					
		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
F-SP	F2					12						9		22						11	8		
	F3				13				13				6		6			21			10		
	F9		7							**31**	5		5					12					10
	F10				20			10				9			8	7		7				7	
	F11			12		26	16	22	6													**19**	5
	F12			16		13																	
	F13					17	6	13	8			8									10		
F-ES	F1		8				10								15					14			
	F4		5							27						12							**29**
	F5		5							17			5	16								7	
	F6		7							27			12	12									17
	F7		6		5	7				9		12									5		11
	F8		**12**							12	9		10									10	9
F-I	F14	11		16		14		13	7				5	15			5			25		15	10
	F15	18			9	**31**	6		14					14	6						6	14	8
	F16	15	8										7					8					17

Designations: * *1- micro enterprises, 2 - small enterprises*

The comparison of the possible effects between the financial indicators and the main budgeting goals in the small and micro enterprises leads to the conclusion that the budgeting objectives of the small companies are of larger influence on the importance level of the financial indicators.

Evaluation of the results of the regression analysis of the non-financial indicators (dependent variable) and the main budgeting objectives (independent variable) in accordance with the enterprise category leads to the conclusion that, in the micro-small companies, a statistically significant result exists between the budgeting objective *IEB* and the non-financial indicator *NF8.* The objective *IEB* determines the level of importance of the indicator *NF8* by 5%. A larger number of interrelated influences between the budgeting objectives and non-financial indicators are observed in the small and micro enterprises, therefore, the author has compiled Table 7 to summarize the potential impact between the non-financial indicators and the main budgeting objectives in the small and micro enterprises.

TABLE 7.

POTENTIAL IMPACT (R^2) BETWEEN THE NON-FINANCIAL INDICATORS (DEPENDENT VARIABLE) AND THE MAIN BUDGETING OBJECTIVES (INDEPENDENT VARIABLE) IN THE SMALL AND MICRO ENTERPRISES (%)

Factor groups	Code	Main budgeting objectives																					
		AR		IT		IP		IEP		IEB		ICS		IMS		ISS		IQ		PD		IR	
		Enterprise categories*																					
		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
NF-E	NF5		11		7	8	7	21	10	21	7							**21**			6		
	NF6		6					**22**	9		7							12			5		
	NF7						**16**										10	**21**	5				
	NF8			7			8													19	7		
	NF9	7		13			14	7						10				9				7	
NF-C	NF1					10	9					7						17		15			
	NF2															14							
	NF3		11	7	19	15		8	6					15				15					
	NF4																						
	NF10		7		6			13			16	9		11						7	6		
	NF11									23						**37**							

Designations:* *1 – small enterprises, 2 – micro enterprises*

In the small enterprises, more significant possible influence is observed regarding the budgeting objective *IQ,* which determines the importance of six out of the eleven non-financial indicators in the achievement of this objective. The highest impact by this objective is on the non-financial indicators *NF5* and *NF7*, determining their importance by 21%. In the small enterprises, a larger potential effect is observed as well regarding the budgeting objective *IEP*, which determines the importance of five out of the eleven non-financial indicators in the achievement of this objective. The highest is the impact of this objective on the non-financial indicator *NF6,* determining its importance by 22%. The influence of the budgeting objective *ISS* on the importance of the non-financial indicator *NF11* should be emphasized, as it has produced a statistically significant result – 37%.In the micro enterprises, the highest potential impact is observed in relation to the budgeting objective *IP*, which determines the importance of five out of the eleven non-financial indicators in the achievement of this objective. The highest influence of this objective is on the non-financial indicator *NF7*, determining its importance by 16%.

The comparison of the extent of the possible impact of the main budgeting goals on the non-financial indicators in the small and micro enterprises, it can be concluded that the probable influence on the non-financial indicators are higher in the small enterprises. In its turn, the comparison of the potential impact on the financial/ non-financial indicators by the main budgeting goals, leads to the conclusion that, generally, the main budgeting objectives have higher possible impact on the importance of the financial rather than non-financial indicators.

The practical research is under the development; in the result of the study, a system of the business performance assessment indicators will be developed providing the managers of the companies with a possibility to evaluate and monitor performance of the company in an integrated and efficient way.

IV CONCLUSION

The opinions among the respondent groups regarding the main budgeting goals of the companies differ. In the small enterprises, a moderate correlation between the respondent groups and their answers regarding the compliance of the specific objective with the main budgeting goal – development of new products/services (PD) – exists, demonstrating that the managers and staff of financial departments, as opposed to the business owners and managers, consider this objective to be one of the main budgeting goals of the company.

There are correlations between the main budgeting objectives of the companies. In the small enterprises, a moderate correlation exists between the goal related to the development of new products/services and the goal related to the increase of the market share of the company. Furthermore, moderate correlations are observed between the budgeting objective related to the improvement of the corporate image and the budgeting objectives related to the increase of profits, increase of profitability and efficiency, increase of the market share, increase of the employees' satisfaction, improvement of the quality of products and services.

In the small enterprises, a higher possible impact is observed as regards four out of the eleven main budgeting objectives: increase of profits, increase of profitability and efficiency, increase of the market share, and the improvement of the products/services quality; these four determine the importance of two out of the five factor groups in the achievement of these objectives. The highest impact of the budgeting objective related to the profit increase is on the factor group F-I, determining its importance by 22%. A higher potential impact is also observed regarding the budgeting objective related to the products/services quality improvement, which determines the importance of the factor group NF-ISS by 18%.

The comparison of the possible influences between the financial/ non-financial factor groups and the main budgeting objectives in the small and micro enterprises leads to the conclusion that the potential influence is larger in the small enterprises.

The overall impact of the main budgeting objectives on the importance of the F-I financial group indicators comprises 73%, and all of the main budgeting objectives are statistically significant. The overall impact of the budgeting objectives on the importance of the non-financial factor group NF-E indicators comprises 54%, and seven out of the eleven main budgeting objectives (*IP, IEP, IEB, ICS, ISS, IQ, IR)* are statistically significant.

In the small enterprises, the main budgeting objectives have a larger potential impact on the importance level of the financial and non-financial indicators if compared with the other enterprise categories being examined. The comparison of the possible impact of the main budgeting objectives on the importance level of the financial indicators and the non-financial indicators leads to the conclusion that the larger possible impact is related to the importance of the financial rather than non-financial indicators.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 168-173

Assessment of Urban Sustainable Development: Example of Rezekne City

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Abstract. **Since 90s of the 20th century sustainable development has become a global issue which is receiving increasing attention. Successful sustainable development is only possible from the bottom to the top, which means that the human and environmental mutual relations must be taken into account not only on a global scale as a whole, but also focus on the much smaller territorial units.**

The role of the city as the administrative territorial unit has significantly increased in recent years, the acknowledgment for that can be found in the European Union Cohesion Policy, polycentric development policy, spatial planning policy, etc., in the figures of the rapid population growth in urban areas, about joining of separate scientific disciplines in order to study current issues in the cities.

In sustainable development studies special attention is paid to mega cities or capitals, which have the most significant impact on the environment, based on certain key indicators - CO2 emissions, the amount of municipal solid waste generated in cities, etc.

The planning documents, that provide a picture of the specific urban sustainable development priorities, play an important role in ensuring sustainable development.

The aim of the article is to explore the sustainable development strategies of the city of Rezekne for 2013-2030 in conformity with the five dimensions of sustainable development and to assess the development possibilities of Rezekne.

During the study the sustainable development strategy of Rezekne for 2013-2030 was evaluated, strategic aims, long-term priorities, and actions were established. As a result, it was concluded that they meet all five dimensions of sustainable development, but in the strategy for these actions, it is necessary to focus on the essence of the concept of sustainable development, that meets the needs of the present without compromising the ability of future generations to meet their own needs [1].

The evaluation of current performance shows that the strategy of planned targets may not materialize and as a result have a significant impact on sustainable development, so it is necessary to make appropriate adjustments in the operational plans.

Keywords: **city, dimensions, planning documents, sustainable development.**

I INTRODUCTION

The importance of sustainable development is growing in a fast-paced era of globalization, which is reflected in the solution of urgent global problems (global warming, deforestation, etc.) using different levels of planning documents. In the European Union and its Member States, the sustainable development strategy has been developed at all levels: at the level of the European Union, national, regional and / or local level. It is important that each lower-level document is hierarchically subordinated to a higher level document. This creates confidence in the progress towards common strategic objectives.

Sustainable development is often associated with the environmental problems, although in essence it is a diverse set of aspects, including socio-economic, political, cultural, etc. issues. It was necessary to develop a sustainable development strategy for 2013 - 2030 at Latvian national, regional and local levels.

Getting acquainted with the Regional Development and Local Government Ministry developed "Methodological recommendations for the sustainable development strategies and development program for the regional and local levels" (23.09.2010) [2] should be concluded that the concept of "sustainable development" is mentioned in this document, but its explanation is not given.

Sustainable development is one of the concepts that are integrated into the European Union's planning and policy documents (e.g. "Europa2020"), thus emphasizing its importance. For the first time the concept of sustainable development was mentioned at the United Nations Conference on man-made environment (in 1972) [3]. In the following years, it was highlighted in various reports and statements: in Brandt Commission's report "North-South: A Programme for Survival" (1980), in Gro Harlem Brundtland Commission's report "Our Common Future" (1987) [3], in the Rio Declaration on

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.269

Environment and Development and the Action Plan for the 21st Century (Agenda 21) (1992) [3], in Rio + Conference Declaration "The future we want" (2012) [3].

Sustainable development is the latest manifestation of a centuries-old ethics related to human and environmental relations and the present generation responsibility towards future generations [4].

Sustainable development meets the needs of this generation without compromising future generations to meet theirs. (..) It promotes a dynamic economy with full employment, a high level of education, good health care, social and territorial cohesion and environmental protection in a peaceful and secure world, respecting cultural diversity [5]. "

The definition also states that sustainable development is not only related to ecological issues, but there is much more to be analyzed.

Canadian International Development Agency's evaluation of sustainable development states that it is necessary to take into account three aspects: economic, environmental and social. Each of the aspects is analyzed based on certain indicators. Economy: unemployment rate, job, economic growth. Environment: green spaces, energy efficiency, water quality / availability, air quality, waste, mobility. Social: compact city, housing, quality public spaces, education, sanitation, health [6]. Each of these indicators is analyzed in accordance with sustainable development. This model is more appropriate to assess the situation in the field of sustainable development, but it does not take attention to conditions that may substantially affect sustainable development.

Allen explains the sustainable development as a five-dimensional model: economic sustainability, social sustainability, ecological sustainability, the sustainability of the built environment, and political sustainability. After analyzing the essence of each aspect, it is concluded that the productive use of sustainable development resources brings long term benefits, secures the certain standard of living using natural, physical and economic capital, respects cultural heritage and cultural diversity, taking into account the interaction between the state and the use of environmental resources, buildings and infrastructure do not damage and erode the environment. Political sustainability, which is regulating the other four dimensions involved in the relationship, is unifying in this model [7].

S.K. Cheng, Q.W. Min and L.F. Li [8] in the analysis of sustainable development use a four-dimensional model: economic dimension, ecological dimension, environmental dimension, and multi-dimensions. Analyzing sustainable development by the model proposed by the authors, the above mentioned information should be taken into account.

E.Römpczyk [4] explains sustainable development as the five dimensions - a strong economic development, cultural diversity, biological diversity, equal opportunities for all, democratic relations between the state and society [4] - the interaction between time and space. This shows that the analysis of the sustainable development must be based on a long-term process of research, because only then obtained results and the corresponding conclusions will be objective.

Therefore, the article aims to explore the compliance of sustainable development strategy of Rezekne for 2013-2030 with the five dimensions of sustainable development and to assess the development possibilities of Rezekne.

To achieve this goal, the following tasks were set:

- Explore the theoretical aspects of concept of "sustainable development";
- To assess the compliance the sustainable development strategy of Rezekne city for 2013 - 2030 with five dimensions of sustainable development;
- To estimate just a few performance indicators mentioned in the strategies because of a limited size of the article

II MATERIALS AND METHODS

Data analysis techniques used in the research: logical constructive method, monographic method.

Data collection methods used in the research: document analysis method.

Data were analysed using the SPSS program.

Practical research base: Sustainable development strategy of Rezekne for 2013 -2030, statistical analysis of the data for the period from 2010 to 2014.

Rezekne sustainable development strategy for 2013-2030 (hereinafter - the strategy) is used as a base for the research. The strategy is one of the most important planning documents that reflect the city's long-term development plans in accordance with sustainable development.

This document sets out four strategic objectives of Rezekne each of which corresponds to one of the long-term priorities: "Rezekne - internationally competitive economic development centre", "Rezekne - creativity, Latgalian, cultural tourism and leisure centre", "Rezekne - education, research and sports development centre "," Rezekne - human and environment-friendly, safe and modern city " with a number of actions. The author carried out a content evaluation of each action mentioned in the strategy in order to determine the overall compliance with sustainable development. Each of the actions was evaluated according to five dimensions, answering a question with a "yes" or "no."

III RESULTS AND DISCUSSION

Based on the theoretical literature studies, the author in her study will use a five-dimensional model:

economic, social, environmental, and political (institutional), cultural and cultural history.

Economic Sustainability means economic growth, respecting sustainable development.

Environment sustainability means environmentally friendly buildings and infrastructure, green areas in the city, ecological issues, taking into account sustainable development.

Social Sustainability means people's quality of life, in a criminal case (security issues), education and health systems availability and quality, situation in social housing, sanitation and hygiene situation, infrastructures and the quality of the parks in accordance with sustainable development.

Political (institutional) sustainability is characterized by democratic relationship between specific users of the area (municipality, investor citizenships, different groups of community etc.) in accordance with sustainable development.

Cultural and cultural history sustainability is the basis for the previous four dimensions. This aspect determines what the sustainable development will be, taking into account the past, the situation today and future visions.

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This document sets out four strategic objectives of Rezekne each of which corresponds to one of the long-term priorities: "Rezekne - internationally competitive economic development centre", "Rezekne - creativity, Latgalian, cultural tourism and leisure centre", "Rezekne - education, research and sports development centre "," Rezekne - human and environment-friendly, safe and modern city " with a number of actions. The author carried out a content evaluation of each action mentioned in the strategy in order to determine the overall compliance with sustainable development. Each of the actions was evaluated according to five dimensions, answering a question with a "yes" or "no." As a result, it was determined that in total the planned actions correspond to all five dimensions of sustainable development (Table 1), but there is a different percentage distribution.

TABLE 1
LONG-TERM PRIORITIES DEFINED IN THE MAIN ACTION IN ACCORDANCE WITH DIMENSIONS, % [12]

Dimensions	No	Yes
Economical	60,9	39,1
Environment	68,8	31,3
Social	46,9	53,1
Cultural and cultural history	81,3	18,8
Political (institutional)	70,3	29,7

Most of the planned activities (53.1%) relate to the social dimension, but smallest number to the cultural and cultural history dimension (18.8%). The action assessment of strategy shows that the largest number of activities is aimed to solving social problems, as well as priorities, that are specific to social dimension, are identified. Cultural and cultural dimension history is the basis for sustainable development, because it provides development options and directions for other dimensions, but it is not a primary one compared to other dimensions.

It is necessary to evaluate strategies not only after the certain deadline, but also to make an inter-assessment in order to draw appropriate conclusions about the feasibility of the planned objectives.

Due to the wordage limit the author carried out analysis only of the most important indicators that describe sustainable development.

It is planned in the strategy that the population of the town of Rezekne will grow to 32,000 till 2020, while in 2030 to 35 000 inhabitants (Fig.1.). However, assessing the dynamics, it is concluded that since 2012 the population has declined by 6%, and currently has less than the planned 32 000 inhabitants in 2020.

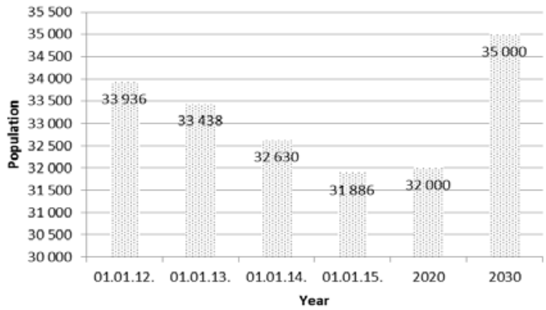

Fig. 1. Population of Rezekne in 2012-2030 [9]

The natural growth rate and net migration significantly affect the number of population.

It is planned in the strategy that by 2020 there won't have been a negative tendency in natural increase, but already by 2030 this figure will have changed to positive (Fig.2.).

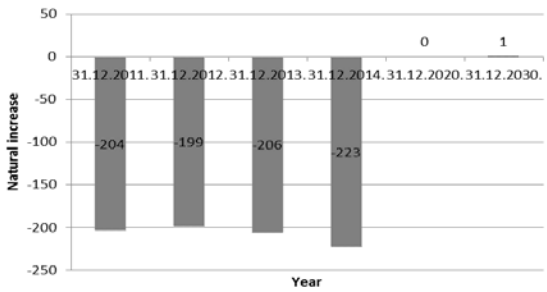

Fig. 2. The natural growth of population in Rezekne in 2011 -2030 [9]

However, statistics show that since 2011 dynamics in the natural growth has remained negative, which means that it would be difficult to achieve planned indicators in this area of the strategy.

It is planned in the strategy that by 2020 the negative trend of net migration will have been stopped, but already by 2030 this figure will have had a positive trend. The current figures show that during the analyzed period this figure varies each year (Fig.3.). In 2011 it increased by 10.9% compared with 2010, but in 2012 decreased by 49.88% compared with the previous year, but in 2013 there was again an increase of 29.73%, compared with 2012. But despite annual fluctuations, in 2013 compared with 2010 net migration decreased by 19.95%, which means that, in theory, by 2020 it is possible to achieve strategic objectives.

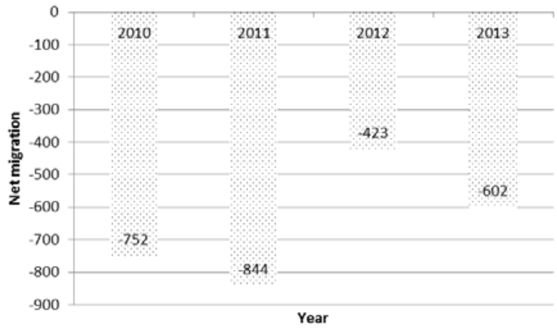

Fig. 3. Net migration in Rezekne in 2010-2013. [9]

It is planned that by 2030 the economically active number of units of the market sector will have increased. Analysis of available statistical information shows that the number of units of the economically active sector of the market in 2013 increased by 6.77% (fig.4.) And generally positive dynamics is seen.

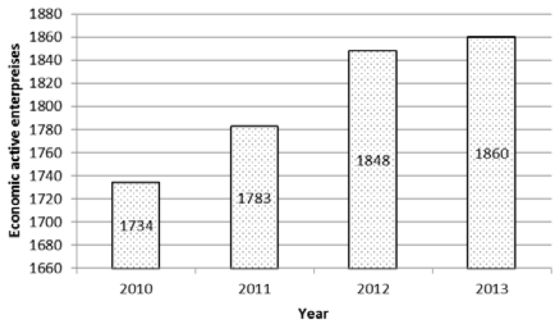

Fig. 4. Economically active units of market sector in Rezekne in 2010 - 2013 [9]

Business development is the basis for a favourable socio-economic situation, however, for the full evaluation of this issue it is necessary to analyze units of the economically active market sector by size and business forms.

TABLE 2
ECONOMICALLY ACTIVE UNITS OF MARKET SECTOR IN REZEKNE AFTER THE FORM OF ENTREPRENEURSHIP IN 2010 - 2013 [9]

Form of business	2010	2011	2012	2013
Self-employed people	775	799	830	825
Sole proprietorships	184	183	173	179
Commercial companies	760	787	834	844
Farms and fisheries	15	14	11	12

The dominant form of business in Rezekne is a self-employed person and a commercial society in which more than 800 companies are involved (Table 2). The number of self-employed people during the analyzed period has grown by about 6% in 2013 compared with 2010, but compared with the year 2012 has decreased by 0.6%.This reduction is due to changes in legislation, as since 2014 changes to the personal income tax entered into force, which provided a minimum fee of 50 EUR in cases if one is registered as a self-employed person, but economic activity is not implemented.

From a city development point of view it should be admitted that the interest and the desire of people to become entrepreneurs have serious grounds for long-term development. With increasing number of companies, the appropriate positive trends should be monitored for the unemployment rate.

Historically, many large companies operated in Rezekne, where the number of employees was several hundred or even in some exceeded 1,000. Disruption of large enterprises contributed to the strong increase of unemployment level in the city.

Despite the fact that continually new businesses start up, rapid decrease of the unemployment rate does not occur. Around 91% of enterprises in Rezekne are micro- enterprises, but rather only 0.1% of enterprises are large companies (Table 3). According to the European Commission Regulation No.800 / 2008 [10], micro enterprises are those with fewer than 10 employees and a turnover or balance sheet of those does not exceed 2 million EUR. In order to significantly reduce the unemployment rate in Rezekne a much faster increase of economically active market sector units in the micro or small business category or at least a start-up of one large company is necessary.

TABLE 3
UNITS OF ECONOMICALLY ACTIVE MARKET SECTOR IN REZEKNE AFTER SIZE IN 2010 - 2013 [9]

The size of the group	2010	2011	2012	2013
Micro	1568	1618	1683	1698
Small	145	143	138	137
Average	19	20	25	25
Large	2	2	2	2

It should be taken into account that a start-up of a large manufacturing business is unlikely probability, as the automation of the production process requires a minimum number of employees.

As a result, unemployment in Rezekne is still an urgent and important problem, which significantly affects the socio-economic situation and threats to long-term strategic objectives. Figures show that in 2012, compared with 2011, the unemployment rate rose by 1.9%, but since 2012, the unemployment rate decreased by 4.6% (Fig.5.), which affects not only the growth of economic active market sector units, but also the overall population decrease in Rezekne.

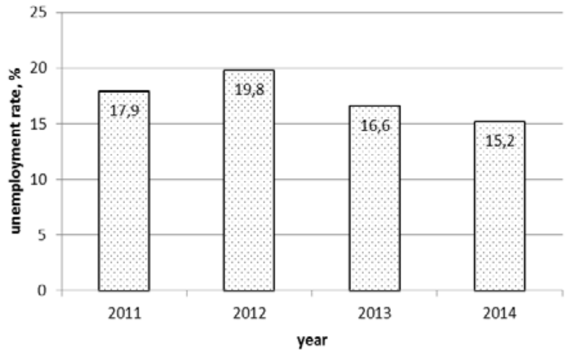

Fig. 5. The unemployment rate in Rezekne in 2011-2014 [9]

The socio-economic situation in the city is characterized not only by unemployment, but also by the security level.

Number of criminal offenses registered in Rezekne is variable (Table 4). In 2012, the registered criminal offenses decreased by almost 25% compared with 2011, but in 2013 increased by approximately 10% compared with 2012. In 2014 number increased by 6% compared with 2013. Analyzing the number of offenses per 10 000 inhabitants, it is concluded that the increase is faster (by 12.4% in 2013 compared with 2012. In 2014 number increased by 6.3% compared with 2013. The overall trend shows a decrease of security level in Rezekne. According to the author, this situation is also partly affected by the elimination of Rezekne municipal police in 2014.

TABLE 4
NUMBER OF CRIMINAL OFFENSES IN REZEKNE IN 2010 – 2014

Year	Registered number of criminal offenses in Rezekne	Number of criminal offenses per 10 000 inhabitants in Rezekne
2010	867	249
2011	907	283
2012	685	220
2013	762	251
2014	811	268

Environmental dimension characterize ecological issues like waste management, water and air quality. Rezekne city implemented projects (for example, to improve the quality of drinking water. Waste management, etc.) indicates the municipal interest in ensuring a sustainable environment.

IV CONCLUSIONS

In the strategy of the city of Rezekne five dimensional model of sustainable development is taken into account, as the planned actions are focused on the solving of the economic, social, environmental, cultural, and political issues. However, the author believes that in the strategic objectives, priorities and long-term actions there is a lack of emphasis on the concept of "sustainable development" essence. For example, keep to the principles of sustainable development in the construction of new buildings or arrangement of brown field sites.

Strategy and statistical analysis of information about the city of Rezekne provides answers for the realization of the planned performance indicators. It must be concluded that there are greatest doubts concerning the demographic execution because the current dynamics show negative trends. Decrease in the number of population shows socio-economic problems in the city. The high unemployment rate contributes to population migration; it negatively affects the rate of natural growth and safety in the city.

According to the author, it is necessary to activate the political (institutional) dimension, in order to promote entrepreneurship and activate tourists' interest in the city with the help of municipal disposal instruments (projects, tax credits, etc.).

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 174-180

The impact of human capital development on the economic and social development of a country: empirical study

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Abstract. **Methodologically this research is based on the approach of many social scientists who argue that there is a bidirectional link: one runs from human capital development to economic growth and overall human development, when human capital helps increase national income and society development; the other runs from economic growth to human capital development, as the resources from national income are allocated to activities contributing to human capital development. The study aims to empirically verify the existence of this interaction by carrying out a correlation analysis of the human capital development level among 120 countries, assessed by the Human Capital Index, and the world's national economic development level, as demonstrated by the Global Competitiveness Index, as well as the level of development of the world's nations (societies) as demonstrated by the Human Development Index.**

The result of the analysis empirically demonstrated a strong link between the human capital development with the country's economic ($r = +0.944$, $p = 0.000$) and national development ($r = +0.882$, $p = 0.000$) in total by all countries. Nevertheless, carrying out the correlation analysis by groups of countries, which are divided according to the calculation methodology of the Global Competitiveness Index, depending on their stage of economic development, the relationship between human capital development and nation's development is becoming weaker in some groups of countries, with the remaining strong correlation between the development of human capital and the economic development of a state in all groups of countries. This means that only highly developed human capital can contribute to the country's economic development, and vice versa, national economic performance increases human capital development in the framework of effective development policy. On the other hand, not always a close interaction between nation's development and human capital development can be faced, since a highly developed human capital means the quality of the developed human capital.

Keywords: **economic growth, global competitiveness index, human capital, human capital index, human development index.**

I INTRODUCTION

Human capital is a set of person's abilities and skills, having direct impact on one's economic and social activity potential. The definitions of human capital usually emphasise the individual's education, skills, abilities and knowledge that increase the productivity of his economic activity, however, the content of the concept is much broader. Human capital includes both technical and social skills. The concept of "human resources" is also widely exploited, and refers to the number and the proportion of working age people in the society [1].

The main difference between the concept of "human capital" and the concept of "human resources" is investing in a factor. Human capital can be interpreted as an economic concept if investments into human resources, including employees, are made, i.e., contribution of financial resources, which is an individual, business or government expenditure with the aim to increase the capital. Investments in human capital are today's targeted expenditure to ensure additional income in the future [2].

The concept of human capital is primarily related to the economic behaviour of individuals, especially in the way in which their accumulated knowledge and skills boost their productivity and income, thereby increasing the productivity and income of the society on the whole. By purposefully contributing its efforts and means into education and skills, the society can achieve the desired economic return - both at the individual and society levels. On the other hand, many human capital components not only enhance the efficiency of individual economic activity, but also influence one's personal and social well-being [1, 3].

Investments in human resources and human capital are becoming a key factor for the development of a company, branch and country as a whole [3, 4].

The first economist who articulated the idea that population with its productive capacity is the nation's wealth was William Petty [5].

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.268

Under the conditions of the scientific and technological revolution taking place in the 50ies of the twentieth century, the world was struck by the deficit of highly qualified staff, with thereby growing educational qualification when much attention was devoted to the level of peoples' attained education. Therefore, beginning with the 60ies of the twentieth century, special attention was granted to the quality of the labour force, namely to the level of education and professional training in particular. *The human capital theory* emerged within this period, embracing people's knowledge, skills and abilities, as well as other people's qualities that provide individual economic and social benefits. The development of the concept of human capital is associated with T. Schultz [6, 7, 8, 9], G. Becker [10, 11], B. Weisbrod [12], G. Mincer [13], W.L. Hansen [14], M. Blaug [15], R. Layard [16], and other authors' works.

Contemporary foundations of the human capital theory were established and defined in the works of famous American economists T. Schultz [6, 7, 8, 9] and G. Becker [11]. T. Schultz in his theory justified economic efficacy of public expenditure on inhabitants' education, medical care, vocational training, i.e. financial expenditure on education is modified resulting from such human intellect and culture development, which in its own way is a form of fixed remuneration and profit for both a person and society as a whole. The more qualified people's work is, the higher is their capital and, consequently, the yield on capital (labour income). Human capital is viewed as one of the most significant factors of economic growth and the growth of economic potential [6, 7, 8, 9].

Becker, performing the subsequent development of The human capital theory, concluded that the investment in human capital can bring the highest degree of income to the national economy, thus stimulating its growth. These investments also determine the need for new knowledge, innovation boosting the field of technology and contribute to the overall development of a country [10, 11].

It should be noted that the human capital theory sees people as a key factor in the economic growth of territories. In the XXI century an individual and his/her potential has become a vital driving force for the economy and hence territorial development. Thus, all investments in a person, his/her intelligence and health become in advance beneficial for the society and the country as a whole. Accordingly, the investment in culture, education, spiritual sphere is to be seen as a highly economically effective investment in human capital. In developed countries, investment in human capital is becoming the underlying fundamental for the territorial competitiveness and economic growth. Human capital is a foremost, crucial national wealth re-growth factor. Human resources have become a key factor in achieving competitive advantage in today's economy [17].

The value of human capital is also analysed in the R. Florida's Creative Class theory, which is grounded on economic and regional development and its facilitation instruments. Florida's theoretical conclusions are based on three key development factors, the so-called 3T - Technology, Talent and Tolerance. If a company / city / region / territory has all these 3T, it is able to attract creative workforce with the ability to innovate and contribute to economic growth. According to the Creative Class theory, the class of creative people under the conditions of modern economy is vital for the economic growth of a region. Knowledge as a source of wealth creation and economic growth has replaced the efficiency of natural resources and physical labour. Today, talent has become the main factor of production, and the competitive advantages are inherent to those areas which are able to create, maintain and attract the best human capital [18, 19].

The present study aims to empirically demonstrate human capital development link with the country's economic development (in this study - the country's competitiveness) and the overall development of society (in this study – nation's development).

II MATERIALS AND METHODS

The empiric study of the authors, presented in this article, is secondary and is based on three global comparative researches: Human Capital Report of the World Economic Forum [20], Human Development Report of the United Nations Development Programme [21] and Global Competitiveness Report of the World Economic Forum [22].

Human Capital Index (HCI) is a new measure for capturing and tracking the state of human capital development around the world, and it was first calculated in 2013. The index is based on 4 pillars, containing a total of 51 indicators: 3 core determinants of human capital – education (12)[1], health (14) and employment (16), plus those factors that allow these three core determinants to be translated into greater return – enabling environment (9). Each pillar's significance weight is 0.25 of the total index value. When calculating the indicator values, the data are standardised employing z-score statistics as standard deviations from a mean, therefore, the total value of the index may also be negative [20].

Human Development Index (HDI) has been used since 1990 and it was the first attempt to incorporate different aspects of quality of life. It was modified and redefined in 2010. This composite index aggregates 3 dimensions: a long and healthy life, measured by life expectancy at birth; access to knowledge, combining mean and expected years of schooling; a decent standard of living, measured by Gross National

[1] The number of indicators in each pillar is indicated in brackets

Income per capita (PPP US$). Higher value means better well-being for nations. The values of the index vary in a range from 0 to 1, where 1 is the highest level of human development in a country [21].

Since 2005, the World Economic Forum has based its competitiveness analysis on the **Global Competitiveness Index** (GCI), a comprehensive tool that measures the micro- and macroeconomic foundations of national competitiveness. GCI involves static and dynamic components as a weighted average of many different aspects. GCI is based on 12 pillars, which contain 114 indicators: institutions (21), infrastructure (9), macroeconomic environment (5), health and primary education (10), higher education and training (8), goods market efficiency (5), labour market efficacy (10), financial market development (8), technological readiness (7), market size (4), business sophistication (9) and innovation (7). A nation's level of competitiveness reflects the extent to which it is able to provide rising prosperity to its citizens and GCI has examined various factors enabling national economies to achieve sustained economic growth and long-term prosperity. The value of the index is measured in a scale from 1 to 7, where 7 is the maximum value, namely, it indicates the highest level of competitiveness [22].

In the course of the present empirical study the authors worked with HCI values referring to 2013 (HCI 2013), HDI values for the year 2013 (HDI 2013) and GCI values for the period 2014-2015 (GCI 2014-2015). In overall, 120 world's countries were analysed, which have all three index values. For the detailed research of interrelation of human capital (HCI) and the country's economic development (GCI) and the nation's development (HDI), the correlation analysis of a total of 120 group of countries was conducted in the SPSS programme, as well as performed separately in each of the five groups of countries in which they are divided according to their GCI stage of development: according to the GCI calculation methodology, various world's countries appear to be in five stages of economic development, depending on their level of GDP per capita and competitiveness of individual growth factors:

1) Stage 1: factor-driven economies,
2) Transition from stage 1 to stage 2 economies,
3) Stage 2: efficiency-driven economies,
4) Transition from stage 2 to stage 3 economies,
5) Stage 3: innovation-driven economies [22].

III RESULTS AND DISCUSSION

The conducted correlation analysis of the countries' HCI 2013, HDI 2013 and GCI 2014-2015 shows that (see Table 1):

1) in all 120 group of countries there is a strong positive statistically significant correlation between both HCI 2013 and GCI 2014-2015, where $r = +0.944$, $p = 0.000$, as well as between HCI 2013 and HDI 2013, where $r = +0.882$, $p = 0.000$. This means that among the state human capital development and national competitiveness as well as nation's development there is a close relationship observed, which is manifested as follows: when the value of human capital in a country increases, the economic return on human capital also grows, promoting the competitiveness of the country, the nation's development also increases together with the development of human capital. In its turn, the improvement of national economic indicators (in this study - competitiveness) and the increase in nation's development, in the framework of qualitative development policy, also leaves a positive effect on the development of human capital, since there is a bidirectional link connecting these phenomena;

2) a strong positive statistically significant correlation is observed among the HCI 2013 and GCI 2014-2015 in all five groups of countries of national economic development stages: stage 1 group of countries $r = +0.897$, $p = 0.000$; transition from stage 1 to stage 2 group of countries $r = +0.751$, $p = 0.000$; stage 2 group of countries $r = +0.812$, $p = 0.000$; the transition from stage 2 to stage 3 group of countries $r = +0.815$, $p = 0.000$; stage 3 group of countries $p = +0.932$, $p = 0.000$, which certainly confirms the theoretical assumptions on the fact that exactly the developed human capital is a successful driving force of the economic development, and vice versa, since the countries with high economic performance are interested in the development of their own human capital, implementing the country's overall development policies aimed at the country's main resource, i.e. enhancement and growth of the human capital;

3) a strong positive statistically significant correlation is observed between the HCI 2013 and HDI 2013 in the economic development of stage 1 group of countries $r = +0.709$, $p = 0.000$ and stage 3 group of countries $r = +0.752$, $p = 0.000$. This is justified by the fact that the stage 1 group of countries according to the GCI calculation methodology includes countries with low GDP per capita, where there is mostly unskilled labour and low productivity, and which specialise in the extraction of natural resources, hence the low HDI values result from low HCI values, and vice versa. Stage 3 group of countries according to the GCI calculation methodology includes countries with a high GDP per capita, where there is skilled labour and which compete by producing goods using the most sophisticated production processes and by innovating the new ones, therefore these countries have a highly developed human capital (high HCI), which also contributes to the overall nation's development (high HDI) and vice versa;

TABLE 1

CORRELATIVE INTERRELATION AMONG HCI 2013, GCI 2014-2015AND HDI 2013 ACROSS ALL COUNTRIES AS A WHOLE (N =120) AND IN THE BREAKDOWN OF GROUP OF COUNTRIES OF GCI ECONOMIC DEVELOPMENT STAGE, PEARSON CORRELATION COEFFICIENTS

			GCI 2014-2015	**HDI 2013**
Stage 1: Factor driven economies BGD, BFA, CHM, CMR, CIV, ETH, GHA, GUI, IND, KEN, KGZ, LAO, LSO, MDG, MWI, MLI, MRT, MOZ, NIC, NGA, PAK, SEN, TZA, UGA, VNM, YEM[2]	HCI 2013	Pearson Correlation	,897**	,709**
		Sig. (2-tailed)	,000	,000
		N	26	26
Transition from stage 1 to stage 2 economies DZA, AZE, BTN, BOL, BWA, HND, IRN, KWT, MDA, MNG, PHL, SAU, VEN	HCI 2013	Pearson Correlation	,751**	,429
		Sig. (2-tailed)	,003	,143
		N	13	13
Stage 2: Efficiency-driven economies ALB, ARM, BGR, CHN, COL, DOM, EGY, SLV, GEO, GTM, IND, JAM, JOR, MKD, MAR, NAM, PRY, PER, ROM, SRB, ZAF, LKA, THA, TUN, UKR	HCI 2013	Pearson Correlation	,812**	,524**
		Sig. (2-tailed)	,000	,007
		N	25	25
Transition from stage 2 to stage 3 economies ARG, BHR, BRB, BRA, CHL, CRI, HRV, HUN, KAZ, LVA, LBN, LTU, MYS, MUS, MEX, OMN, PAN, POL, RUS, SUR, TUR, ARE, URY	HCI 2013	Pearson Correlation	,815**	,451*
		Sig. (2-tailed)	,000	,031
		N	23	23
Stage 3: Innovation-driven economies AUS, AUT, BEL, CAN, CYP, CZE, DNK, EST, FIN, FRA, DEU, GRC, ISL, IRL, ISR, ITA, JPN, KOR, LUX, MLT, NLD, NZL, NOR, PRT, QAT, SGP, SVN, ESP, SWE, CHE, TTO, GBR, USA	HCI 2013	Pearson Correlation	,932**	,752**
		Sig. (2-tailed)	,000	,000
		N	33	33
All economies	HCI 2013	Pearson	,944**	,882**
		Sig. (2-tailed)	,000	,000
		N	120	120

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Source: compiled by the authors utilising correlation analysis of the data of [20], [21], [22].

4) in two groups of countries between the HCI 2013 and HDI 2013 a moderate positive statistically significant correlation is observed: stage 2 group of countries r = +0.524, p = 0.007 and the transition from stage 2 to stage 3 group of countries r = +0.451, p = 0.031. According to the GCI calculation methodology these groups of countries include the countries that have a relatively high GDP per capita indicator values (for stage 2 economies: $ 3,000 <GDP per capita <$ 8,999, for transition from stage 2 to stage 3 economies: $ 9,000 <GDP per capita <17,000 $), where labour productivity, production efficiency and quality of output growth is observed, being directly dependent on the level of human capital development. The fact that this case reflects a moderate correlation is due to the fact that this group of countries includes some countries with uncharacteristic HCI values that do not correspond to the HCI trends of the rest of countries included in these groups of countries. For instance, at stage 2 group of countries the average HCI 2013 value = -0.230 and the average HDI 2013 value = 0.709 (see Table 2), this group includes Paraguay with HCI 2013 = -0.546 and HDI 2013 = 0.676, Dominican Republic with HCI 2013 = -0.499 and HDI 2013 = 0.700, Namibia with HCI 2013 = -0.534 and HDI 2013 = 0.624. Also the transition from stage 2 to stage 3 economies group with the total average HCI 2013 = 0.144 and the average HDI 2013 = 0.785 (see Table 2) includes some countries with uncharacteristic HCI values typical for this group of countries, for instance, Argentina with HCI 2013 = -0.120 and HDI 2013 = 0.808, Lebanon with HCI = -0.220 and HDI = 0.765, Suriname with HCI 2013 = -0.420 and HDI 2013 = 0.705. As it can be seen, less developed human capital can be observed in these countries, compared with the other countries represented in the group, but it does not affect the whole level of nation's development of these countries.

[2] United Nations 3-letter countries codes

5) the moderate statistically insignificant correlation r = 0.429, p = 0.143 is observed in the transition from stage 1 to stage 2 group of countries between HCI 2013 and HDI 2013. In this case, it is justified by the fact that exactly this group of countries primarily includes the countries with a relatively underdeveloped human capital (the average value of the HCI 2013 in this group of countries is -0.357), while the average value of the nation's development indicator in this group of countries HDI 2013 is 0.708, which is close to the world's average HDI 2013 value 0.727(see Table 2). For instance, Algeria HCI 2013 = -0.954 and HDI 2013 = 0.717, Kuwait HCI 2013 = -0.059 and HDI 2013 = 0.814, Venezuela HCI 2013 = -0.564 and HDI 2013 = 0.764.

TABLE 2

THE AVERAGE VALUES OF GCI 2014-2015, HCI 2013 AND HDI 2013 ACROSS ALL COUNTRIES AS A WHOLE (N = 120) AND IN THE BREAKDOWN OF GROUP OF COUNTRIES OF GCI ECONOMIC DEVELOPMENT STAGE

		GCI 2014-2015	**HCI 2013**	**HDI 2013**
Stage 1: Factor driven economies	Mean	3,569	-,728	,505
	N	26	26	26
	Std. Deviation	,353	,326	,074
Transition from stage 1 to stage 2 economies	Mean	4,102	-,357	,708
	N	13	13	13
	Std. Deviation	,441	,293	,073
Stage 2: Efficiency-driven economies	Mean	4,146	-,230	,709
	N	25	25	25
	Std. Deviation	,301	,226	,045
Transition from stage 2 to stage 3 economies	Mean	4,380	,144	,785
	N	23	23	23
	Std. Deviation	,378	,260	,033
Stage 3: Innovation-driven economies	Mean	4,998	,788	,881
	N	33	33	33
	Std. Deviation	,483	,379	,035
All economies	Mean	4,295	-,00015	,727
	N	120	120	120
	Std. Deviation	,645	,640	,144

Source: compiled by the authors employing mean comparison analysis of the data of [20], [21], [22].

Many researchers and scientists, when analysing human capital development and economic growth, conclude that there is a bidirectional link: one runs from economic growth to human capital, as the resources from national income are allocated to contributing activities to human capital development; the other runs from human capital to economic growth, when human capital helps increase national income [23, 24, 25, 26].

There are many studies on how the increase in the human capital development level facilitates the economic growth of a country [23, 27, 28, 29]. Certainly a well-educated and healthy human capital is a significant factor in creating the state competitive advantages, it influences the labour efficacy and productivity, which, in its turn, attracts foreign direct investment in a country, in other words, better health and education attract money to a nation's economy. An educated and healthy labour often becomes a fundamental influence factor for foreign investors when making a decision regarding the capital investment [30].

The empirical studies [31] confirm that there is a link between the development of human capital and economic growth at both micro and macro levels. At the micro-level the individual income growth is associated with advanced levels of education, which can be considered as an essential foundation for the enhancement of an individual's labour productivity and the introduction of novelty, which, in its turn, contributes to the overall competitiveness of the country. Of course, the level of people's education itself cannot achieve a significant transformation in the economy, but in a symbiosis with a sound national policy it has a major impact on domestic and foreign investments, thus imposing economic activity performance [32]. With regard to the impact of education on economic growth at the macro level, a number of empirical studies [33, 34] show the positive impact of education, but its degree varies depending on the quality of educational activities. It should be noted that it is insufficient just to educate people, there should also be the opportunity to "use" them productively. Also here, the great importance is placed on the implemented state policy in enhancing national competitiveness. The improvement of economic competitiveness requires well-educated and trained people, technological and network readiness as well as knowledge and skills to work in an innovation-rich world [34].

IV CONCLUSION

The findings of the research reflect the visible link establishing connection among the human capital development and the country's economic growth and competitiveness, as well as the development of a society (nation). Undoubtedly, only the quality resource, in this case - the developed human capital is the country's economic and nation's development basis. The authors of this article conclude that investment in human capital has two objectives: the economic objective means that the state, investing in people's development, is hoping to achieve the financial-economic return on the invested capital, hence country's competitiveness and economic growth, but the public objective means that human development is the final destination of the territorial development process, which can be achieved through the economic processes. Human capital concept allows understanding that at the early stages of the territorial development process the key role is granted to an individual, his accumulated knowledge, skills and abilities, which when skilfully exploited, ensure successful achievement of the outcome of this process. In the context of such territorial development an individual is both a "tool" and an "objective".

Nevertheless, with regard to the human capital development connection related to the development of a nation (society), it is somewhat weaker, especially in the country groups of economies at the transition stage of development (according to the methodology for calculating GCI) as human capital development is influenced by various factors, which may not be very developed, even in countries which have developed in accordance with the Human Development Index. For instance, in order to achieve a relatively high HDI value, it is necessary for people to have the longest possible life expectancy at birth, adequate human training process and the relatively large GNI per capita. In the case of HCI, it is not enough, because it takes into account not only the quantitative indicators, but also the qualitative ones, as only through qualitative analysis one can judge on the level of human capital development. Consequently, there are countries with relatively developed nations, but underdeveloped human capital. As it is revealed in Table 2, only in the transition from stage 2 to stage 3 group of countries, and innovation-driven group of countries, the average HCI 2013 value is positive, it means that in most of these countries, the human capital is "qualitatively" developed, which is logical, for these countries being in these economic development groups of countries.

The countries should implement the human capital development policies that enhance human potential and national industry opportunities, and allow the countries to avoid "commodity trap" as well as to diversify the economic activity. The enhancement of the developed human capital contributes to transformation process of "resources economy" turning into a "knowledge economy" when the quantity becomes quality and extensive economic growth - intensive. Economic growth creates the necessary fiscal space for investments in human capital as well as leads to the synergy of economic and social policies. Investment in human capital is not only the investment in improving the state of health, education and social security perfection, it is also the success basis for the dynamic and competitive global economy. In order to make efficient use of human capital, a coherent public education, labour market and social protection system should be elaborated.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 181-189

Meteorological Forecasting for renewable energy plants. A case study of two energy plants in Spain

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Abstract. **Energy resources are the engines that drive every economy [1,2,3], Therefore, it is necessary to develop their exploitation in a friendlier, environmentally and sustainable way indeed it is a critically needed nowadays. Then, it is necessary to improve efficiency and optimize renewable energy in order that replace polluting energy sources. This work aims to relate the use of forecasting on meteorological variables such as wind speed, wind direction, solar radiation, among others, obtained by mathematical models implemented on computer to forecast energy production in renewable energies plants. It has been implemented and automated one of the most used models by the scientific community in this field, WRF (Weather Research and Forecasting Model). WRF is a next generation mesoscale model, designed to serve as a tool for meteorological research in addition to provide forecasts in operational regime. This research introduce the topic of energy forecast, mainly of renewable energy, focusing on wind and solar energy, basing the study on a better forecasting of meteorological variables in order to use as income in energy production forecast. A case study in two Spanish renewable energy plants is exposed.**

Keywords: **Energy forecasting, meteorological model, WRF.**

I INTRODUCTION

The state of the atmosphere is always a conditioning factor of human activity. Weather forecasting is a staple tool for today's society [4,5]. Moreover, the complexity of the physical processes involved imply the need for intensive calculations using numerical models for its resolution, with a high computational cost and sometimes also with human cost. In addition, the non-linear nature of the involved processes limits the temporal validity of the forecasts made, so these need to be recalculated, based on new experimental data [6,7].

The physics of the atmosphere tries to understand and explain the thermodynamic and transport processes involved in the evolution of the atmosphere in a deterministic manner. The equations of energy conservation and continuity are established as coupled systems through differential equations that describe the atmospheric dynamics. In general, this system of differential equations does not allow an analytical solution, so that’s why the use of techniques for solving numerical calculations is necessary. The validity of the results obtained through simulation depends greatly on the quality of the physical model used, accuracy of numerical methods implemented for resolution and of data fed into its models.

Deterministic approach used in the description of atmospheric dynamics allows making forecasts of conditions from different variables of interest from the initial conditions [8]. However, the nonlinear nature of the equations governing the evolution of the system implies a certain chaotic nature which affects the validity of the long-term forecast [9,10].

In this context a meteorological model is a set of differential equations (involving the majority of atmospheric physics variables) whose complexity resolution is translated into a computer program that produces meteorological information to a time in the future for certain parts of the world and certain altitudes [1,12].

The models are based on data from meteorological probe, weather satellites, and ground observations. These observations are processed by data assimilation and objective analysis methods that perform quality control and obtain values used by mathematical algorithms [13]. Then these data are used in the model as a starting point for forecasting.

The calculations performed by these equations begin to use meteorological data and determine the rates of change of different atmospheric variables. The rates of change forecast the state of the atmosphere within a short time in the future. The following equations apply to this new state of atmosphere to calculate new rates of change, and those new rates forecast a state of atmosphere for a next time in future [14,15]. This process of small increments over the

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.262

time is repeated continuously until the solution reaches time wanted, to obtain the forecast. The time lapse of each temporary increase depends on the distance at which two points are on the grid, or spreadsheet cell. Time steps in global climate models may be on order of ten minutes, while time steps used in regional models may vary from a few seconds to a few minutes [16].

The MM5 (Mesoscale Meteorological Model 5th generation) model is well known within the international scientific community, which has been validated in a number of works [17,18]. Currently there is an advanced version of that model known as WRF (Weather Research and Forecasting Model). WRF Mesoscale Model is a next generation, designed to serve as a tool for atmospheric researches in addition to provide forecasts in operational regime [3,24].

On the other hand, energy resources are the engines that drive every economy [2,3], the need to develop their exploitation in an environmentally friendlier and sustainable manner is a critically needed nowadays. Due to that, it is necessary to improve their efficiency and optimize it; in order to finally they can replace the polluting energy sources.

This research sought to introduce the topic of energy forecasting, mainly from renewable energy sources, focusing on wind and photovoltaic. Basing the study on improving the input data (meteorological variables) for energy forecast models in these kinds of energy plants.

To obtain a better forecast of weather variables (irradiation, wind speed and direction, etc.) is essential to improve the forecast system reliability in these plants [11,21]. This work is focused on the implementation and automation of a numerical weather forecasting models under a computer system. Particular goals of this research were the implementation and automation [1] of a numerical weather forecast model (WRF) for automatic daily forecasting in two domains (Iberian Peninsula and Northern Spain) with spatial resolutions of 27 and 9 km, respectively, in order to improve forecasting process in the production of energy in two selected renewable energy plants.

The paper are divided in four sections, the first one shows the introduction about the topic under study. The second introduces the materials and methods used in this research. In the third section are presented two studies cases where was implemented the energy forecast on base of the forecast of meteorology variables. Finally the conclusions are presented.

[1] **Computer Automation:** the use of computerized systems or electromechanical elements for controlling machinery and/or process replaces human operators. In the context of this paper refers to the creation of software for autonomous execution of the meteorological model.

II MATERIALS AND METHODS

A. Meteorological model WRF

The structure of manuscripts:

WRF is an Eulerian [2], non-hydrostatic [3] and compressible [4] model. Their vertical coordinates are from hydrostatic pressure and the use of an Arakawa[5] C-grid. WRF is suitable for a wide spectrum of applications across scales, ranging from meters to thousands of kilometers. Fig. 1 shows the basic flow of WRF model execution.

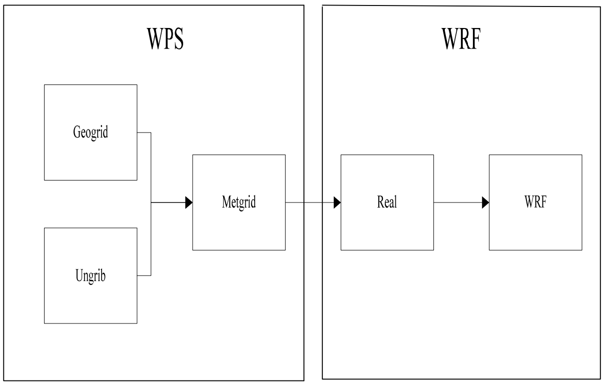

Fig. 1. Basic flow of WRF model execution (Michalakes et al., 2004)

WRF Preprocessing System (WPS) is the module responsible for performing the pre-processing of information. This module consists of the following components: i) geogrid.exe that interpolates the terrestrial data for calculation domains (Static), ii) ungrib.exe that unpack the GRIB weather data and pack it into intermediate format files, iii) metgrid.exe that interpolate horizontal meteorological data within the domain of the model.

WRF is the main module of the model and is responsible for conducting the simulation, it consists of: i) real.exe that interpolates vertically the *met_em* files (generated metgrid.exe), creating boundaries and initial conditions files and some evidence of consistency, ii) wrf.exe that generates the model forecast.

[2] **Eulerian model**: a fixed reference system (usually the focus issuer) is established, and tries to solve the balance equations of mass, energy and momentum, with different degrees of approximation.

[3] **No hydrostatic model**: includes a predictive equation for the vertical movements. This allows direct processes include hydrostatic or buoyancy and dynamic pressure perturbations. In contrast, hydrostatic models have no prognostic equations for vertical movements and can only indirectly include the effects of buoyancy.

[4] **Compressible:** compressibility of flow is basically a measure of the change in density. The gases are generally very compressible; however, most liquids have compressibility.

[5] **Arakawa:** This grid system shows different ways to represent and calculate physical orthogonal quantities, in particular speed and the masses of the corresponding quantities.

B. Type of input and output data

The input data required for the implementation of WRF both prediction mode, and re-analysis mode, come from the Global Forecasting System (GFS) that is a global forecast model by NOAA [22,23]. The reason for using WRF in this work is to increase the resolution and accuracy of the forecast on the domains under the study.

The GFS model runs four times per day and produces forecasts up to 16 days in advance, but with decreasing spatial and temporal resolution. It is widely agreed that forecast of more than 7 days is very general and is not accurate enough. The model is executed in two parts: the first has a higher resolution; it goes up to 180 hours (7 days) in the future, the second part goes from 180 to 384 hours (16 days) on a lower resolution. The resolution varies in each part of the model: Horizontal, splits the surface of the earth cells in 35 or 70 km. Vertical, divides the atmosphere into 64 layers and through time produces a forecast for every 3 hours for the first 180 hours, after which are produced for every 12 hours.

Input files for WRF have a temporal spatial resolution of 35-70 km and 3 or 6 hours depending on whether are forecasting or re-analysis. The format of these files is GRIB2. GRIB (gridded binary) is a mathematically concise data format, commonly used in meteorology to store historical and forecast meteorological data. As output, WRF returns a NetCDF files (Network Common Data Format). The feature of this format is that it contains enough information to know what kind of data is in the file (variable, units, dimensions, institution that created it, etc.), unlike other formats that require an additional file for proper interpretation.

Data analysis and generation of the figures and maps were carried out by NCAR Command Language (NCL) routines. This is an interpreted language designed specifically for analysis and visualization of scientific data.

C. Execution Model Formats

This research raised two formats of model configuration: *a) Forecasting for 48 hours*. In this configuration the inputs to the model are from the first forecast of the GFS (0:00H) with a forecast up to 48 hours on the domains under the study. The speciations of the files used for forecasting process are i) Name: gfs.t00z.pgrbf00.grib2. ii) Model: GFS. Iii) Cycle: 00Z. iv) Forecast: analysis. v) Number of Records: 299. *b) Reanalysis of 48 hours*. In this configuration the input data also come from one of the executions of the GFS, but data that is used in this case, contain information from data assimilation modules and a greater number of observations. The output data of the assimilation process (National Centers for Environmental Prediction, NCEP FNL) have a resolution of 1.0x1.0 degrees and are operationally prepared every six hours. These come from the system of global data assimilation (GDAS) that is continuously collecting data from observation of the Global Telecommunications System (GTS) and other sources, which are subjected to many tests for interpretation and final assimilation. Therefore, with a greater amount and more reliable data as input for WRF a reanalysis simulation of the last 48 hours is obtained as result of this configuration.

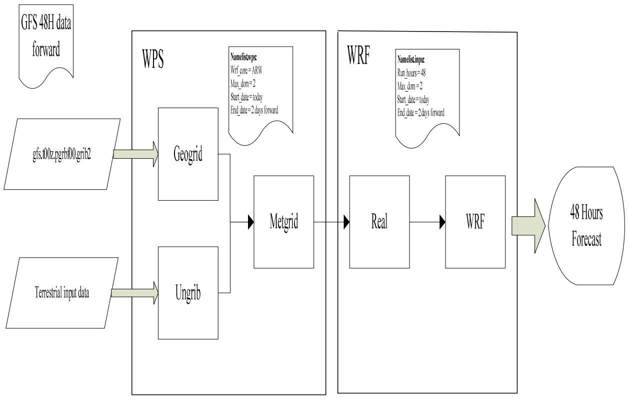

Fig. 2. Forecasting for 48 hours

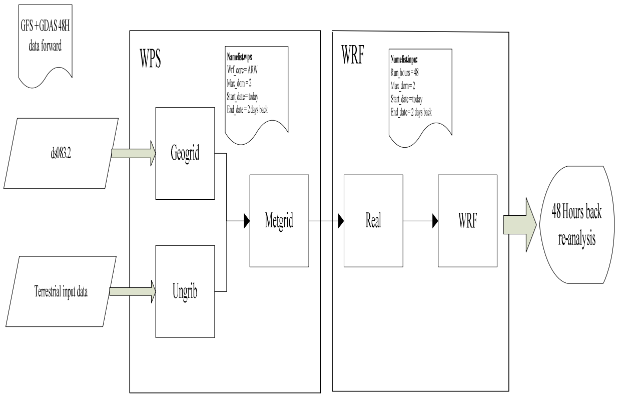

Fig. 3. Reanalysis for 48 hours

D. Operating Mode

The operational mode refers to the formats of operational configuration of the model for specific purposes of this research. To create these modes was used the formats discussed above, implementation tailored to each of demands. In this case the mode runs a 48-hour forecasting simulation for the next two days and five 48-hours reanalysis simulations - for the five days immediately preceding execution date. This configuration is achieved to obtain a weather forecast (methodological variables) for the next 48 hours over selected domains in less than 20 minutes.

Moreover, reanalysis data (Simulations with GDAS) for the last 5 days help to conduct validation studies and test the meteorological model, and energy forecasters as well.

E. Operating Mode

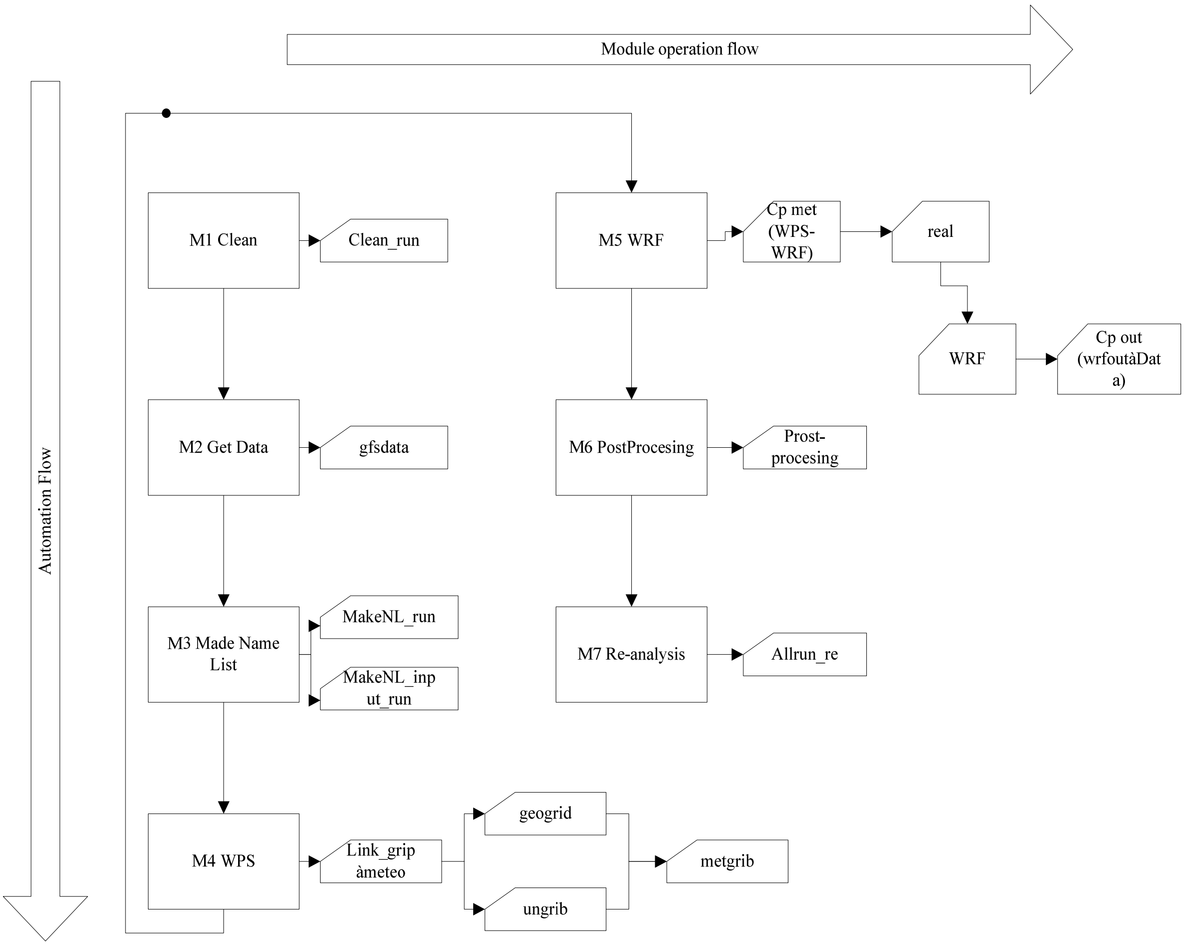

Fig. 4. Model automation scheme

The Fig. 4 shows the general operation flow chart of the automation program. The different execution activities of the model were divided in order to achieve the automation. These activities were programmed into independent modules that execute defined tasks to be linked into a global structure (Allrun_xx.sh script file). In this way the overall process is performed by executing a single script thread launching necessary to achieve the task. The automation was performed by including the general script in the scheduled list of the system (cron daemon) under Linux.

Further is described precisely the purpose of each of the modules, in addition - the corresponding scripts and main characteristics also are mentioned: *i) Cleanup Module (M1 Cleaning):* The overall purpose of this module is to delete all additional files that have been created in the last run of the model. It has a single script for forecasting and reanalysis modes. The module routines run in less than one second. *ii) Data Collection Module (M2 Get Data):* Daily, this module downloads all data GRIB2 which is necessary for the model to start to work. The forecast modes have a unique script and the reanalysis modes uses three files that perform and set the download field, do the downloading and ordering of the input files respectively. These routines run in an average of five minutes, depending on the availability of data on the remote server. *iii) Module creation initialization file (M3 Make Name List):* The module aims is to create initialization files (namelist.wps and namelist.input), which are used by the model to start the simulation. This module has two autonomous scripts in order to generate both files in each configuration. The first file determines simulation hours, start date, end date, time interval of the input files, georeferencing and resolving domains for the WPS module. The second file determines simulation hours, start and end dates, georeferencing and physical models used in the simulation to run the WRF module.

The average execution of this module is from 1 to 5 seconds, depending on execution format and it is an independent module of the input data. *iv) WPS preprocessing module (M4 WPS):* The module is responsible for automating task of the WPS preprocessing. The module performs the automatic execution of all necessary subroutines to run WPS. This module is dependent on the input data and previous made for previous modules and it has four scripts: EXECUTED link_grib (1 second), EXECUTED geogrid (25 seconds), EXECUTED ungrib (60 seconds), EXECUTED metgrid (120 seconds) MODULE EXECUTED WPS (206 seconds). *v) WRF simulation module (M5 WRF):* This module is responsible for automating WRF simulation tasks. Module performs automatic execution with all necessary simulation subroutines to run WRF. This module is dependent on the generated data in the preprocessing WPS module and in the generating initialization files process. It is the module that demands more computing and time resources. It has four scripts: EXECUTED copy meth (5 seconds), EXECUTED Real (25 seconds), EXECUTED wrf (12 minutes), EXECUTED copy out (60 seconds). *vi) Module automatic validation (M6 Validation):* The purpose of this module is to provide an automatic validation of the reliability of the model used for weather forecasting. It is accomplished by comparing output data of the forecasting processes with the output data of the reanalysis process for each of the variables analyzed. It has 1 script that has an average 60 seconds execution time.

F. Validation Format -Meteorological Model

The validation process of the output data of weather model has been set using a routine that calculate the mean square deviation (RMSD) with the forecasting and re-analysis data for each simulation period and each spatial point of the domain under study. In this way an efficient evaluation of effectiveness of the forecast is achieved continuously. The RMSD is widely used in a quantizer verification of numerical models and is defined as:

$$RMSD(\theta_1-\theta_2)=\sqrt{E((\theta_1-\theta_2)^2)}=\sqrt{\frac{\sum_{i=1}^{n}(x_{1,i}-x_{2,i}))^2}{n}} \quad (1)$$

Where θ_1 represents data generate in the forecasting process, θ_2 represents data generate in the process of re-analysis and at the same time θ_1 y θ_2 are defined as:

$$\theta_1=\begin{bmatrix}x_{1,1}\\x_{1,2}\\..\\x_{1,n}\end{bmatrix} \qquad \theta_2=\begin{bmatrix}x_{2,1}\\x_{2,2}\\..\\x_{2,n}\end{bmatrix} \qquad \text{(2) and (3)}$$

n is the number of points used for the forecasting and reanalysis process.

Specifically, the RMSD process takes a point within the forecast domain and subtracting it from its counterpart in the re-analysis domain to find the specific deviation, then it has to be squared to remove negative factors and a sum is performed within the entire interval n, it is divided to the number of samples to get the average value; finally the square root is removed. This procedure extends it to all points within the timeline by which was made the forecast.

Fig. 5 shows the RMSD time trends of two wind components (V and U) for 48-hours simulation. In general, the RMSD follows the same trend and has the same magnitude for all domains under the study and for every period of 48 hours. RMSD value is increasing as the forecasting period increases. This is due to accumulation of errors in both the forecast and re-analysis process, besides the non-linearity of the differential equations that govern these physical phenomena.

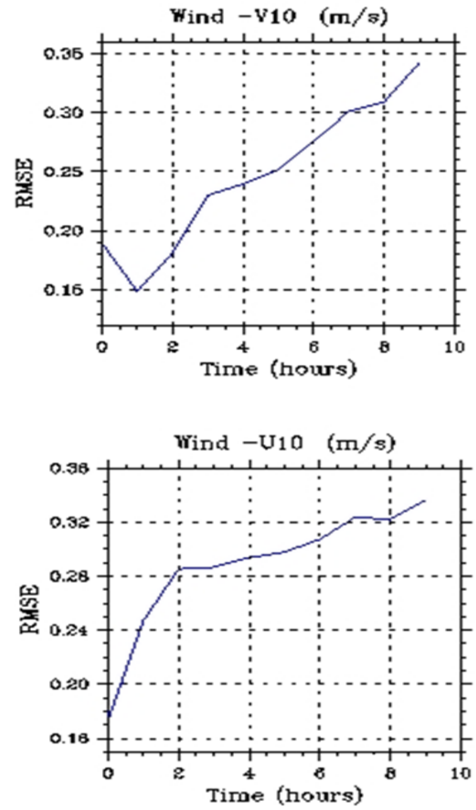

Fig. 5. Validation (RMSD between forecasting and data re-analysis data for domain 1 for variables U and V wind).

III CASES STUDY

A. Case study: Wind energy plant (Cabo Vilan, Spain)

In this section is presented a case study of a wind energy plant in the north of Spain, for which is taken real data from a meteorological stations controlled by AEMET (Agencia Estatal de Meteorología, Spain), which had been contrasted with the data obtained by the execution of the model in order to forecast the energy production in a wind turbine in the plant. The period of analysis is 61 days. Data recorded by the meteorological station at Cabo Vilan, in the province of A Coruña, Spain, from the network of stations AEMET, the frequency of the data available were 10 minutes. The geo-position is: Latitude: 43.160556, Longitude: -9.210833, Altitude: 50 meters.

The Fig. 6 shows the average wind speed, it can be observed that both modeled and experimental data show similar patterns, particularly in qualitative aspects (in the manner that they shown variations). On the quantitative aspect, we can see less similarity, where it can be seen that the curve from the model is softer than from experimental data pattern.

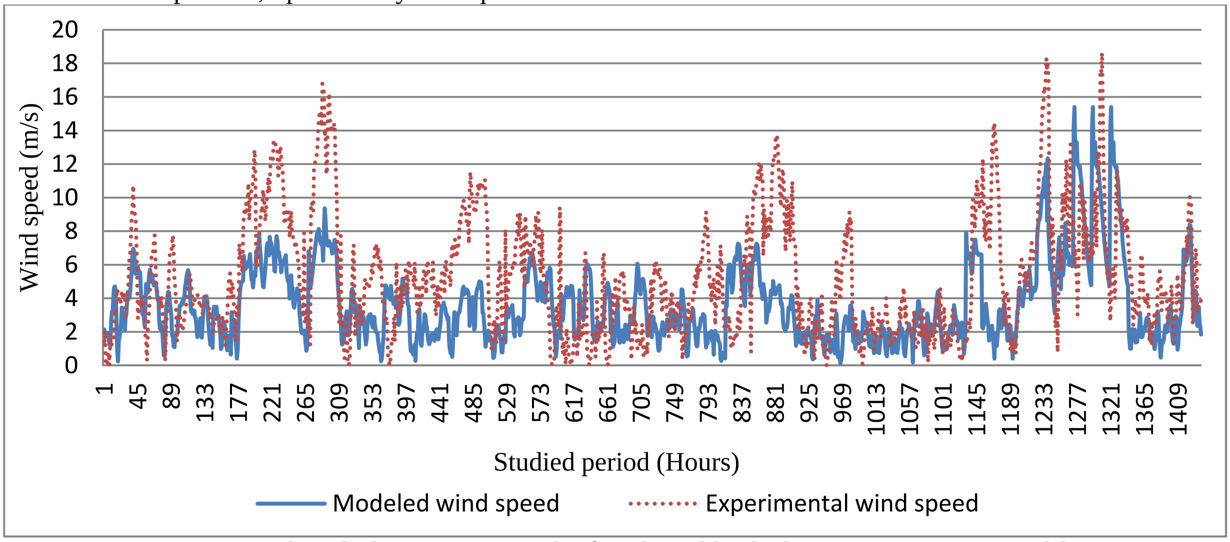

Fig. 6. Average wind speed. Blue curve represents data from the model and red curve represents experimental data.

An important feature of wind energy is that the power output of a wind turbine is proportional to the cube of the wind speed (Hellmann‘s exponential law) and a own characteristic curve-potential of each turbine. Therefore a greater precision is required in the data associated with this type of action than for other applications. In this study were used the potential-curve that shows it on Fig. 7 (theoretical curve), it represents standard conditions: Ambient 15 ° C, pressure 1013 mbar and air density of 1.225 kg/m3, rotor blades clean and no disturbed horizontal airflow.

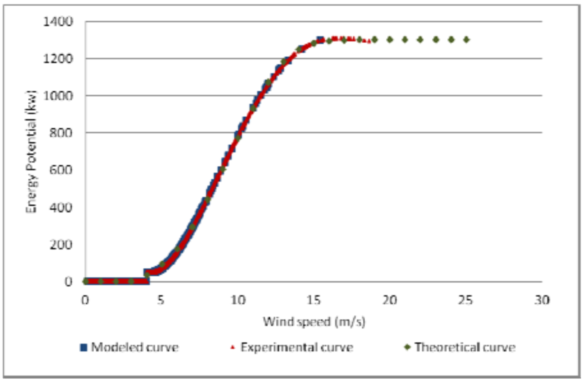

Fig. 7: Potential-curve. Blue curve represents modeled curve, red represents experimental curve and green represents theoretical curve.

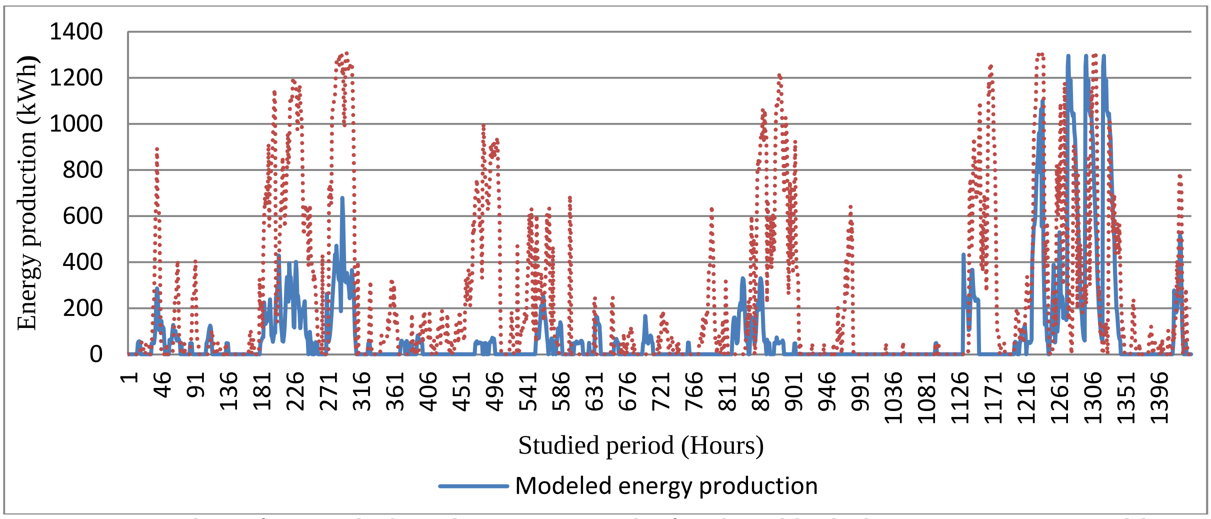

Fig. 8. Energy production from a wind turbine. Blue curve represents data from the model and red curve represents experimental data.

Now, in order to get energy forecast, was used the data set from a model on this specific variable and the potential-curve presented above.

Fig. 8 shows both curves, first that come from the model and the second comes from experimental data; we can discern that there is some similarity between two curves, especially in qualitative terms. However in quantitative aspect there is already a major difference caused mainly, as is mentioned before, by the accumulation of errors of the average wind speed variable that come from meteorological model. The mean square deviation for each of considered variables (wind speed and energy production) was performed. There are some values that represent major errors, therefore they should be discarded in order to neither distort nor hinder the study. Regardless of these major errors, which are specific values, most points considered, show a standard deviation about 3.5 for wind speed variable and 352 for energy production. Once again, it should be mentioned that the resulting error in the energy production is proportional to the cube of error introduced in the average wind speed of the meteorological model because of the cubic relationship between these two, in our specific study case this proportion was around four times. On the other hand the total forecasted energy production by the model during the studied period was around 124 Mw meanwhile the experimental energy production was around 339 Mw by turbine (63.5% of error).

B. Case Study: Photovoltaic energy plant (Valladolid, Spain)

In this section is presented a case study of a photovoltaic energy plant in the north of Spain, for which are taken real data from the photovoltaic plant of Valladolid, which had been contrasted within obtained data by running model and treated to forecast the energy production. The period of analysis is 61 days. The geo-position is: Latitude: 41.6451, Longitude: -4.8146.

Fig. 9 shows the irradiation variable, as in the wind case it can be observed that both modeled and experimental data show similar patterns, particularly in qualitative aspects (in the manner that they shown variations). On the quantitative aspect, we can see less similarity, where it can be seen that the curve from the model is softer than from experimental data pattern, but certainly shows a better approximation than wind case.

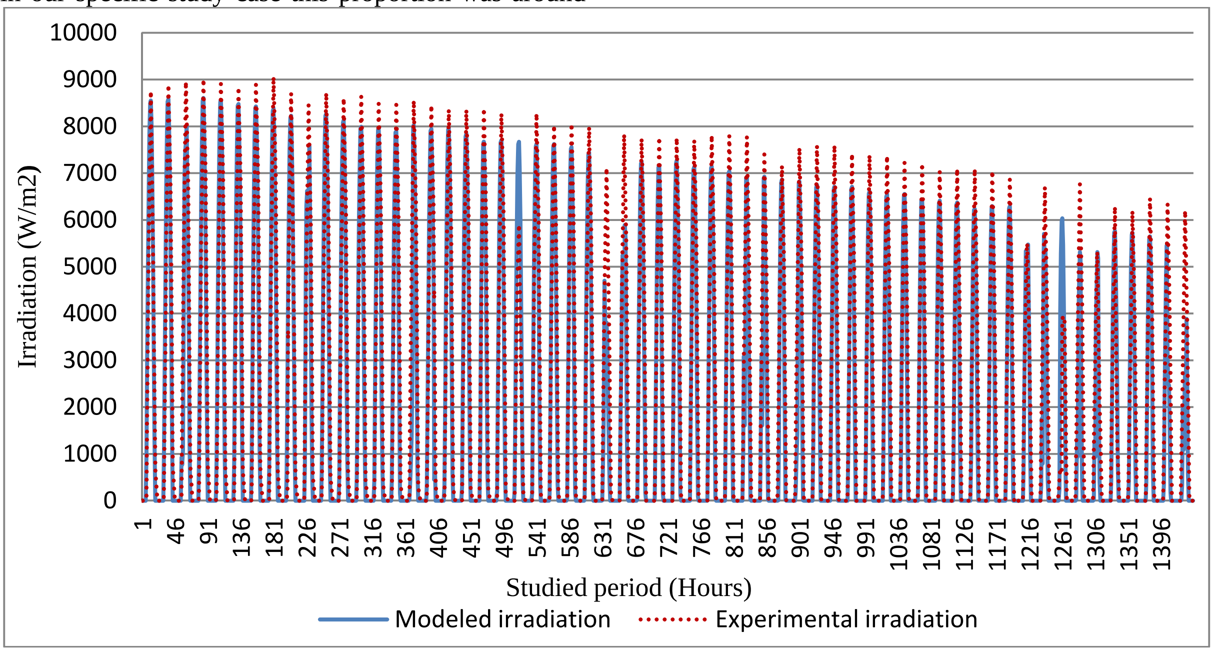

Fig. 9. Irradiation. Blue curve represents data from the model and red curve represents experimental data.

In order to forecast energy productions, in this case have been energy forecasters, which take as input variable the solar radiation (meteorological variable). This forecaster was constructed, based on experimental data of production from photovoltaic plant as an intervals function, like it is shown in Formula 4. Note that, the resulting forecast error is dependent of the forecaster used.

$$EngP=\begin{cases}0 & \text{if radiation} < 1860\\ 8654{,}8 * \text{Ln(radiation)} - 63011 & \text{if radiation} \geq 1860\end{cases} \qquad (4)$$

As in wind case, we can see that there is a similarity between these two, especially in the qualitative aspect, regarding to the actual energy production data. However in the quantitative aspect there is already a major error, caused primarily, as mentioned before, by the accumulation of errors from the meteorological forecast model and from the energy forecaster used. Also, the mean square deviation for each of considered variables (irradiation and energy production) was performed. Therefore most points considered show a standard deviation about 895 for irradiation variable and 3782 - for energy production. On the other hand the total forecasted energy production by the model during the studied period was around 6025 Mw meanwhile the experimental energy production was around 5392 Mw (10.5% of error).

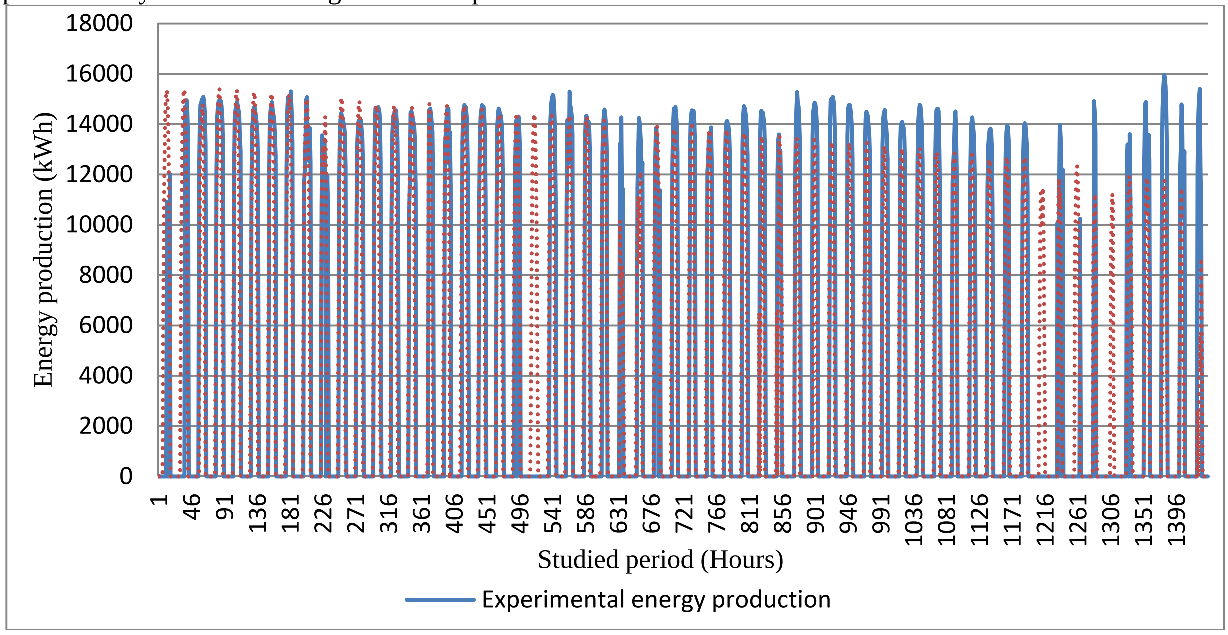

Fig. 10. Energy production from the photovoltaic plant. Blue curve represents data from the model with static forecaster and red curve represent experimental data.

IV CONCLUSIONS

In order to have an optimal manage of renewable energy sources such as wind or solar, it is essential to have a system of accurate, robust and reliable energy forecast. Better understanding and accuracy in the forecasting of meteorological variables affect directly the forecasting of energy in plants that use the natural resources mentioned. An accurate forecast can generate significant both economic benefits and energy efficiency, especially in electricity markets where there are penalties by inaccurate energy forecasts (liberalized markets). On the other hand, In these markets also there are benefits when the forecasts are conform to the actual energy production. So, to ensure greater profitability to renewable energy plants, it is essential that energy producers have a reliable energy forecast system.

Case studies showed significant deviations in the forecast of the variables under the study. However it is important to mention that further improvement in energetic forecasters would significantly improve the results obtained with these systems. This improvement in these forecasters has been outside of the scope of the study but is a line of research to continue. Also it is important to mention that the variations, observed in cases study, are due to some specific circumstances, such as: intrinsic special characteristics of the study site (land mass, front water mass), the accumulation of errors in the model and non-linearity of differential equations governing the phenomenon.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 190-196

Bioenergy Resources in Latvia

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Abstract. **The paper presents results of study aimed to evaluate issues of current development of bioenergy in Latvia, taking into account restrictions, which may affect future progress of main biomass sources. These restrictions are based on latest European Union (EU) regulations and recommendations; and worldwide concerns of scholars on sustainability, particularly environmental (e.g. biodiversity, ecosystem resilience, carbon sequestration) of bioenergy (biomass) development. The appropriate qualitative and quantitative research methods have been used in the process of study. The results of examination suggest that biomass possesses one of the greatest potentials for further increasing renewables production, particularly in Latvia. The characteristics and perspectives of main biomass sources' development are assessed for compliance with the EU latest regulations, recommendations and policies, particularly Common Agricultural Policy (CAP) 2014-2020, and they demonstrate [reveal?] several limitations. The restrictions under the CAP regulations' so-called 'greening' requirements mainly affect the production of energy crops, limiting monocultures' growing. For some types of biomass production (e.g. energy cultures, wood biomass), several limitations or restrictions are considered, in particular, those related to environmental issues such as biodiversity, soil properties, agro-ecosystems and landscape. Forest origin, non-food plants (e.g. perennial grasses) and different kind of residues and waste could be the most important, perspective and sustainable biomass sources in Latvia. Besides, the dominance of a single bioenergy source would be unsustainable in the long run, and diversifying of the energy system is preferred.**

Keywords: **bioenergy, biomass, energy crops, forests.**

I INTRODUCTION

The European Commission (EC) has set the mandatory target for the share of energy from renewable energy sources (RES) to be at least 20% of the total energy consumption in the European Union (EU) by 2020 and 40% in Latvia. Even though the intermediate savings target (34.1%) in Latvia was exceeded by 1.7%, reaching 35.8%, attaining the sustainable end target is under threat in the opinion of the EU experts. At the same time, the energy dependency must be lowered, as in Latvia (56.4%) it is higher than on average in the EU (53.3%).

Three following dimensions with main aspects of sustainability of renewable energy, *inter alia*, bioenergy, development can be distinguished: 1) economic - growth, efficiency and stability; 2) environment - resilience and biodiversity, natural resources and pollution; and 3) social – social inclusion and governance [1].

Along with the benefits of bioenergy generation, such as increased carbon sequestration and reduced greenhouse gas (GHG) emissions, the different negative influence caused by some types of bioenergy is also stressed [2; 3]. The majority of such objections are related to the biomass production from the agricultural lands and field crops [3], and also increasing levels of wood harvesting will lead to reductions of forest carbon stocks [4].

Taking into consideration the above mentioned, the aim of study was determined - to evaluate issues of current development of bioenergy in Latvia, taking into account restrictions, which may affect the further development of main biomass sources. These restrictions are based on the latest EU regulations and recommendations and worldwide concerns of scholars on sustainability, particularly environmental (e.g. biodiversity, ecosystem resilience, carbon sequestration) of bioenergy (biomass) development.

II MATERIALS AND METHODS

The principal materials used for the studies are as follows: different sources of literature, e.g. scholars' articles, research papers and the reports of institutions, including EC and governmental; published and unpublished data from Central Statistical Bureau of Latvia (CSB), data from Eurostat databases, data of the forest monitoring done by "Silava"; as well as unpublished data from the database of Latvian Rural Support Service (RSS); and the results of the survey of owners of biogas installations carried out in 2014.

The appropriate qualitative and quantitative research methods have been used in the process of study: monographic; analysis and synthesis, data grouping, correlation and regression, spatial analysis using GIS, logical and abstract constructive, expert, etc.

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.257

III RESULTS AND DISCUSSION

The European Commission (EC) has set the mandatory target for the share of energy from renewable energy sources (RES) to be at least 20% of the total energy consumption in the European Union (EU) by 2020 and 40% in Latvia. Even though the intermediate savings target (34.1%) in Latvia was exceeded by 1.7%, reaching 35.8%, attaining the sustainable end target is under threat by opinion of EU experts. At the same time, the energy dependency must be lowered, as in Latvia (56.4%) it is higher than on average in the EU (53.3%).

In Latvia the energy dependency, however statistically insignificant, has decreased in the period from 2001 until 2012 as opposed to the European Union (EU) Member States (average) and Lithuania, in which statistically significant increase has observed (Table I). Estonia obtains better results and decreases import dependency significantly during the same period.

TABLE I

TRENDS OF ENERGY DEPENDENCY OF EU 28 (AVERAGE) AND BALTIC COUNTIES, 2001-2012

Country	r	α*
EU 28 (average)	r=0.85	α<0.01
Estonia	r=-0.89	α<0.01
Latvia	r=-0.44	α>0.05
Lithuania	r=0.86	α<0.01

* - significance level or critical probability value

Despite this trend, Latvia has failed to meet the targets of RES energy share in the total consumption of energy, and stronger efforts are necessary.

The RES include: solar energy, wind power, hydro power, tidal power or ocean energy, geothermal power and biomass, which is one of the oldest energy sources [5].

Considering the fact that the hydro resources have reached its peak, the bioenergy is more perspective and adjustable among other types of RES sources in Latvia [6]. The bioenergy is any form of energy derived from biomass - living organisms or their metabolic products [7].

On the EU level [8], 'biomass' has defined as "…the biodegradable fraction of products, wastes and residues from biological origin". The sources of different kind of biomass feedstocks could be divided in three groups: plants grown from land, residues and wastes (Fig. 1).

The fuelwood commands the biggest share of the primary energy consumption in Latvia (Fig. 2).

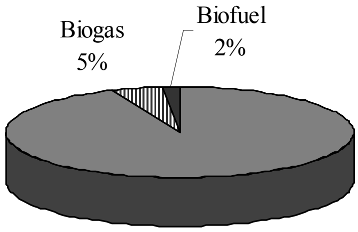


Fig. 2. Biomass energy primary consumption by the main types in Latvia, 2013

Biogas installations in rural areas

The Latvian RDP 2007-2013 targets bioenergy production from biomass of agricultural and forestry origins, where a total investment of EUR 45 million was predicted; besides, there are also additional opportunities for support of renewable energies in the farm modernization measures [3].

Pilvere [9], analyzing the potential of agricultural land area for bioenergy production, estimated that in Latvia are 302,000 hectares of unutilized agricultural area; and considered that 93,000 of them could potentially be used for agricultural production, *inter alia,* for biomass production.

She argues that in the medium-term perspective the number of biogas installations in Latvia could be increased by 2.3 times, reaching 250.

Moreover, it is believed that the long-term perspective number of biogas installations could reach 2400.

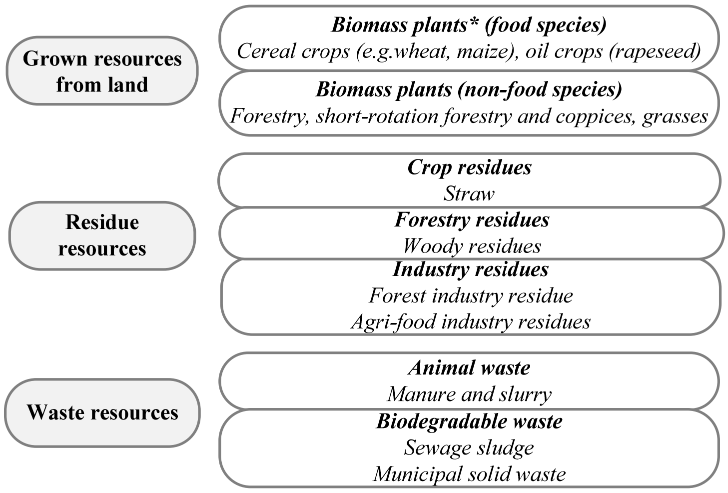
This possibility is threatened by several restrictions, with two of them being the most important.

Firstly, the decision of Ministry of Economy, which has introduced a moratorium on new tenders for the right to sell electricity within the scope of mandatory procurement and the acquisition of the right to receive a guaranteed fee for installed electric from 2011 May until 2016 [10].

Secondly, the new Common Agricultural Policy (CAP) 2014-2020, providing rules for payments granted directly to farmers, defined the mandatory agricultural practices [11].

These so-called 'greening' practices are beneficial for the climate and the environment, crop diversification; they maintain existing permanent grassland; and have an ecological focus area on the agricultural area [12].

For example, where the arable land of the farm covers more than 30 hectares there should be at least three different crops on that arable land; and the main crop should not cover more than 75% of that; besides arable land and the two main crops together should not cover more than 95% of that arable land.



* - so called energy crops

Fig. 1. Categories of biomass and specific resources or feedstocks of its

Bentsen and Felby [13] stressed that the assessments of the bioenergy potentials vary substantially due to methodological inconsistency and assumptions applied by individual authors.

Questioning the rapid development of biogas plants in the Latvia's rural areas, scholars offer a reasoned opinion [14], arguing that the biogas projects are usually characterised by long breakeven periods and the commercial benefits are small. One of the ways to make biogas plants profitable is the sales of digestate as a fertilizer [14].

In Latvia, apart from the plant biomass, especially maize, the main feedstock, used in rural biogas installations or plants is livestock manure, including slurry. The cattle manure is the most common and biggest by volume (71.6%), but pig - 23.5%, and poultry – 4.9%.

Energy cultures

The bioenergy production method with intensively managed monocultures of annual food crops have some negative environmental consequences, including the loss of habitat and the off-field impacts of fertilizer and pesticide runoff [15].

Conversely, the increasing grasslands' area has the environmental benefits of biodiversity and ecosystem as a whole [3; 15]. Besides, the diversification of crops provides an aesthetic value of the landscape [12].

The total sown area has not increased as rapidly and substantially ($r=0.69$; $\alpha>0.05$) in Latvia as areas of cereals (mainly wheat) and rape which have increased statistically significantly, $r=0.90$ ($\alpha<0.01$) and 0.95 ($\alpha<0.01$) respectively, in the last decade (Fig. 3). This leads to raising the proportion of monocultures in the sown area.

There is strong tendency observed that the larger farms boosted the proportion of arable land, especially utilizing the agricultural area (UAA). At the same time, the proportion of area of meadows and perennial grasses has decreased essentially (Fig. 4), particularly in the group of the largest farms. For example, farms with area of 500 ha and more do not grow permanent crops and have a very small proportion of meadows. Decreasing area of the perennial cultures affects biodiversity [3; 15].

Current EU bioenergy policy is focused on returning the unused UAA or surplus land in the production of feedstock, subsequently improving the quality of the environment, particularly, biodiversity and the landscape [3].

Lately biogas plants have been located chiefly in those territories of Latvia with highest proportion of UAA and the highest soil fertility [3], in which the area of maize has increased due to support of biogas projects (Fig. 5). This fact contradicts above mentioned policy framework.

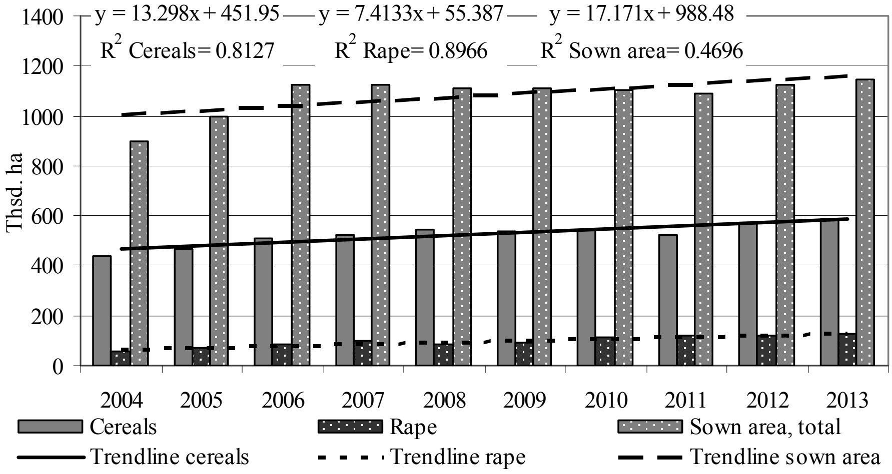


Fig. 3. Trends of total sown area and area of cereals and rape (thsd. ha) in Latvia, 2004-2013

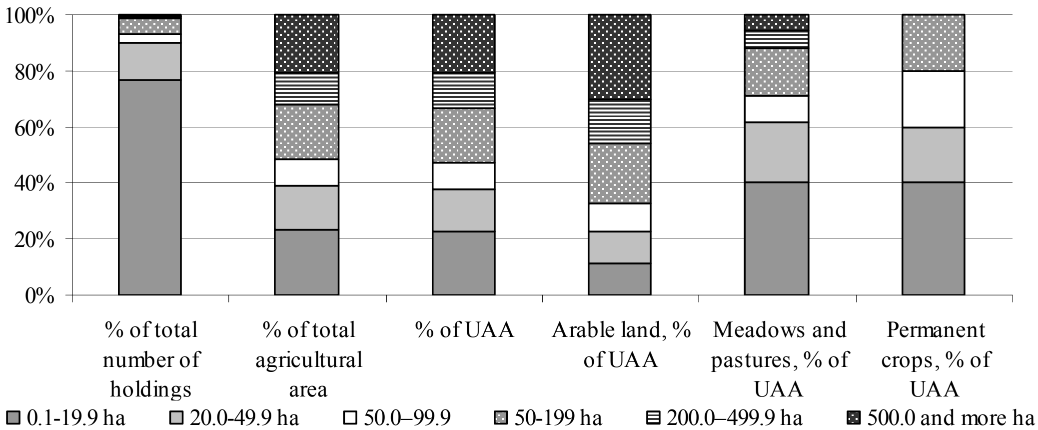


Fig. 4. Groups of agricultural holdings by agricultural area and its structure in Latvia, 2010

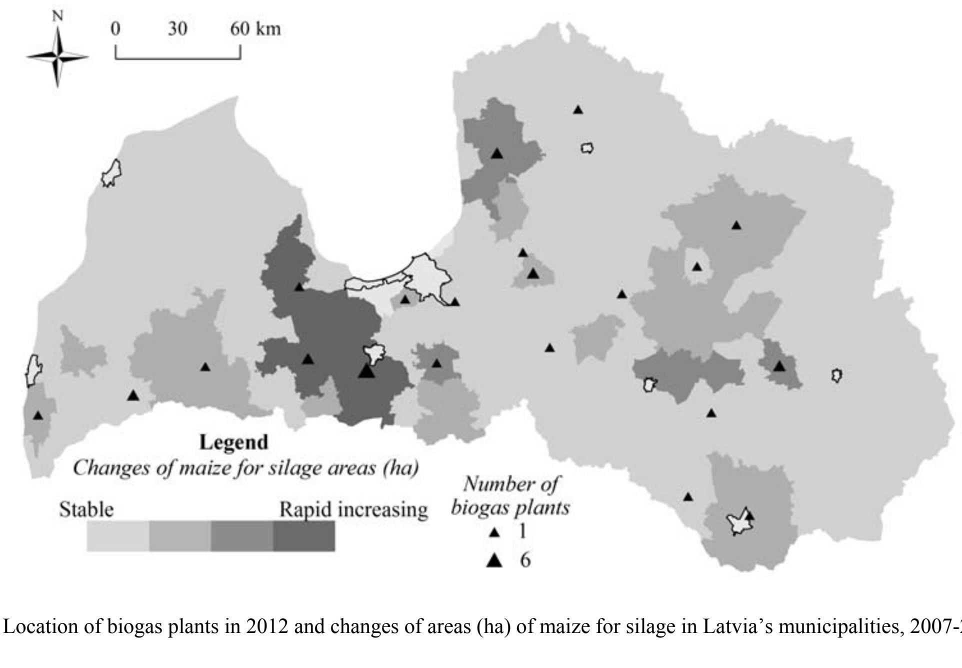


Fig. 5. Location of biogas plants in 2012 and changes of areas (ha) of maize for silage in Latvia's municipalities, 2007-2012 [3].

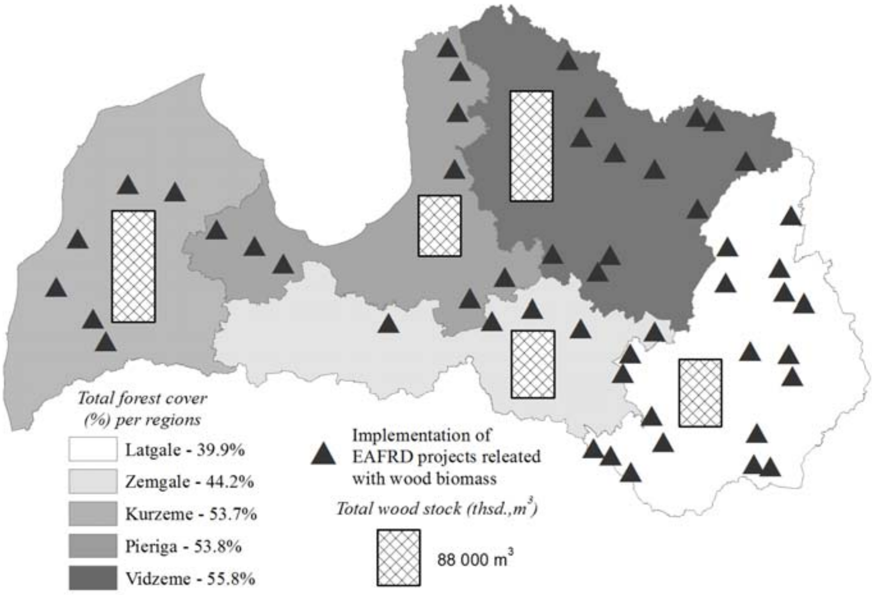


Fig. 6. Total forest cover (%) and total wood stock (thsd. m^3) per region and implemented EAFRD projects related wood biomass, 2013

The proposed potential non-food cultures in Poland, the Baltic countries (Estonia, Latvia, and Lithuania) and Nordic countries (Finland, Sweden) are: willow, poplar, reed canary grass, rape etc. [16], which could be cultivated on marginal or surplus land.

Although forest biomass, agricultural residues and energy crops constitute the three major sources of biomass for energy, the land use and the changes thereof is a key issue in sustainable bioenergy production as land availability is an ultimately limiting factor.

In future, the sustainable biomass production must be grown on the abandoned farmland and especially unused degraded land, which does not compete with other uses, and could be seen as comprehensive area potentially available for the cultivation of bioenergy plants.

Forest or wood biomass

The forestland (%), potential wood stock (thsd. m^3) and spatial distribution of RDP 2007-2013 projects supporting wood biomass production in the different regions, show that the potential for further development of the wood biomass output is observed in Vidzeme and Kurzeme (Fig. 6).

A growing number of scholars [17] argue that in the evaluation of potential of the forest resources, maintenance of forests' ecological processes could be taken into consideration as they are essential for ecosystems resilience. Particularly, the scholars stress the multiple uses and functions of the forests (e.g., wood production, collecting non-wood forest products, recreation, protection of soil and water resources, biodiversity conservation, carbon sequestration) which aim to provide various social, cultural, environmental and economic values [4; 17].

Nevertheless, Matthews with co-authors [4] argue that there is widespread recognition that increasing the levels of wood harvesting in existing forest areas will, in most cases, lead to reductions in the overall levels of forest carbon stocks compared with the carbon stocks in the forests under previous levels.

Moreover, it is argued that the forest bioenergy further development must be realized through increased utilization of harvest residues including poor-quality stem wood and trees, the use of sawmill co-products and recovered waste wood, avoiding the utilization of wood suitable for high value applications for biomass [4].

Other biomass resources such as perennial grasses and willow are investigated in Latvia. However, their development is in early stages and/or in negligible quantities, for example, willow was grown in small area, only 261 ha in 2012 [18]. Also, very small amounts of straw are used as feedstock. Besides, it is considered that the straw as a biomass source for energy has some following constraints: high concentration of ash and nitrogen, and the lack of suitable machinery and short season optimal to harvest [19].

Because perennial biomass crops could be grown on more marginal agricultural land and are non-food crops, they have the potential to offer sustainable bioenergy production [20]. Solid biomass from short rotation coppice (SRC) has been identified with high potential to significantly contribute to European renewable energy targets [21; 22]. SRC helps to improve water quality, enhance biodiversity, prevent erosion, reduce chemical inputs (fertilizers, pesticides) and mitigate climate change due to carbon storage [21].

The dominance of a single energy source and system, no matter how "perfect" it might be at a time, would be unsustainable in the long run. Before continuing our quest for a "perfect" solution for sustainable development and energy security, let us digress for a moment into other fields for enlightenment [23]. Diversification of energy systems should be anticipated to be healthy and beneficial for humanity and the environment as a whole, and energy diversity may be the key for sustainable development and energy security [23]. Potential sustainable resources of bioenergy, which are proposed on world and EU level, include different residues and wastes from agricultural, municipal, animal, food industry, and forestry sources [15].

IV CONCLUSIONS

The dominance of a single bioenergy source and system would be unsustainable in the long run, because each of them has beneficial and negative impact, mainly on the environment (biodiversity, ecosystem and landscape) and GHG emissions.

Besides, the sustainability of the various services in the rural areas, based on biodiversity, ecosystems, landscapes and the countryside, for example, recreation, leisure, tourism etc., must be taken into consideration for evaluation of further bioenergy supporting measures.

Diversification of energy systems should be anticipated to be healthy and beneficial for humanity and the environment as a whole, and energy diversity may be the key for sustainable development and energy security [23].

However, all biomass sources: wood biomass, field crops, inter alia short rotation coppice, uncultivated biomass such as sludge and manure, are significant for the further development of bioenergy in Latvia, the accent must be put on more sustainable types of them.

The non-food crops (plants) have the potential to offer sustainable biomass for the bioenergy production, when its cultivation will be realized on the abandoned farmland and especially unused degraded land, which does not compete with other uses.

V ACKNOWLEDGMENTS

This study was funded by the Latvian Council of Science; Project No 448/2015-3.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 197-201

Evaluation and long-term conservation perspectives of woodland key habitat bryophyte and lichen indicators in Latgale

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Abstract. **Nowadays human impact to habitats and species are stronger then ever before. Latvia is typical example of fragmented landscape, where forest patches are mixed with agricultural land and waterbodies. Latgale is one of typical such a fragmented landscape parts of Latvia. Around 6.41 % of Latgalian forests were evaluated as Woodland Key Habitats (WKHs) or potential WKHs (PWKHs) after WKH inventory. The aim of this paper is to evaluate the current status and draw the further perspectives of WKH bryophyte and lichen indicator species conservation in Latgale. Data were analyzed with Generalized Linear model. In total 16 WKH types, suitable for bryophyte and lichen indicator species existence were identified in Latgale. As a result WKH type, forest stand age and area were significant factors influencing bryophyte and lichen specialist and indicator species richness in forest stand level. WKH status did not provide any official conservation status for habitats or species based on current legislation in Latvia. Therefore establishment of conservation areas as microreserves for habitats and species and Nature Reserves in areas, with high (P)WKH density is an effective tool for their long-term conservation in Latgale. Further scientific studies of bryophytes, lichens and WKHs are necessary for planning the best conservation scenarios taking into account also forest ecosystem services.**

Keywords: **Woodland key habitats, bryophytes, lichens, conservation.**

I INTRODUCTION

Habitat fragmentation is among the major threats of biodiversity loss worldwide [1], including forest ecosystems [2]. Forest fragmentation also decreases the species population sizes leading to the species extinction debt [3]. Latvia represents an example of fragmented forest landscape due to the past history of land-use [4]. Latgale show one of the most fragmented regions in Latvia, where maintaining forest landscape should play an especially significant role for the forest dwelling species conservation in a future.

Forest cover is around 38.6 % of total area of Latgale. The highest forest cover represents northern and southern parts of Latgale. Several conservation categories exist in Latgale – National park, Protected landscape region, Nature Park, Nature Reserve, Microreserve, Nature monument for habitat conservation, including partly also forest habitat conservation [5].

Woodland key habitat (WKH) is an area which contains habitat specialists, that cannot sustainably survive in stands managed for timber production. A well-founded expectation that a habitat specialist exists within an area is a sufficient criterion for designating the area as a WKH. Potential WKH (PWKH) is a habitat, that if it is managed in such a way as to promote its biodiversity value, may become a WKH during the next 20 years in stands of pine and spruce, during the next 30 years in stands of oak, ash, lime, elm, and during the next 10 years in stands of aspen, birch and alder [6]. Around 3.4 % of Latvian State forests were evaluated as WKHs based on data obtained from WKH inventory projects (1999.–2003.). Around 6.41 % of Latgale forest cover were evaluated as (P)WKHs [7]. The aim of WKH inventory was to found out the information about the (P)WKHs in state forest, identify biological value and suggest the suitable management activities for their conservation.

Several (P)WKH concentration areas with bryophyte and lichen specialist and indicator species hotspots were identified also in Latgale [8]. Today WKH status did not provide any official conservation status for habitats or species based on the current legislation in Latvia, but in many cases, these habitats correspond to microreserve criteria [9,10].

Habitat specialist is a threatened species that is dependent on a certain level of quality in specific

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.283

WKHs and will become extinct if these habitats are subject to detrimental treatment. Indicator species is a species that has rather high demands on its living conditions but not as high as those of a habitat specialist. WKHs in Latgale were inventored only in Latvian state forests [8]. Bryophytes and lichens are important forest dwelling organisms as they are sensitive to changes of forest microclimate and indicates specific conditions of WKH, where also other organism groups may exist.

The aim of this paper is to evaluate the current status and draw the further perspectives of WKH bryophyte and lichen indicator species conservation in Latgale.

II MATERIALS AND METHODS

Study area

The study area was located in Latgale, representing wide part of eastern Latvia (Fig. 1). The annual rainfall in Latgale vary from 540 to 650 mm. The average temperature in January is less than -7^{o}C, the average temperature in July is more than +17^{o}C [11].

Data were obtained from WKH inventory collected in Latvian State forests from 1999 till 2007 in Latgale from Forest State Service data base. In total 32168 (P)WKHs from 16 WKH types were analyzed – aspen forest (APS), spring influenced forest (AVOT), beaver activity (BEBR), ravine forest (GRAV), giant tree (KOKS), riparian forest (KRAST), other deciduous forest (LAP), black alder wetland forest (MELN), mixed coniferous – deciduous forest (MIS), slope forest (NOGAZ), broad-leaved forest (PLAT), coniferous forest (SKUJ), spruce and mixed spruce-wetland forest (SLAP_EG), broad-leaved wetland forest (SLAP_PL), pine and pine-birch wetland forest (SLAP_PR), wind fallen forest (VEJG) including P(WKH) area and forest stand age. (P)WKH area varied from 0.1 ha to 28.3 ha and forest stand age - from 10 to 224 years.

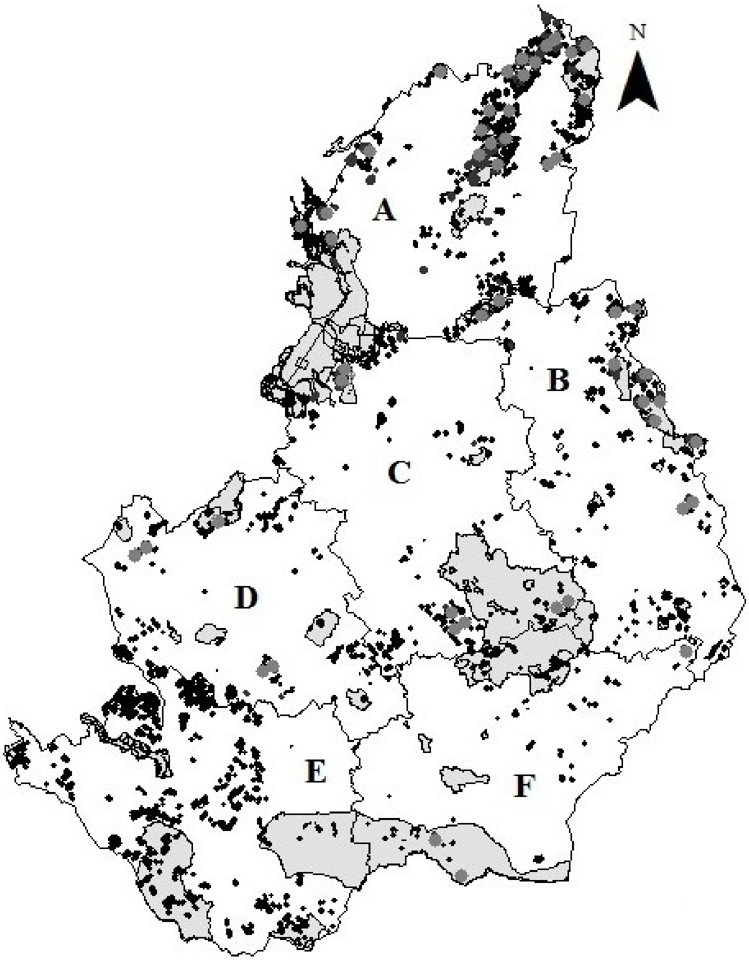

Fig. 1. The current valuable territories for forest conservation in Latgale. P(WKH) (black), microreserves (dark grey circle) and specially protected territories (light grey). A-Balvu district, B-Ludzas district, C-Rēzeknes district, D- Preiļu district, E- Daugavpils didtrict, F-Krāslavas district.

Data analysis

WKH indicator and specialist species were compiled as "indicator species" to facilitate the data analysis process in abstract, materials and methods, results and discussion, conclusions sections of this paper. The map with current valuable territories for forest conservation was generated with ESRI Arc View GIS 10.0 using database GIS Latvija 9.2.

Generalized linear model (GLM) with poisson family in R programme (Version 2.11.1) was applied for analyzing WKH lichen and bryophyte species indicators in relation to forest type, area and forest stand age. In total 16 bryophyte and lichen species occurrences in relation to (P)WKH type, area and stand age were analyzed (in total 32168 samples).

III RESULTS AND DISCUSSION

WKHs are located in a highly fragmented landscape in Latgale (Fig.1), where wide agricultural lands and waterbodies are mixed with relatively small forest patches. Based on data from Razna national park [12] – around 50 % of park area are covered by forests, but these forests are intensively managed and conservation of long-term biodiversity is threatened (73% of all forest stands are less then 60 years old, older than 100 years are only 3 % of forest stands). Forest cover in Nature Park "Daugavas loki", located in southern Latgale, is 58 % of park area, around 45 % of forest stands, are 51-100 years old. Forest stands older than 100 years cover 40 % of forest area [13]. Based on data about WKH inventory – most of (P)WKHs are not located in specially protected territories (Fig.1). Therefore (P)WKHs outside the specially protected territories are forming clusters indicating also suitable conditions for WKH lichen and bryophyte indicator species existence. Such clusters may serve as hotspots for WKH bryophyte and lichen indicators noting suitable conditions for occurrence also for other organism groups.

In total 20 lichen and 17 bryophyte indicator species were found in studied (P)WKHs in Latgale. The most common lichen indicators in Latgale were *Graphis scripta* (921 records), *Menegazzia terebrata* (361 records), *Arthonia spadicea* (355 records), *Lobaria pulmonaria* (247 records). The most common bryophyte indicators – *Neckera pennata* (845 records), *Homalia trichomanoides* (788 records), *Jamesoniella autumnalis* (398 records).

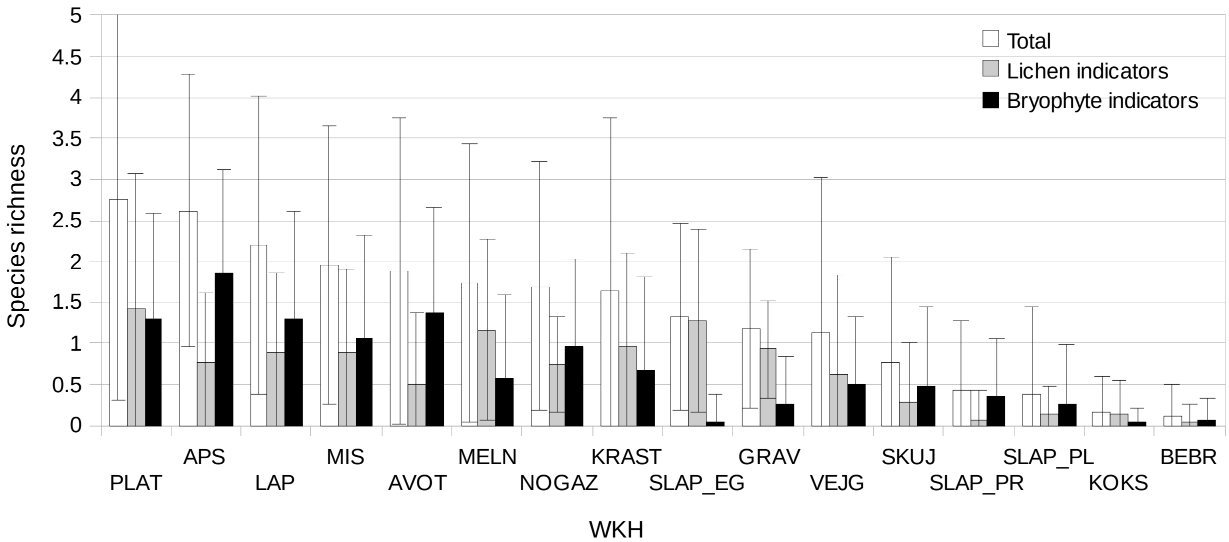

Fig. 2. The average bryophyte and lichen indicator richness among studied WKH types in Latgale. WKH abbreviations defined in Materials and methods section. Data include (P)WKHs.

Differences were found in bryophyte and lichen indicator species richness among studied WKH types (Fig. 2). The highest total and lichen indicator species richness was found in broad-leaved (P)WKHs, the highest bryophyte indicator richness was found in aspen (P)WKHs. These species richness differences may be explained with different microclimatic requirements for lichens and bryophytes. Previous studies noted the importance of deciduous forests for existence of epiphytic species being explained by suitable tree species and bark characters in Latvia [14,15,16].

Table 1. Indicator species richness in relation to (P)WKH variables after GLM analysis. Significance level 0.05.

Variables	Z-value	p	Z-value	p	Z-value	p
	Total indicator richness		**Bryophyte indicator richness**		**Lichen indicator richness**	
Full model	8.98	<0.01	6.97	<0.01	-2.5	0.01
Size	7.85	<0.01	5.67	<0.01	5.27	<0.01
Age	-9.24	<0.01	-10.32	<0.01	-2.71	<0.01
Beaver activity	-6.08	<0.01	-5.04	<0.01	-3.27	<0.01
Ravine forest	-2.53	0.01	-5.04	<0.01	2.39	0.02
Giant tree	-5.36	<0.01	-3.75	<0.01	-2.51	0.01
Broad-leaved forest	3.86	<0.01	-	-	4.55	<0.01
Aspen forest	3.11	<0.01	2.72	<0.01	-	-
Coniferous forest	-5.45	<0.01	-4.57	<0.01	-2.16	0.03
Broad-leaved wetland forest	-3.96	<0.01	-3.16	<0.01	-2.13	0.03
Pine and pine-birch wetland forest	-9.81	<0.01	-6.66	<0.01	-6.91	<0.01
Wind – fallen forest	-2.54	0.01	-3.37	<0.01	-	-
Riparian forest	-	-	-2.89	<0.01	2.69	<0.01
Black alder wetland forest	-	-	-6.29	<0.01	3.98	<0.01
Spruce and mixed spruce-wetland forest	-	-	-7.38	<0.01	4.41	<0.01
Other deciduous forest	-	-	-	-	2.66	<0.01
Mixed coniferous-deciduous forest	-	-	-	-	2.83	<0.01

(P)WKH type was found as a significant factor influencing bryophyte and lichen species richness in forest stand level (Tab 1). However, some variations were found among total, bryophyte or lichen indicator richness groups in relation to forest type. These results showed, that different species groups have different requirements in demands of (P)WKH type, what is important to bear in mind for planning long-term conservation for bryophyte and lichen indicator species.

(P)WKH age and area were significant ($p<0.05$) factors in forest stand level explaining bryophyte and species indicator species richness. (P)WKH age was significantly related to lichen species diversity in Estonian forests [17], but Rogers and Ryel [18] did not find significant relationship between species richness and forest stand age. Forest stand area was found to be an important driver for long-term population existence [19] and epiphyte richness [20]. Both WKH age and area play an important role in species dispersal to suitable habitats and substrates. Bryophyte and lichen diaspores should pass long-distances in fragmented landscape until meet the suitable substrate and conditions for their long-term existence. Systematic conservation planning at landscape level is important for fragmented habitats as WKHs [21]. Fragmentation reflects severe conditions for species existing in fragmented forest patches. Establishment of network with WKHs is one of the steps towards the successful management of biodiversity suggested in Sweden. Biodiversity conservation planning should take into account the landscape scale [2] as well as ecosystem services of forest habitats [23] and researchers as biologist's should be involved. Ecosystem services of Protected territories ensure the highest ecosystem services supply in terms of habitat preservation for threatened species, climate regulation, erosion control and water flow maintenance [24]. Further scientific studies of bryophytes, lichens and WKHs are necessary for planning the best conservation scenarious taking into account also forest ecosystem services.

Based on present results about (P)WKHs and bryophyte as well as lichen indicator species occurrence in these forests in Latgale, we suggest to stimulate and fasten the establishment of microreserves, where separate WKHs are located, but Nature Reserves should be established in areas, where density of WKHs is higher especially in northern, eastern and southern parts of Latgale for long-term conservation planning. Conservation priority should be given to older WKH stands. Establishment of Nature Reserves as wider conservation unit will gain higher benefit for WKHs as well as bryophyte and lichen indicator species conservation in long-term.

IV CONCLUSIONS

1) Latgale has strictly fragmented forest landscape, but forest patches with high biological value were

left representing diversity of bryophyte and lichen indicator species in 16 WKH types in relatively small forest patches.

2) The current conservation of WKH bryophyte and lichen indicator species is not enough for their long-term existence as most of suitable (P)WKHs are located outside of conservation areas and their future perspectives are not clear.
3) We suggest to establish new microhabitats and Nature Reserves for WKHs in Latgale conserving not only forest habitats with high biological values and WKH bryophyte and lichen indicator species long-term conservation, but ensuring conservation also for other forest dwelling organisms and maintaining ecosystem services.

V ACKNOWLEDGMENTS

Thanks is given to Forest State Service for data about (P)WKHs in Latgale. We are grateful to Sandra Ikauniece for fruitful discussions about forest habitats.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 202-206

Automated detection and enumeration of fluorescently labelled bacteria with flow cytometry

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Abstract. **Rapid identification of specific microorganisms in their natural environments is of high importance when their cultivation is either impossible or cannot provide valid results. One of the tools available for such purposes is flow-FISH where classical microscopic identification of microorganisms is combined with an automated enumeration system. Despite the high potential of flow-FISH there are still many unsolved issues to introduce the method. The aim of this research was to determine potential quantification limits of a simple flow-FISH protocol to ensure specific and rapid automated identification of target cells.**

The results of the study showed that at optimal hybridization conditions (16 hours of hybridization, 15 minutes post-hybridization washing and 3 ng/µl probe concentration) it is possible to specifically determine all main proteobacteria groups and Grampositive bacteria and discriminate among β and γ proteobacteria. Detection of α-proteobacteria was not achieved in this study. Despite the promising application potential of flow-FISH, high attention must be made to extensive cell loss (up to 59%) during preparation of samples for the analyses.

Keywords: **bacteria, flow cytometry, fluorescence *in situ* hybridization.**

I INTRODUCTION

For many years it has been shown that microbial cultivation on nutrient rich media might not be suitable for detection and enumeration of environmental microorganisms, due to their presence in a nonculturable state [1], specific growth requirements (methanogenic Archaea in anaerobic digestion) or slow division rates [2]. Thus, to effectively enumerate and control overall population dynamics or specific microbial species other methods should be applied.

Fluorescence *in situ* hybridization (FISH) has become one of the most powerful tools developed in modern microbiology for direct specific detection of target microorganisms in their natural environments [3]. The main advantage of this method is that microorganisms are detected without prior need for cultivation. Moreover, targeting cellular mRNA [4] or effective combination with molecular viability assays [5] has enabled the discrimination of viable target cells among all FISH positive cells. However, the conventional FISH approach is generally linked with fluorescence microscopy which often makes the method time and labor consuming. This in turn makes the method inapplicable for rapid on-site evaluation of environmental systems, e.g., biogas, biofuel stations, natural waters. As an alternative to microscopy flow cytometry has been suggested as a high-throughput quantification method which allow simultaneous phenotypic separation of cell populations based on their surface characteristics. Efficient combination of FISH with flow cytometry (flow-FISH) has been shown for various species, like *Staphylococcus aureus* [6], lactic acid bacteria [7] and anaerobic fermentation liquid [8]. A substantial feature of flow cytometry is that it is fast, accurate and quantitative in estimating total or viable population counts [9], however, quantitative limits of flow-FISH are still not fully explained. Thus, the aim of this study was to determine potential quantification limits of a simple flow-FISH protocol to ensure specific and rapid automated identification of target cells. To achieve the aim various factors, like, hybridization time, probe concentration, post-hybridization washing time, of the FISH protocol were evaluated prior quantification to

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.284

ensure optimal target signal intensity and avoid any unspecific binding.

II MATERIALS AND METHODS

A. Bacterial cultures and fixation

Escherichia coli ATCC 25922, *Pseudomonas fluorescens* ATCC 13525, *Burkholderia cepacia* LMKK 491, *Sphyingomonas paucimobilis* LMKK 624 and and *Bacillus subtilis* ATCC 6633 grown on R2A agar (Oxoid Ltd., UK) were inoculated into tryptone soya broth (Oxoid Ltd., UK) and incubated with constant shaking (150 rpm) overnight or for 18 hours at 30°C.

For fixation of the cultures a known amount bacterial suspension was inserted into a vial and centrifuged for 2 min (2000g). Then the pellet was twice washed with sterile phosphate buffered saline (PBS: 200 mM NaH_2PO_4 x H_2O, 200 mM NaH_2PO_4 x H_2O, pH 7.2) and supplied with three volumes of ice-cold 4% paraformaldehyde-PBS buffer for 2 hours at 4°C. After fixation the samples were thrice washed with PBS buffer and reconstituted in C_2H_6O-PBS mix (3 v/v C_2H_6O: 1 v/v PBS) and stored at -18°C until further use.

B. Cell enumeration

To determine the total number of cells in the samples microscopy analyses or flow cytometry staining with SYBR®Green I nucleic acid stain (Sigma, Germany) were performed. The stain was 1:100 diluted in dimethyl sulfoxide (Sigma, Germany), added to the cell suspension and incubated in dark at room temperature for 15 min before measurements with flow cytometer (section D).

For microscopy fixed suspensions were filtered on 25-mm-diameter 0.2-µm-pore-size filters (25 mm diameter, Track-etched; Whatman plc), washed with sterile distilled water, air-dried and stained with 10 µg/mL DAPI (4`,6-diamidino-2- phenylindole, Merck) for 10 minutes, washed with sterile distilled water and air-dried. Cell concentration was determined by epifluorescence microscopy by counting cells in 20 random fields of view (Ex: 340/380 nm; Em: >425 nm, dichromatic mirror 565 nm, Leica DM, LB).

C. Sample preparation for Flow-FISH

A known amount of fixed cells were placed into a microtube and inserted into a dry-block heater (46°C) for 15 minutes to evaporate ethanol. Then 0.2 mL of hybridization buffer and probe (labelled with FITC) mix (Table 1) was added to the sample. After vortexing the samples were incubated in the dark for 3 hours at 46°C. Then 0.5 mL of pre-warmed washing buffer (70 mMNaCl; 20 mMTris-HCl, 5 mM EDTA) was added to the sample, vortexed and centrifuged for 2 min (2000g).

After centrifugation 0.6 mL of the supernatant was removed and replaced with 0.5 mL of fresh washing buffer. The samples were vortexed and incubated at 48°C for 15 minutes. After washing the samples were centrifuged and thrice washed with sterile PBS (pH 8). All time correct follow up of the volumes added and removed was performed. After the last centrifugation PBS (pH 8) was added to obtain the total volume of 1 ml of the sample.

TABLE 1.

OLIGONUCLEOTIDE PROBES USED FOR FLOW-FISH AND CORRESPONDING HYBRIDIZATION CONDITIONS

Name	Sequence 5' - 3'	Formamide, %	Target	Reference
EUB338	GCTGCCTC CCGTAGGA GT	35	Domain Bacteria	10
Non338	ACTCCTAC GGGAGGC AGC	35	Competitor to EUB338	10
ALF968	GGTAAGGT TCTGCGCG TT	20	Alfa proteobacteria	11
BET42a	GCCTTCCC ACTTCGTT T	35	Beta proteobacteria	12
GAM 42a	GCCTTCCC ACATCGTT T	35	Gamma proteobacteria	12

D. Flow cytometry measurements

Flow cytometry was performed using CyFlow instrument (Partec, Hamburg, Germany) equipped with 200 mW laser, emitting a fixed wavelength of 488 nm, and volumetric hardware. Green fluorescence was collected at 520 nm, red fluorescence - at > 615 nm and all data were analyzed with the Flomax software (Partec).

The specific instrumental gain settings for these measurements were as follows: green fluorescence (FL1) = 430 and red fluorescence (FL3) = 570. All samples were processed at speed 300 µl/min. Where necessary, samples were diluted before measurements in cell-free water for the concentration measured by Cyflow not to increase 1000 cells/min.

III RESULTS AND DISCUSSION

A. Adjustment of flow-FISH

Generally it is accepted that for probes EUB338 and non338 0-50% formamide concentrations are used. To determine the optimal formamide concentration for flow-FISH, formamide series were performed in this study. The results indicated on good signal strength of up to 50% formamide. Further increase in formamide concentration notably decreased the fluorescence intensity. For further analyses 35% formamide was used as it was reported previously for epifluorescence microscopy analyses [13] and showed high signal intensity.

To effectively remove unbound or unspecifically bounded probes post-hybridization washing is performed. Correct adjustment of the washing time ensures optimal positive signal with simultaneous low or no level of unspecific binding [14]. Most commonly used washing times of 10, 15 and 20 minutes were tested with the probes EUB338 and non338. The results of flow cytometry showed that the lowest noise ratio was achieved after 15 minutes of washing and represented a false positive cluster of 2.7% from all positive events recorded. At shorter washing times the false positive level increased to 4.6%. After 20 minutes washing the amount of detectable target cells decreased, thus, increasing the proportion of false positives (3%). The overall cell loss during washing was neglected due to the hybridization in liquid conditions [15]. Thus, 15 minutes of washing were used in all further tests.

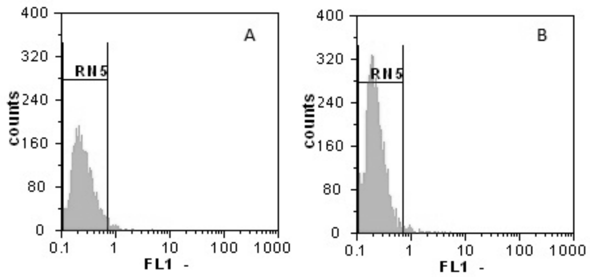

Fig. 1. Amount of fluorescent *E. coli* cells with 1.5 ng/µl (A) and 3 ng/µl (B) of EUB338-FITC labelled probe. FL1 on X-axis is represented as fluorescence intensity in green channel. RN5 represents the region of interest.

Further the effect of hybridization time and probe concentration was evaluated. Generally 1 – 5 ng/µl probe concentrations have been recommended for flow-FISH [10]. Comparison of 1.5 and 3 ng/µl showed that better signal intensities are obtained in samples with higher probe concentrations (Fig. 1). At the same time no increase in unspecific staining with non338 was observed when the probe concentration was increased. Prolonged hybridization time of up to 16 hours (when compared to 3 hours) produced higher fluorescence signals within all cell suspensions tested (Fig. 2). For all cells, except *B. cepacia*, more than tenfold increase was observed, indicating on better binding and more intense signals. Moreover, the observed noise ratio was lower at 16 h hybridizations and ranged from 0.83% for *S. paucimobilis* to 5.6% for *B. subtilis.* At 3 hours of hybridization the proportion of false positives (hybridized with non338 probe) in *B. subtilis* samples reached up to 20%.

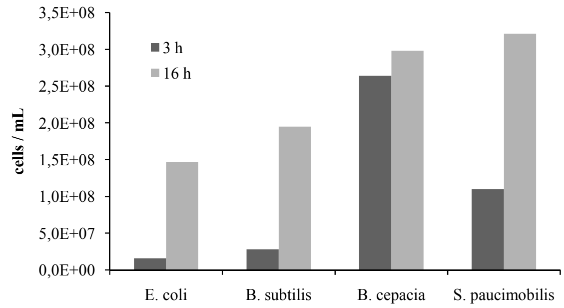

Fig. 2. Amount of cells identified with flow-FISH (probe EUB338) in control suspensions after 3 and 16 hours of hybridization.

Despite apparent improvements in signal intensities and decrease in noise levels after 16 hours of hybridization, it must be taken into account that prolonged hybridizations will limit flow-FISH as a potential tool for rapid analyses. Thus, further prcess optimisation and evaluation of target populatons must be taken into account prior analyses.

B. Evaluation of various probes

After the set up of potential FISH parameters various probes were tested with the available microbial samples (Table 2). Low or no fluorescence intensities were observed for all bacterial samples when hybridized with no added probe or non338 (Fig. 3). Generally slightly more false positive signals were observed for non338 probe indicating on potential non-specific binding issues. However, the percentage of non-specific binding did not exceed 5% for Gramnegative and 10% for Grampositive bacteria tested

Group specific BET42a and GAM42a probes gave positive signals for tested target species. The amount of fluorescent *E. coli, B. cepacia* and *P. fluorescens* cells hybridized with BET42a or GAM42a ranged from 73 to 82 % from the fluorescent cells detected with EUB338 ($p > 0.05$).

TABLE 2.

FLOW-FISH FLUORESCENCE SIGNALS OBSERVED FOR VARIOUS BACTERIA WITH VARIOUS PROBES.

Species	Proteo bacteria group	Probe			
		EUB 338	BET 42a	GAM 42a	ALF 968
E. coli	γ	+	-	+	-
P. fluorescens	γ	+	-	+	-
B. subtilis	-	+	-	-	-
B. cepacia	β	+	+	-	-
S. paucimobilis	α	+	-	+*	-

* non-target fluorescence

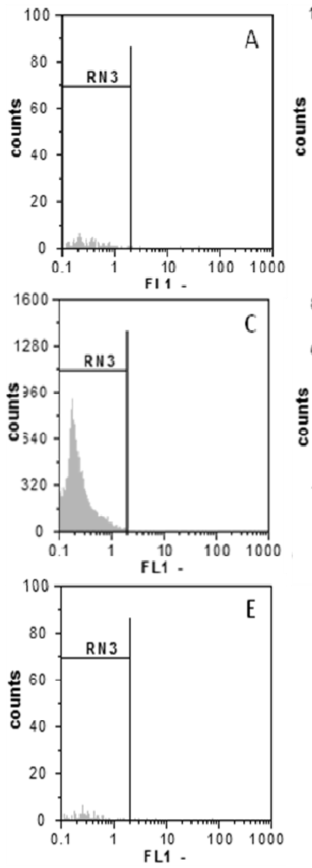

Fig. 3. *Pseudomonas fluorescens* fluorescence signals when hybridized with no probe (A), non338 (B), EUB338 (C), GAM42a (D) and BET42a (E). FL1 on X-axis is represented as fluorescence intensity in green channel.

No fluorescent cells were observed with probe ALF968. Fluorescence intensity for *S. paucimobilis* (α-proteobacteria) hybridized with ALF968 was significantly lower ($p < 0.05$) than fluorescence observed with EUB338. At the same time epifluorescence microscopy produced fluorescent *S. paucimobilis* cells indicating on problems associated only with flow-FISH and not FISH protocol in general. Along with the optimization of the protocol, the application of other available α-proteobacteria targeting probes can be taken into account [16]. Further analyses with *S. paucimobilis* produced fluorescent signals when hybridized with GAM42a (Table 2). The amount of the observed fluorescent objects constituted 33% from all identified objects with EUB338, indicating on a potential problem in flow-FISH. No such fluorescence was observed with epifluorescence microscopy.

C. *Enumeration of cells with flow-FISH*

Apart from high specificity, the main issue in having flow-FISH as a quantitative method is to omit or replace treatment steps which produce high decrease in total cell counts. One of the identified treatments include post-hybridization washing where the samples have to be centrifuged and re-suspended many times [10]. To evaluate cell losses during flow-FISH treatment cells were collected after hybridization, after 1st and 2nd post-hybridization washing, after final washing with PBS and after re-suspending (final). The collected samples were directly stained with SYBR green and enumerated with flow cytometry (Fig. 4) to determine total counts.

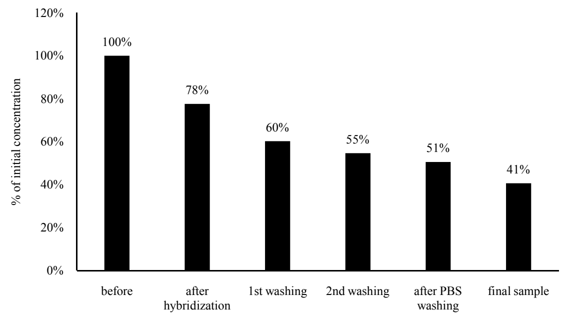

Fig. 4. The amount of cells lost during sample preparation for flow-FISH.

The results showed that there is no single treatment step which produce significant cell decrease. A mere decrease is observed within all treatments and resulted in 59% of lost cells during sample preparation for flow-FISH. When analysing samples with high cell content, e.g. biogas, this might not affect the overall outcome of the test result, however, due to the detection limits of the method itself (around 10^3/ml) [17] even minor cell loss in samples with low density target cells might seriously affect the results.

IV CONCLUSION

It is possible to detect positive flow-FISH signals in positive samples. Background noise and false positives can be easily distinguished with flow cytometry, thus, rapid automated identification of target cells was possible. At the moment the quantification limits of the method are target cell counts above 10^5/ml because of high (around 59%) overall cell decrease during sample preparation for flow-FISH.

An optimal FISH protocol suitable for flow cytometry was developed. 16 hours of hybridization in liquid conditions and 15 minutes of post-hybridization washing allowed to obtain the highest positive signals with the lowest noise. Flow-FISH showed to be a good tool to distinguish among various classes of bacteria – γ-proteobacteria, β-proteobacteria and Grampositive *bacilli* were differentiated correctly. However, high non-specific binding was observed for α-proteobacteria.

Flow-FISH at its current stage seems to be a promising tool for automated assessment of microbial cultures with high initial cell concentration in nutrient rich environments, e. g. biogas systems. However, further research for application of this method in low-nutrient environments and its potential rapidity is still necessary.

V ACKNOWLEDGMENTS

This work has been supported by ESF project „Involvement of Human Resources for Development of Integrated Renewable Energy Resources Energy Production System", No. Nr.2013/0014/1DP/ 1.1.1.2.0/13/APIA/VIAA/026.

Ms Kristina Tihomirova is acknowledged for assistance with flow cytometry measurements.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 207-218

Harmonization of piece-by-piece measurement methods in all stages of roundwood manufacturing processes

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Abstract. **In the sawmill industry in Latvia the roundwood represents about 70 % of the total production cost. The quantity measurements of the round wood are required throughout the logic chain of wood from forest to the sawmills but inspite of a large proportion of the total cost the term "true volume" of roundwood is equally actual for supplies and processors of wood. The roundwood volume results differ measured the same load by measuring the diameters of log in short intervals using harvester measurement systems and in sawmills by measuring the diameters of log in short intervals using electronic 3D systems or measured manually using the most accurate method according to the requirements of standard LVS 82:2003 by measuring top and butt diameter. This means that it is a great interest in industry to develop the measurement methods and systems to have a lower cost and more efficient algorithm to determine the wood volume.**

The purpose of this study is to compare the wood volume calculation results made by the most accurate manual and automatic measurement methods and give the recommendations for minimizing difference between them.

The research is a continuation to the work done in the project „Harmonisation of piece-by-piece measurement methods of roundwood approved by Standard LVS 82:2003 „Apaļo kokmateriālu uzmērīšana" (Miklasevics, Z., 2013).

Keywords: **roundwood; piece-by-piece measurement methods; volume.**

I INTRODUCTION

Measurement operations where wood is the subject of business are sensitive to accuracy. Different calculation methods are used in wood harvesting, sale, purchase and wood processing using manual or automatical measurements. According to technical possibilities of measurement equipment methods of wood volume calculation and approach to problems, more procedures have been proposed to determine the "true volume". Due to results in the determination of volume electronic procedures are not consistent with manual methods or with each other and their results do not correspondent to "true volume" of measured assortiments (Janak, K., 2005, Janak, K., 2007, Miklasevics, Z., 2013.)

The analyse of the measurement results obtained in Latvia sawmills where the most accurate piece-by-piece manual measurement method (2) (Fig.7.) based on the top and butt diameter measurements is being used, have shown that the volume values especially of spruce logs from neiloid zone usually are overestimated comparing to results obtained by measurement methods based on measuring diameter in short intervals using harvester measurement systems and by measuring diameter in short intervals using electronic 3D systems (Patterson, D.W.). It is explainable because of irregular form of roundwood, the volumes of logs are determined through simplified approach and the different algorithm of volume calculationare being used.

The main characteristics of each measurement method used in the investigation are sequential:

1. *according to the top and butt diameter measurements by standard LVS 82:2003 (2) (Fig.8.)* For calculating the log volume the neiloid-shape profile of the log assume to be a conus in zone among the top and 0.5 m from the butt. Butt zone 0-0.5 m of the log assume to be a cilinder. The algorithm of the volume *(3.2.) (Fig.7.)*calculation formula partly ignore the natural shape of the log. Therefore the volume values possibly are overerestimated.
2. *by measuring diameter in short intervals using harvester measurement systems.*

There are couple of different formulas for calculating the log volume by harvester bucking computer (Circular VMR 1-99). In Finland only cylinder formula is used in practice. Other possible volume calculation formulas are truncated cone, Nilson (Estonian), Huber and Smalian (Räsänen, T., 2007, Reg 918/66/97). The corresponding variables related to the investigation are defined below:

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.232

DBH ($d_{1,3}$) - diameter at 1.3 m from felling cut (cm)

Spp-file - stem prediction parameters

StanFordstandard- Standard for Forestry Data and Communication

Ktr-file - harvester calibration and control measurement file. Sent from digital callipers to (on-board) merchandishing (bucking) computer, and from merchandishing computer to the office computer

Prd-file - production of the harvester (measurement certificate)

Pri-file - production-individual. Data of each log made from the site.

The volume calculation (V1) of the first 1.3 meter part (3.2.) (Fig.7.) of the butt log is calculated a bit differently from the other logs. Calculation based on extrapolated butt diameter. Diameter of butt end on butt logs (0.0-1.3 m) is estimated on the height of 1.3m from felling cut based on measured diameter DBH($d_{1,3}$). Calculation carried out based on either functions or tables (Černy, M., 1995., EN 1309-2. 2006., Wood,G.B. and Wiant, H.V. 1995). Volume of 0.0-1.3 m section (starting from butt-end of first log) is usually calculated in 1 to 10 cm steps. Diameters for those points are estimated as a function of DBH($d_{1,3}$) or actually diameter at 1.3 m distance from cutting point (Fig. 1.).Tables and functions give the extrapolation coefficient of a certain point as a result of measured diameter at DBH($d_{1,3}$) and distance (height) of the extrapolation point from the point of the felling cut.The measured diameter at reference height multiplied with the given coefficient will give the extrapolated diameter. Volume of butt end using these estimated diameters is to be done in the same way as the upper part of the log. Harvesters could use either tables or functions depending on their present method or processing capacity. The coefficients given in tables are based on specific taper curve and stump height models for pine, spruce and birtch separately and have been developed by Metsäteho ("Spp-file in StanForD" (Räsänen, 2007.)). In Finland it is a legal requirement to use the function. In Latvia it is possible to use the function in all major harvester systems but it depends on the market whether it is activated in harvester and computer caliper although it is known that there might be some deviations in the stem profiles for certain areas.

Distance from felling cut, m

$d_{1,3}$, cm	0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1	1,1	1,2	1,3
8	1386	1302	1241	1197	1164	1138	1116	1098	1081	1064	1048	1032	1016	1000
9	1381	1297	1237	1192	1159	1133	1112	1094	1077	1061	1046	1031	1015	1000
10	1375	1293	1233	1188	1155	1129	1108	1090	1074	1059	1044	1029	1015	1000
11	1370	1289	1229	1184	1151	1125	1104	1087	1071	1056	1042	1028	1014	1000
12	1364	1285	1225	1181	1147	1121	1101	1084	1068	1054	1040	1027	1013	1000
13	1358	1281	1222	1178	1144	1119	1098	1081	1066	1052	1039	1026	1013	1000
14	1353	1277	1219	1175	1142	1116	1095	1078	1064	1050	1037	1025	1012	1000
15	1347	1273	1216	1173	1140	1114	1093	1076	1062	1049	1036	1024	1012	1000
16	1342	1270	1214	1171	1138	1112	1091	1075	1060	1047	1035	1023	1012	1000
17	1337	1267	1212	1169	1136	1110	1090	1073	1059	1046	1034	1023	1011	1000
18	1332	1264	1210	1168	1135	1109	1089	1072	1057	1045	1033	1022	1011	1000
19	1327	1261	1208	1167	1134	1108	1088	1071	1056	1044	1032	1021	1011	1000
20	1323	1259	1207	1166	1133	1107	1087	1070	1056	1043	1032	1021	1010	1000
21	1319	1256	1206	1165	1133	1107	1086	1069	1055	1043	1031	1021	1010	1000

Fig. 1. The example of extrapolation coefficient table for pine using 130 cm as reference height (coefficients for butt end profile, %) (Räsänen, T., Poikela, A., Arlinger, J. 2007.)

The analyse of the measurement results obtained in Latvia sawmills where measurement methods are based on measuring diameter in short intervals using electronic 3D systems have shown that especially neiloid-shape profile of the logs butt end is not predicted well enough by using harvester measuring systems. The main reasons which cause these differences in harvester measurement systems are sequent.

Different calculation methods are used in harvesters for extrapolating butt end diameter values from the first measured values:

1. Different harvester head models start diameter measuring at different heights.
2. Falsely extrapolated diameter values lead to incorrect volumes of the butt end.
3. Incorrect volume values are the sequence of incorrectly estimated volumes of the butt end diameter.

Harvester measurerement system algorithm used in investigation based on functions defined in Spp file (Räsänen, 2007.).

3. by measuring diameter in short intervals using electronic 3D systems (3.1.) (Fig.8.).

There are no legislative norm that would determine the requirements for methods of processing the measured data and methods of calculating the logs volume in Latvia sawmills. The algorithm of the volume calculation using 3D scanner Mikropuu Oy (FIN) by measuring diameter in short intervals is given (3.1.) (Fig.8.).

according to the top and butt diameter measurements by model of volume calculation developed for Swedish roundwood systems (3.1.) (Fig.8.) (Anon 2000).

In Sweden as the most accurate piece-by-piece measurement method based on the algorithm model of the formula were developed for roundwood of Scots pine (Pinus silvestris) and Norway spruce (Picea abies) (Anon 2000). The formula were obtained from 10 751 logs from middle and southern Sweden measured in sections and at the small (10 cm from top) and large end (50 cm from large end for butt logs and 10 cm from large end for other logs).

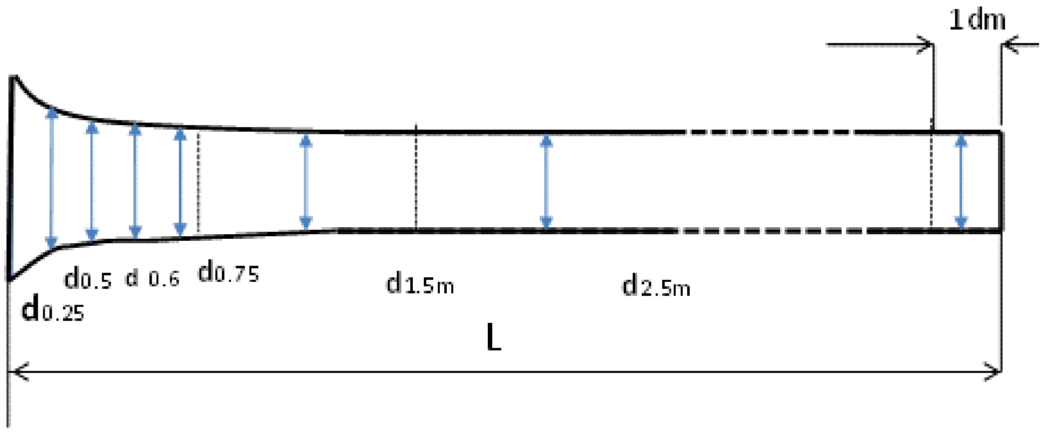

Fig.2. Control measuring points for developing of the volume calculation algorithm

The data needed for developing the volume calculation algorithm was prepared according to the measurement scheme (Fig.2.). The first diameter measurement taken at 25 cm from the log butt means that the most but not all buttress volume is included in the volume.

The calculation algorithm bases on „α" constant which redistributes the weight of those two diameters so that the small end diameter gets a larger influence on the diameter that represents the log in the formula. According to investigations made in Sweden (Anon 2000, Nylinder, M., 2010) predict the volume of roundwood obtained by measuring sections by using the small and large end diameter and lenght of the log will give more accurate volume results comparing to other manual measuring methods. The algorithm of the volume calculation formula is based on the natural shape of the log. Therefore measurement method is being chosen as the reference formula in this investigation.

The purpose of this study is to assess the wood volume calculation results made by the proposed manual, harvester and electronic measurement:

1. according to the top and butt diameter measurements by model of volume calculation developed for Swedish roundwood (Anon 2000),
2. according to the top and butt diameter measurements (LVS 82:2003),
3. by measuring diameter in short intervals using harvester measurement systems,
4. by measuring diameter in short intervals using electronic 3D systems and by analyzing the reasons of difference of the results to find and to prove that the industrial implementation of the most appropriate manual measurement method which provide the least roundwood volume deviation comparing to the results given by harvester and electronic measurement is feasible.

II MATERIALS AND METHODS

The study was carried out in March 2014 in the region Kurzeme in Latvia. Large buttress of the first log of the stem causes the wide dispersions of the measurement results. The wood felling area (Fig. 3.) was chosen (As)-Myrtillosa mel.*(Woodlands on drained mineral)* because of the shape of spruce stems with large buttress. The wood falling time was chosen because of the minimal risk of debarking in the process of harvesting.

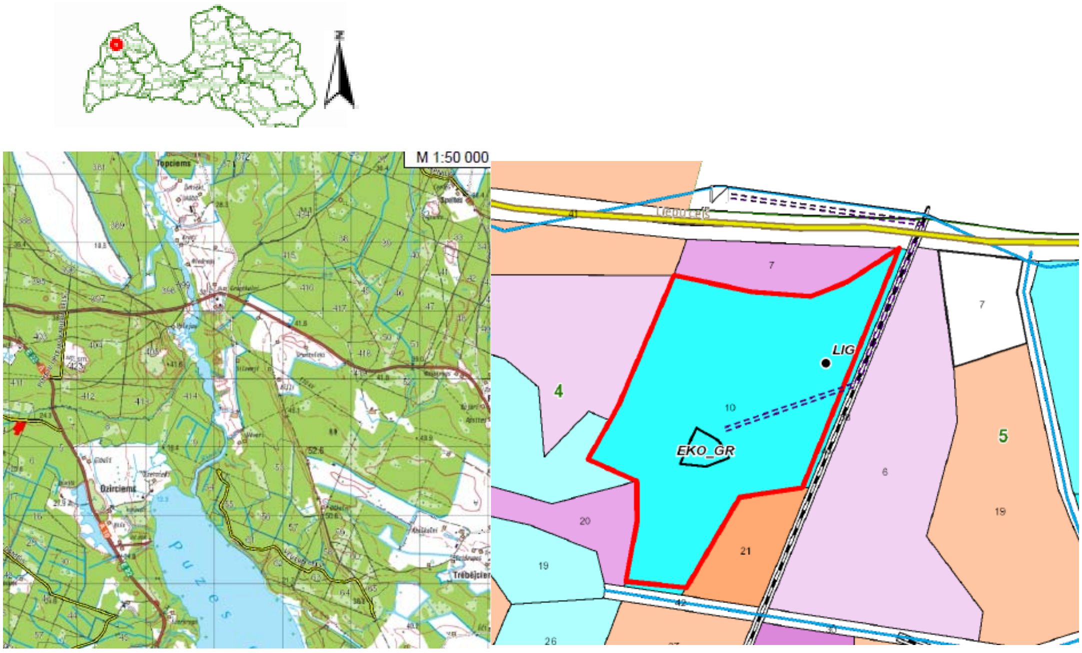

Fig. 3. Wood felling area and the technological scheme of harvesting

The typical shape of spruce stem in wood felling area is shown (Fig.4.)

After harvesting each log was manually measured with a caliper and a ruler for its diameter and lenght. The sequent log parameters were measured: D butt. max. sob. (mm); D butt. average sob. (mm); D 0.5 sob. (mm); D1.0 sob. (mm); D top. sob. (mm); butt swelling (cm/m); taper (mm). All logs were numbered to facilate the identification. After this measurement all 55 logs were measured once more to determinē the accuracy and repeatability of the manual measurement. This action was made by other scaller. The diameters were measured on bark but the volumes of roundwood assortiments measured on bark were estimated without bark by using the formula (1) (Fig.9.).

For spruce roundwood assortiments the double bark thickness at the point of measuring were determined:

$$B=3,08+0,0404xD \qquad (1)$$

The following procedures were used to achieve the required objective:

1. To control the measurement accuracy of manual, automatic measuring (caliper, girthing tape to measure circumference, log measuring ruler, automatic device etc.)according to requirements of standard LVS 82:2003, to requirements of model of volume calculation developed for Swedish roundwood (Anon 2000) and technical requirements for automatic and harvester measuring systems (Ktr-file).

where: D – diameter of roundwood assortiment, mm.

Fig. 4. The typical shape of spruce stem in wood felling area (As)-Myrtillosa mel.

2. To identify the spruce stems before harvesting and to measure the parameters of identified stems according to scheme (Fig. 5.)
3. To identify the first logs after harvesting and to measure the dimension parameters according to the scheme (Fig. 5.)
4. To collect and to analyse the harvester mesurement Prd- file and Pri-file data in connection with manually measured parameters of logs.

5. To measure the identified logs in sawmill by measuring diameter in short intervals using electronic 3D systems.
6. To calculate the volume of logs according to the top and butt diameter measurements methods according to requirements of standard LVS 82:2003 and by model of volume calculation developed for Swedish roundwood (Anon 2000) (Fig.5.)
7. To analyse the measurement deviations.
8. To control the algorithm of the volume calculation in each technological stage of roundwood processing.
9. To determine the dependences between the volume of logs determined by automatic devices and results of manual comparative measurement methods.
10. To give the recommendations for the most appropriate manual measurement method which provide the least wood volume deviation comparing to the results given by harvester and electronic measurement.

All calibrated measuring devices ensured measuring accuracy appropriate to requirements of standard LVS 82:2003 and the technical requirements for automatical and harvester measuring systems (Fig.6.; Table 1.).The length was determined with an accuracy 1cm for manual and automatical measurement devices and 3 cm for harvester measuring devices; the diameter was determined with an accuracy 1 mm for manual and automatical measurement devices and 3 mm for harvester measuring devices.

Harvester measurement accuracy were assessed through comparison with manual log measurements and volume calculation where volume standard deviation was 0.06% (Fig.6.)

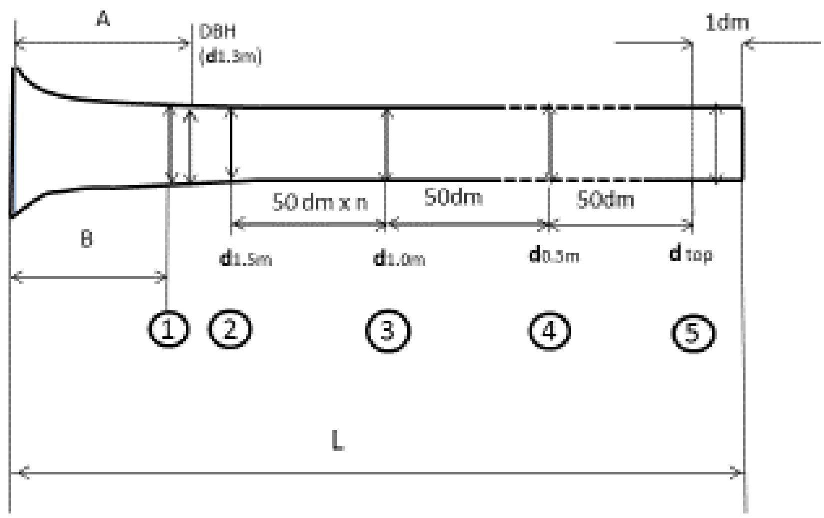

Fig.5. The scheme of the measuring points of the roundwood assortiment based on manual control (operator) measurements with caliper, where: A - the first measuring point DBH ($_{d1.3m}$) done by harvester measuring system for butt diameter prediction (A=130 dm), B - the first manual measuring point to control the harvester accuracy for the first log of stem : John Deer (B=120dm); Ponse (B=50 or 120dm); TimberJack (B=120dm)

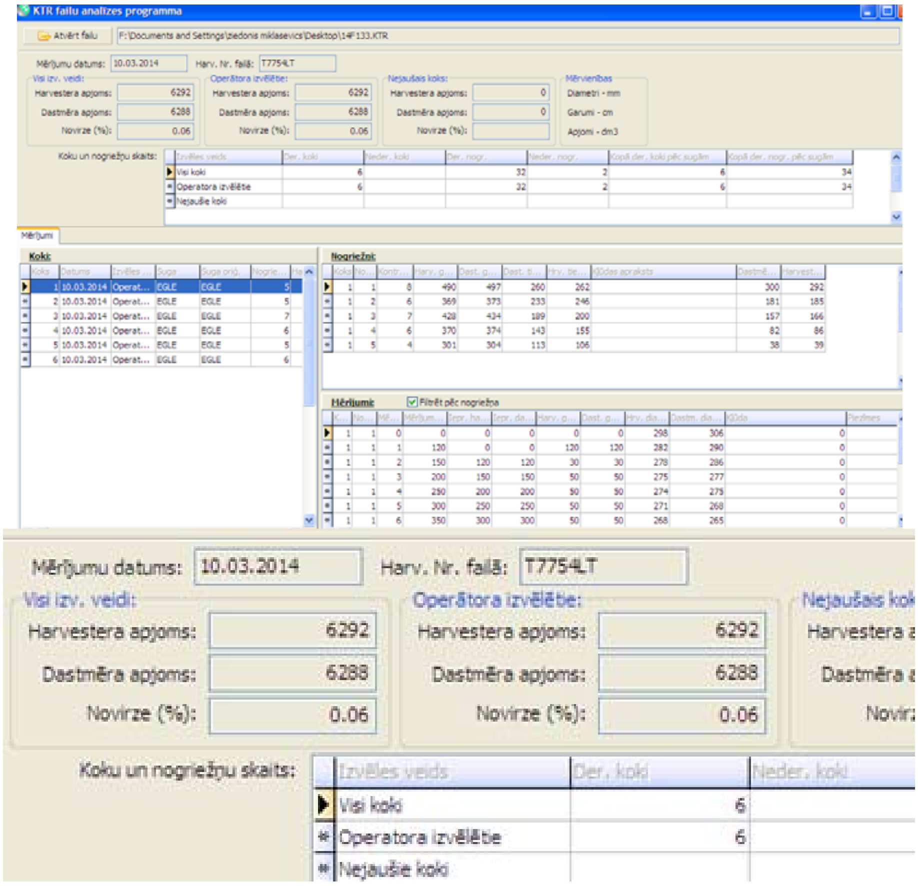

Fig.6. The result of control of harvester measuring system,where 6 control stems, 34 round wood assortiments, 96 diameter were measured. Standard deviation is 0.06%

For volume estimation the sequent measuring methods were applied (Fig. 8) by using manual measuring equipment, harvester measuring system (harvester John Deer 1270; harvester head HD 758; measuring equipment TimbermaticH 300; caliper version: SKALMAN 5.16) and automatical measuring system (3D scanner Mikropuu Oy (FIN) OPMES 604/614

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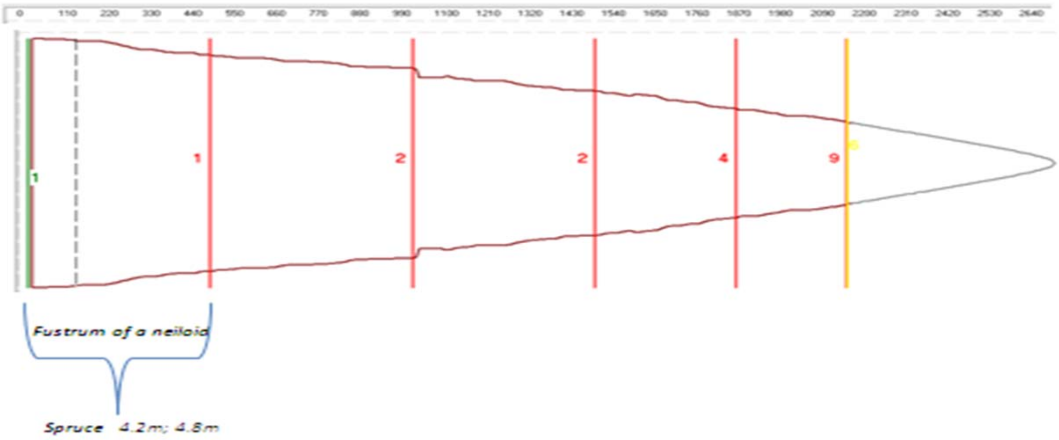


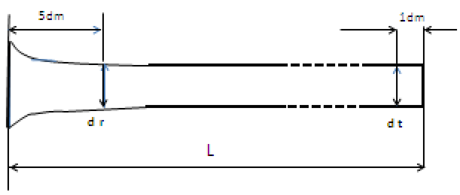
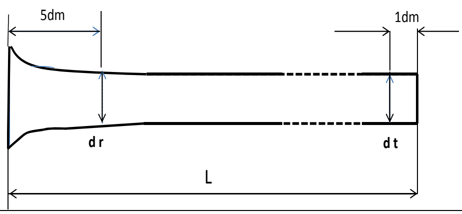
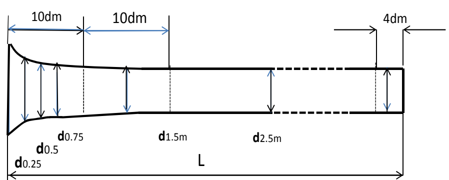
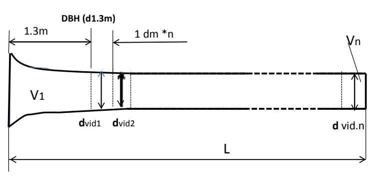
<table>
<tr><th>Method</th><th>Determination of the Volume</th><th>The formula</th><th>Measurement method for logs from neiloid zone of stem</th></tr>
<tr><td>1</td><td>According to the Top and Butt Diameter Measurements by model of volume calculation developed for Swedish roundwood (Anon 2000)</td><td>$$v=\frac{1}{100000}\times\frac{\pi}{4}\times l\times\left[\alpha\times Dr^2+(1-\alpha)\times Dt^2\right]$$
For the constant α in the formula, the values presented in the following table should be applied:
<table>
<tr><td></td><td>Length class (cm)</td><td></td><td></td></tr>
<tr><td>Top diameter (cm)</td><td>-349</td><td>350-449</td><td>450+</td></tr>
<tr><td>-14</td><td>0.485</td><td>0.485</td><td>0.485</td></tr>
<tr><td>15-24</td><td>0.465</td><td>0.460</td><td>0.455</td></tr>
<tr><td>25-</td><td>0.440</td><td>0.430</td><td>0.420</td></tr>
</table></td><td>
</td></tr>
<tr><td>2</td><td>According to the Top and Butt Diameter Measurements by LVS 82:2003</td><td>$$V_{tr}=\frac{\pi\times\left(d_t^{\,2}+d_r^{\,2}\right)\times l}{4\times 2\times 10000}$$</td><td>
</td></tr>
<tr><td>3.1.</td><td>By Measuring Diameter in Short Intervals using electronic 3D systems</td><td>$$V_s=\frac{\pi\times(d_t\times d_t+d_t\times d_r+d_r\times d_r)\times l}{120000}$$</td><td>
</td></tr>
<tr><td>3.2.</td><td>By Measuring Diameter in Short Intervals using harvester measurement systems</td><td>$$V=V1+\left(\frac{\pi\times d_{v1}^{\,2}\times 1}{4\times 10000}\right)+\left(\frac{\pi\times d_{v2}^{\,2}\times 1}{4\times 10000}\right)+Vr$$</td><td>
</td></tr>
</table>

Fig.7. Measuring methods applied in investigation for roundwood assortiments from neiloid zone of stem, where L=4.2m; 4.8m

TABLE 1

The control results of the 3D scanner Mikropuu Oy (FIN) OPMES 604/614

Etalon Nr.	**51011630**	**51011730**	**51011830**	
Etalon diameter, mm	110,3	200,7	315,5	
Average, mm	0.6	-0.5	-0.8	Accepted, mm
Standard deviation, mm	0.1	0.18	0.21	±1
Maximal positive, mm	1.0	-0.3	-0.5	+2
Maximal negative, mm	0.2	-0.8	-1.3	-2

III RESULTS AND DISCUSSION

The characteristics of the roundwood assortiments according to the manual piece-by-piece measurement are given in the Table 2.

The volume values of spruce roundwood assortiments from neiloid zone of stems were calculated according to the measuring methods applied in investigation for logs from neiloid zone of stem (Fig. 7.) by using manual measuring equipment, harvester measuring system (harvester T1386LH; measuring equipment TimbermaticH 1.13.14.; caliper version: SKALMAN 5.16) and automatical measuring system (3D scanner SAWCO POS A181). The results were compared with the volume values calculated according to the Top and Butt Diameter Measurements by model of volume calculation developed for Swedish roundwood (Anon 2000). The measurement and volume results are given (Fig. 9; 10; 11).

TABLE 2

The characteristics of the roundwood assortiments

Variable	**Parameters**
Number of roundwood assortiments	55
Amount of butt assortiments (%)	100
Top diameter (mm)	
Average	235
Std	2
Butt diameter (mm)	
Average	337
Std	3
D 1.0 (mm)	
Average	279
Std	2
D 0.5 (mm)	
Average	262
Std	4
Butt swelling (cm/m)	
Average	7
Std	0.1
Taper (cm/m)	
Average	0.7
Std	0.03

Fig. 8. The example of control of the harveaster measuring system, where:
the log N^o 3 participated one of the 34 round wood assortiments used in the process of control of harvester measuring system

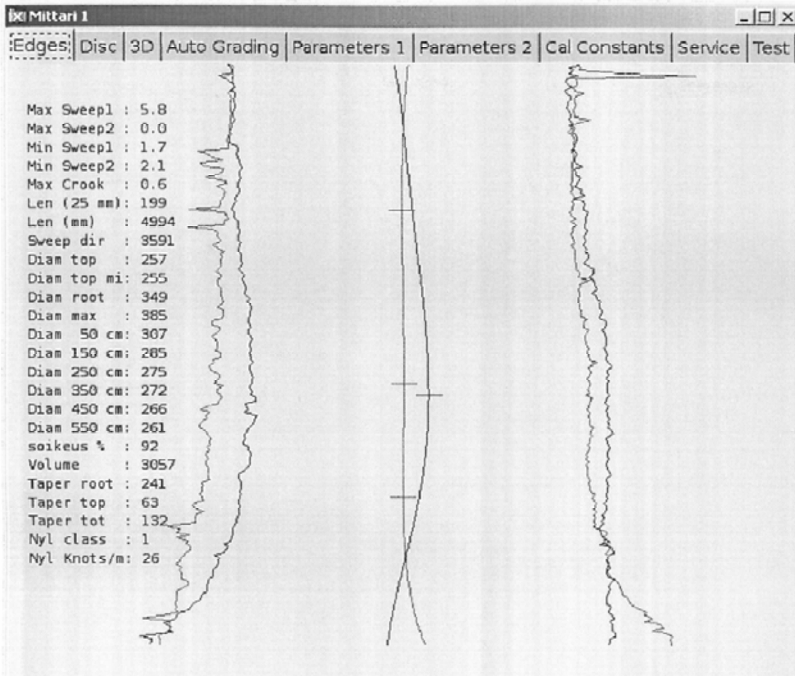


Fig.9. The measurement parameters of the sample N^o 3 (Fig.8.) by measuring diameter in short intervals using electronic 3D systems

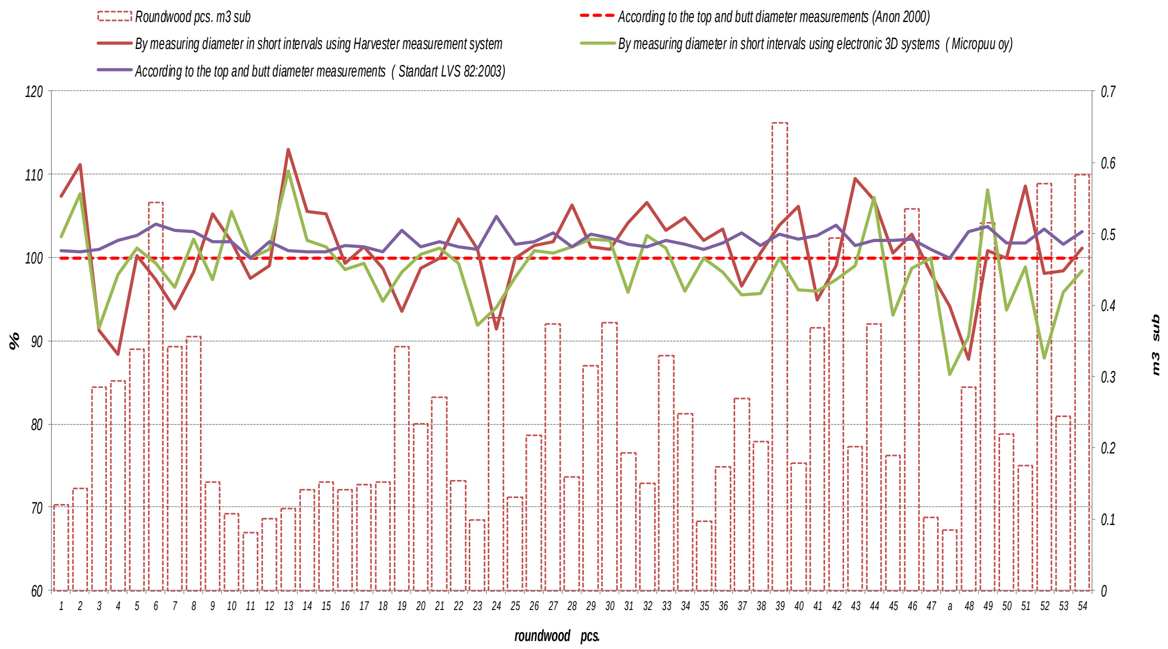


Fig.10 The volume results of spruce roundwood assortiments from neiloid zone of stems estimated according to measuring methods applied in investigation

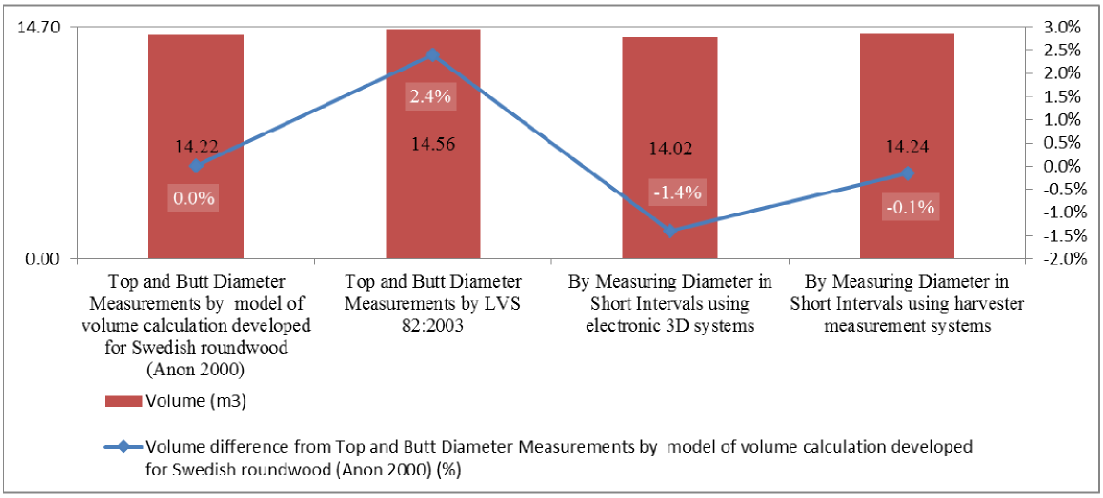


Fig.11. Roundwood load volume comparison using different measuring methods

a. The results of measuring are sequential:

The volume of roundwood assortiments determined according to the Top and Butt Diameter Measurements by model of volume calculation developed for Swedish roundwood (Anon) was 2.4% lower than the volume determined by the Top and Butt Diameter Measurement method (LVS 82:2003).

The volume of roundwood assortiments determined according to the Top and Butt Diameter Measurements by model of volume calculation developed for Swedish roundwood (Anon) was 1.4% lower than the volume determined by Measuring Diameter in Short Intervals using electronic 3D systems.

The volume of roundwood assortiments determined according to the Top and Butt Diameter Measurements by model of volume calculation developed for Swedish roundwood (Anon) was 0.1% lower than the volume determined by Measuring Diameter in Short Intervals using harvester measurement systems.

b. The results of of multiple regression analyse are sequential:

The results of multiple regression analyse between measurement diference (%)measured manually (according to requirements of standard LVS 82:2003 and to requirements of model of volume calculation developed for Swedish roundwood (Anon 2000)), butt swelling (cm/m) and taper (cm/m) are given in the Table 3.

TABLE 3

Multiple regression analyse

	Butt swelling (cm/m)	Measurement difference (%)	Taper (cm/m)
Butt swelling (cm/m)	1		
Measurement difference (%)	0.597656954	1	
Taper (cm/m)	0.349620121	0.565747656	1

The correlation between measurement difference (%)measured manually (according to requirements of standard LVS 82:2003 and to requirements of model of volume calculation developed for Swedish roundwood (Anon 2000)) and butt swelling (cm/m) is an average firm r=0.597656954.

The correlation between measurement difference (%)measured manually (according to requirements of standard LVS 82:2003 and to requirements of model of volume calculation developed for Swedish roundwood (Anon 2000)) and taper (cm/m) is an average firm r=0.565747656.

The correlation between butt swelling (cm/m) and taper (cm/m) is weak r=0.349620121.

The correlation between measurement diference (%) and taper (cm/m) is an average firm r=0.565747656. Standard error of the regression coefficient r=0.565747656 is s_r=0.1132

The actual value of the test t=4.9948; the critical value of the test $t_{\alpha v}=t_{0.05;53}$ indicating the number of degrees of freedom to characterize the distribution. The formula result is (-)1.67412. It shows that with a 95% confidence the multicollinearity is existing between features because of /t/=4.9948>$t_{0.05;53}$=(-)1.6741.

The correlation between measurement diference (%) and butt swelling (cm/m) is an average firm r=0.597656954. Standard error of the regression coefficient r=0.597656954 is s_r=0.1101. It shows that with a 95% confidence the multicollinearity is existing between features because of

/t/=5.4268> $t_{0.05;53}$ = (-)1.6741.

IV CONSLUSION

To increase the accuracy of volume values, to decline the commercial profability and to remove diferences originating among particular procedures of measurements it is proposed:

to base manual measuring on determination of the volume of spruce roundwood assortiments from neiloid zone of stem according to to the top and butt diameter measurement method according to requirements of volume calculation developed for Swedish roundwood (Anon 2000), to base harvester measuring system algorithm on functions defined in spp file (Räsänen, 2007.), in sawmils to determine the volume by measuring diameter in short intervāls using electronic 3D systems.

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Environment. Technology. Resources, Rezekne, Latvia
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Assessing the potential of coniferous greenery from logging residues in Latvia using a system dynamics model

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Abstract. **Latvia is the fourth most forested country in Europe. 52 % of the country's area is covered by forest lands. Approximately 41 % of the forests are composed of conifers that are the most harvested among the tree species in Latvia. Therefore, as a result of logging, large amount of coniferous residues are created and abandoned in forests. There are several alternatives for sustainable use of coniferous residues. Still, the exact quantity of the resource is not known. Thus, it is not clear, whether its amount is sufficient for products' manufacturing. The aim of the study is to assess the potential of the coniferous greenery from logging residues' extraction in Latvia. A system dynamic's model that allows simulation of complex forestry processes depending on various endogenous and exogenous factors has been built for this purpose.**

Keywords: **biomass, coniferous, greenery, logging residue, system dynamics.**

I INTRODUCTION

In the European Union development strategy "Europe 2020'' [1] has been mentioned that bioeconomy is as a key element to the smart and green development in Europe. In the 2012 European Commissions confirmed strategy "Innovating for Sustainable Growth: A bioeconomy for Europe" [2], that includes sustainable production from renewable resource, which is based on closed cycle (circular) economy. In this kind of cycle wastes from one process are resources for another. If we would implement principles of bioeconomy, the economic situation in Latvia could evolve based on the strongest sectors in country – agriculture and forestry.

Unfortunately, utilization of forest resources in Latvia cannot be called sustainable. It is particularly distinct for forest logging residues that are usually left to rot in felled forests in huge amounts [1]. The most common way to utilize woody waste part from forest exploitation is forest woodchip production, but coniferous needles usually falls down and stays in forest, where it become nutrition for next trees. This makes coniferous needles from forestry residues a completely unexploited forest resource.

Coniferous needles have been studied mostly in association with the value of biologically active components in their chemical composition [3, 4]. Nowadays extract production from coniferous greenery (small branches with needles) is the only industrial way how this resource is used. Consequently, actually utilized amount of coniferous greenery in Latvia is only approximately 50 ton per year [5]. During the last year several studies have assessed possible uses of coniferous greenery from fogging residues as heat insulation material [6, 7]. Historically coniferous greenery has been used for vitamin-meal production, which was used as high quality animal feed [8]. But it was outrivaled by combined feed. As a result production of coniferous greenery vitamin-meals has stopped.

The above proves that there are several ways how to utilize coniferous greenery residues from logging in sustainable way. But it is still not known how much of this resource is available in Latvia and is it enough to be used for other product manufacturing. Also it is not known if the resource will be sufficient for this purpose in the future. Previously, authors of this article had researched the amount of coniferous wood waste in the Baltic States [9]. In that research the approximate amount of coniferous greenery from logging in Baltic States has been determined to be approximately 700 thousand m^3 per year. Also Latvia State Forestry research institute "Silava" had made research in which they determined that 0.8 million ton of coniferous greenery are left in forests after logging each year [10]. Unfortunately these studies do not answer the question how the accessible amount of coniferous greenery from logging in Latvia could change depending on the development of forestry. Therefore this research has aims to determine the

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.240

potential of coniferous greenery from logging residues using dynamic approach, which would allow making forecasts of the tendencies for this resource accessibility in the future. To reach this aim, system dynamic (SD) modelling method has been used. SD was developed by Jay Forrester in 1950's [11]. Since then SD has been applied to a diverse set of problems to solve them by simulating their complex dynamic systems. It has to be noted, that the aim of SD modeling is to present the trend of dynamic behavior of the real system, not to give projection of exact values [12]. Thus, the focus is on the relationships rather than on the precision of simulated parametric values.

As far as we know, models that would allow to assess forest resources depending on the development of forestry, also including accessible coniferous greenery have not been developed previously, Therefore, in this research we developed system dynamics model that will be useful instrument for determination of the amount of coniferous greenery residues from logging forecasting and would help to evaluate possibilities of industrial utilization of this resource. System dynamics model developed in this study is based on historical and theoretical data about coniferous trees (pine and spruce) in Latvia, but it is also possible to adapt it to be used in other countries.

II MATERIALS AND METHODS

In our study, *Powersim Studio 8* software was used to develop the system dynamic model. Historical data about existing wood supplies, recovery of forest area, changes in tree species proportions and logging volumes were obtained from Latvian State Forest Service (LSFS) statistical database [13]. The amount of accessible coniferous greenery was simulated for the time period from 2005 till 2070.

SD model (see Fig. 1) was used to simulate the tendencies of logging and recovery of coniferous trees.

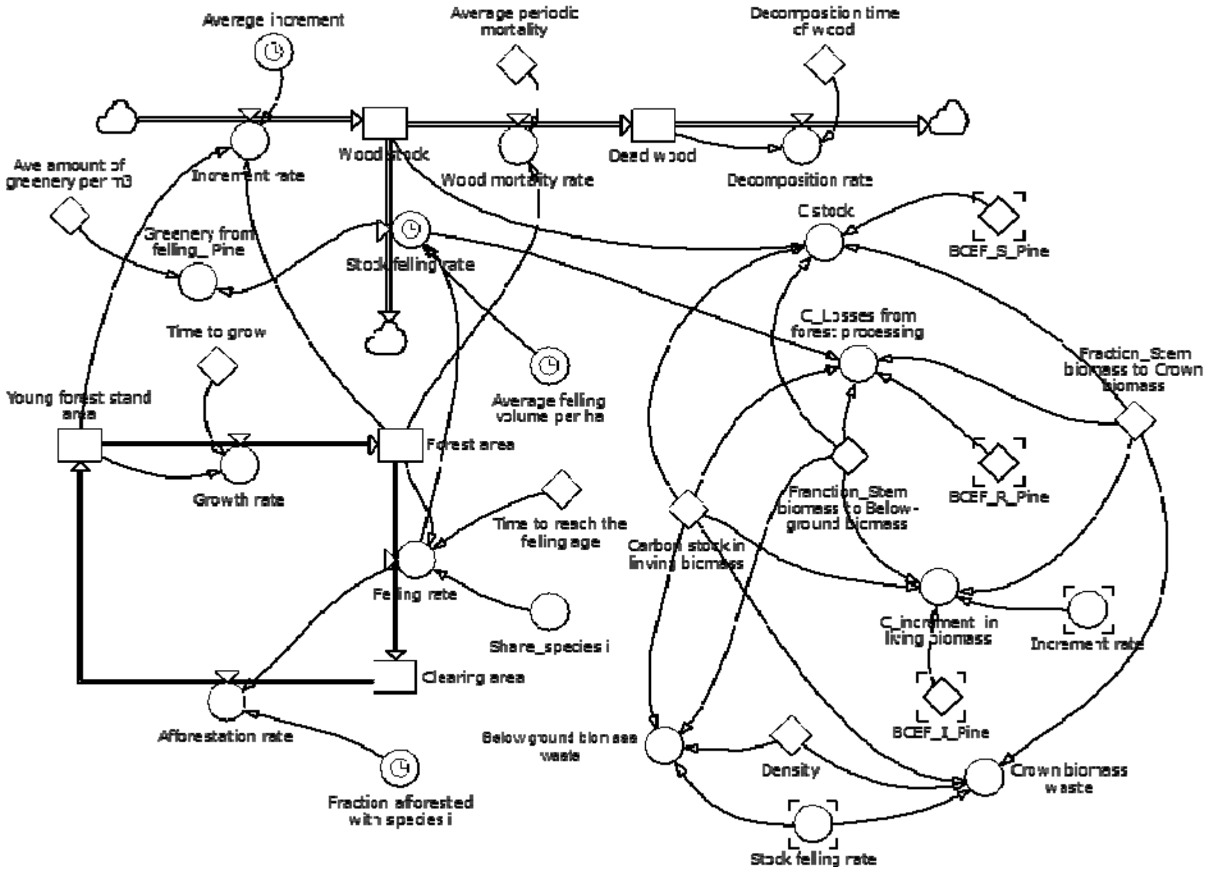

Fig. 1. Stock-and-flow diagram of the coniferous greenery from logging residues

The existing and future amount of accessible coniferous greenery depends on these tendencies. Determination of the amount of accessible coniferous greenery is based on coniferous logging volume and existing coniferous wood stock. It is influenced by average periodic gross increment, average periodic mortality [14] and loses from free damages [15]. The average pine greenery quantity per 1 m^3 of trunk wood is 78 kg [16]. The average weight of spruce greenery per 1 m^3 of bole wood is 117.7 kg [17]. These values were used for the further calculations. Calculations had been made separately for each coniferous tree species (spruce and pine), because they have a different management tendency and different amount of greenery.

Tendencies from historical data separately for state and other forests (private and local government) were used to forecast logging tendencies. One of the factors influencing forest logging is a price of wood, exponential function for logging volume in dependence on historical wood prices for each of wood specie has been included in the SD model.

Forest felling in the main felling, depending on the dominant tree species and forest regeneration, is determined by the laws and regulations of the Republic of Latvia (LR) [18]. In Latvia in the main felling it is permitted to cut pine trees with age more than 110 years and spruce trees older than 80 years. Average time to make forest regeneration after logging is 7 years. All these factors influencing forest life cycle are included as part of this SD model

Also in the SD model technological losses in logging time has been considered (see Fig. 2). Model was developed based on the coniferous logging volume in main felling, therefore technological losses are assumed to be 30 % of the amount [19]. In other felling types logging volume is not as big [13] and consequently there are less logging residues. Consequentially, it would be more technically and economically feasible to obtain logging residues in big amount only from the main felling.

In LR the existing regulations and standards for sustainable forestry certification (PEFC - Program for the Endorsement of Forest Certification [20], and FSC - Forest Stewardship Council [21]) do not determine what quantity of logging residues in felling should be left in order to ensure the development of necessary quantity of organic substances. FSC Standard establishes that in forest management logging residues should be decreased [21]. Based on it, the base scenario of the SD model has extra coefficients which would regulate the quantity of logging residues left in felling left. It was assumed that technological losses from felling are sufficient for new forest development.

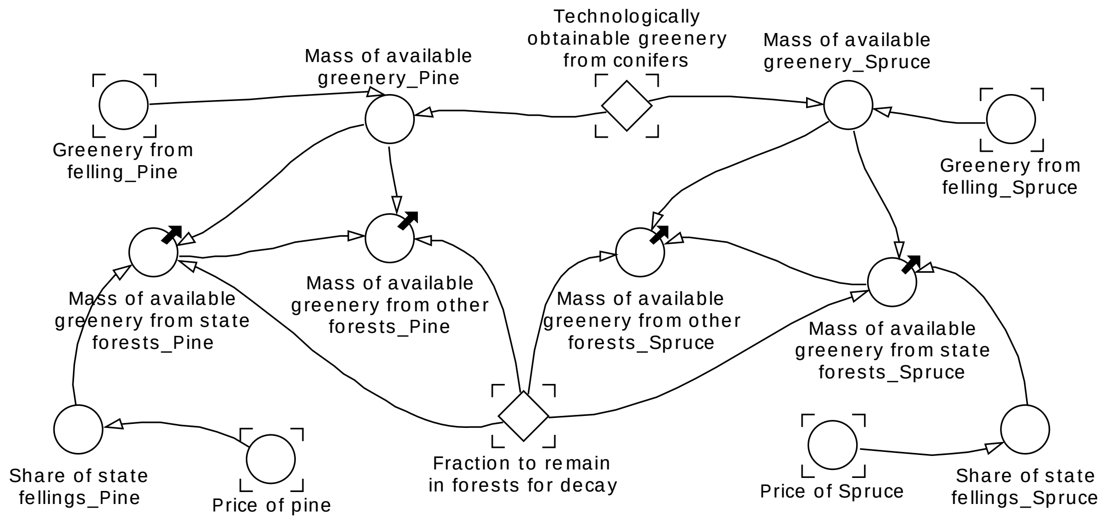

Fig. 2. Stock-and-flow diagram of the technologically obtainable amount of greenery from conifers

As mentioned above, technologically available volumes of coniferous greenery can be sustainably used for multiple products, for example, needle extract and feed production. Recent studies [6, 7] have proved that coniferous greenery can be successfully used for thermal insulations material production. With a help of the SD model it is possible to evaluate how much thermal insulation material we could possibly produce from technologically accessible amount of coniferous greenery (see Fig. 3).

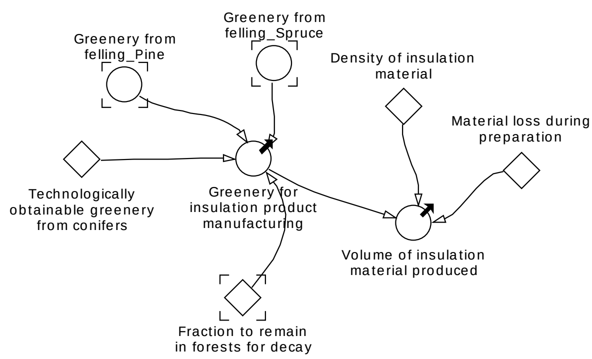

Fig. 3. Stock-and-flow diagram of the greenery for insulation product manufacturing

In order to determine the dynamics of conifer greenery potential, 5 scenarios were developed and analyzed. In the base scenario technologically accessible amount of pine and spruce is represented. It is the amount that can be obtained each year from logging residues in main felling based on historical data and tendency. Five other situations were modeled based on the results of the base scenario.

In scenario I describes situation when only 50 % of estimated technologically accessible coniferous greenery from logging residues are used for manufacturing. .The rest would stay in forest. In this case more biomass would be left for nutrition in forests. This can be regulated, introducing changes in normative acts that would be establish the amount of greenery that must be left in forest (50 % in this case) in order to practice sustainable forest management and logging.

Scenario II reflects changes in the amount of coniferous greenery in case of 20 % increase of coniferous tree planting. This scenario is assessed because new outlet market for coniferous greenery will increase demand for this recourse. Up till now the price of coniferous wood has been between the highest in comparison with other species of wood. Additional profit obtained selling forestry residues may contribute to increase of coniferous share in new woods. However it must be taken into account that results of such tendency can be detected only after considerable time delay, because coniferous trees have the greatest felling age.

Scenario III reflects similar situation, however in this case it was assumed that, due to increasing demand, felling volumes would increase by 20 %.

Scenario IV combines two previous scenarios (scenario II and III) and evaluates the tendency in case if both the felling and planting of trees would increase by 20 %.

III RESULTS AND DISCUSSION

According to historical data 233 thousand tons of coniferous greenery was technologically accessible in 2014, from that approximately 112 thousand tons of pine greenery and 121 thousand tons of spruce greenery. Taking into account that from 1 m^3 of pine bole wood we can obtain 50 % more greenery than from spruce, the total amount of greenery obtained from pine and spruce trees are almost the same, because pine is felled by 50 % less than spruce [13].

The results of SD model base scenario (see Fig. 4.) shows that, according to current trends, accessible amount of forest greenery from forests belonging to the state, has tendency to decrease.

This is the case with both pine and spruce greenery. Even though historically the situation has been totally opposite, the majority of coniferous greenery was produced in state forests. This can be explained, with the reduction in the amount of forests in felling age, due to intensive felling in state forest that could be observed in the past.

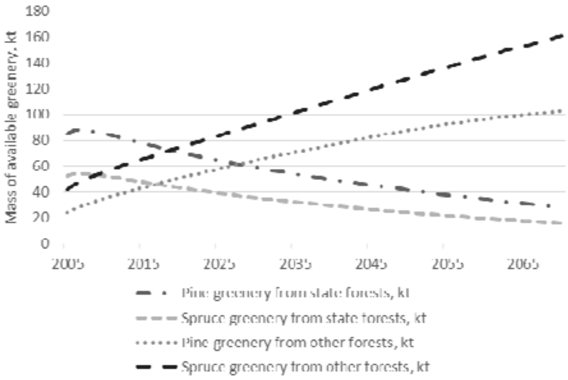

Fig. 4. Mass of available greenery in Latvia from coniferous logging residues in base scenario by the ownership and conifer species

Different situation can be observed in case of private forests. Felling volumes in forests belonging to private owners has tendency to increase.

In practice it would be easier to organize procurement of coniferous greenery for industrial uses in great amounts from single or few big forest owners.

In the best case it would be “Latvian State Forests” (LSF), as they own half of all Latvian forest areas. However base scenario model proves that in the future LSF will not have enough resources for logging to produce the same amount of forest residues as before. Therefore, extraction of coniferous greenery resource in great amounts depends on the cooperativeness of private forest owners and their interest in collection and trading of this resource. Modeled baseline scenario clearly shows that there are different amount of greenery available from different coniferous species, in main fallings of state forests as well as those of private owners.

It is possible to obtain more spruce greenery from LSF felling, and more pine greenery in fellings of other owners.

This is significant in cases if greenery from specific coniferous species is necessary for production of some product. As it was mentioned before developed SD model is also used to determine approximate amounts of insulation material, which can be produced from available coniferous greenery.

If all technologically accessible amounts of greenery from currently ongoing felling would be used to produce heat insulation material with average density of 242 kg/m^3 [6] approximately 485 thousand m^3 of environmentally friendly heat insulation material can be produced in year 2015 (taking into account that average moisture content in greenery is 50 %).

Evaluating all developed scenarios (see Fig. 5), it can be seen that the highest increase in coniferous greenery mass can be obtained in case of scenario 4, when felling and planting volumes are increased by 20 %. The results of scenario 3, in which only felling volume is increased, are also close to this level. This result is obtained because the effect of increase in planting volume does not show pronounced results as early as in 55 years modeling time.

The same can be observed in relation with scenario II, which very gradually increases the amount of accessible greenery. We can conclude that increase in coniferous greenery planting would increase the amount of accessible greenery only after more significant period of time. Therefore increase of raw material availability for new product cannot be based on this strategy.

Least coniferous greenery would be available, in case of strict sustainable forestry regulations were set in place that would prohibit removal of more than 50 % of technologically accessible amount of forest residues from felling (scenario I and V). However in reality this regulation would be hard to enforce and control, it would provide conditions for sustainable development of industry without serious harm to forest biotopes and their development.

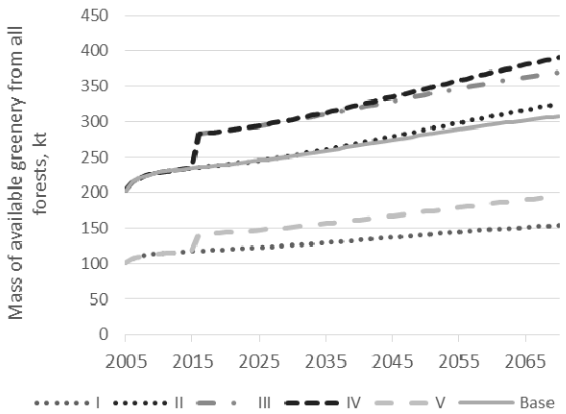

Fig. 5. Results of the effects of various scenarios on available coniferous greenery mass dynamics, 2005–2070

Opinion of authors of this article is that the best and most likely to take place is development similar to scenario 5 .The increase of the demand for coniferous greenery should lead to result in increase in supply. In order to meet the demand felling volumes will increase. Felling volumes are constricted by the amount of coniferous trees in felling age and planting of coniferous trees. 50 % extraction volume from technologically accessible coniferous greenery may not be set in legislation, as a constriction factor in order to ensure sustainable development, however, this amount quantitatively may be that which can be realistically obtained from forest owners and forestry workers. Therefore, when planning production of new products from coniferous greenery and assessing the availability of raw resources, maximal volume to be considered is 117 thousand tons per year (based on the results of scenario V in 2015 that is obtained from historical data), in future (year 2070) this number will likely be approximately 195 thousand tons. In all scenarios technologically accessible amount of coniferous greenery shows tendency to increase in comparison with year 2015.

IV CONCLUSIONS

Few studies have focused on accessible amount s of coniferous greenery and none so far shows their possible development and how these amounts are affected by different factors. System Dynamic model developed in this study shows dynamic future development tendencies of the technologically accessible amount assessed raw material and allows to forecast tendencies for the availability of this material in the future.

From base scenario we can conclude that coniferous greenery can be obtained from forestry residues in significant amount and this amount is sufficient to be used as raw material for production of new products. As one example of such product we would like to mention thermal insulation material. In this case maximal amount of insulation material produced from coniferous greenery would be 485 thousand m^3. Tendencies show that coniferous greenery in the future will be available from private forests in larger amounts than from state forests. Currently pine and spruce greenery can be technologically accessed in similar amounts, however slight tendency towards decrease of the amounts of spruce greenery were observed.

Simulated scenarios indicate that increase in planting of coniferous trees will take effect only after longer time period, which is not considered in this study. By contrast, increase in felling notably increases accessible amounts of coniferous greenery. Legislative acts related to increase in felling volumes and the limited amount of forest resources, which are slow to regenerate, must be taken into account. Implementation of sustainable forestry principles and sequential harvesting of only part of technologically accessible amount of coniferous forestry residues would reduce available amount of raw material, however it would ensure wholesome development of forest biotopes. Using only 50 % of technologically available coniferous greenery would currently allow accessing 117 thousand tons of raw materials yearly, forecasts for year 2070 shows that in would be possible to obtain approximately 195 thousand tons of coniferous greenery under the same conditions. Accordingly, even implementing sustainable forestry principles it is possible to obtain coniferous greenery in amounts that are sufficient to be used as raw material for industrial production.

V ACKNOWLEDGEMENTS

The work has been supported by the National Research Program "Energy efficient and low-carbon solutions for a secure, sustainable and climate variability reducing energy supply (LATENERGI)".

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 225-231

A geomorphological approach for enhancing environmental management and conservation of landforms as protected nature objects in the Upper Daugava spillway valley

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Abstract. **This paper describes the application of geomorphological approach for environmental management and conservation of landforms. Specifically, we discuss the contribution of geomorphological field survey and adapted matrix methodology (in combination with understanding of geology) to identification, study and evaluation of those abiotic nature elements which represent geological and geomorphological heritage. We describe a case study carried out in that part of the protected landscape area "Augsdaugava" which encompasses the Upper Daugava spillway valley. The study programme reported in this paper was realized to perform inventory of landforms and geological features for recognition of objects of particular interest in terms of including them in the list of protected nature monuments. After the field reconnaissance and survey of such objects in situ, the assessment based on several criteria like scientific, aesthetic and paleogeographic value, type, rareness, integrity and representativeness was performed. Obtained data is sufficient to make a well-founded selection of the abiotic nature elements and components of geodiversity, including geological and geomorphological features, e.g. particular landforms as protected nature objects, and to substantiate the need for their conservation. Hence, the output of performed study can be used for enhancing environmental management and conservation of nature diversity and values in this region.**

Keywords: **environmental management, landforms, protected nature objects.**

I INTRODUCTION

The appropriate environmental management of territories is a matter of high importance both in terms of planning of socio-economical development and conservation of elements of natural diversity [1], [2]. However, application of the geomorphological approach and assessment of geodiversity as integral part of territorial planning, environmental management and nature conservation is retarded by lack of information as well as by lacking "geo-literacy" of most decision makers and members of local authorities [3].Though, environmentally sustainable management of territories, particularly those which are protected nature areas, requires an integrated understanding of the area to be managed and detailed information about the sites and objects to be protected. In such a context, across Europe, including Latvia, obtaining of data and planning of nature protection measures mainly are focused on elements of biodiversity and biotic nature conservation targets like protected species or habitats [4], [5].

At the same time, the quality and quantity of geological and geomorphological data usually is insufficient to make a well-founded selection of the abiotic nature elements and components of geodiversity, including terrain features, e.g. particular landforms as protected nature objects, and to substantiate the need for their conservation. In turn, the lack of available scientific geomorphological data limits the understanding and insight of local authorities, planners and officers responsible for environmental management in key questions addressed to objects of abiotic nature: what, where and why should they be protected.

One of the solutions to such problems is a geomorphological approach for identification, assessing and mapping of the abiotic nature values, or more specifically, landforms and their complexes with scientific, ecological or landscape importance [6] - [10].

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.252

Landforms are essential part of geodiversity, which, according to Gray [11] can be defined as 'the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (landform, processes) and soil features. It includes their assemblages, relationships, properties, interpretations and systems. Also this term can be explained as the diversity of geological and geomorphological objects, phenomena and processes in a defined area [12].

Similarly to biodiversity, geodiversity belongs to Earth's nature heritage which must be protected and preserved for next generations [11], [13]. It is also necessary to note, that until the last decade experts do not give so much attention to geodiversity when compared with biodiversity. However, a review of the relevant literature indicates that geodiversity affects much of landscape and ecosystems, or on a larger scale – underpins biodiversity [14] - [16]. It has been recognized, that in areas with higher geological and geomorphological heterogeneity, e.g., areas characterized by explicit relief vertical development or complex patterns of bedrocks and soils, the biodiversity is higher, too [17], [18], and its spatial distribution to a high degree is determined by patterns of landforms [19].

Besides its role in supporting biodiversity, geodiversity simultaneously recognizes both the wider importance as significant information source for the environmental management and conservation, and as background of geoheritage of defined territory. In its turn, geoheritage (like cultural heritage), in terms of socio-economic potential and values for society, is prerequisite for development of local business, e.g. tourism and associated services, allowing diversification of economic activities in the community. Hence, the studies focused on the identification of abiotic nature values and assessment of geodiversity is very important from different viewpoints, including enhancing environmental management and conservation of landforms.

In such a context, the matters mentioned above entirely can be attributed to the Upper Daugava spillway valley. However, until now only very few studies have been focused on these issues [20], [21]. Currently, the legal status of nature monuments is established only to six geological and geomorphological objects which are located in the Upper Daugava spillway valley [22]. However, in this NATURA 2000 site there are many other objects, including geomorphological features, with outstanding scientific or historical meaning, and it is necessary to include them into the list of national or local nature monuments. In other words, the Upper Daugava spillway valley is relatively 'unexplored' in respect of its geodiversity and geoheritage potential. Thus, the geomorphological expertise and detailed geomorphological studies as a basis of the development of the conceptual framework to contribute geomorphic data to the nature conservation policy and management of abiotic nature values in this area is particularly relevant. Without this geomorphic framework, appropriate territorial planning, which has to consider interests of geoconservation, would not be feasible. Hence, geomorphological studies of landforms have straightforward, practical meanings and applications for well-considered and sustainable spatial development.

Therefore, in order to enhance environmental management and conservation of landforms as protected nature objects in the Upper Daugava spillway valley, within the protected landscape area "Augsdaugava", integrated field and desk-based geomorphological study programme presented in this paper were carried out in order to identify and to obtain data about geomorphological objects, in particular, about unique landforms with status of potential nature monuments localised within landscape area "Augšdaugava", as well as to work out necessary measures for their protection.

II MATERIALS AND METHODS

The results presented in this paper are based on data obtained in a course of more than 17 field surveys and desk-based studies conducted in the period 2009–2014.

Complex geomorphological approach and studies were performed by applying cartographic analysis, field research, GPS and GIS techniques.

First of all, topographic maps at scale 1:10,000 and elevation contour interval of 2 m, as well as thematic geomorphological and geological maps were analyzed to identify and to locate complexes of landforms and pronounced relief features within the Upper Daugava spillway valley. In order to fulfil this task, the standard method [23] of interpreting landforms from maps was applied.

Thereafter field studies of landforms identified by means of cartographic analysis and selected for detailed research were carried out. During the field expeditions, relevant data on their geological, morphological and topographical characteristics were obtained. Such data are essential for additional assessment of geological and geomorphological features in a context of their scientific and scenic/landscape value according to standardized criteria and by application of matrix method.

The matrix method mentioned above, based on scoring procedure proposed by Pralong [24], was adapted and modified considering the type of assessed features as well as the specific character of landscape and local physiogeographic conditions of territory under study. The adapted and modified matrix methodology is based on the evaluation of two groups of criteria: scientific value and scenic/aesthetic value. This methodology can be successfully used for assessment of landforms as geological-geomorphological nature monuments in Latvia [25].

Concerning the scientific value, the following sub-criteria were taken into account: palaeogeographical significance, representativeness, rarity and integrity. Concerning the scenic/aesthetic value, the following sub-criteria were taken into account: perception, average distance, spectacular aspect and colour contrasts. Therefore, visual inspection of the geological and geomorphological objects is essential to an accurate assessment according to criteria by a given matrix method, particularly of their integrity, landscape and aesthetic values. In very details criteria and specific scales of scoring have been described by Pralong [24]. Therefore, considering limitations of the length of the article, authors omit the layout of this methodology. After the assessment *in situ* both scientific and scenic/aesthetic values were summarised allowing to score studied landforms and to identify geomorphological features with the highest scoring values. Therefore, the application of scoring procedure enables, on the one hand, a comparison of the specific value of different geomorphological objects and, on the other hand, an identification of landforms of the highest scientific, ecological or landscape importance. Moreover, from the criteria scores, well-founded arguments of nomination of landforms to nature monument conservation status may be underlined.

The cross-profiles of landforms were generated by *AutoCAD 2008 LT* software from the data collected during measurement of slope gradients. These measurements were performed according to conventional geomorphological technique [26] by precise digital clinometer *DigiPas DWL-80G* (accuracy of measurements 0.1°) placed on the rod of 1 m length, hence reducing the impact of microtopography.

In order to get insight into geochronology of landform formation and thus better to understand their paleogeographic context, the radiocarbon dating was carried out. For these purposes, samples of organic matter were collected within the two types of landforms outstanding in terms or their morphology, i.e. glaciokarst kettles and the U-shaped gully with a local name *Aleksandrin rov*. The latter on is one of the largest fluvial erosion landforms among those draining headwater catchments adjacent to the Upper Daugava spillway valley. In some of the glaciokarst kettles, small raised bogs have formed. For that reason, it was possible to collect peat undisturbed cores with an *Eijkelkamp* half-cylindrical chamber peat corer. In such a way, peat samples from depths of 8.20 m, 7.35 m and 6.35 below the surface were collected. For needs of dating, plant remains were separated from peat samples by wet sieving (deionized water, stainless steel sieve 250 µm). These samples were dated by accelerator mass spectrometry (AMS) ^{14}C method at the Poznan Radiocarbon Laboratory. In its turn wood fragments buried under colluvium in the *Aleksandrin rov* gully were collected from contact between old gully bed and colluvium cover by split core sampler. The wood fragments AMS ^{14}C dating was accomplished in the Erlangen AMS Radiocarbon Laboratory of the University Erlangen-Nürnberg. All dates were calibrated and converted to calendar years using the online version of the *OxCal v.4.2* software [27] and the *IntCal13* calibration curve [28].

Additional survey and in situ inspection of landform complexes, which already are included in the list of protected nature monuments [22] also were carried out. It was necessary to verify the conformity of boundaries of areas with protected nature monument status defined by the official regulations with the real situation and location of geomorphological features, which are the protection object of these regulations.

The precise delineation and mapping of all objects was carried out during field surveys by high-precision GPS *TRIMBLE Pathfinder ProXRT*. Finally, desk-based studies were carried out by application of geographic information systems software and its mapping and visualization tools.

Hence, the integrated geomorphological approach allowed to distinguish the most prominent landforms or their groups with high scientific meaning as elements of geodiversity and geoheritage which should be protected in the Upper Daugava spillway valley.

III RESULTS AND DISCUSSION

The results obtained by application of geomorphological approach and corresponding studies carried out in the Upper Daugava spillway valley indicate, that the area has high geodiversity and geoheritage potential, respectively, high concentration of landforms different in terms of their origin, geological structure and morphology within relatively small area. The realized studies allow to identify the presence of a large variety of geomorphological features like permanent gullies, circular closed depressions of glaciokarst origin, landslide cirques, etc. which are potential protected nature objects.

Analysis of information and applying of matrix method allow to distinguish between other two types of landforms within the study area, which are the most remarkable and valuable in scientific and scenic/aesthetic context. These landforms or their groups are large permanent gullies with U-shaped cross profile and the glaciokarst kettles. During the assessment and scoring procedure both geomorphological features obtain the highest scoring values, i.e. 20 and 21 points of scientific value, 26 and 28 points of scenic/aesthetic value. Therefore detailed geomorphological data, discussed hereinafter, were obtained on permanent gullies and the glaciokarst kettles.

In the group of permanent gullies, there are more than 350 erosion landforms dissecting slopes of the

Uppers Daugava spillway along the 50-km-long river stretch from Kraslava town down to Krauja village. However, assessment of these relief elements by matrix method on purpose to identify potential protected geological-geomorphological nature monuments, allowed to highlight one object - the gully *Aleksandrin rov*. This geomorphic and landscape feature representing landforms formed during long-term water erosion processes, is located on the right slope of the spillway valley near Slutiski village, Daugavpils district. The gully *Aleksandrin rov* is U-shaped, flat-bottomed permanent gully with very high aesthetic and landscape value (Fig. 1) and belongs to the largest fluvial erosion landforms among those draining headwater catchments.

Fig. 1. Old flat-bottomed dry gully *Aleksandrin rov* with typical U-shaped cross-profile. Gully is located in the Upper Daugava spillway valley near Slutiški (55°55'00"N; 26°53'05"E).

Such geomorphological features which have a local name *vecgravas* look similar to small dry grassed valleys and equals to East European *balkas*. There is no evidence of current erosion processes in the *Aleksandrin rov* due to the dense cover of grass vegetation. This landform is characterised by impressive morphology, i.e. its max. depth is 18 m, max. width is 115 m, length exceeds 2.0 km, and gully has a typical U-shaped or trapezoidal cross-sectional profile (Fig. 2).

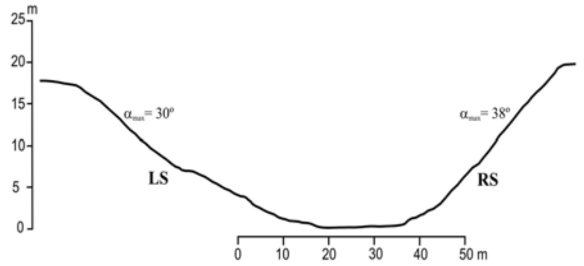

Fig. 2. Cross profile of the gully *Aleksandrin* rov. **LS** = left sidewall of gully; **RS** = right sidewall of gully; $\boldsymbol{\alpha_{max}}$= maximal slope gradient of measured cross-profile.

The ^{14}C dates of wood buried under colluvium in this gully reveal age 1990±75 BP, ca. 195 cal BC – 178 cal AD (Erl-10456), hence indicating that the infilling and stabilization of this old gully in the Upper Daugava spillway valley took place before the beginning of intensive agricultural activities in this region. Considering the dimensions of this gully and results of paleohydrological modelling [29], the *Aleksandrin rov* refers to the Pleistocene or late-glacial old gullies. The formation of such late-glacial old gullies was initiated in periglacial conditions by intensive streams resulting from melting stagnant glacial ice blocks during the retreat of ice sheet from SE part of Latvia. Considering its scientific, paleogeographic and landscape values, this landform should be included in the list of protected geological-geomorphological nature monuments in Latvia.

Among other landforms, the glaciokarst kettles are outstanding in terms of their morphology, paleogeographic and scientific values. These kettles are presented as semi-circular, slightly elongated funnel-like closed depressions, which form groups in the Upper Daugava spillway valley. Within groups, the longitudinal axes of these negative landforms have similar orientation. GIS-based geospatial analysis elucidates that the groups of glaciokarst kettles in planar view are distributed in a form of slightly undulated band. (Fig. 3).The local name of glaciokarst kettles within the Upper Daugava spillway valley is '*valna dubes* (devil's holes)'. Such morphologically similar landforms, characterized by the steep radial hillslopes which encircle isometric or elongated funnel-like depression, have been reported in the literature as landscape features of north-eastern Europe within territories formerly covered by the Late Weischelian glaciation [30].

Dominant explanation reported in the literature on origin and morphology of these negative landforms associates their formation with glaciokarst processes [31].

Hence, glaciokarst kettles have been formed by melting out from dead ice blocks, which were buried under glaciofluvial sediments deposited by ice meltwater streams in the Late Pleistocene.

In total, there are 58 glaciokarst kettles within the stretch of spillway valley stretch from Kraslava town down to Krauja village. The results of the field studies show that those geomorphological objects are relatively large, e.g. their dimensions may reach hundreds of meters. These landforms are located on a surface of different terraces of the spillway valley, and at varying hypsometric levels. Their depth ranges from several m to maximum 36 m, values of coefficient of roundness lies between 1.01 and 2.34, and ratio of a/b-axis is from 5.04 to 1.09. The most impressive and deepest closed depressions are located within the Tartaka meander of the spillway valley (Fig. 4).

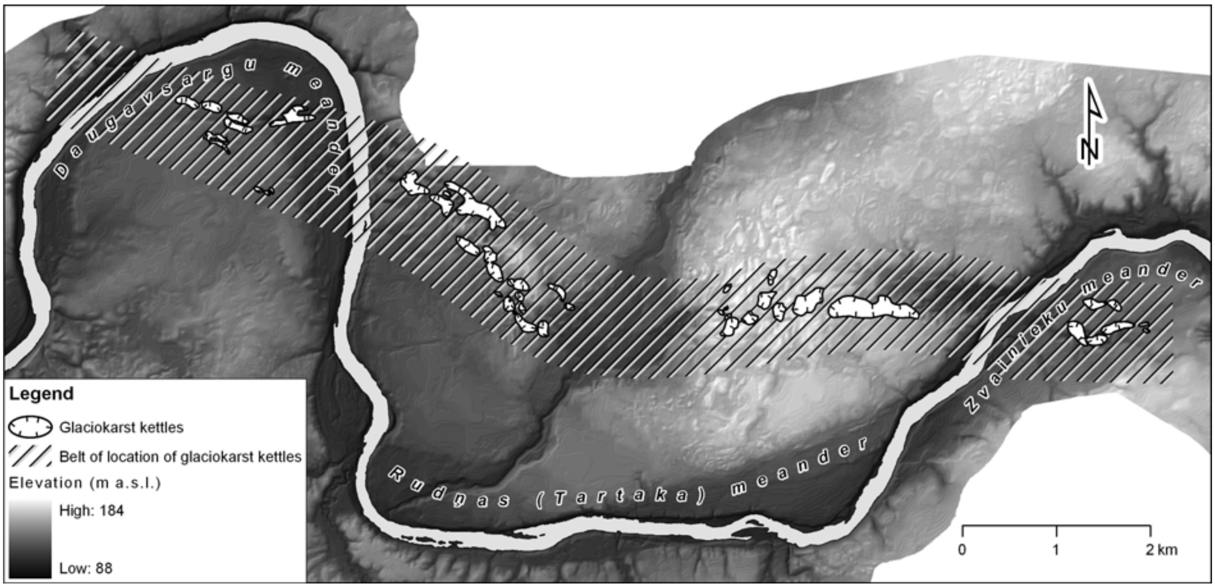

Fig. 3. Geographical distribution of glaciokarst kettles within the middle part of the Upper Daugava spillway valley, showing relief by a shaded DEM in the background.

In several such depressions, small raised bogs have been formed with a thickness of peat layer up to 8.75 m. The fragments of plant remains collected from the peat samples from one of glaciokarst kettle at depths of 8.20 m, 7.35 m and 6.35 below the surface yielded AMS ^{14}C dates of 10,704 ± 50 cal yr BP (Poz-60631), 8510 ± 40 cal yr BP (Poz-60633) and 7935 ± 35 cal yr BP (Poz-60634), respectively. These results indicate that the formation of glaciokarst kettles can be referred to the end of the Late Pleistocene and beginning of the Early Holocene. However, additional studies like optically stimulated luminescence dating of sand which composes the slopes of glaciokarst kettles as well as using of ground penetrating radar for better understanding of geological structure of these landforms should be performed.

Moreover, these landforms, which formed during the subsequent development of the spillway valley, also provide relevant paleogeographic information about the processes of their formation and the time when it occurred.

Consequently, considering their scientific and landscape significance, part of glaciokarst kettles should be registered in the list of protected nature objects of national importance.

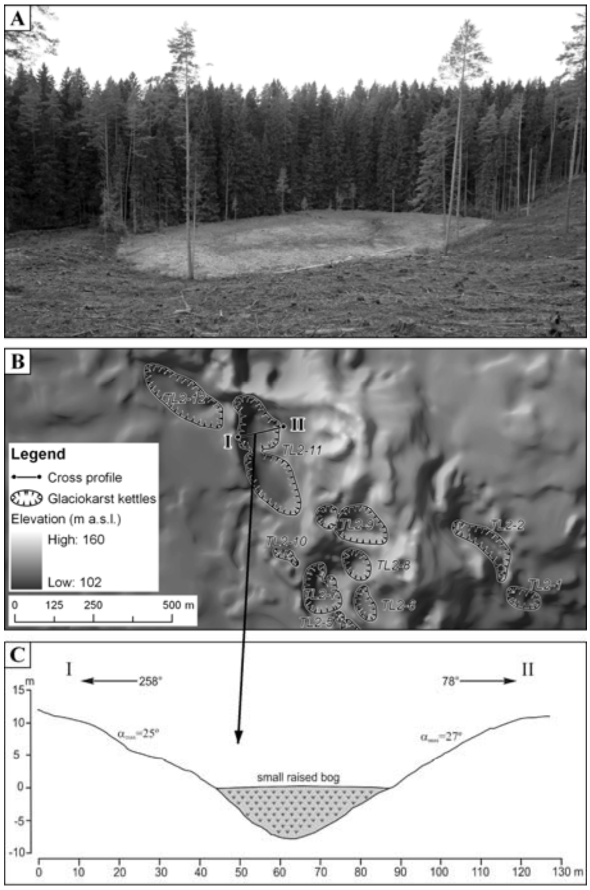

Fig. 4. (A) Photo of the glaciokarst kettle TL2-11 with small raised bog within it, where peat core were obtained for AMS 14C dating. (B) Digital elevation model of cluster of glaciokarst kettles TL located in the eastern part of the Tartaka meander. (C) Cross profile of kettle TL2-11.

At last it is necessary to note, that additional survey and *in situ* inspection of landform complexes "*Sandarisku karengravas*" and "*Sprogu gravas*", which both already are included in the list of protected nature monuments, also were performed. Results of the survey indicate that boundaries of these protected nature monuments defined by the official regulations [22] and depicted in corresponding maps do not conform to the real situation. Thus, 43% of the area, where hanging gullies with very high paleogeographic and scientific value is located, are outside the recent location of the nature monument "*Sandarisku karengravas*". Similarly, 17% of the area of landslide-gully complexes in the nature monument "*Sprogu gravas*" is located outside the borders of protected territory. This fact highlights the obvious need of implementation of changes in existing regulations and precise delineation of borders of geological-geomorphological nature monuments in terms of enhancing their environmental management and conservation within the Upper Daugava spillway valley.

IV CONCLUSIONS

The results of the given research permit to draw several important conclusions about the options and reliability of the application of geomorphological approach for enhancing environmental management and conservation of protected nature objects in the Upper Daugava spillway valley.

The integrated studies by application of geomorphological field survey, GIS techniques and adapted matrix methodology have advantages in terms of identification, assessing and mapping of the abiotic nature values, and, in particular, landforms as well as their complexes with scientific, ecological or landscape importance. The geomorphological approach allows to come up with answers to key questions addressed to objects of abiotic nature: what, where and why they should be protected. Hence, the communication of scientists and experts in nature protection with local authorities and decision makers can be substantially improved in respect of matters of territorial planning at municipal and even at the national level.

The results of studies allow to distinguish among other landforms the gully *Aleksandrin rov* and glaciokarst kettles as the most valuable and important part of geodiversity and geological heritage of the Upper Daugava spillway valley. These landforms should be included in the list of protected geological-geomorphological nature monuments in Latvia, as well as regulations aimed to provide their conservation and protection should be elaborated. In order to reduce negative socioeconomic effects associated with limitations due to protection and conservation measures, it is necessary to realize further studies focused on development of nature tourism based on sustainable usage of potential of nature values including landforms, hence enabling the development of local business. Thus, the geomorphological expertise and detailed geomorphological studies of landforms have essential meanings and applications for spatial development planning without conflicting interests of geoconservation in the Upper Daugava spillway valley.

Last but not least, the obvious need for additional research in order to find other geomorphological and geological objects, which are an important part of geodiversity and nature heritage of this region.

V ACKNOWLEDGMENTS

The authors are grateful to prof. Aija Melluma for her suggestion to perform these researches, as well as to M. Petrovs, A. Puckins, V. Semjonovs, A. Treijs, A. Skrupskis, J. Varsbergs and D. Kursits for their assistance in the fieldwork.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 232-234

Climate dynamics of the Beloe Sea catchment area

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Abstract. **The climate of the Beloe Sea catchment area (total size 717.7 km^2, 714 of which belongs to Russia) is described. The territory is characterized by several geographic zones, thus substantial diversity of climatic conditions is observed. Climate variability in the region was studied using data from the longest available instrumental observations at weather stations (WS) and gauge sites of the Russian Federal Hydrometeorology and Environmental Monitoring Agency located in the study area, covering the period from the beginning of observations at the stations until 2012-2013. The data obtained were statistically processed with due regard to the research tasks. Modern observational data are analyzed to distinguish the changes in the climatic regime of the main parameters, i.e. air temperature, precipitation, sunshine length, etc. Since 1989, the stable increase of mean annual air temperature (1-2°C) over a climatic norm is observed. The most intensive warming is typical for the winter months. The analysis of changes in precipitation over the study area demonstrates the stable increase of annual sums, deviation of which from the climatic norm in the first decade of XXI century is about 50-100 mm.**

***Keywords*: air temperature, changes in the climatic regime, precipitation, weather stations.**

I INTRODUCTION

The total area of the Beloe (White) Sea watershed is about 717.7 km^2, 714 of which belongs to Russia. It spans more than 1000 km from north to south and about 900 km from west to east [1]. The significant part of the sea is found beyond the Arctic Circle. Several biogeographical zones, from tundra to southern taiga, are found in the Beloe Sea region. As a result, the area is subject to diversity of natural habitats and climatic conditions. The climate variability and changes over the Beloe Sea catchment area are described in this study.

II MATERIALS AND METHODS

Data on key climate parameters and characteristics were gathered to identify major trends in climate change in the White Sea drainage basin. Climate variability in the region was studied using data from the longest available instrumental observations at weather stations (WS) and gauge sites of the Russian Federal Hydrometeorology and Environmental Monitoring Agency located in the study area, covering the period from the beginning of observations at the stations until 2012-2013. Data from 7 WS in Karelia, 5 WS in the Murmansk Region, 7 WS in the Arkhangelsk Region, 4 WS in the Vologda Region, 2 WS in the Nenets Autonomous District, and 2 WS in the Komi Republic are used (Fig. 1). The data obtained are statistically processed with due regard to the research tasks.

III RESULTS AND DISCUSSION

The region in question features a variety of physiographical and climatic characteristics. The climate of the study area can be described as subarctic, with a transition in northernmost parts to arctic climate in the Nenets District, subarctic maritime with some continentality in the Murmansk Region and northwestern Arkhangelsk Region, transitional from maritime to continental in Karelia, and temperate-continental in the Vologda Region and Komi Republic. The climatic conditions are shaped by Arctic and Antarctic air mass transfers. Frequent shifts of air masses cause constant weather variations.

Multi-annual means of annual air temperature range from -1.0°C in the northwestern Arkhangelsk Region and from 0°C on the Beloe Sea and Barents Sea coasts to -2.0°C in central and -3-4°C in mountainous parts of the Kola Peninsula [1, 2], -1.0°C around Cape Kanin Nos and to + 2.4..+2.6°C in central parts of Karelia and the Vologda Region. The duration of the frost-free season increases southwards from 50-60 days in the Nenets District and central Murmansk Region to 120 days in the Vologda Region.

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.238

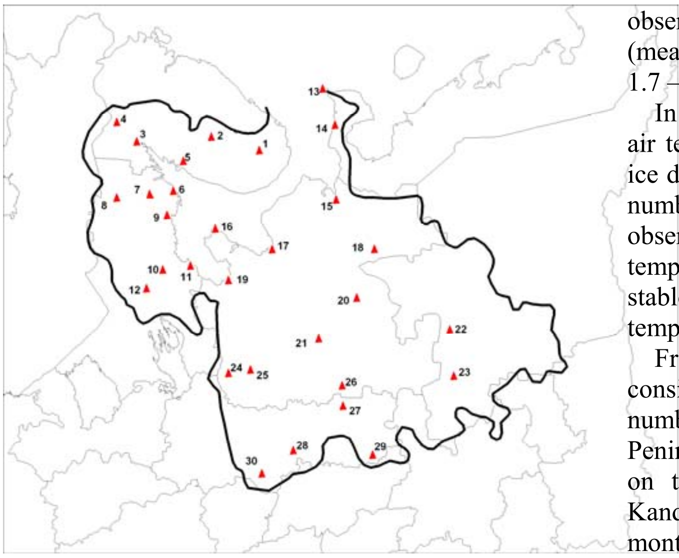

Fig.1. Locations of weather stations.

The estimates of change in surface air temperature based on long-term gauged measurements in the Beloe Sea drainage basin portray the general features and trends of lower atmospheric temperature in the Northern Hemisphere in the 20th – early 21st centuries. Observational data analysis reveals that mean annual air temperature variation was nearly synchronous throughout from Kanin Nos to Kalevala and Kargopol, with quasi-periodic oscillations at a time scale of around 2, 10 and 30 years.

If long-term air temperature data are considered as abnormalities (deviations from the climate normal), one can find that no further rise of temperature values is observed, though positive air temperature abnormalities have prevailed throughout in the past 20-25 years. In the late 20th – early 21st century, multi-annual means of annual air temperature (1991-2013) have exceeded the climate normals by 0.9-1.2°C throughout the study area (Fig. 2) [3].

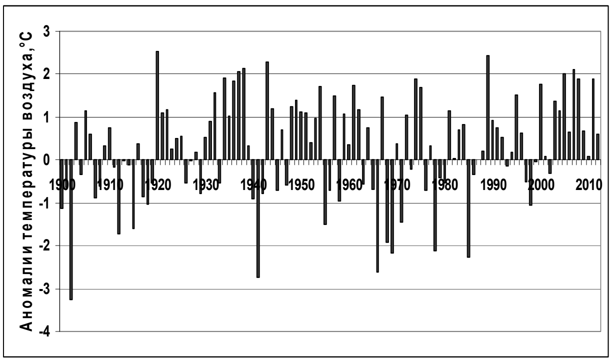

Fig. 2. Deviations of mean annual air temperature from the climate normal (1961-1990). WS Arkhangelsk.

Assessment of the change in multi-annual means of monthly air temperatures showed that seasons differed in the rate of change. The highest temperature rise was observed in winter months, especially in January (means over 1991-2013 exceeded climate normals by 1.7 – 3.0°C).

In winter months, when the rise in mean monthly air temperatures has been the highest, the number of ice days has decreased throughout the study area. The number of frost days has been decreasing, thawing is observed 10-15 more days over the winter; the temperature regime in winter seasons has grown less stable, resulting in a rise in mean monthly air temperatures in winter months.

Frequently passing cyclones bring about considerable cloudiness in all seasons. Annual mean number of overcast days in the north of the Kola Peninsula is 193–210, in its central parts – 180–190, on the coast of the Beloe Sea and the Gulf of Kandalaksha – 170–175 days. The least cloudy months in the Arkhangelsk Region are May-July, when the probability of overcast sky is less than 60%. In January the probability rises to 75%. The most cloudy periods are autumn and early winter because of higher frequency of cyclones.

With such considerable cloudiness, the region annually gets on average only part of the solar radiation theoretically possible for these latitudes. The Kola Peninsula get slightly more than a half of the annual incident solar radiation, the Arkhangelsk Region and Nenets District – nearly 60% of the available potential. In some years with very high cyclonic activity, only 25% of the potential radiation reaches the ground, and in years with high anticyclonic activity the value rises to 75-80%. Average annual sunshine duration is 1200 hours in the northern Murmansk Region and Nenets District, 1560-1600 hours on the Karelian Coast of the Beloe Sea, and 1650-1700 h in the Arkhangelsk Region.

Sunshine duration over the past 10-15 years showed little deviation from the climate normal (the Murmansk Region and northern parts of Karelia), and exceeded multi-annual averages in the Arkhangelsk Region.

The entire Beloe Sea drainage basin falls within an excessive moisture zone. Annual precipitation ranges from 400 mm in the north of the Nenets District to 500-650 mm in the Vologda Region and Karelia, and to 700 mm in the Komi Republic. The annual amount of precipitation in mountainous parts of the Murmansk Region is 900-1300 mm [1, 4].

By the beginning of the 21st century, annual precipitation totals have increased throughout the Beloe Sea drainage basin. The number of years with total precipitation higher than the climate normal is much greater than the number of years with negative deviations (Fig. 3). At some stations however (Koynas, Vologda, Tot'ma), precipitation has either slightly decreased early in the 21st century, or remained unchanged (Sura).

Mean annual number of days with precipitation is generally 190-210, with up to 220 days in some parts. In the last decade of the 20th century and early 21st century, the annual number of days with precipitation was within the climate normal or slightly below it. Given that total annual precipitation has increased whereas the number of days with precipitation remained the same, the question is where the rise in annual totals comes from? The answer is in the data on heavy precipitation (10 or more mm in a day). In the 1991-2012 period, the annual number of days with heavy precipitation exceeded the climate normal in most cases.

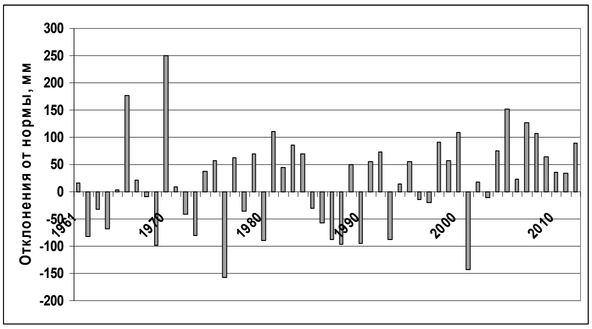

Fig.3. Deviations of total annual precipitation from the climate normal (1961-1990). WS Kandalaksha.

A steady snow cover usually forms in the Murmansk Region in the course of October, stays on the Khibines and Chuna-tundra tops for an average of 220 days, and in the rest of the territory for 180 days. In flatland areas, average multi-annual late winter snow cover height is 70 cm. On the Murman Coast, where snow is blown away by wind, the average depth is 40 cm. In Karelia, the snow cover stays for 160 days in the south and for 190 days in the north. Its average depth is usually within 50-60 cm, with up to 110 cm in some years. The snow cover in the Kanin Peninsula forms early in November. It fully melts away by early June. In the Arkhangelsk Region, snow cover appears in November and begins melting is April, with a delay until early July possible in northernmost parts. Its duration is from 237 days in the north to 160 days in the south of the Region. Snow depth would reach 50-60 cm late in winter. Steady snow cover duration in the Vologda Region is 160-170 days. It establishes in early to mid-November, and melts away in the second half of April. Snow depth in March is up to 60-65 cm.

The Beloe Sea drainage basin falls within an excessive moisture zone. The considerable air humidity in winter and autumn (85-95%) is due to warm air masses arriving from the Atlantic, and in summer and spring (70-90%) it is controlled by evaporation from melting snow, bodies of water and wetlands in the context of persistent overcast weather and fairly low air temperatures. The number of days with relative air humidity above 80% tends to increase from 140-160 in the southern Arkhangelsk Region, 150-170 in Karelia and 165-170 in the Murmansk Region to 220-235 days in the northern Arkhangelsk Region and 280 days in northern Nenets District.

IV CONCLUSIONS

Thus, analysis of long-term data on key climate parameters and characteristics has brought about the following conclusions. Since 1989, mean annual air temperatures have consistently exceeded the climate normal by 1-2°C, but no further rise of air temperature has been observed. Warming has been the greatest in winter months, due to frequent thaw periods caused by cyclones passing the area from the Atlantic. The increased western disturbance and cyclonic activity lower atmospheric pressure, especially in the cold season. Analysis of changes in precipitation amounts in the study area revealed an overall rise in total annual precipitation, deviations from the climate normal in the first decade of the 21st century, being 50-100 mm. At the same time, the total number of days with precipitation was mainly below or equal to the normal. In 1995-2013, rainfall in Karelia was more intensive than its long-term averages, and the number of days with heavy rainfall was greater than the normal throughout the study area.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 235-240

Effects of crop rotation and field management methods on weed density and species composition in the southeastern part of Latvia

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Abstract. **Integrated weed management (IWM) is a complex approach to weed control that is based on use of several different methods complementing each other, instead of relying on one single method, like chemical weed control. Weed control methods that can be used as parts of IWM strategy include mechanical weed control, application of herbicides, low tillage, changes in the rate and application time of fertilizers, use of undersown crops and crop rotation. Weed surveys were carried out in 2013 and 2014 in the southeastern part of Latvia. The aim of this study was to assess the effect of crop rotation and other field management practices on weed density and weed species composition using the data collected in the surveys. Survey was carried out in the arable fields of conventional farms within four different size categories. One of the significant factors that explained the variation of weed composition within a field was a proportion of cereals in crop rotation within a four year period. Further surveys are required to estimate the effects of climatic variables. Density-dependence can also be important for practical management decisions for particular weed species and should be investigated.**

Keywords: **Integrated weed management, crop rotation, weed survey.**

I INTRODUCTION

Integrated weed management (IWM) is a complex approach to weed control that is based on use of several different methods that complement each other, instead of relying on one single method like chemical weed control. Weed control methods that can be used as parts of IWM strategy include mechanical and chemical weed control, reduced tillage methods, changes in the rate and application time of fertilizers, use of undersown crops and crop rotation (reference). To choose the combination of methods for a successful IWM strategy in a particular situation, it is necessary to take into account climatic, edaphic, economic and even social factors in the region. It is also essential to know the composition of local weed flora.

Crop type in general and crop rotation has been shown as defining factors of weed species composition [1], [2], [3]. However, some of the IWM methods used in a number of countries may not be appropriate for conditions in Latvia. Crop rotation is practised in many farms in Latvia. Therefore it is important to find out how crop rotation in particular conditions affects overall weed density and weed composition, to be able to advise best practice for successful weed control as well as balanced weed flora in the fields [4].

The aim of this study was to assess the effect of crop rotation on weed density and weed species composition in the southeastern part of Latvia using the data collected during field surveys.

II MATERIALS AND METHODS

Weed survey was carried out in summer 2013 and 2014 in 72 fields from 12 conventional farms in the South-Eastern part of Latvia. Weed species and density of each species was determined according to the method developed by Rasiņš and Tauriņa [4]. The surveys were performed from the 3rd decade of June to the 2nd decade of July, when the majority of weeds were in the flowering stage and were easier to identify.

Canonical correspondence analysis (CCA) of the data was performed with species data from 72 fields (2014) and 58 fields (2013), the dataset from 2013 was smaller due to incomplete information on field management. Six constraining variables were chosen for the analysis. Crop group in the year of the survey and the preceding crop (crop group in the previous year), the crop groups were: Spring cereals, Winter

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.275

cereals, Spring oilseed rape, Winter oilseed rape and other crops (maize, root crops and legumes) in the year of the survey (2013 or 2014). Proportion of cereals in crop rotation in the last four years (2014) or proportion of cereals in crop rotation in the last three years (2013) including the current year. Number of herbicide applications in the year of the survey.

TABLE I

GROSS AND NET EFFECTS (PROPORTION OF CONSTRAINED VARIANCE) OF FIELD MANAGEMENT FACTORS IN THE WEED DENSITY DATASETS COLLECTED IN 2014 AND PROPORTION OF VARIANCE EXPLAINED WHEN ALL 6 FACTORS WERE USED AS CONSTRAINING VARIABLES. NUMBER OF FIELDS IN THE ENTIRE DATASET WAS 72, IN THE SUBSET OF SPRING CEREALS – 31, WINTER CEREALS – 21. IN EACH CASE SIGNIFICANCE WAS TESTED WITH 999 PERMUTATION TESTS (*** - P < 0.001; ** - P < 0.01; * - P < 0.05).

	Entire dataset			Spring cereals			Winter cereals		
	All variables	Separate CCA	Partial CCA	All variables	Separate CCA	Partial CCA	All variables	Separate CCA	Partial CCA
Cereal proportion	***	0.03 **	0.024 **	**	0.066**	0.061**	**n.s.**	0.055	0.061
Crop 2014 (group)	***	0.12 **	0.10**	---			---		
Previous crop (group)	**n.s.**	0.06	0.05	---			---		
Herbicide applications	**n.s.**	0.02	0.02*	*	0.057*	0.055*	*	0.092*	0.083*
N fertilizer	**n.s.**	0.019	0.018*	**n.s.**	0.034	0.036	**n.s.**	0.066	0.054
Farm size	**n.s.**	0.015	0.015	**n.s.**	0.041	0.041	**	0.075	0.082*
Proportion of constrained variance	**0.254**			**0.198**			**0.294**		

Size of the farm (four values were assigned: (1) <100 ha; (2) 100-500 ha; (3) 500-1000 ha; (4) >1000 ha). Amount of nitrogen fertilizer applied as supplement to the pre-sowing fertilizer (four values were assigned: (1) 0 – 50 kg/ha; (2) 50-100 kg/ha; (3) 100-140 kg/ha; (4) >140 kg/ha). Separate and partial CCA analysis with individual factors were performed (in partial CCA other factors were included as co-variables), to estimate gross and net effect of the significant factors according to the method described by Lososova *et al.* [5] and Fried *et al.* [1]. In each case, significance of the overall model and individual variables was tested by 999 permutation tests. Additionally, two subsets were analysed within the data table containing weed density observations in 2014: Spring cereals (Spring wheat, Spring barley, oats: 31 fields) and Winter cereals (Winter wheat, Winter rye Winter triticale: 21 fields). Four constraining variables were used due to smaller number of observations. Species association with gradients of the factors that were significant in each crop subset were identified in partial CCA plots where each factor was used as a constraining variable and other factors as co-variables. Pearson correlation of each species' density and site loadings (weighted species scores) was tested. All tests were performed using R (The R Foundation for Statistical Computing Platform, 2014) and particularly the package vegan, version 2.2-1 [7].

III RESULTS AND DISCUSSION

In total, 119 weed species were detected during the survey in 2014. Average number of species per field was 19.8, ranging from 5 to 43 species. Average weed density in the field was 73.5 plants m^{-2} ranging from 8 to 160 plants m^{-2}. The most frequent species detected in 97% of the fields was *Viola arvensis* Murray. Other frequent species found in more than 50% of the fields were *Equisetum arvense* L., *Polygonum convolvulus* L., *Galeopsis* spp., *Elymus repens* L., *Galium aparine* L., *Lamium purpureum* L., *Veronica arvensis* L., *Chenopodium album* L., *Polygonum aviculare* L., *Tripleurospermum inodorum* (L.) Sch. Bip., *Fumaria officinalis* L. and *Euphorbia helioscopia* L. The weeds with highest average density were *Viola arvensis* (13.6 plants m^{-2}) and *E. repens* (8.8 plants m^{-2}). In the CCA analysis of 2014 weed density data with all nine field variables used as constraints (Fig. 1) proportion of constrained variance was 25.4% of the total variance (Table I), the overall model was significant ($P < 0.005$). Significant terms in 2014 were crop group ($P < 0.005$) and proportion of cereals in crop rotation ($P < 0.005$).

TABLE II

GROSS AND NET EFFECTS OF FIELD MANAGEMENT FACTORS IN THE WEED DENSITY DATASETS COLLECTED IN 2013 AND PROPORTION OF VARIANCE EXPLAINED WHEN ALL 6 FACTORS WERE USED AS CONSTRAINING VARIABLES. THE NUMBER OF FIELDS INCLUDED IN THE ANALYSIS WAS 58. IN EACH CASE SIGNIFICANCE WAS TESTED WITH 999 PERMUTATION TESTS (*** - P < 0.001; ** - P < 0.01; * - P < 0.05).

	All variables	Separate CCA	Partial CCA
Cereal proportion	**n.s.**	0.081	0.022
Crop 2013 (group)	***	0.085**	0.073**
Previous crop (group)	**n.s.**	0.080**	0.056
Herbicide applications	**n.s.**	0.025	0.019
N fertilizer	**	0.034**	0.029
Farm size	**	0.025	0.025*
Proportion of constrained variance	**0.248**		

The proportion of cereals in crop rotation was also significant in the subset of Spring cereals, and in both cereals subsets number of herbicide applications was significant (Table I). In CCA analysis with all field variables in the subset of Spring cereals the overall model was significant ($P < 0.005$), proportion of constrained variance was only 19.8% of the total variance. The model analysis with all field variables in the subset of Winter cereals was also significant ($P < 0.005$), proportion of constrained variance was 29.4% of the total variance. In total, 121 weed species were detected during the weed surveys in 2013. Average number of species per field was 15.5 ranging from 5 to 31 species. Average weed density in the field was 54.1 plants m^{-2}, ranging from 6 to 254 plants m^{-2}. The most frequent species were *Equisetum arvense*, *Viola arvensis*, *Elymus repens*, *Chenopodium album*, *Polygonum convolvulus*, *Polygonum aviculare*, *Euphorbia helioscopia* and *Veronica arvensis*. The weeds with highest average density across all 72 surveyed fields were *Elymus repens* (11.1 plants m^{-2}) and *Viola arvensis* (6.1 plants m^{-2}). In the CCA analysis of 2013 weed density data with all six field variables used as constraints (Fig. 2) proportion of constrained variance was 24.8% of the total variance (Table II), the overall model was significant ($P < 0.05$). Three factors were significant when tested with 999 permutations: farm size, crop group and nitrogen fertilizer dose (Table II). Increased use of herbicides and nitrogen fertilizer are reported to be main field management factors that determined dramatic decrease of both density and species number of weeds in Germany [9]. The effect of nitrogen fertilizer on weed species composition was not evident in 2014, but it requires further investigation in a larger dataset comprising data from other regions of Latvia.

Proportion of constrained variance did not exceed 25% in both years, it means that some important factors that influence weed density and species distribution have not been identified in this study. Potentially important are edaphic factors – moisture, soil properties, and field management factors such as crop density, sowing date, kind of herbicides applied.

Also, factors that were not accounted for in this analysis could have influenced weed density and species composition in a particular year, like weather conditions in the current year. Crop rotation data were only available since 2011, so proportion of cereals and other crops in crop rotation was not analysed equally for both years.

One of the significant factors in 2014 in the subset of Winter cereals and in 2013 was the size of the farm. This factor is associated with a complex of farming practice that is often difficult to interpret. Generally, larger farms tend to implement more intensive farming methods, but in our case the largest farms were mixed dairy and crop farms, where proportion of grassland in crop rotation was relatively high. This influences both farming practice and weed species composition associated with the farm size.

In both years a major factor explaining data variation was crop group (Tables I, II). This means that field management practices associated with certain crops – time of ploughing, doses of fertilizer, herbicide application and crop rotation – are important for the resulting weed species composition.

Species associated with significant factors in cereal subsets are shown in Table III. In Spring cereals species most strongly associated with low proportion of cereals in crop rotation were *Vicia cracca*, *Chenopodium album and Artemisia vulgaris*; species associated with high proportion of cereals were *Avena fatua and Viola arvensis*. Species most strongly associated with less herbicide applications in 2014 were *Apera spica-venti* and *Poa pratensis*; species associated with more applications were *Trifolium repens* and *Elymus repens*. In the subset of Winter cereals species most strongly associated with small farm size were *Geranium pusillum*, *Polygonum persicaria, Poa pratensis and Atriplex patula*; species associated with large farm size were *Vicia spp*., *Thlaspi arvense, Melandrium album*. Species associated with less herbicide applications were *Poa pratensis*, *M. recutita*, *Capsella bursa-pastoris*, *Convolvulus arvensis*, *A. spica-venti, A. fatua*, *E. crus-galli*, while species associated with more herbicide applications where *Erodium cicutarium*, *Equisetum arvense*, *Lolium perenne* (Table III)

TABLE III

SPECIES ASSOCIATED WITH GRADIENTS OF INDIVIDUAL FIELD FACTORS IN SPRING AND WINTER CEREAL SUBSETS OF DATA 2014. ASSOCIATION WAS DETECTED BY PERFORMING PARTIAL CCA ANALYSIS WITHIN THE SUBSET USING THE INDIVIDUAL FACTOR AS THE CONSTRAINING VARIABLE AND OTHER FIELD FACTORS AS CO-VARIABLES. PEARSON CORRELATION COEFFICIENTS OF THE SPECIES DENSITY VS SITE LOADINGS ARE SHOWN IN PARENTHESES.

Spring cereals		Winter cereals	
Cereal proportion	Herbicide applications	Farm size	Herbicide applications
Low	One	< 100 ha	None
Vicia cracca (0.34)	*Apera spica-venti (-0.66)*	*Geranium pusillum (0.53)*	*Poa pratensis (-0.41)*
Euphorbia helioscopia (0.25)	*Poa pratensis (-0.22)*	*Polygonum persicaria (0.62)*	*Capsela bursa-pastoris (-0.55)*
Chenopodium album (0.32)		*Poa pratensis (0.51)*	*Convolvulus arvensis (-0.38)*
Artemisia vulgaris (0.38)		*Atriplex patula (0.48)*	*Apera spica-venti (-0.59)*
		Lycopsis arvensis (0.52)	*Avena fatua (-0.52)*
		Avena fatua (0.42)	*Juncus bufonius (-0.42)*
		Rumex crispus (0.34)	*Cerastium arvense (-0.49)*
			Echinochloa crus-galli (-0.49)
			Veronica agrestis (-0.44)
Apera spica-venti (-0.31)	*Elymus repens (0.41)*	*Myosotis arvensis (-0.47)*	*Equisetum arvense (0.38)*
Viola arvensis (-0.42)	*Achillea millefolium (0.28)*	*Juncus bufonius (-0.49)*	*Veronica arvense (0.43)*
Erodium cicutarium (-0.26)	*Trifolium pratensis (0.43)*	*Melandrium album (-0.47)*	*Lolium perenne (0.33)*
Capsela bursa-pastoris (-0.26)		*Thlaspi arvense (-0.54)*	*Erodium cicutarium (0.35)*
Avena fatua (-0.42)		*Vicia spp. (-0.44)*	
High	Two	> 1000 ha	Three

Annual monocot weed species (*Apera spica-venti*, *Echinochloa crus-galli*, *Avena fatua*) were associated with fields with high proportion of cereals in rotation and less herbicide applications (Table III). All of these species are common in cereal crops. Although in Germany *E. crus-galli* is reported to be associated mainly with maize fields, its seedbank was larger in cereal monoculture in a long-term study in USA [8], [9]. This association can be explained with the use of herbicides that do not provide sufficient control of monocot species as well as favourable conditions for them in cereal monocultures. Monoculture promotes development of less diverse weed flora that is difficult to control, for example, long-term wheat monoculture is favourable for proliferation of a persistent weed *Avena fatua* [10].

Association of *Avena fatua* with smaller farms (Table III) may be due to use of non-certified seed material contaminated with *A. fatua* seeds. Annual *Poaceae* species were also associated with smaller number of herbicide applications. Insufficient control of these weed species can promote further infestation of the fields as well as adjacent fields. While more intensive use of herbicides may not always be the best option due to high costs and possible contamination of the environment, integrated weed management methods must be explored more intensively, especially appropriate crop rotation, sowing rates and use of certified seed material.

In 2014 *Elymus repens* was associated with more herbicide applications (Table III). This association may be due to low efficacy of the applied herbicides on this species. *E. repens* was one of the most frequent species across the surveyed fields in both years. Decrease of *E. repens* in cereals in Finland and Denmark with more intensive use of glyphosate-containing products [11]. In the surveyed fields in both 2013 and 2014 glyphosate containing products were used in less than 50% of the fields. Other options, such as mechanical control, could be used where possible. Association of some species with more herbicide applications is probably due to lack of effective herbicides or inappropriate application.

Species often recorded in oilseed rape fields (Fig. 1, 2) are *Sinapis arvensis*, *Erysimum cheiranthoides, Thlaspi arvense*. Fried *et al*. [1] reported that due to changing field management methods, especially use of herbicides, in the last few decades weed species composition in oilseed rape in France changed from species typical for Winter wheat to species that are specialists for oilseed rape. This process may not yet be advanced in Latvia, where growing oilseed rape became popular later, but still indicates that appropriate crop rotation is advisable to prevent these specialist species from spreading. Crop rotation and enhances weed control by increasing variation in environmental conditions, increasing competition and allelopathic effect among weeds and crops and, as a result, create more unstable conditions, unfavourable for proliferation of certain weed species. However, for more successful weed control, different complementing methods should be used alongside with crop rotation, like intercropping and a choice of competitive crop cultivars [10].

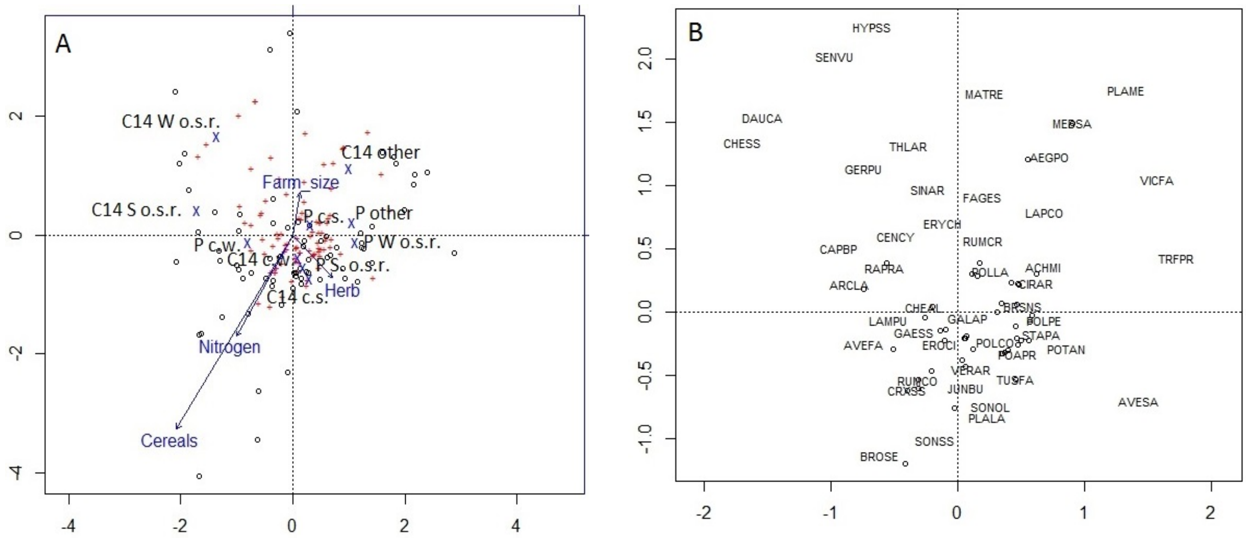

Fig. 1. CCA analysis (axes 1 and 2) of the entire data set from 2014 containing weed densities, with 6 field variables included as constraints (A constraining variables displayed; B species codes displayed). The constraining variables were: crop group in 2014 (C14) and preceding crop (P) where c.s. – Spring cereals; c.w. – Winter cereals; S o.s.r. – Spring oilseed rape; W o.s.r. – Winter oilseed rape; proportion of cereals (Cereals) in crop rotation in last four years; number of herbicide application times in 2014 (Herb); dose of supplementary N fertilizer applied in 2014 (Nitrogen); size of the farms (Farm_size). Significance was tested with 999 permutation tests ($P < 0.05$). Species codes are used according to the Bayer code system [14].

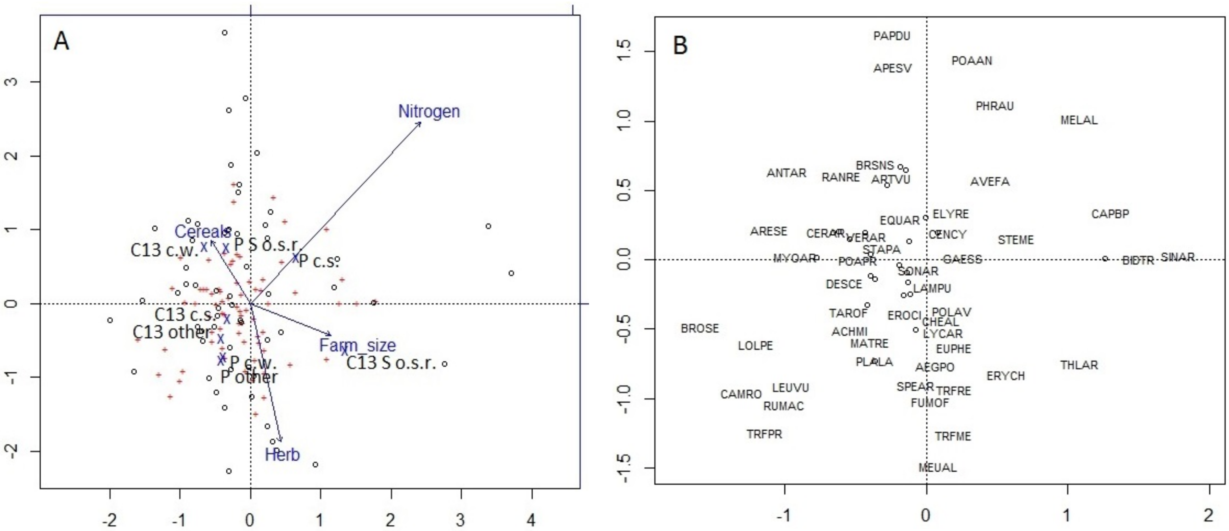

Figure 2. CCA analysis (axes 1 and 2) of the entire data set from 2013 containing weed densities, with 6 field variables included as constraints (A constraining variables displayed; B species codes displayed). The constraining variables were: crop group in 2014 (C13) and preceding crop (P) where c.s. – Spring cereals; c.w. – Winter cereals; S o.s.r. – Spring oilseed rape; W o.s.r. – Winter oilseed rape; proportion of cereals (Cereals) in crop rotation in last four years; number of herbicide application times in 2014 (Herb); dose of supplementary N fertilizer applied in 2014 (Nitrogen); size of the farms (Farm_size). Significance was tested with 999 permutation tests ($P < 0.05$). Species codes are used according to the Bayer code system [14]

The effect of crop rotation on weed control must be evaluated taking into account the number of crops included in rotation and rotation period [12], [13]. In the present survey there were 11 fields (15.3%) with cereal monoculture in the four-year-period, where only Winter and Spring cereals were grown. This could explain the significance of cereal proportion in crop rotation in the analysis. However, the dataset of explaining variables was very heterogeneous and for some factors there may not have been sufficient number of replications. This is caused by the survey method that was chosen, surveying weed populations in the same fields every year and not in the fields with the same crop. Analysis of the survey data from a larger territory and in a longer time period may reveal effects of pH, soil properties, temperature and other environmental and field management factors. Further surveys of the weed populations is also required to determine the significance of density-dependence in particular weed species because it can influence the success of weed control methods and therefore, is important for practical management decisions [12].

IV CONCLUSIONS

Crop type was the most influential factor explaining variance in weed composition within weed survey data collected in 2014 and 2013 in the southeastern part of Latvia. In 2014 the proportion of cereals in crop rotation during last four years was one of the statistically significant factors that explained the variation of weed community composition. Herbicide application intensity was an important factor influencing weed flora in 2014 in both Spring and Winter cereals. Further research is needed to identify other important factors that determine weed species composition in this region.

V ACKNOWLEDGEMENTS

We thank Guntis Brūmelis and Didzis Elferts (University of Latvia) for help with the statistical analysis of the data, Ineta Vanaga, the leader of the project “Integrated pest management for weed control in arable crops for sustainable use of the environment and resources”, and the owners of each farm where the weed surveys were conducted.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 241-243

Thermodynamic cycle with two-component working fluid

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Abstract. **The article deals with the implementation of the thermodynamic cycle using the two-component working fluid. An estimated calculation of the efficiency of using the two-component working fluid, and a variant implementation of the thermodynamic cycle rotary vane engine with an external heat supply are described.**

Keywords: **thermodynamic cycle, two-component working fluid, rotary-vane engine.**

I INTRODUCTION

It is well known that the efficiency of the engines graphically is determined by the area of the working process "compression-expansion" of the working fluid, and the efficiency does not depend on engine design and operating characteristics of the working body.

Real processes in internal combustion engines (gas turbine engines, steam turbines etc.) differ from the ideal process, but in the calculation engines all adhere paradigm proposed by Sadi Carnot – working body participating in a cycle heat engine, always by weight, and is a gas.

The proposed method for producing mechanical motion into a heat engine that uses a loop with two-component working body – a new scientific and technical direction.

II COMBINED THERMODYNAMIC CYCLE

There are obvious prerequisites for the assertion that we should expect global change throughout the heat cycle diagram with increasing mass of the working fluid in the expansion stroke and reducing the mass of the working fluid in the compression stroke.

Currently, there are analogs of the thermodynamic cycle, for example, a well-known combined cycle [1, 2, 6]. Combined-cycle plant is a combination of gas turbine and steam turbine plants. A simplified scheme is shown in Fig. 1. In a combustion chamber supplied with fuel and air compressed by the compressor. Combustion products, having worked in a gas turbine enters the heater, which heat the feed water to the boiler, and removed to the atmosphere. The superheated steam produced in the boiler expands in the steam turbine and is condensed in the condenser. The condensate is pumped into the heater, where is heated and then fed into the boiler. Net power generated by gas and steam turbines, generators of electric current is passed.

The ideal cycle of combined-cycle plant in the Ts-diagram is shown in Fig. 2. The cycle is built for 1 kg of feed water and the amount of gas per 1 kg of water. Cycle gas turbine plant – 1-2-3-4-5-1, Rankine cycle steam turbine parts – 6-7-8-8'-9-9'-6. With the implementation of separate gas turbine and steam turbine installations heat being applied in the cycle gas turbine plant, measured by the area a-1-2-d, and useful work – an area 1-2-3-4-5. Heat supplied to the steam turbine cycle, measured by the area c-6-7-8-8'-9-f, and useful work – an area 6-7-8-8'-9-9 '. The amount of heat measured area 3-5-a-d, given in the useless 3-5 exhaust gases to the environment. In the same apparatus combined cycle heat, represented by the area 3-4-b-d, is given in the 3-4 exhaust gases of the feed water. This area is the area of c-6-7-e (shaded), which determines the amount of heat produced during 6-7 feedwater. Consequently, for the same total power amount of heat supplied to the combined-cycle plant, compared with separate set area decreases by c-6-7-e. This gain in heat consumption and determines the efficiency of combined-cycle plant.

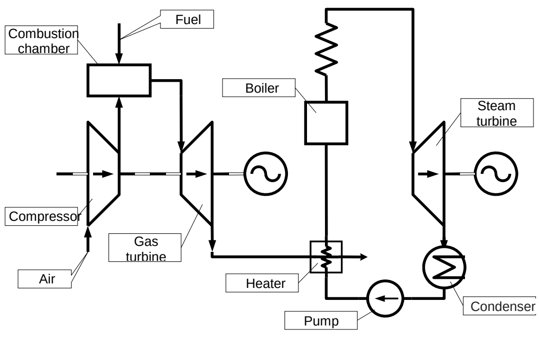

Fig. 1. Scheme of combined-cycle plant.

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.261

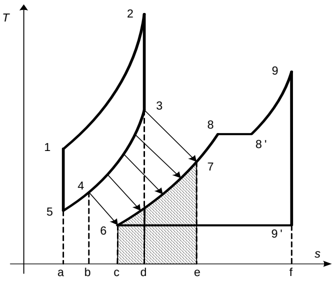

Fig. 2. The ideal cycle of combined-cycle plant.

Indicators of efficiency of modern energy machines are illustrated by the data shown in the Table 1 [2].

TABLE 1.

Type of energy machine	Efficiency, %
External combustion engines	25…39
Diesels	35…46
Jet engines	15…20
Gas turbines	30…38
Combined (diesel with gas turbine)	40…45
Steam turbines with high steam parameters	36…38
Combined-cycle (gas and steam turbine) installation	52…60

For example, the new North-West CHPP - one of the most modern power plants not only in Russia but also in Europe, built using advanced technology combined cycle. This ensures the efficiency of the station at 51.5%, saving up to 20-25% of fuel and reduce by one third the volume of emissions. The use of scheme of heat output increases the efficiency of the North-West CHP to 76%.

Experiments are known on the water injection at the end of combustion of fuel in an internal combustion engine, resulting in an increased capacity, reduced thermal load on the piston and fuel economy group to 20%, however, the formation of sludge, water in crankcase oil, adversely affect the reliability of operation of the engine in general.

III THERMODYNAMIC CYCLE WITH TWO-COMPONENT WORKING FLUID

Modernization and improvement of engine are doing continuously. The history of development shows that the background of this continuity, there are periods of sharp transition from one to the other types of engines. This has happened in the transition from steam engines to internal combustion engines, the latter to a turbojet aircraft. At the heart of the transition is the change in the thermodynamic cycle of converting thermal energy into mechanical work.

In thermodynamics, known thermal cycles Carnot, Otto, Diesel, Rankine, Stirling et al., based on which are calculated all known engines and their characteristics. Generally, the use of each of these cycles resulted in a significant change in engine design [3, 6, 7].

Simplified thermodynamic cycle of converting thermal energy into mechanical movement with a two-component working medium in engines with an external supply of heat can be represented as follows (Fig. 3):

1) compressing a first component working fluid – gas mass M_1 (curve 1-2);
2) introducing a supply of heat to the working cycle of the second component of the body – with liquid mass M_2 transfer of the second component in the gas (line 2-3 ');
3) expanding the gas mixture and obtaining mechanical work (curve 3'-4 ');
4) recovering the condensation heat of the second component of the working fluid in a closed volume (4'-line 1).

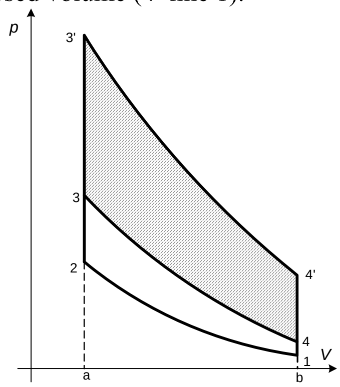

Fig. 3. Thermodynamic cycle with two-component working fluid.

Useful work is measured by area 1-2-3'-4 '. The gain compared to the conventional cycle is square 3-3'-4'-4 (shaded).

Expansion stroke is an isothermal process with temperature. Then the work of expansion for the first component (Curve 3-4):

$$A_{E1} = M_1 R_1 T_E \ln\left(\frac{V_E}{V_C}\right),$$

where R_1 – gas constant of the first component of the working fluid; V_{COL} и V_{EXP} – volumes in collapsed and expanded states.

Job expansion of two-component working medium (curve 3'-4 ')

$$A_{E2} = (M_1 + M_2) R T_E \ln\left(\frac{V_E}{V_C}\right),$$

where $R = \frac{R_\mu}{M_1 + M_2}\left(\frac{M_1}{\mu_1} + \frac{M_2}{\mu_2}\right)$ – gas constant two-component working fluid.

Thus, one can roughly estimate the increase in the proposed work expansion cycle compared to conventional:

$$k = \frac{A_{E2}}{A_{E1}} = 1 + \frac{M_2}{\mu_2}\frac{\mu_1}{M_1},$$

where μ_1 and μ_2 – molar mass of the first and second components.

For example, if used as the first component of the air, and the second – the water with the same mass, the increase in expansion work will be times. Selection of qualitative and quantitative composition of the working fluid can be achieved a significant increase in this indicator.

IV CONCLUSION

This example cycle may be carried out in one engine, which will be its distinction and advantage.

The general scheme of the engine with an external supply of heat [4, 5, 8-12] using a new cycle is shown in Fig. 4.

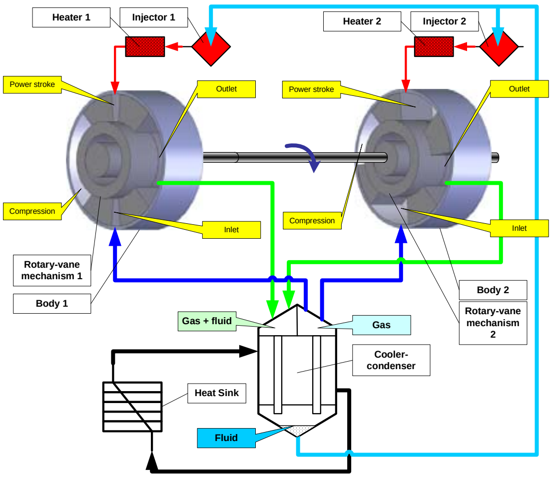

Fig. 4. Scheme of the engine rotary-vane type with external supply of heat and a two-component working fluid.

The first component of the working fluid – gas during the intake stroke flows into the working volume and the contracts. In cycle working stroke by means of the heater nozzle of the second component is added to – liquid heat supply is carried out at high pressure. In the exhaust stroke mixture enters the cooler-condenser, which is cooled and separation of the working fluid into gas and liquid due to condensation. The radiator is used in the coolant circuit to maintain the desired cooling temperature of the working body. Double chamber version of the engine ensures that no dead pixels and the ability to start rotating from any position without the application of an external torque.

It should be noted that when working on the four stroke cycle, the new engine is equivalent to a 16-cylinder internal combustion engine with a working volume of the same magnitude.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 244-250

DISTRIBUTION OF IRON AND IRON COMPOUNDS IN THE KEMERI - JAUNKEMERI OCCURENCE OF SULPHIDE WATER

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Abstract. **Iron concentrations, distribution and migration forms, depending on pH and oxidation – reduction potential, were analyzed in case of the Kemeri-Jaunkemeri occurrence (area about 240 km^2) of sulphide containing water (maximal sulphides concentration – 74 mg/l), located in Latvia. Iron content was investigated in 457 wells located within all area of occurrence. Those wells were installed to two aquifers: the Quarternary multi-aquifer and Salaspils aquifer, where occurrence of sulphide containing groundwater is distributed. All groundwater of occurrence is classified in four types depending on oxygen, sulphides and organic matter content in the groundwater. Modeling of groundwater migration forms was carried out, and it is stated that iron migrates basically as Fe^{2+} in oxygen and suphides non-containing water. Migration forms are influenced by concentration of organic matter in the aquifer. The portion of Fe^{2+} migrating in a form of free decreases due to formation of complexes with fulvic and humic acids, which can reach 36.5% of all migration forms. Iron migrates as $Fe(OH)_3$ in oxygen containing water (more than 99% of determined forms). Presence of iron is ascertained also in sulphides containing water, where iron migrates basically as (98.8% of determined forms). This occurs due to formation of complexes with sulphydes – $FeHS^-$ and $Fe(HS)_2^o$.**

Keywords: **groundwater exploration, hydrochemistry, iron, sulphides, Latvia.**

I INTRODUCTION

Iron in groundwater is one of elements which significantly influences groundwater quality, and distribution of iron forms in groundwater are depending on oxidation – reduction potential (Eh) and acidity/basicity (pH) of water media [1]. Simultaneously geochemistry of iron in groundwater is rather complicated, because iron can migrate in groundwater not only as divalent ferrous iron (Fe^{2+}), trivalent ferric iron ($Fe^{3+)}$ and their hydroxides, but also in a form of complexes with many inorganic and organic ligands. Iron state, concentrations and migration forms were investigated in the Kemeri - Jaunkemeri occurrence of sulphides containing groundwater, because knowledge of iron geochemistry was important in order to understand genesis and distribution of sulphides in groundwater of the occurrence. The study area is located in Latvia, 40-60 km western form the capital of Latvia – Riga City (see Fig.1).

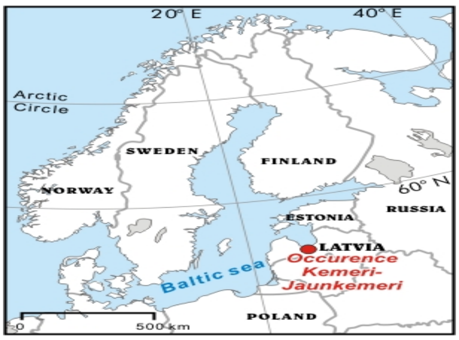

Fig.1 Location pf the Study area

Area of the occurrence is about 240 km^2, and it is distributed within the Salaspils aquifer of the Upper Devonian consisting of dolomite, gypsum, marl, clay deposits, in average 20 m thick. This aquifer is covered and here and there is in hydraulic link with the multi- aquifer of the Quaternary deposits [10].

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.626

II METHODS, THEIR SIGNIFICANCE AND SCOPE OF THE WORK

Adequate sampling and conservation of groundwater samples and use of accurate analytical methods are required for acquisition of reliable data on iron concentration in water. Iron occurs in groundwater in dissolved and colloidal forms, and both of them include inorganic and organic forms of iron compounds. Therefore dissolved and colloidal forms of iron have to be separated before analysis if it takes place in situ. Conservation of sample must be provided, if it is delivered for analysis to the laboratory. Besides it has to be taken into account that difference in sizes of mentioned forms is rather relative. For example, size of iron hydroxides and sulphides is <0.2 μm, but size of complex iron compounds with fulvic acids is >1 μm. For that reason the membrane filter 0.45 μm was used for filtration. Still, as it is stated in study [3], insignificant part of colloidal forms are passing filter. Nevertheless the difference observed for 0.45 μm and for smaller size membrane filters, looking from analytical and hydrochemical viewpoints, is unessential for groundwater does not containing sulphides. Different is situation when groundwater contains sulphides, because very frequently colloidal forms of iron (for example, mackinawite - FeS) are found. Due to this reason membrane filter 0.2 μm was applied. pH of groundwater distributed in the borders of occurrence is about neutral (excluding water from boggy deposits). In general water filtration is mandatory if Fe^{3+} is found, because in such conditions Fe^{3+} migrates only as colloid or complex compound with organic matter. Filtration is not necessary if water contains only Fe^{2+}.

Samples were acidified with the HCl to pH ~1, when they were delivered for analysis to the laboratory. It has to be emphasized that only total content of iron may be determined for acidified samples. In particular case it was important to determine directly Fe^{2+} and Fe^{3+} concentrations. Therefore major part samples, as rule, were analysed in situ. Hermetic sampling (excluding aeration) was provided in case of samples delivery to the stationary laboratory specially created at Kemeri in order to provide analysis within 0.5-1.5 hours after sampling (time which was necessary for transportation). Photometric analysis was applied, where α,α′-dipyridyl was used for iron determination. All complex compounds of iron where destroyed before analysis using HNO_3 and H_2O_2 and heating samples whilst they were completely evaporated. Non-evaporated samples were analysed in parallel in order to determine part of iron complexes in total content of iron [6]. The thiocyanate method was applied only for rough analysis in single cases, where it was actually, in order iron content in field conditions, and obtained results are not used in this work.

Special programme "Echo" was elaborated for a modelling of migration forms of elements in groundwater taking into account principles described in the work [9], i.e. programme was based on unstableness constants of substances, taking into account pH and Eh, chemical composition of water, gases content and organic matter concentrations as background information for a modelling purpose.

Iron content was investigated in 457 wells located within all area of investigations (see Fig.2). This was combined with pH, Eh and H_2S HS^- determination in field conditions, as well as with groundwater sampling for determination of chemical composition (Ca^{2+}, Mg^{2+}, Na^+, Fe^{2+}, Fe^{3+}, HCO_3^-, SO_4^{2-}, Cl^-, NO_3^{2-}), gasses content (O_2) and determination of organic matter ($C_{org/tot}$, fulvic acids and humic acids).

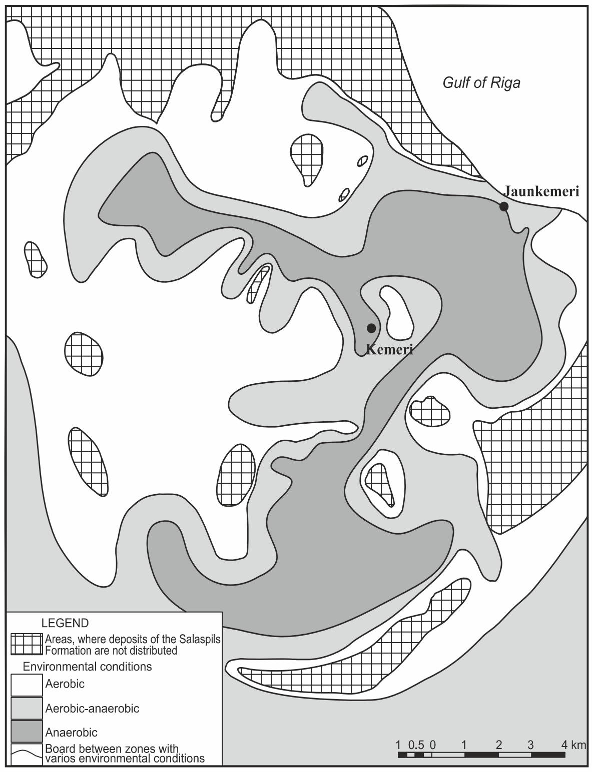

Fig. 2 Location of wells and zoning of oxidation – reduction conditions of the occurrence

A. Theoretical aspects and classification of water of the occurrence

Hypothetical plot showing a stability-field of different dissolved iron forms and compounds typical for groundwater, where Eh varies from –400 mV to +500 mV, but pH from 4 to 10, is presented in study [2] (see Fig. 3, part "a"). High clarke of iron (4.65 g/t) [9] determines existence of iron abundance gradient in the system "sediments-water". Consequently – any water containing sediments may be a source providing a presence of iron in groundwater.

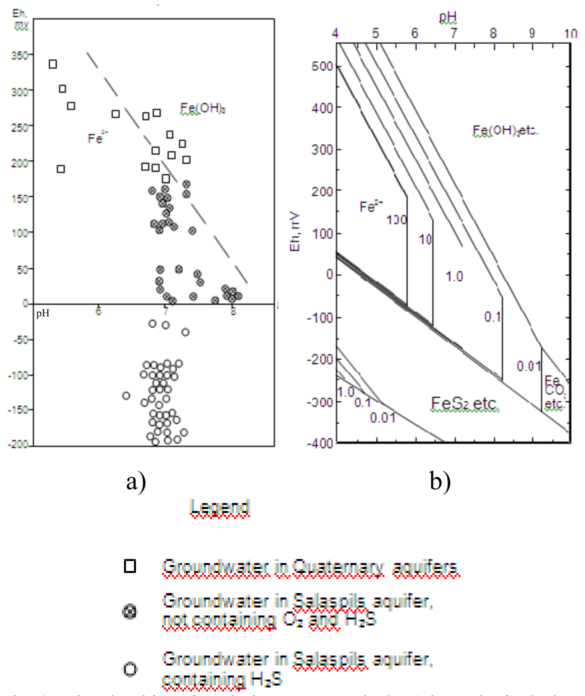

Fig. 3. Dissolved iron in relation to pH and Eh: a) hypothetical plot [2]; b – plot for the Kemeri – Jauņķemeri occurrence of sulphides containing groundwater

Nevertheless, the direct link among iron content in sediments and in related groundwater is not stated [7]. Iron migration from sediments to water is possible only in particular oxidation – reduction conditions, in general are determined by the pH and Eh. Therefore iron distribution in groundwater, looking both from quantitative and qualitative aspects, is extremely different.

The iron forms in groundwater, taking into consideration that iron may be found as reduced divalent ferrous (Fe^{2+}) and oxidized trivalent ferric (Fe^{3+}), are determined by variety of factors. The most essential among them are five [7,8]:

- poor $Fe(OH)_3$ and good $Fe(OH)_3$ solubility in water; their solubility constants are: $3.8*10^{-38}$ and $1*10^{-15}$,
- oxidation of Fe^{2+} in presence of O_2 with further hydrolysis creating $Fe(OH)_3$,
- formation of poorly soluble compounds in sulphides containing water - FeS and FeS_2 having solubility constants $1*10^{-20}$ and $1*10^{-30}$,
- formation of poorly soluble compounds with anions distributed in groundwater,
- formation of complexes with ions and organic matter, especially with humic and fulvic acids.

All mentioned factors also have the particular role during the process of origin and existence of the Kemeri-Jaunkemeri occurrence of sulphides containing water. Very different types of water are distributed in the rather small area (240 km^2) - starting from oxygen and ending with sulphides containing; moreover – groundwater has very different composition and content of dissolved substances. Further only types of groundwater, characteristic for the Kemeri-Jaunkemeri occurrence of sulphides containing water, are examined (see Fig. 3, part "b"), and classified taking into consideration values of pH, Eh, O_2, sulphides (H_2S + HS^- + S^{2-}) and organic matter:

1) I type: oxygen (up to 4.2 mg/l) containing and sulphides non-containing water with relatively low content of organic matter ($C_{org.tot}$ <20 mg/l), where pH and Eh values varies from 6.5 to 7.5 and from +245 mV to +390 mV correspondingly. This type of water is dominantly distributed in the Quaternary multi-aquifer, but also can be found in local areas in the Salaspils aquifer, where it is recharged, due to absence of glacial sediments, by water from the Quaternary multi-aquifer,
2) II type: oxygen and sulphides non-containing water, relatively poor with organic matter ($C_{org.tot}$ <15 mg/l). This type of water is distributed in the Salaspils aquifer, where pH and Eh values varies from 6.8 to 7.5 and from +10 mV to +160 mV correspondingly. Link among Eh and pH has inverse character – minimal and maximal Eh values observed in cases of maximal and minimal pH, i.e. Eh=10 mV if pH=7.4 and Eh=160 mV if pH=6.8,
3) III type: oxygen and sulphides non-containing water, rich with organic matter ($C_{org.tot}$ – up to 90 mg/l), where pH is less than 6.5 and Eh varies from +60 mV to +189 mV. This type of water is distributed in the Quaternary multi-aquifer, basically in aquifer of boggy sediments,
4) IV type: oxygen non-containing and sulphides containing water relatively poor with organic matter ($C_{org.tot}$ <15 mg/l). Sulphides content reaches 74 mg/l. pH and Eh values varies from 6.8 to 7.3 and from -10 mV to -190 mV correspondingly.

B. Distribution of iron in oxygen containing groundwater

Oxidation and hydrolysis take place in groundwater containing oxygen and relatively poor with organic matter, where pH value varies from 6.5 to 7.5 (I and II types of water). Following equations of reactions are describing those processes:

$Fe^{2+} \rightarrow Fe^{3+} + e^-$ (1)

$Fe^{3+} + OH^- \leftrightarrow FeOH^{2+} + OH^- \leftrightarrow Fe(OH)_2^+ + OH^- \leftrightarrow Fe(OH)_3^0 + OH^- \leftrightarrow Fe(OH)_4^-$ (2)

The most stable compound, when pH is about neutral, is $Fe(OH)_3$. Formation of colloids both in surface water and groundwater takes place, if solubility expression ($3,8*10^{-38}$) of ferric iron is reached. G.Solomin has determined Fe^{2+} migration forms in oxygen containing groundwater already in 1967 [12], and has ascertained that those forms may be presented in following order:

$Fe(OH)_3^O >> Fe(OH)_2^+ > Fe(OH)^{2+} > FeSO_4^o, FeCl^{2+}$

where $Fe(OH)_3^o$ absolutely dominates (>99% of determined forms). $Fe(OH)_2^+$ and $Fe(OH)^{2+}$ content is very low (n*0.1 %), but $FeSO_4^0$ and $FeCl^{2+}$ presence has rather theoretical character (less than n*0.01 %). Similar conclusions provided also in other studies. For example, in study [2] it is mentioned that in presence of oxygen $Fe(OH)_3^0$ forms 99.0-99.9% of total iron forms.

When groundwater is saturated with $Fe(OH)_3$, taking into account its low solubility, initially $Fe(OH)_3$ is transformed to colloidal form with following precipitation forming brown colour sediments. Stability constant for the reaction $Fe(OH)_3$=$FeOOH$+H_2O is ~$3,4*10^6$. It, taking into account stability constants of other forms, allows to determine the maximum free Fe^{3+} content which is in equilibrium with precipitation of $Fe(OH)_3$. According [12] this concentration cannot be more than 17 mg of Fe^{3+} per liter. This allows to make important conclusion – hydrolysis of Fe^{2+} and after of Fe^{3+} is taking place in groundwater containing oxygen. Consequently iron in groundwater of occurrence, where it contains oxygen, has to be completely precipitated.

This fact was proved during investigations, i.e. iron content in I type of water varies from 0.00 to 0.54 mg/l. It is important to emphasize that this conclusion has not only local, but also general character. According study [5], where iron distribution in groundwater in Lithuania was analysed, it is stated that maximum iron content does not exceed 0.38 mg/l if average concentration of O_2 in groundwater is 0.38 mg/l.

C. Iron migration in groundwater non containing O_2 and H_2S poor with organic matter

Formation of oxygen and sulphides non containing water (II type) takes place in closed systems, where high concentrations of iron are possible only in case, when Eh of groundwater is lower that oxred potential of the reaction (1). This type of water is distributed in zone of occurrence of Fe^{2+} (see Fig. 3, part "b"), where iron content depends of solubility of the less soluble compound. For water, where pH is about neutral, these are carbonates. Following equation describes the solubility process in particular case [8]:

$FeCO_3 + H_2O + CO_2 = Fe^{2+} + 2HCO_3$ (3)

Analyzing the reaction, it has to be concluded that carbonate equilibrium shall be diverged towards HCO_3^-. Therefore iron concentration in water will not be determined by the weak soluble $FeCO_3$ (solubility constant - $2.3*10^{-11}$), but by the high soluble $Fe(HCO_3)_2$ [4]. Presence of CO_2 in groundwater is mandatory precondition for an increase of iron concentrations. In particular conditions source of CO_2 are: oxidation of organic matter, biochemical processes and others.

Data on iron migration in water does not containing O_2 and sulphides is presented in Table 1 both for the Quaternary multi-aquifer and for the Salaspils aquifer. pH and Eh of this type of water varies from 6.7 to 7.4 and from +50 mV to +200 mV correspondingly. It is ascertained that in the Quaternary multi-aquifer more than 83% of iron migrates as Fe^{2+}, and subordinated significance have following compounds: $FeSO_4$, $FeHCO_3$ and $FeCO_3$. Similar results are obtained for the Salaspils aquifer, where more than 63% of iron migrates as Fe^{2+}. Nevertheless the part of complex compounds reaches 37%, and essential increase of $FeCO_3$ and $FeHCO_3$ is observed. Reason is very clear – water mineralization is 0.3-0.6 g/l and 2.2-2.6 g/l correspondingly in the Quaternary multi-aquifer and in the Salaspils aquifer.

Total iron content in aquifers is different, and varies from 8.4 mg/l to 36.0 mg/l in the Quaternary multi-aquifer and from 1.58 mg/l to 5.2 mg/l in the Salaspils aquifer.

D. Iron distribution in O_2 and sulphides non-containing water rich with organic matter

Different situation observed in case when water is rich with organic matter, especially with humic and fulvic acids. With them iron forms stabile complexes, and for that reason migration of it occurs also in oxygen containing waters due to stability of complex compounds.

In literature [7,8, others] it is mentioned that iron forms complexes also with low-molecular carbonic acids (C1-10 – acetic acid, oxalic acid, citric acid, vinic acid and others). This item was not analyzed during our investigations, because the main attention was paid to the boggy sediments aquifer and to other aquifers significantly influenced by the water from boggy sediments aquifer providing essential increase of content of organic matter. Also it has to be emphasized that water of the boggy sediments aquifer does not contain carbonic acids [11].

pH of water in boggy sediments aquifer varies from 5.0 to 6.5, but Eh - from +75 mV to +205 mV. Forming of complexes with fulvic, humic acids and other organic compounds significantly slow down oxidation of Fe^{2+}, and in single cases completely prevent the oxidation process, even more – reduction of Fe^{3+} to Fe^{2+} takes place in presence of organic matter. Moreover – created complexes are not subjected to hydrolysis in the particular media.

Kinetic of hydrolysis of Fe^{3+} depends on pH and ratio of fulvic acids and Fe^{3+} concentration in water. Therefore maximal Fe^{3+} concentrations (to 47.5 mg/l) are found in water of the boggy sediments aquifer very rich with fulvic and humic acids (third type of water).

Table 1.
REVIEW OF IRON MIGRATION FORMS IN GROUNDWATER OF THE KEMERI – JAUNKEMERI OCCURENCE OF SULPHIDE CONTAINING WATER

Parameter	Measure-ment unit	Well or spring, aquifer													
		V-4	III-4	V-3e	V-3c	LG-5	LG-2	LG-3	751	P	XVIII-3/2	XVIII-3/z	XVIII-3/d	709	950
		lg Q_3bl	lg Q_3bl	$D_3slp(1)$	$D_3slp(1)$	$D_3slp(1)$	$D_3slp(1)$	$D_3slp(1)$	$D_3slp(1)$	$D_3slp(1)$	$D_3slp(1)$	$D_3slp(1)$	$D_3slp(1)$	$D_3slp(2)$	D_3slp (2)
Fe^{2+}, determined	mg/l	36,0	8,4	0,4	1,2	0,3	0,6	0,9	0,4	0,2	0,54	0,2	0,4	1,5	1,1
ΣFe^{2+}	g-ions/l	$5,157*10^{-4}$	$8,594*10^{-5}$	$7,162*10^{-6}$	$2,149*10^{-5}$	$5,372*10^{-6}$	$1,074*10^{-5}$	$1,611*10^{-5}$	$7,162*10^{-6}$	$3,581*10^{-6}$	$9,669*10^{-6}$	$5,370*10^{-6}$	$7,162*10^{-6}$	$2,686*10^{-5}$	$1,970*10^{-5}$
Activity of Fe^{2+}	g-ions/l	$4,301*10^{-4}$	$7,303*10^{-5}$	$2,081*10^{-8}$	$7,260*10^{-8}$	$1,868*10^{-8}$	$3,819*10^{-8}$	$5,218*10^{-8}$	$2,106*10^{-8}$	$2,785*10^{-8}$	$2,667*10^{-8}$	$3,171*10^{-8}$	$1,724*10^{-8}$	$1,701*10^{-5}$	$1,261*10^{-5}$
Migration forms															
Fe^{2+}	% no Fe^{2+}	83,4	84,97	0,3	0,34	0,35	0,36	0,32	0,29	0,78	0,27	0,55	0,37	63,34	64,02
$Fe(OH)^+$	% no Fe^{2+}	0,14	0,16	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	0,15	0,25
$FeSO_4^0$	% no Fe^{2+}	11,4	3,35	0,07	0,09	0,09	0,10	0,08	0,09	0,20	0,07	0,15	0,10	10,13	10,29
$Fe(SO_4)_2^{2-}$	% no Fe^{2+}	0,29	0,02	<0,01	<0,01	<0,01	0,01	<0,01	0,01	0,02	<0,01	0,01	<0,01	0,45	0,42
$FeHCO_3^+$	% no Fe^{2+}	3,72	8,89	0,09	0,12	0,12	0,11	0,11	0,08	0,15	0,10	0,12	0,11	17,89	14,78
$Fe(HCO_3)_2^0$	% no Fe^{2+}	0,02	0,11	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	0,69	0,46
$FeCO_3^0$	% no Fe^{2+}	0,99	2,45	0,04	0,05	0,05	0,05	0,04	0,03	0,04	0,03	0,06	0,03	7,19	9,52
$Fe(CO3)_2^{2-}$	% no Fe^{2+}	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	0,11	0,18
$FeHS^-$	% no Fe^{2+}	-	-	56,10	57,81	58,29	58,70	57,15	56,42	71,06	54,41	66,40	59,57	-	-
$Fe(HS)_2^0$	% no Fe^{2+}	-	-	43,38	41,58	41,08	40,67	42,28	44,08	27,74	45,10	32,69	39,81	-	-
Calculations															
Fe^{2+}, max	mg/l	13,1	5,3	357,9	283,6	272,8	248,8	319,5	442,8	285,4	431,9	228,6	397,9	1,80	1,36
Fe^{2+}=det/max	-	2,75	1,58	$1*10^{-3}$	$4*10^{-3}$	$1*10^{-3}$	$2*10^{-3}$	$3*10^{-3}$	$9*10^{-4}$	$7*10^{-4}$	$1*10^{-3}$	$4*10^{-4}$	$9*10^{-4}$	0,83	0,81

Legend:

springs: LG- Luznu gravis; P – Parka

aquifers: lgQ_3bl –aquifer of limnoglacial sediments of the Baltic Ice Lake; $D_3slp(1)$ un $D_3slp(2)$ – Salaspils aquifer, sulphide containing (1) and non-containing (2) water

Fe^{2+}, max – maximal possible concentration of Fe^{2+} assuming that Fe^{2+} should be in equilibrium with $FeCO_3$

Fe^{2+}=det/max - rate among the determined and maximal possible Fe^{2+} concentration calculated theoretically

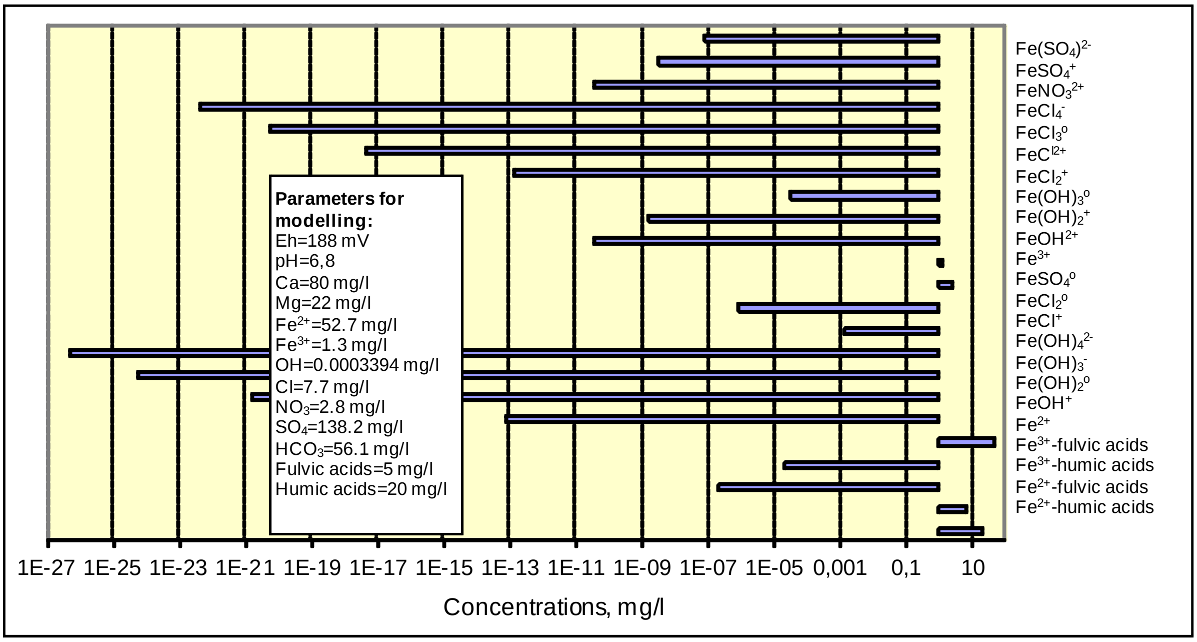

Fig. 4. Iron migration forms in the Baltic Ice Lake limnoglacial sediments aquifer

OH^- ions activity essentially increases if alkalinity of water rises up, but is has to be emphasized that even in case of pH = 7 and fulvic acids - Fe^{3+} ratio = 10, the rather high Fe^{3+} concentrations (10 – 20 mg/l) still remain in the third type of water. It has to be concluded that actual iron concentrations comparing with theoretically calculated ones are significantly higher due to creation of complexes among iron and humic and fulvic acids.

Forming of complexes among iron and organic matter has high hydrogeochemical importance, because:

- hydrolysis of the complex compounds of Fe3+ and fulvic and humic acids is very weak,
- standard oxred value for fulvic and humic acids is lower than for system Fe3+/Fe2+, what determines reduction of Fe3+ in presence of those organic compounds,
- fulvic and humic acids in large extent prevent oxidation of Fe2+ in cases when conditions of aqua – media are changing [7].

Fig. 4 shows distribution of iron migration forms in the Quaternary multi-aquifer in case when concentrations of fulvic and humic acids are relatively low and water does not contain O_2 and sulphides. These conditions are typical for the Baltic Ice Lake limnoglacial sediments aquifer , and the sampled well was located at the eastern part of the Lielais Tirelis bog, where aquifer, to a greater or lesser extent, is recharged by water from the boggy sediments aquifer.

In particular conditions Fe^{2+}, according modelling results, migrates both in form of free ion and complex compounds. Furthermore – the sum of complex compounds is higher than value migration in a form of Fe^{2+}, but Fe^{3+} basically migrates in a form of free ion. Rank of the main migration forms is following:

Fe^{2+} > Fe^{2+}-humic acids > Fe^{2+}-fulvic acids > $FeSO_4$ > Fe^{3+}

Taking into account that Fe^{2+} is one the main oxred forming components in the Quaternary multi-aquifer, it has to be concluded that:

- Fe^{2+} forms complexes not only with fulvic and humic acids, but also with sulphates,
- abnormally high content of Fe^{2+} in the boggy water is determined by low pH causing great increase of migration ability of iron and simultaneous creation of complexes of it with fulvic and humic acids

Distribution of iron in sulphides containing water

Iron migration, according results of investigations, is ascertained also in sulphide containing water (IV type). This occurs due to creation of Fe^{2+} complexes basically with HS^-:

$Fe^{2+} + nHS^- \leftrightarrow Fe(HS)_n^{2-n}$ [4]

Rise up of pH of water determines increase of alkalinity, and consequently increase of concentration of S^{2-} ions. In this case, simultaneously with reaction [4], the following process is ongoing:

$Fe^{2+} + S^{2-} \leftrightarrow FeS)\downarrow$ [5]

Nevertheless the process [5] has only theoretical character in case of the Kemeri – Jaunkemeri occurrence, because pH value normally does not exceed 7.2-7.4.

In general iron concentrations in this type of water are low and very rarely exceed 1 mg/l (maximal concentration is 1.2 mg/l). Simultaneously formation of pyrite (FeS_2) and mackinawite (FeS) was observed in the Salaspils aquifer, where it is recharged by oxygen containing groundwater from the Quaternary multi-aquifer. Oxidation of H_2S^0 and HS^- causes not only decrease of their concentrations, but also destruction of $Fe(HS)_n^{2-n}$ complexes. Process causes increase of pH of water due to involvement of H^+ ion in reactions. This process is described by following equations:

$HS^- + H^+ = H_2S\uparrow$ [6]

$2HS^- + 2H+ + O_2 = 2SO + 2H_2O$ [7]

Concentrations of S^- are increasing in water due to deviation of pH towards alkaline conditions. This, jointly with processes [6] and [7] determines deposition of pyrite and mackinawite. Processes are described by following equations:

$Fe^{2+} + S^{2-} = FeS\downarrow$ 8]

$Fe^{2+} + S^{2-} + S^0 = FeS_2\downarrow$ [9]

Further oxidation of sulphides takes place releasing H+ ion, what leads to decrease of alkalinity. Those processes are describing following equations:

$H_2S + 2O_2 = SO_4^{2-} + 2H^+$ [10]

$HS^- + 2O_2 = SO_4^{2-} + H^+$ [11]

$2SO + 2O_2 + 2H_2O = 2SO_4^{2-} + 4H^+$ [12]

Two iron migration forms - $FeHS^-$ and $Fe(HS)_2^0$ (see Table 1) are dominating in the Salaspils aquifer, where water contains sulphides. They present absolutely dominating part of migration forms – 98.8%. Distribution of other migration forms: Fe^{2+}, $FeOH^+$, $FeSO_4^0$ and $FeHCO_3^+$, is very limited (0,1*%).

Finally it has to be mentioned that maximal actual concentration of iron (1.2 mg/l) in this water is very far from theoretically possible (see Table 1).

III Results, conclusion and discussion

Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as “3.5-inch disk drive”.

If you must use mixed units, clearly state the units for each quantity that you use in an equation.

Study results of the Kemeri-Jaunkemeri occurrence of sulphide containing groundwater allow to provide following conclusions:

1) Mainly Fe^{2+} is distributed in groundwater of the occurrence, excluding particular locations where in aquifers have water containing O_2. $Fe(OH)_3$ absolutely dominates in this type of water.

2) Iron concentration, its migration forms and saturation of water with iron are extremely different not only for different aquifers, but also within the productive Salaspils aquifer as well. Therefore during mixing of various types of water, most frequently, degradation of occurrence takes place. Hereto the main role in those processes is playing oxygen, but presence of iron in water also has rather serious influence – form example, it determinates formation of pyrite and mackinawite. Especially a formation of mackinawite causes serious problems, because the most intensively this process is ongoing in zone of air –water contact in wells (water table fluctuations are 1.2-1.8 m/year), what causes the fast degradation of a well.

3) Results of investigations proved that iron forms complexes with organic matter, in particular case – with fulvic and humic acids what leads to significant increase of total iron concentrations in groundwater rich with mentioned substances. Those organic acids can not be used by sulphate reduction bacteria, but still is opened question – does iron forms complexes with organic substances which may be consumed by mentioned bacteria? This is problem has to be investigated in future in order to understand rate of influence of this process to origin and distribution of sulphides in groundwater of the occurrence.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 251-255

Aeroexpress public transport system introduction in Almaty and its impact on greenhouse gases emissions decrease in Almaty city transport sector

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Abstract. **In Almaty, there are currently more than 500,000 vehicles registered and there is an average of another 200,000 vehicles that enter the city from outlying Almaty Oblasts during working hours. The road network of Almaty has not grown since 1990 when the municipality estimated the number of cars in Almaty to be 100,000.**

Almaty public transport system degrade and became ineffective with significant loss of safety and comfort level by the reason of privatization and occurring of "shadow" taxi at the service market. [1]

Almaty airport is not connected with railway stations Almaty 1, Almaty 2 and city center by a straight and comfortable public transport route. Thus, the prevailing number of airport visitors prefer travelling on personal transport or taxi. Which is, in turn, brings a negative environmental loads. In current circumstances, the Moscow Aeroexpress transport analogue may become a good solution for Almaty.

Keywords: **public transport, greenhouse gases, pollutants, emissions decrease, sustainable transport**

I INTRODUCTION

The primary impacts of this economic growth during 1990s-2000s in Almaty as well as other cities of the former Soviet Union are:

- growth of urban sprawl of these cities, and the rapid increase in the use of private motor vehicles for urban transport;
- large increases in traffic congestion in these cities particularly during peak hours; and
- irregular development of public transport and an associated deterioration in the quality of service delivery.

The viable alternative to private cars should be public transport. Unfortunately, Almaty's public transport has evolved into a system that does not provide for comfort, convenience and efficient services to commuting passengers. Currently, almost all public transport has been privatized; only electric transport (i.e. trolleybuses and trams) is still owned and managed by the municipality under Almatyelectrotrans, a public utility company. Their service, however, is unable to compete with individual cars and private bus operators.

Almaty's public transit has evolved into a system characterized by:

- poorly maintained aged vehicles;
- overcrowding especially at peak hours that allows bus operators to maximize profits;
- lack of services in off-peak hours;
- poor mobility on roads due to traffic congestion and lack of priority for buses; and
- a lack of cleanliness on board. These complaints, however, remain unaddressed by private bus operators, while the municipality lacks control and enforcement mechanisms to ensure compliance of operators with technical and safety regulations and schedules. [1]

Almaty underground may become a good solution as a safe, regular and comfortable transport. But such barriers as small line distance 11,52 km including Sairan and Moscow stations low work load and absence of on ground transport infrastructure connected to underground make it less effective than in other cities. This fact is also aggravated by worsening of economical conditions which followed by the republic of Kazakhstan president proposal to cut funding of underground second turn construction funding. [2]

Thus, soon organization of sustainable passenger transport channel connecting railway station Almaty-1 with the city center turns questionable. Which reflects

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.239

negatively on Almaty environmental conditions as personal transport has significant advantages in this circumstances.

Current paper goal is the evaluation of greenhouse gases (GHG) emission decrease by the introduction of Moscow Aeroexpress public transport system introduction for connection of Almaty city airport on the travel line: Almaty city airport - railway station Almaty 1, railway station Almaty 2, Rosy Bakieyv str./ Tole Bi str. cross (AZTM plant in previous) and definition of other possible positive impacts from such transport system implementation.

Almaty airport is connected with Almaty center by the automobile road (travel time by a taxi or private transport is about 15-30 minutes, depending on the traffic). The airport passenger turnover was 4589000 of people in 2014 year [3], which is about 12572 of people per day.

By the reason of high traffic loads during the rush hours travel time might rise for several times. Which, in turn, brings a negative environmental load of ineffective automobile engines functioning "stop – slow wheeling" regime.

By the experts evaluation, the CO2 emissions from Almaty automobile transport in 2015 year will become 16,8 million of tones, in 2020 – 24.0 million of tones.[1]

II EMISSIONS CALCULATION METHODOLOGY

Transport GHG emissions calculation at the route Almaty airport – Almaty-1 railway station – Almaty-2 railway station – Rozy Bakiyev street and Tole bi street crossing were made according to the United Nations Framework Convention on Climate Change (UNFCCC) \ Intergovernmental Panel on Climate Change (IPCC) "Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories" [4] and National "Road transport GHG atmosphere emissions and emissions reduction calculation methodology" document project [5], containing national emission factors.

The next equations were used:

$$\text{Fuel consumption}ij = nij * kij * eij, \tag{1}$$

where: i = transport kind,
j = fuel kind,
n = transport quantity,
k = kilometers quantity per year [4]

$$\text{Emissions} = 44/12 \sum (\text{Fuel} * \text{EFa}) \tag{2}$$

where:
«Emissions» – emissions in kg;
Fuel – quantity of fuel burnt in TJ;
EFa – CO_2 emission factor, equal to carbon content in one fuel kind (kg/TJ);
a – fuel kind (gasoline, diesel fuel, etc.). [5]

III INITIAL DATA

Analyzing transport routes using online service Google maps and other reference [8, 10,12], the initial calculation data are represented in tables 1-3.

Table 1 – Information on contemplated route parts length. [8,10]

Route part	Average one way length by car	Public transport routes	Average one way length by bus
Almaty airport (Akhmetov str./Maylin str. crossing) – Almaty-1 railway station	8,7 km	Bus №106	8 km
Almaty-1 railway station – Almaty-2 railway station	9,5 km	Bus №2, №73	9,25 km
Almaty-2 railway station – Rozy Bakiyev street and Tole bi street crossing	6,5 km	Bus №37, №59,№100	6,43 km
Almaty airport (Akhmetov str./Maylin str. crossing) – Almaty-2 railway station	12,7 km	Bus №86, №92, №79	12,2 km
Almaty airport (Akhmetov str./Maylin str. crossing) – Rozy Bakiyev street and Tole bi street crossing	18,3km	Bus №106	25 km
Note: *from the airport territory during the night time there is one bus route № 3 to the city center which was not taken into account as the route as uncompetitive with the daytime routes. **From the closest to airport bus station (Akhmetov str./Maylin str. crossing) moving one more route №10 which was also not taken into account as uncompetitive for the route length.			

Table 2 – Airport – city center routes timetable. [9]

Route number	Working hours	Time interval
100	6.00 – 23.40	6 мин.
106	5.26 – 23.26	8 мин.
2	6.10 – 24.00	7 мин.
27	6.30 – 23.00	5 мин.
37	6.00 – 23.45	5 мин.
59	6.00 – 23.53	6 мин.
73	6.10 – 24.00	5 мин.
79	6.00 – 00.00	6 мин.
86	6.00 – 23.30	7 мин.
92	5.30 – 00.10	6 мин.
96	5.30 – 00.10	5-6 мин.

Current paper according major requirements of "Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories"[4] contains disaggregation of transport flow by transport type (gasoline, diesel, natural gas, liquid gas).Table 3 represents required data disaggregation with information on fuel consumption per 1 km.

Table 3 – Transport flow by kind and fuel disagregation.

	Transport kind	Body type	Model	Fuel type	Fuel consumption, l/ 100 km	Fuel consumption, l/1 km
Public transport	Route№79	Bus	Yutong ZK6120HGM	Compressed gas	30	0,3
	Route№2	Bus			30	0,3
	Route№92	Bus			30	0,3
	Route№73	Bus			30	0,3
	Route№37	Bus			30	0,3
	Route№86	Bus	Hyundai	Diesel	22	0,22
	Route№100	Bus	HYUNDAI		22	0,22
	Route№106	Bus	MAN		35	0,35
	Route№27	Bus	DAEWOO		22	0,22
	Route№ 59	Bus	DAEWOO		22	0,22
Personal transport	Eco taxi	Light vehicle	SsangYoung Kyron	Liquid gas	16,85	0,17
	Unoffical taxi	Light vehicle	-	Gasoline	9,3	0,09
	Private vehicle	Light vehicle	-	Gasoline	16,7	0,17
	Private vehicle	General purpose vehicle, off-road vehicle	-	Diesel	13	0,13

IV ESTIMATION

According to observations, from the airport territory and the near bus station by routes №№79, 86,92,106 by every travel arrive/ depart about 3 passengers. Thus, as the airport annual passenger turnover, passenger turnover per day 12572 we obtained the quantity of airport visitors using public transport. (Table 4).

Table 4 – Airport visitors quantity by routes.

Route number	Working hours quantity per day.	Route tour quantity per day.	Airport visitors passengers quantity per day
79	18	180	540
86	17	150	450
92	19	190	570
106	18	135	405
Total		555	1965

Considering obtained figure 1965 public transport passengers one may resume that 10607 (84,4%) airport visitors use personal transport (private vehicles, taxi, unofficial taxi).

Using coefficient 0,5 to determine vehicle quantity streaming to the city center from the airport, thus obtaining 5303 passengers per day.

According to visual analysis of airport parking content about 24% of transport are general purpose

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.239

vehicles. As the significant share in off road transport has diesel engines, we consider that 1273 diesel cars arrive/ depart to airport parking per day. About 10% of vehicles are equipped with gas engines (municipal taxi service ”Eco taxi”) which is equal to 530 cars arriving and departing from the airport territory per day.

Using the above appointed figures one can calculate GHG emissions (Table5).

Table 5. – Transport flow CO_2 - equivalent GHG emissions results.

Transport kind		Fuel type	CO2 emissions, tones/ day	CO2 emissions tones/year	CO2 equivalent CH4 emissiont, tones/day	CO2 equivalent CH4 emissiont, tones/year	CO2 equivalent N2O emissiont, tones/day	CO2 equivalent N2O emissiont, tones/year
Public transport	M.№79	Compressed gas	0,00084	0,31	0,0000051	0,0019	0,00000017	0,000061
	M.№2		0,00052	0,19	0,0000032	0,0012	0,00000010	0,000038
	M.№92		0,00086	0,31	0,0000052	0,0019	0,00000017	0,000062
	M.№73		0,00077	0,28	0,0000047	0,0017	0,00000015	0,000056
	M.№37		0,00054	0,20	0,0000033	0,0012	0,00000011	0,000040
	Group total		**0,0035**	**1,29**	**0,000022**	**0,0079**	**0,0000007**	**0,00026**
	M.№86	Diesel	1,09	398,29	0,00021	0,08	0,00021	0,08
	M. №100		0,6	230,71	0,00012	0,05	0,00012	0,05
	M. №106		3,2	1168,61	0,00062	0,23	0,00062	0,23
	M.№27		1,5	530,06	0,00028	0,10	0,00028	0,10
	M.№ 59		0,7	260,78	0,00014	0,05	0,00014	0,05
	Group total		**7,09**	**2588,45**	**0,0014**	**0,51**	**0,0014**	**0,51**
Personal transport	Eco taxi	Liquid gas	**0,000034**	**0,01**	**0,0000099**	**0,0036**	**0,000000032**	**0,000012**
Personal vehicle	Unofficial taxi	Gasoline	6,9	2531	0,012	4,42	0,0012	0,43
	Private vehicle	Gasoline	12,5	4545	0,022	7,94	0,0021	0,77
	Private vehicle	Diesel	8,6	3120	0,002	0,61	0,0017	0,61
	Group total		**28,00**	**10196,00**	**0,04**	**12,97**	**0,01**	**1,81**
	TOTAL		***35,***	***12786***	***0,04***	***13,48***	***0,006***	***2***

Discussion. Analysing the GHG emissions figures it is clear that the most input occurs from private vehicles functioning on gasoline and diesel fuel. The considered public transport input occurs only from Diesel engine buses and equal to 20% vs.79,8% from private vehicles (Diagram 1).

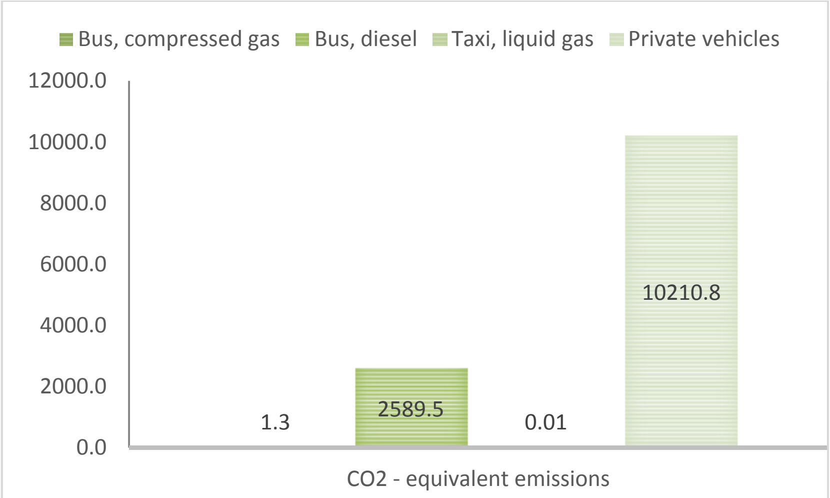

Diagram1 – GHG emission from various transport kinds within the explored route transport flow.

V CONCLUSIONS

1. As one can see the analogue of Moascow city Airexpress transport system functionin at the line Almaty city airport - railway station Almaty 1, railway station Almaty 2, Rosy Bakieyv str./ Tole Bi str. cross providing regular passenger conveyance along with some restrictions in separate groups of vehicles entering to the airport territory, excluding public transport, official taxi and flight passengers personal vehicles can decrease GHG emissions up to 5700 – 2500 tones annually.
2. Such measures will promote public transport infrastructure turning it to more sustainable transport system and improving passenger conveyance safety and comfort.
3. This introduction will positively reflect on Almaty city environmental conditions and reputation as of the modern mainstreaming city and meeting its obligations in terms of international agreements and conventions.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 256-260

Investigation of European shot-hole borer, *Xyleborus dispar* (Coleoptera, Scolytidae), in apple orchards of Latvia

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Abstract. **European shot-hole borer is known to occur on a wide range of deciduous trees and frequently found on fruit trees in most of the Holarctic. During the last years increased activity of this beetle contributed necessity for investigation of it in apple orchards of Latvia. Because of the latent behavior it is difficult to control distribution of *Xyleborus dispar*. Often insecticides are not effective, especially if not used in an appropriate time and methods of integrated or biological plant protection are needed. In the current study, results of two year monitoring of *X. dispar* flying activity and effectiveness of two types of sticky traps, Rebell Rosso and Csalomon Palx, bitted with 50% alcohol are presented. Four traps of each type were placed in each orchard at the beginning of May in 2013 and at the middle of April in 2014. Differences among respective orchards were recorded: the highest number of beetles was found in the largest orchard surrounded by wide deciduous forests; the lowest number was recorded in the orchard surrounded by the agricultural lands. The first emerging *X. dispar* female was caught at the middle of April. During the vegetation season the highest flying activity of beetles was at the end of April - beginning of May (17th – 18th week). Afterwards number and flying activity of beetles decreased and at the middle of June (25th – 26th week) reached zero. In orchard with the highest number of European shot-hole borer, significantly higher number of beetles was recorded on Rebell Rosso traps; for the rest two orchards higher number of *X. dispar* was recorded on Csalomon Palx traps.**

Keywords: **ambrosia beetle, sticky traps, monitoring.**

I Introduction

Ambrosia beetle, European shot-hole borer *Xyleborus dispar* F. is known to occur on a wide range of deciduous trees and frequently is found on fruit trees in most of the Holarctic. *X. dispar* attacks almost all deciduous tree species in the forests, as well as city-growing trees like *Crataegus*, *Sorbus*, *Acer*, *Castanea* [1,2]. This beetle is an important pest in orchards and vineyards in Europe [3-11]. Young apple, pear and stone-fruit trees are those mainly attacked by *X. dispar* and sometimes damage caused in orchards results in significant yield losses [10,12].

Ambrosia beetles spend their entire life within a woody stem and generally prefer weakened or stressed trees [10]. In spring, first adult females emerge at temperatures 14–20 °C [9,13], fly for considerable distance and make holes in sapwood, where they lay eggs and a new generation develops. Imagoes overwinter within the sapwood galleries. *X. dispar* establishes a complex symbiosis with fungus *Ambrosiella hartigii* that allows larvae to develop in wood tissues, which are poor in nutrients [6].

There are no studies in Latvia concerning the European shot-hole borerdistribution. However, some authors have mentioned these beetles as pests in orchards [14-16]. According to the recent observations, the damage of *X. dispar* is gradually increasing [17, Salmane et al. unpublished data].

The development of insecticide resistance and concern about the detrimental effects of these chemicals on non-target arthropods, the environment, and human health have increased interest in alternative insect control agents [8]. There are very few publications on use of ethanol-baited traps for Scolytidae attraction purposes in Europe (Slovakia, France and Greece) [18-20]. Ambrosia beetles are attracted to ethanol because of their preference for aged wood characterized by anaerobic respiration-generated ethanol [20-22].

The aim of the present study was to monitor flying activities of *X. dispar* and effectiveness of two types

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.279

of sticky traps in limiting the numbers of these pests in orchards in conditions of Latvia.

II MATERIALS AND METHODS

This study was conducted in the three commercial orchards of Latvia and during the 2013 and 2014 monitoring of *Xyleborus dispar* was performed. The study was conducted in Jelgava, Beverina and Talsi municipality to cover various climate conditions (Fig.1).

Two types of traps, Rebel Rosso (Andermatt Biocontrol, Switzerland) and Csalomon Palx (Plant Protection Institute, Czech Republic) sticky traps with 1 liter plastic bottles bitted with 50% alcohol were used. Four traps of each type were placed at each apple orchard in two parallel lines and hung out about 1 m above the ground. Alcohol was changed every week during the assessment time. Traps were placed in the apple orchards at the April 30 and May 1 in 2013 and on April 8–9 in 2014. Assessment was made once a week and beetles were counted until no beetles were found. Means and standard deviations were calculated using Excel (Microsoft Corporation). Significant differences between trap types, orchards and in respect to time were evaluated by ANOVA using a Tukey-Kramer test. Correlation between the number of insects and climate variables was estimated using KaleidaGraph 4.5 (Synergy Software).

Fig. 1. Map of Latvia with location of study sites.

III RESULTS AND DISCUSSION

In 2103, sticky traps were installed in time which already coincided with a peak of flight activity of *X. dispar* adult females, as indicated by the number of captured insects (Fig. 2). In 2014, traps were installed before any flight activity of *X. dispar* started.

The overall tendency was to have higher numbers of captured *X. dispar* individuals on Csalomon Palx traps. The total number of individuals on Rebel Rosso traps was 2862 and 4376, in 2013 and 2014, respectively, while it was 4893 and 5741 on Csalomon Palx traps. However, statistically significant higher average number of captured individuals on Csalomon Palx traps in 2013 was found only on week 19 in Beverina municipality and Jelgava municipality, and in 2014 on week 17 in Jelgava municipality, and on week 21 in both Beverina municipality and Talsi municipality. In contrast, statistically significant higher number of captured individuals on Rebel Rosso traps was found in 2013 in Beverina municipality on weeks 21 and 22, and in Talsi municipality from week 19 till 23.

Comparing the efficiency of different sticky trap types, the total number of *X. dispar* caught by Csalomon Palx was higher in both 2013 and 2014. Still significantly higher number of beetles on these traps was found on separate weeks more related to the beginning of flying activity, and significantly higher number of *X. dispar* on Rebell Rosso traps was found in few weeks at the middle or closer to the end of the flying period. Some authors have admitted Rebell Rosso traps as the most efficient and practical trap type [11,13,20,23]. Rebell Rosso sticky traps have been compared with Mastrap L traps and considered to be more efficient [6] or equially efficient [9] in hazelnut plantations. However, modified Mastrap L traps are considered to be more selective and friendly to the environment, as other insect species are captured by red winged traps in addition to *X. dispar* [9]. Some other authors suggest that Rebell Rosso traps are not as efficient as funnel-type and ribbed cage traps [5]. In the present study it seems that in the case of high flying activity both types of traps are equal or Rebell Rosso are more efficient, but in the case of low activity Csalomon Palx traps are more efficient.

In both years, significantly higher number of *X. dispar* was captured in orchard in Talsi municipality, 5488 and 5383 individuals in 2013 and 2014, respectively, in comparison to Beverīna (1287 and 3268) and Jelgava (980 and 1466) municipality. The assessed orchards were situated in various climate and landscape conditions. Orchard in Jelgava municipality is surrounded by agricultural lands, near orchard only single old lime-trees and oaks are located. Probably that is a main reason why the least number of *X. dispar* was caught there (Fig. 2A). Orchard in Beverina municipality is surrounded by fragmentary mixed-pine forests, but along the one of the longest sides are growing row of tall deciduous trees. The higher number of beetles was recorded there in comparison to previous orchard, still it was almost half of the number found in Talsi municipality (Fig. 2A, C). Higher number of beetles was recorded in 3 of 8 traps, located closer to the large deciduous trees. Orchard in Talsi municipality is densely surrounded by wide deciduous forests and by fruit orchard from one of sides. The highest number of *X. dispar* was recorded in this orchard. It is well known that the European shot-hole borer attacks many deciduous tree species and closeness of forests may significantly increase number of *X. dispar* in orchards, as they prefer sunny and dry places instead of shaded forests [2,7,12,24]. Consequently, closeness of orchard to forest can directly increase the number of beetles caught in traps.

There were pronounced differences in flight activity of European shot-hole borer between two years. In 2014 it started earlier and had two temporarily separated peaks in all three sites. While the first maximum of flight activity coincided for the sites, the second peak occurred on different weeks. The differences of flight activity in timing in 2013 and 2014 were related to differences in respective climatic conditions between the two years and are analyzed in more detail for 2014.

The first flight activity coincided with the increase of average air temperature above some threshold value, which was 10.0, 10.6 and 9.3 °C in the case of Beverina (Fig. 3A), Jelgava (Fig. 4A) and Talsi apple orchard (Fig. 5A), respectively. The first peak of flight activity coincided with relatively low average air humidity (part B of the respective figures) and low level or even no rainfall (part C of the respective figures). However, the number of captured individuals started to decrease in the second (Jelgava and Talsi orchard) or in the third week (Beverina orchard) of active flight, which coincided with decrease in average temperature as well as increase in both air humidity and the amount of rainfall. The second peak of flight activity coincided with low air humidity in Beverina and Talsi orchards but not in Jelgava. In Jelgava site active flight was evident even in the week with relatively high rainfall level.

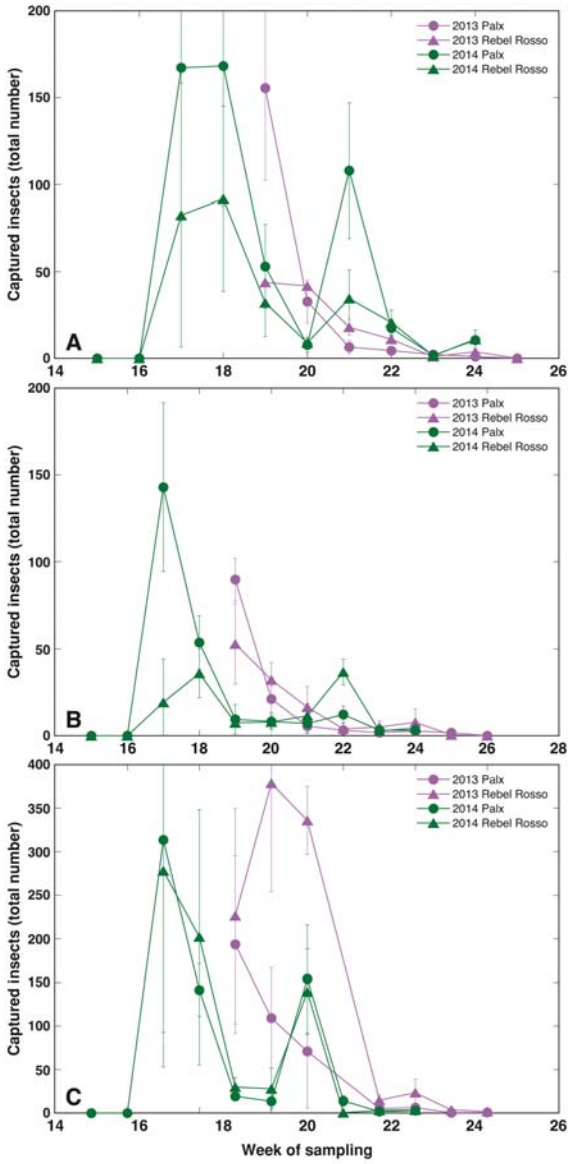

Fig. 2. Comparison of captured number of *X. dispar* individuals depending on trap type and year of study in different sites. A, Beverina municipality; B, Jelgava municipality; C, Talsi municipality. Data are means ±SD.

Because of the evidently complex relationship between the flight activity of *X. dispar* from one side and average temperature, air humidity and the amount of precipitation from the another, the correlation between the activity and climate variables was relatively low (R = 0.26, R = 0.15, R = 0.34, for temperature, humidity and precipitation, respectively). Several authors have noted a negative correlation between rainfall and flying activity of European shot-hole borer [6,9,24]. In the present study one case at Jelgava municipality was found with active beetle flight during the rainy period. Possibly the more active rain was at night hours while *X. dispar* is capable for active flying only during the daytime.

Time of emergence of adult females is various depending on weather conditions of the respective season as well as on North-South location. Dependence of the start of flight activity on the average air temperature in spring was shown by several authors. In more southern-situated regions like Italy, Turkey, Switzerland this temperature threshold was higher, 18–22 °C, in comparison to northward, above 10 °C [3,13,11,24].

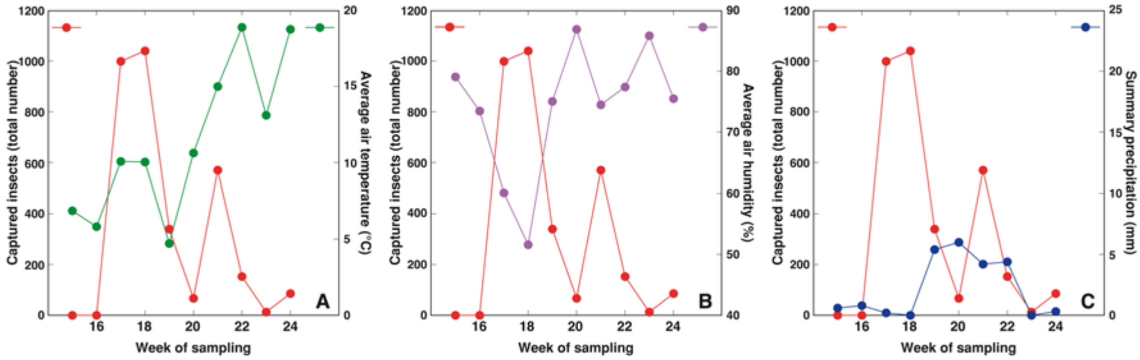

Fig. 3. Relationship between the total number of captured *X. dispar* individuals and average air temperature (A), average air humidity (B) and summary precipitation (C) on site in Beverīna municipality in 2014.

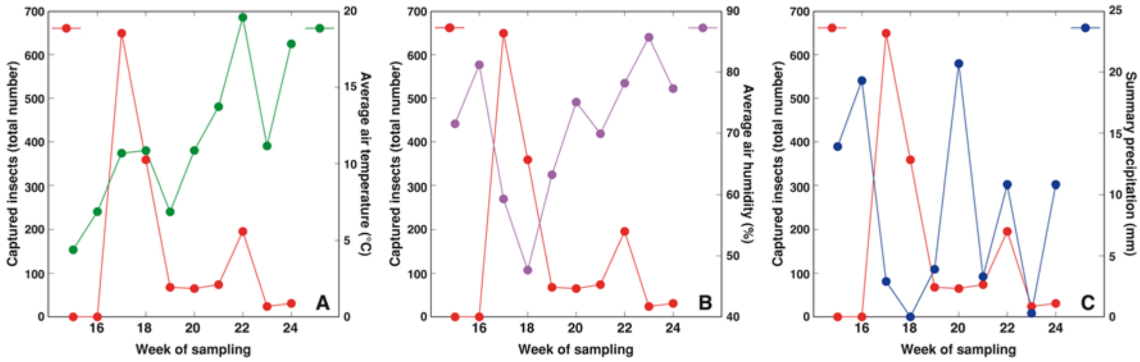

Fig. 4. Relationship between the total number of captured *X. dispar* individuals and average air temperature (A), average air humidity (B) and summary precipitation (C) on site in Jelgava municipality in 2014.

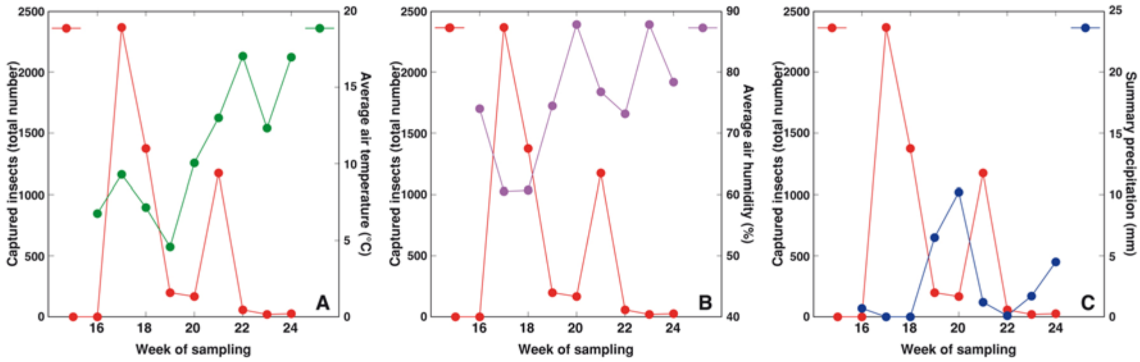

Fig. 5. Relationship between the total number of captured *X. dispar* individuals and average air temperature (A), average air humidity (B) and summary precipitation (C) on site in Talsi municipality in 2014.

IV CONCLUSIONS

Number of the *Xyleborus dispar* was significantly higher in orchard located close to the forest, especially deciduous one. Single large deciduous trees also may play impact on *X. dispar* reproduction and dispersal. Flying activity is affected by climatic conditions in long term, as well as in the respective day. The first emerging *X. dispar* was caught at the middle of April in 2014. During the vegetation season the highest flying activity of beetles was at the end of April – beginning of May (17^{th} – 18^{th} week). Afterwards number and flying activity of beetles decreased and at the middle of June (25^{th} – 26^{th} week) reached zero. In orchard, where the highest number of European shot-hole borer was found, higher number of beetles was recorded on Rebell Rosso traps, in the rest two orchards higher number of *X. dispar* was recorded on Csalomon Palx.

V ACKNOWLEDGEMENTS

This study was performed by the project Nr. 211211/c-120 funded by the Ministry of Agriculture, Latvia.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 261-266

The role of collaboration municipality – regional university in sustainable tourism development: Case study of Dagda county

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Abstract. **Research of different studies related to collaboration municipality ─ university allows to establish a fact that it is very important for both partners and has distinctive forms. The core questions of this research are as follows: Is the regional university significant player in regional sustainable tourism development? What forms of collaboration among regional university and municipality are possible? The aim of this research is to examine the experience of regional university in sustainable tourism development in regional area. This research is performed on the illustration of collaboration among regional university (Rezeknes Augstskola) and Dagda county, which is one of the 19-th rural county in Latgale region. A new approach to the collaboration municipality ─ regional university is offered taking into account the possibilities of regional university in improvement of human resources capacity, in improvement of municipality administrative capacity, and in development of sustainable tourism products. The offered approach was set up by taking into account the interests of all stakeholders in this area.**

Keywords: **sustainable tourism, collaboration, municipality, university.**

I INTRODUCTION

The Latgale planning region (Latvia) includes 19 counties. Each of them has developed own Development programme, which includes an strategical part (further- Strategy). The strategical directions of the county development are defined in its Strategy. Each county of Latgale region forseens '*Tourism development'* as one of the strategical direction. Tourism is the most environmentally friendly industry. This direction is based on picturesque environment with many lakes, rivers, and forests, rich culture and historical resources, e.t.c. In spite of this the main resources for tourism development are human resources, which are capable to transform tourism resources in attractive and sustainable tourism products. Kamalanabhant,T.,and Nagaraj,I. [1] underlined, that human capital is a relevant source of economic growth. Human resources should have the valuable distinctive competencies with aim to create a competitive advantage. The major challenges for the tourism business were defined by Cooper et.al [2]: the challenges facing the tourism industry will only be met successfully by a well-educated, well-trained, bright, energetic, multi-lingual and enterpreneurial workforce who understand the nature of tourism and have professional training. A high quality of professional human resources in tourism will allow to gain a competitive edge and deliver added value with their service.

By the *Municipality Law* the each municipality is responsible for improvement of business environment into its territory. Improvement of business environment is extended to the tourism business environment as well. There are many aspects of tourism sustainability like the municipality policy related to protection and maintanance of tourism resources, the attitude of local inhabitents to tourism development [4] and their willingness to take part in this process, e.t.c.. This study includes exclusively one aspect: opportunities of collaboration among municipality and regional university for tourism sustainable development in the territory of the county.

The aim of this study is to analyse the role of regional university in sustainable tourism development in regional area by use the illustration of collaboration among regional university (Rezeknes Augstskola (further ─ RA)) and Dagda county, which is one of the 19-th rural county in Latgale.

The '*Nature tourism development'* as the strategical direction is defined in the Strategy of Dagda county[3].

To achieve this aim several objectives are defined:

- to interpret the theoretical aspects related to collaboration municipality ─ university;

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.266

- to examine the experience of regional university in sustainable tourism development of the county;
- to create a new approach to development of the sustainable tourism offer in regional area by use collaboration opportunities among municipality and university;
- to develop conclusions about collaboration opportunities among municipality and university.

Research object: Collaboration municipality — regional university.

Research subject: Factors, which influence on sustainable tourism development by use collaboration among municipality and regional university. Hypothesis of this research: It is possible to promote sustainable tourism by use the collaboration opportunities of municipality — university. This collaboration recovers new creative potential in tourism development and provides its sustainability.

To obtain the objectives of this study the following research methods were used: content analyses, analysis and synthesis, logical and abstract constructive methods.

Research base - Dagda county.

II THE THEORETICAL ASPECTS OF COLLABORATION AMONG MUNICIPALITY AND UNIVERSITY

Nowadays the cooperation among universities and municipalities takes part in many countries in different forms. Thus for instance Linkoping municipality (Sweden) 'sees universities, colleges and other educational institutions as key partners for the development of its own activities, for community development as well as business growth in the municipality and the region. Having a successful university within its community also brings with it the challenge of offering an open and proactive municipal organisation that can exploit the results of research and education.' [5]. Linkoping municipality has developed Strategy for cooperation with universities and colleges. There are three fundamental reasons for collaboration with universities, colleges and other educational institutions defined in this strategy [5].

1) The municipality needs the skills, resources and results that come with the university in order to improve and develop its operations. If the municipality is to offer its citizens the best possible service, it requires competence that is based on recognized expertise, proven experience and the latest knowledge in science. Collaboration with the university is also important for Linköping so that it may strengthen the development and growth of the municipality as well as the region.
2) Close cooperation with universities is vital from an employment and growth perspective. Proximity in particular to Linköping University and its research resources, benefits not least the establishment of knowledge-intensive businesses and activities but also contributes to the establishment of more service operations. Therefore the university supports the municipality's aims to develop a broader business and labour market for greater economic sustainability, increased range of choices as well as contributing towards greater development dynamics.
3) Growth in the number of students in Linköping and in the region also increases the municipality's skills and recruitment base thus contributing positively to the municipality's potential for a positive population growth. The possibility to recruit foreign students also provides opportunities for wider international exchange with access to a larger range of goods, to the services market as well as increased resources for research. Attractive job opportunities, a rich cultural life and ample leisure activities are also important factors for universities if they are to attract staff and students.

The main tasks defined in this Strategy [5]are as follows.

1. The municipality should play a leading role in creating good cooperation with universities and colleges, with particular emphasis on interaction with the students.
2. The municipality should support the establishment and growth of research and development environments that are of importance for the municipality, the business sector and local residents.
3. The municipality should collaborate with universities and colleges within those areas that promote the municipality and its residents as well as the local and regional business community. The municipality will also support entrepreneurship and new enterprises originating from universities and colleges.
4. The municipality should take advantage of the universities and colleges as a resource for the organisation of the municipality ensuring development is based on recognized research and proven experience. The municipality's various departments are to collaborate with universities and colleges in the fields of research and development.
5. The municipality should provide attractive environments in which to live; social and community services that attract students and researchers to establish in the community.

Postma,J [6] examined the cooperation of Twente university (Netherland) with local municipality in social sector. Reseacher noted that small municipalities are advised to pick the form that best suits their needs. Postma,J [6] defined the criteria which allow to most effectivily realise collaboration with universities in social sector. They are as followings: trust, number of participants, goal consensus and need for network ─ level competencies:

Abrahamson and Fairchild [7] have passed an opinion that 'academics may be losing out to other members of the fashion setting community, such as consultants and gurus, in terms of their ability to influence practice.'

Birkenshaw, Hamel and Mol [8] suggested to 'academics to become more creative in the development of new ideas and thought experiments that organizations might put into practice'. They had offered the form of cooperation such as innovation laboratory of London Business Schools' MLab, where researchers and practitioners come together to develop new practices in partnership.

Lennart Nilson,Mickael Planasch [9] noted, that 'cooperation universities ─ municipalities is less common than with companies and industries. Cities take up students for Project work less often probably because they are also(local) authorities. Industries may use 15% of the budget for development of products and research. Cities use close 0%! The most important issues for cities are: waste, energy improvement, investments, economic restructuring, identity and cultural belonging, integration and poor neighborhoods.' These issues are defined in the Project on sustainable city development in the Baltic sea region 1999-2007 consisted of 30 cities, 15 universities, 9 countries

Lennart Nilson,Mickael Planasch [10] had defined the advantages of municipality ─ regional university cooperation for the students, for the company/municipality, and for the university. They are as follows.

For the students:

- many of the thesis Project lead to employment,
- the student does not need to take study loan during thesis,
- opportunity to find out if they would want to work at the company.

For the company/municipality:

- gets a valuable/competent help to get a problem solved or job done that they would not have resources for;
- chance to test a potential new employee;
- competence development.

For the university:

- pedagogic advantages;
- research posibilities;
- competence development.

The Sami university College as well as UiT/The Arctic University of Norway successfuly colloborate with municipalities of Avjuvarri Indigenious region. These universities has developed new study programmes and other training programmes with focus on Sami language and culture as potential sustainable sources for new businesses based on traditional Sami culture [10]

International cooperation among municipalities and universities has significant role because of obtaining new cognitions, experience and knowledge. Thus Rezekne (Latvia) city council [11] entered the public organization „Union of the Baltic Cities"in 1994. In cooperation among Rezekne city Council, Rezeknes Augstskola, and Kalmar municipality (Sweden) the Tourism Commission was set and managed by representatives of both municipalities.

The collaboration municipality ─ university allows to get new contacts, to implement of municipal work into real life that is based on knowledge, and opportunity to apply for international projects. Thus the main objectives of the Operational Programme IPA Slovenia-Croatia 2007 ─ 2013 project 'Living, lived revived cultural heritage" [12] were as follows:

- to support the preservation and revitalization of cultural heritage and thus strengthen the identity;
- to strengthen and develop the knowledge and capacities for heritage preservation, revitalization, and presentation;
- to support the inclusion of cultural heritage among assets for the development of the cross border area.

The added value of this Project was in a higher rate of integrating common material and non-material cultural heritage into the sustainable tourist offer, in new tourim products and in the promotion of the entire cross border area as a tourist destination in new forms and with an improved offer and a better use of natural and cultural resourses, which will ensure new sources of income for the rural areas. There will also be a possibility for the local population to participate in cultural and tourist activities.

The municipality/university(Greece, Romania, Bulgary) collaboration work : Interreg IVC2011 project „Innovative and responsible tourism territories" [13] promotes creation of innovative tourism products linked to the endogenous resources as a fundamental principle of responsible and sustainable tourism.

III III EXAMINATION THE EXPERIENCE OF COLLABORATION AMONG DAGDDA COUNTY AND REGIONAL UNIVERSITY (RA) IN DEVELOPMENT OF SUSTAINABLE TOURISM

Dagda county Development Programme 2013.-2019 [3].indicates that one of the Programme's priority is Improvement and Diversification of Tourism products. Programme does not forsee improvement of county's competitiveness by Human resources management, related to people who are involved in Tourism development process [4].

The Action plan of this Programme[3] does not forsee any education activities related to Tourism development as well. Nevertheless creation of new tourism products with high competitiveness reguires performers with new knowledge and new skills. It means, that successful county's strategy implementation reguires well educated and high skilled human resources who are involved in implementation of county's strategy. For development knowledge, skills, and experience of people the action plan should involve activities which provide them. Creation and development of these factors build the base for qualitative and sustainable development of tourism products. Taking into account above mentioned, the following Implementation model of new Natural Tourism product is reflected in Fig.1.

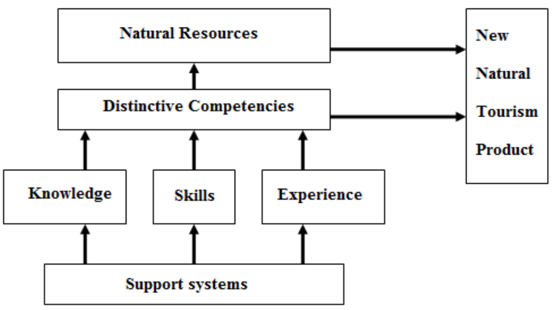

Fig.1.Implementation model of new Natural Tourism Product [15]

This model of implementation of new Natural Tourism Product [15] offered taking into account support systems which related to people, who are involved in creation of new tourism products. Support systems should provide development of knowledge, skills, and experience for these people. Support systems should ensure competitiveness and sustainability of Tourism products in total.

Related to Dagda county. Tourism education opportunities are offered in RA (50 km from Dagda) in bachelor and master level. It is necessary to strengthen cooperation between Dagda county and RA with aim to prepare high quality specialists in tourism field for Dagda county[15].

The agreement about collaboration among RA and Dagda county was signed 3 years ago. This agreement forsees cooperation in the education and research area. Dagda county is one of the rural county in Latgale. It encompasses wide-ranging of natural tourism resources as Razna National park, which includes many lakes, rivers, hills and forests, biodiversity, and ecosystems diversity. Cultural landscape roads P52, P60, P61, P57, P55 via Dagda are important tourism resources for nature tourism development. They are valuable for creation of cycle tracks. Dagda county offers unique cultural heritage, rich history of crafts and revival of crafts' traditions, etc. In accordance with spatial structure of Latgale's region, Dagda county is included in tourism development territory 'Ezerzeme'. Taking into account rich natural resources in the county one of the county's economical specialization defined in Dagda county development programme 2013.-2019 is as Nature Tourism (in the regional, state and European level). Dagda county Vision is defined as 'Dagda county is multifunctional county in Latgale region, where people are active and pleased with their life. There are well developed small businesses, processing of agriculture products with high added value, and natural tourism in this county'. Natural resources and physical cultural resources are important assets for regional competitiveness. There are close link between environmental resources and regional development Further analyses will be related to the county's specialization- *Nature tourism.*

The professional bachelor study programme „Enterprenership" which includes Tourism Management speciality is realized in RA. Under supervision of academical staff the students of this study programme are involvement in this collaboration process. The greatest contribution of students is their creative approach to development of sustainable tourism products. R. Florida [14] underlined, that creativity is able to become significant drive force in regional development.

The main tasks provided by RA students during their internships in Dagda county are as follows:

- to coordinate their activities related to development of new tourism products with local representatives of municipality;
- to research the notable places in Dagda county for development of hiker's routes, cycle routes, auto routes and other tourism products;
- involvement of pupils from local secondary schools in development of new tourism products;
- involvement of local inhabitents in development of new tourism products;
- to formulate a positive opinion of local inhabitents about sustainable tourism development in Dagda county;
- to work out the hiker's routes, cycle routes,and other tourism products and to approbate these new tourism products;
- to submit the concepts of new developed tourism products for approval in Dagda county Council;
- to formulate the findings of their research about the sustainable tourism development in the study works and the graduate works;

- to inform local inhabitants about benefits of sustainable tourism development in Dagda county;
- to present their findings to local municipality Council.

The main links for partnership municipality ─ university which takes place among Dagda county and RA are ilustrated in the tab.1. This collaboration should give the remarkable affects in short term and in long term as well.

TABLE 1.
The main links of partnership municipality ─ university

Links	Short term affects	Long term affects
Human resources training	Training courses in tourism guides programme by involvement of local population Training of municipality inhabitants: Training courses in development of tourism service Training courses in managemenwt of sustainable tourism for local authorities	Improvement administrative capacity in tourism area Consulting Competence development for both sides Valuable and competent help in human resources development
Entrepreneurship	Students of RA have practical placements in the municipality territory. Students develop innovations ─ new tourism products Chance (for municipality) to test a potential new employee	New work places for alumnus in the municipality: High skilled specialists in tourism area will be recruited.
Research	Students together with local people make explorations of remarkable places for development of new tourists' products. Research of the Gastronomy and Naturer tourism opportunities in Dagda county Students perform the Concepts of new tourism products and present their at the Council of Dagda county The main results are prepared and as study works or graduate works are defended in RA and presented to the Dagda county Council. These research works are donated to Council of Dagda county. Scientific publications Use scientific knowledge within municipality in tourism product development	Use scientific knowledge within municipality in working up of tourism marketing development strategies e.t.c. Research posibilities for RA
Research partnership	Exploration of particular tourism products	Transfer scientific knowledge within municipality Join projects Research related activities, consulting.
Informal interaction	Formation of social relationships for Dagda county as the tourism destination. territory. Involvement local population in tourism business.Involvement local domestic producers. Meetings, seminars	Conferences Local population aware benefits from sustainable tourism. They are interested in sustainable tourism development and are involved in tourism business. Domestic producers are involved in tourism service.

The new approach to collaboration municipality ─ regional university is offered taking into account the possibilities of regional university in improvement of human resources capacity, in improvement of municipality administrative capacity, and in development of sustainable tourism products

This approach to collaboration municipality ─ regional university in development of sustainable tourism takes into account the following aspects (Fig.2.):

- improvement and diversification of Tourism products by use students' creativity and their new view on development of tourism products;
- training and education activities related to sustainable Tourism development in county area by use capacity of the university;

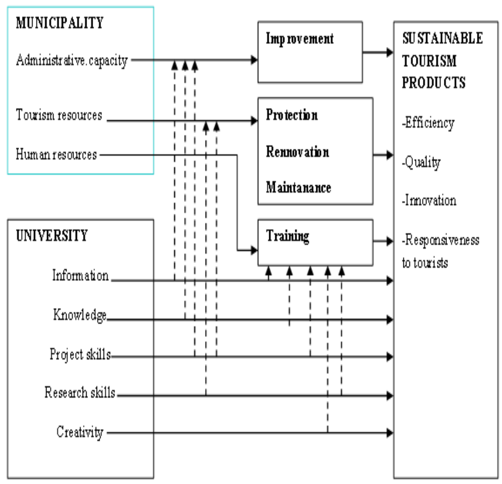

Fig.2. The model of the municipality ─ regional university collaboration in development of sustainable tourism

- improvement of administrative capacity of county by use research and knowledge capacity of the university;
- improvement of county's competitiveness by Human resources management, related to people who will be involved in implementation of the Tourism Development programme;
- maintenace and protection of natural tourism resources which are the base of sustainable nature tourism products.

IV CONCLUSION

Regional university is significant player in regional sustainable tourism development. The forms of collaboration among regional university and municipality are different: training, research partnerships, transfer of knowledge, joint projects e.t.c. 'Universities act as an important driver of economic development and catching up through their role in education and technology absorption, adaptation, and diffusion' [16]. The author offers new approach to collaboration municipality – regional university for development sustainable tourism in regional area. This approach was formed by improvement of municipality's administrative capacity and county's human resources capacity in the field of tourism, and by protection and maintenance tourism resources. The offered approach was set up by taking into account the interests of all stakeholders in this area .

The collaboration among Dagda county and RA during three years proves by facts that it is possible to promote sustainable tourism products by use the following collaboration opportunities: training courses for people of the local municipality who are involved in tourism development activities, involvement inhabitants of the local municipality, involvement academical staff and students in development of sustainable tourism products. Regional university brings into tourism development a new creative potential.

V ACKNOWLEDGMENTS

This study was made feasible by thanks to Dagda county authorities, who are interested in tourism sustainable development in their county, by thanks to internship students of Rezeknes Augstskola who helped to effectively implement tourism products development activities under arrangement between Rezeknes Augstskola and Dagda city county.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 267-273

Amount of Air Ions Depending on Indoor Plant Activity

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Abstract. **Literature sources and earlier researches state that plants may be able to produce a variety of air ions, including negative light ions. In this article, the regularity of influence of plants on the number of ions in the room is being proved, basing on a series of experiments performed with the following plants: Spathiphyllum, Scindapsus, Strobilanthes, Chlorophytum and Pinus mugo. It was concluded that plants, in general, are able to stabilize the indoor ion concentration and reduce its fluctuations. The plants help to increase the concentrations of negative ions and decrease the concentration of positive ones, however the optimal and "healthy" ion concentration was not reached. Plants without artificial illumination work more as ion reducers, not producers.**

Keywords: **air ions, plants, microclimate.**

I INTRODUCTION

Under normal circumstances (temperature 0°C, pressure 760 mmHg), one cubic meter of air contains $2{,}5.10^{25}$molecules. They are in a constant thermal motion, moving randomly and colliding continuously with each other. Very soon, the light atomic or molecular ion attracts conglomeration of molecules and becomes intermediate ion with a much greater mass and lower mobility [1]. When settling on micro-particles, aerosols, dust, etc., these ions are converted into heavy and super-heavy air ions having a large mass and even smaller mobility. These are not ions any more but rather charged aerosols whose concentration depends entirely on the purity of the ionized air [2].

Small air ions are constantly being produced in nature by radioactive components of the soil, by cosmic rays, by the shearing of water droplets, etc. In clean air they can exist for several minutes, but their numbers are depleted by air pollutants, by stray electrical fields and by the mere presence of occupants in a room. Almost always there is a fluctuating equilibrium between ion formation and ion loss [3]. Under normal conditions there is a small difference between the positive and negative ions on the ground floor level in the atmosphere. Any disturbance of ion balance has direct impact on living organisms [4].

The presence of negative air ions (NAI) in the inhaled air is essential for normal functioning of human and animal organisms [5]. Scientific research indicates that the air within homes and other public or office buildings can be more seriously polluted than the outdoor air. Public concern about the effects of indoor air pollution on health has resulted in expanded research of the topic [6]. Some countries have already elaborated legal framework for air ion concentration in work rooms. On 16 June 2003, sanitary and epidemiological rules and regulations "Hygienic Requirements for the Air-Ion Level of Industrial and Public Facilities SanPin 2.2.4 1294-03" [7] (Санитарно-эпидемиологические правила и нормативы "Гигиенические требования к аэроионному составу воздуха производственных и общественных помещений СанПин 2.2.4 1294-03") entered into force in the Russian Federation. According to these Requirements, optimal concentration of light negative ions amounts to 3000 – 5000, while concentration of positive ions should be half as much. However in most cases, the concentration of favorable light, negative air ions indoors does not exceed few dozens, while the concentration of harmful positive ions is growing rapidly, especially if there are people, TVs, computer monitors and similar devices in the room [8].

Ions are particles of the air that have either positive or negative electrical charge. In natural environment they are usually produced to maintain a healthy ratio, but in artificial environment of air conditioning, electrical equipment, fluorescent lighting and even synthetic clothing the balance can be seriously affected [9]. NAI concentration decreases considerably or even falls to zero in the polluted air of cities, in closed and air-conditioned rooms, near operating household and office equipment. The absence of NAI in the air may cause health disorders, whereas inhaling the NAI-enriched air improves health and human comfort [10]. Besides, practical field testing reveals that the somnolence, apathy,

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.247

headaches, etc. ascribed to the "dead" air in enclosed spaces can be conquered effectively by supplying moderate concentrations of negative ions [3]. Air ions may be healing or may harmfully affect human health. This effect depends on ion concentration in the air and on proportions of positive and negative ions. These proportions are characterized by unipolarity coefficient

$$K = \frac{n^+}{n^-}, \quad (1)$$

where n^+ and n^- mean concentration of positive and negative cluster ions.

Interaction of air ions and plants may be expressed in various ways, and nowadays this topic is being studied. Artificially controlled environment of air ions in greenhouses is experimentally used to harvest more vegetables [11] because ionized air particles contribute to a faster exchange of substances in plants [12]. However, numerous cases show that air ions in combination with strong anthropogenic atmospheric pollution can also enhance negative effects on plants. Air ions of different classes, products of radon gas decay and charged aerosol particles which are spread in the atmosphere are considered to be factors causing damages of tree foliage and trunk [13].

Plants are reported to be able to produce various air ions, including NAI, under normal conditions [14]. Most plants emit different types of volatile organic compounds (Bio VOCs) and even micro-amount of Bio VOCs has a great impact on formation processes of cluster ions [15]. This effect is reinforced when volatile compounds are emitted from the plant in ionic form, e.g., Bio VOCs emitted from the needles of conifers are ionized because of charges accumulated in the sharp tips of the needles. Ions of volatile compounds are very good condensation nuclei in the atmosphere that contribute to further formation of mist and clouds. Thus, coniferous forests can even affect the global climate [16]. To a certain extent, most of the plants are air ion generators. Intensity of such generation depends on the daily intensity cycle of metabolic process in these plants [17].

Indoor plants improve quality of the air. Some plants effectively clean the air from organic contaminants [18], while other plants reduce the amount of micro-organisms in the air because of phytoncide effect. Plants produce oxygen and absorb carbon dioxide [19,20]. Many plants humidify intensely the air of the room. As elements of phyto-design, houseplants have a positive impact on the psycho-emotional state of the occupants. As a consequence of people staying indoors, the indoor air is saturated with anthropogenic organic, microbial and aerosol pollution to a greater extent than the natural air. The indoor air contains less small oxygen ions than the natural air [21].

Light-absorbing pigments in photo-organisms capture photons of certain colors and reflect other colors. The energy of a photon is transferred through a long chain of molecules to the reaction center, which splits water to produce high-energy electrons for biochemical reactions. The process of photosynthesis (especially the light phase) is directly related to changes in the difference of potentials on the thylakoid membranes of chloroplasts [22,23].

In chloroplasts, thioredoxin is restored by taking electrons from the recovered molecules of ferredoxin. The recovered thioredoxin is oxidized, giving, in its turn, the electrons to the molecule of enzyme. Thus, during the transition from darkness to light, when the circuit of electron transportation begins in the chloroplasts and the recovery of the molecules of ferredoxin takes place, several enzymes are being activated [18].

Productivity of the photosynthesis of plants is determined by two major parameters: the total surface of leaves (assimilative surface) and the intensity of photosynthetic processes per unit of leaf surface [24]. To make normal growth of plants possible, the light is needed. Almost all greenhouse use partial supplementary lighting of plants with a help of lamps [25].

As any process involving photochemical reactions, photosynthesis is also characterized by the lowest amount of light needed to begin the process. Starting from this point, the dependence of photosynthesis on the intensity of the light can be showed with a help of logarithmic curve. Initially, increase of the light intensity leads to a proportional growth of photosynthesis (area of the maximum effect). Within this level of lighting, the speed of photosynthesis is limited by the light. With further raise of the light intensity, photosynthesis continues to increase, but the process is slower (area of weakened effect). Finally, the light intensity increases, but photosynthesis remains the same (area of light – plateau) (Fig.1) [26].

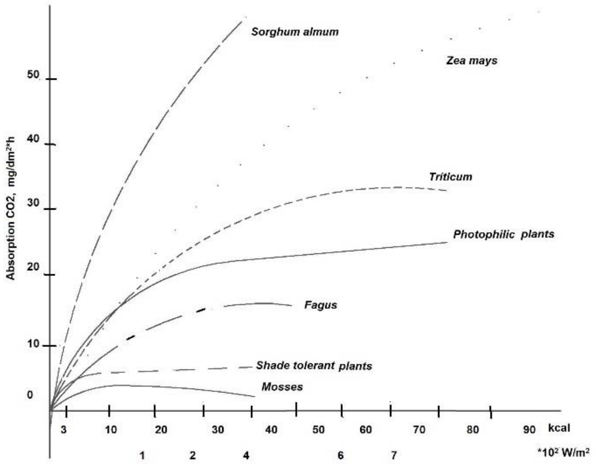

Fig. 1. Photophilic and shade tolerant plants light saturation (the plateau)

II MATERIALS AND METHODS

We used the same plant species [26] and found similar species-dependent differences in the ability to generate NAI. The data presented in this paper prove that the capacity of plants to generate NAI differs. The aim of the experiments was to find the species with the most expressed capability to generate NAI.

In order to perform this study, several plants were selected which, by their nature and taking into account the impact of external factors, can affect the air ion concentration indoors. Therefore, plants with the following characteristics were chosen: large area of leaves, leaves with a pointed tip and hair shaft; developed transpiration function (as a result of transpiration a lot of water is vaporized from plants), dust particle absorption, expressed phytoncide features.

Fig. 2. Scheme of Measuring Devices and Groups of Indoor Plant. Phyto-Module of Strobilanthes.

2.1. Five Plant Phyto-Module

Phyto-module of five plants (Fig.2) (a complex of specially selected plants for environmental improvements) was created basing on the following five plants (Table 1.). The size of the phyto-module is approximately 800x800x800 mm.

Air ion concentration was measured with the portable bipolar air ion counter "Sapfir-3м". This device provides simultaneous measuring of positive and negative air ions with minimum resolution of 10 ions per 1 cm^3 . The device measures air ion concentration in the air (mobility $k \geq 0.4\ cm^2V^{-1}s^{-1}$). This mobility interval is close to the class of cluster ions [27]. During the measurements, air ions, according to their polarities, are channelized to positive or negative aspiration collector in aspiration chamber and, after coming into contact with this collector, the ions are discharged. Afterwards, the charge is sent to amplifiers and then the impulses are counted and displayed. The device counts the charges of air ions, therefore if an ion has more than one charge, it is counted as several ions.

TABLE 1.

PLANTS VARIETIES

Latin name	*Properties [27]*	*Requirements for lightning*	*Size, H/D,cm*
Spathiphyllum	Reduces the amount of benzene and trichloroethylene, high efficiency of phytoncides	Bright, scattered in spring	35/40
Scindapsus	Reduces the amount of benzene and formaldehyde, average efficiency of phytoncides	Indirect, bright	40/50
Strobilanthes	Reduces the amount of formaldehyde average efficiency of phytoncides	Indirect, bright	35/45
Chlorophytum	Reduces the amount of benzene and formaldehyde, high efficiency of phytoncides	Indirect, bright	35/45
Pinus mugo	Reduces the amount of benzene and formaldehyde, high efficiency of phytoncides	Indirect, bright	50/55

Indoor climate parameters were determined using the multi-meter "Easy Sense Q". Systematic measurement error of this device for temperature is ± 0.3 ° C, whereas error for relative humidity is ± 5%. Error for lighting is not specified. The total amount of radioactive α, β and γ radiation was measured in $\mu Sv \bullet h^{-1}$ with the portable device "Gamma-Scout" with systematic measurement error less than 5%. For all devices, the average value of each measurement point was 10 minutes. Each time the measuring devices were placed in a distance of approximately 40 cm from the phyto-module, at a height of 120 cm from the floor.

The measurements were carried out in automatic mode for each photo-module individually. During the first 48 hours, microclimate parameters of the room were measured without any plants. Afterwards, phyto-modules of each plant species were measured, the measuring process was identical for each plant.

The experiment was taking place in a room of 12 m^2 and $36m^3$. The room has one window towards East. The room is located on the first floor, it is closed and without forced ventilation. During the measurements, people were present in the room only once a day to switch on the devices, to turn on online mode for measuring or to change phyto-modules.

When carrying out measurements in natural (non-controlled) lightening, difference in light intensity was a disturbing factor, because the experiment was carried out within a period of several days (some of them were sunny, while other days were cloudy), therefore the level of lightening in the room changed. As a result, it was decided to carry out an experiment when micro-climate parameters were measured under circumstances of controlled lightening.

2.2. Controlled Light

The experiment was carried out in the same room. The window was closed with an opaque tissue not to let the light in. The phyto -module was created of five plant species used in the previous experiment as well. The total number of plants: 30 items. The total surface of the phyto-module amounted to 2 m^2. Arrangement of plants and devices remained the same (Fig.2). Measuring of micro-climate parameters was carried out using the same instruments: in the room with and without plants for 24 hours without lighting (in the dark), 24 hours with fixed lighting (1000 lx). During this experiment, gas concentration in the air was not measured. Meteorological data on ultraviolet radiation provided by Rucava Station were also taken into account [28]. The experiment was carried out repeatedly.

2.3. Phyto-Module of Pinus Mugo

For the needs of the experiment, a phyto-module was created of the coniferous plant Pinus mugo. The experiment was carried out in the above mentioned room without lighting (in the dark). The mode of experiment remained the same.

III RESULTS AND DISCUSSION

After carrying out experiments with five plants, it is not possible to select one particular species that would be the best generator of negative ions. On the first day of the experiment, the best results were shown by Pinus Mugo, but later its capacity to generate ions decreased. The overall conclusion is that the capacity of plants to produce air ions is fluctuating and requires a much longer study period than a few days. Supposedly, air ion balance indoors is also affected by other unintentional and uncontrolled factors.

The experimental data (see Fig.3) show that the number of positive air ions in the given rooms is higher than the number of negative air ions: 20-29% (without houseplants) and 23-68% (with houseplants). Maximum / minimum concentration of positive air ions: 159cm^3/76 cm^{-3} (without houseplants) and 180cm^3/30cm^3 (with houseplants). Maximum / minimum concentration of negative air ions: 110cm^3/54 cm^3 (without houseplants) and 115 cm^{-3}/33cm^3 (with houseplants). These data reveal that, basing on the air ion concentration and unipolarity coefficient, the room used for the experiments is not recommended for human health (if not ventilated). The room has very low concentration of positive and negative air ions and inadequate unipolarity coefficient, because, basing on the SanPin 2.2.4 1294-03, minimal admissible concentration of positive air ions is 400 cm^3, negative air ions 600 cm^{-3}, admissible values of unipolarity coefficient $0.4 < K < 1.0$. During the day, the room temperature increases and relative humidity decreases because of the sunlight. The measured average ambient temperature in the room without plants is about 30C higher than in the room with plants. The average humidity is up to 6% higher in the room with plants than in the room without plants. It means that plants increase the air humidity (the water is evaporated through leaf pores).

3.1. Five Plant Phyto-Module

During the research of phyto-modules of five plants, analysis of data provided by the air ion counter showed that at night the total number of ions is 5 – 15% less than in the daytime.

A significant increase in negative ions was observed during the study of the phyto-module of conifer Pinus Mugo, i.e. Mountain pine. This increase amounted to 5% if compared to a room without plants and to 30% if compared to the indexes obtained during the work with other phyto-modules. Low concentrations of air ions were recorded when working with the phyto-module of Hlorofitum, although this plant is considered to have a positive effect on the environment and to reduce the air pollution. Decrease in the number of air ions was observed on the second day of the study in the presence of plants in the room.

A common trend - without controlled lighting, plants stabilize fluctuations of air ion concentrations in the room. They become predictable, depending on the natural day lighting modes, besides the amplitude of fluctuations is smaller.

At the same time, in a room without plants the total number of ions is 15 – 20% less at night than during the day. The total number of ions in an empty room without plants is 30 – 35% more than in a room with plants (Fig.3).

3.2. Controlled-light

The experiment showed that, regardless of whether there is artificially created dimming or constant artificial lighting, there is a tendency of reduction of the number of air ions during the night and the increase of their number in the daytime. In a room with lighting and plants, the number of ions was 15% higher than in a room with plants and without light. (Fig.4.,5.)

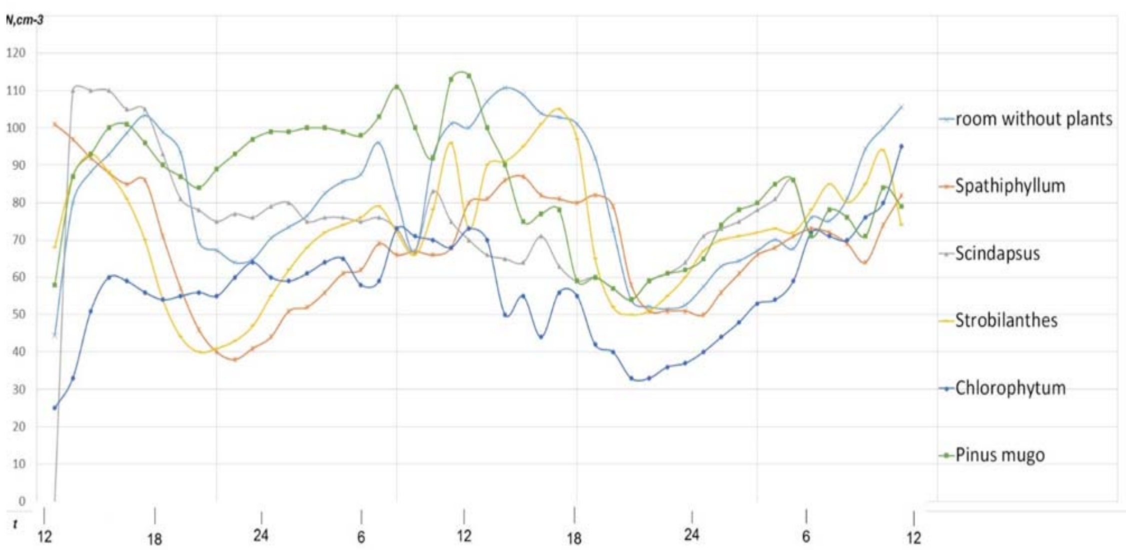

Fig.3. Concentration of negative ions in the air with five photo-modules and in the room without plants.

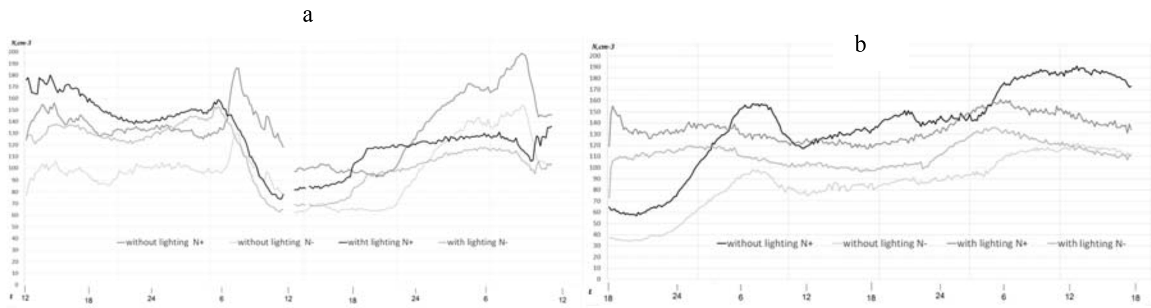

Fig.4. Concentration of negative and positive ions in the air with plants in the room with and without lighting.

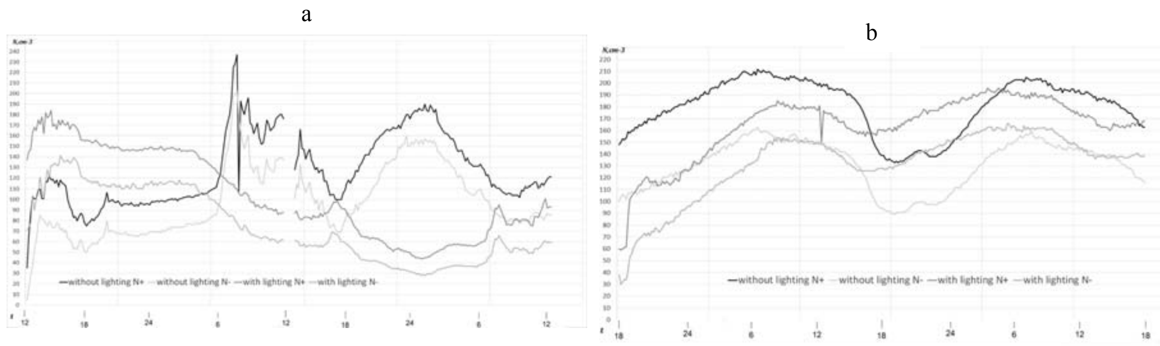

Fig.5. Concentration of negative and positive ions in the room without plants in the room with and without lighting.

Thus, it can be concluded that the light needed for photosynthesis raises the capacity of plants to generate air ions. Without lighting, metabolic processes in plants are slower and less active, so the plants serve as air ion absorbers rather than producers because of the large total surface of their foliage.

TABLE 2.

AVERAGE IONS CONCENTRATION

Conditions/ Parameters	In the dark		With controlled lighting	
	Without plants	With plants	Without plants	With plants
N^-	115	92	103	111
N^+	155	136	134	131
$N^{(total)}$	270	228	237	242
K	1.35	1.47	1.30	1.18

In a dark room with plants, not only the total air ion concentration is significantly lower if compared to an artificially lit room; the value of the unipolarity coefficient K is also lower, which is almost in distinguishable from the K value in a room without plants. It means that if there is no light, plants in the room are not useful because their impact on air ion concentration is minimum.

Analyzing the results obtained at constant artificial light, it can be concluded that the presence of plants in a room increases the concentration of negative air ions and slightly reduces the concentration of positive ions, thus stabilising the K value closer to zero. However, in our experiment this effect did not appear to be sufficient to reach the amount of air ions favorable for human health with a help of plants and to ensure the K < 0, which would be recommended from the medical point of view. (Table 2).

It should be noted that even in the room without lighting and without plants, there were still daily fluctuations of the air ion concentrations, which apparently do not depend only on the sunlight and the presence of plants, but it is caused by other air ion producing and loss mechanisms. Constant artificial lighting slightly reduced these fluctuations by increasing the concentration of ions at night, and slightly decreasing it during the day.

3.3. Phyto-Module of Pinus Mugo

Experiments with Pinus Mugo, as probably one of the plant species that significantly affect the air ion microclimate indoors, deserve a lot of attention in further studies (Fig.7). Analyzing our first study in a room with shielded windows, it can be concluded that this plant species is great in dealing with the rapid and often chaotic air ion fluctuations caused by various factors. Pinus Mugo decreased fluctuations of air ion concentrations to almost constant level that almost does not depend on external factors. It only remains to find an opportunity to stimulate metabolic processed in these plants with the help of adequate lighting and other techniques, in order to achieve the required level of air ion concentration indoors (Fig.6).

Fig.6. Concentration of negative and positive ions in the air with Pinus Mugo in comparison with the room without plants.

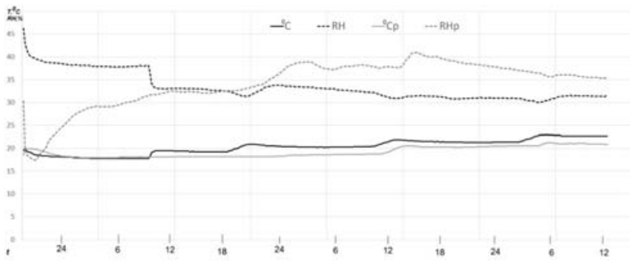

Fig.7. Measurements of temperature and relative humidity in the room with Pinus Mugo in comparison with the room without plants.

IV CONCLUSION

Our experiments have revealed that plants can work as ion generators only in controlled or uncontrolled lighting due to increased photosynthesis and metabolism. In the dark, plants are rather ion absorbers due to the large surface of their leafs. Presence of plants in the room can significantly stabilize uncontrolled fluctuations of ion concentration, however the necessary level of ionization was not reached. Conifers, e.g. Pinus Mugo, might be the best ion producers, however further continuous experiments are needed to identify the plant species that would the best in ion production.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 274-279

Effect of Environmental Factors on Air Ion Concentration

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Abstract. **The paper discusses and analyzes the effect of environmental factors on ion concentrations in urban air. Statistically mathematical method was used to analyze the measurements of air ion concentration collected in a period of several months, with ion size ranging from 0.75 to 36.6 nm. As environmental factors related to air ions, the following chemical and physical parameters of the atmospheric air were analyzed: CO, NO, NO_2, NO_x, SO_2, O_3, PM10, PM2.5, temperature, relative humidity, wind speed and direction. When analyzing data in this combination, there is often a problem of multicollinearity between air chemical and physical parameters. This paper addresses this problem by using the component regression. Regression equations were elaborated to understand the dependence of concentrations of various classes of positive and negative air ions on chemical and physical parameters of the air.**

Keywords: **air ions, air pollution, multicollinearity, multivariate regression, Principal Component Regression (PCR).**

I INTRODUCTION

Research on chemical and mechanical air pollution nowadays is one of the most topical problems in the environmental science. Pollution of the atmosphere is very difficult to localize or eliminate, it is able to spread not only on regional but also on global scale. A special attention is paid to a regular monitoring of the quality of urban air environment, constantly looking for new ways to improve the existing monitoring system. One of possibilities is the inclusion of natural air ionization parameters into the range of parameters to be monitored [1].

In the atmospheric physics, the term "air ion" signifies all airborne particles that are electrically charged and serve as a basis for air conductivity [2, 3]. There are several air ion classifications depending on their size, however the classification that is becoming more popular is based on the physical composition of air ions [4]. Cluster ions consist only of ionized and polarized gas molecules that form clusters, but the heaviest ions are aerosol ions consisting not only of ionized and polarized gas molecules, but also of atmospheric aerosol particles as ion condensation nuclei ion.

Almost for a century, various scientific studies have been revealing and describing the impact of air ions on human beings and all living organisms [5, 6]. Ionized molecules of oxygen and other air components have a stronger effect on the human body. Air ions may be either healthy or harmful to the human health depending on their concentration levels in the air and on the proportion of the positive and negative ions.

Over the past two decades, outdoor studies of air ions have become topical aimed at understanding of interactions of air ions and other natural biotic and abiotic components, which affect not only ecosystems, but also the global climate [7]. There is still a need for relevant and credible information about the influence of anthropogenic pollution on air ions both in urban and rural environment.

The mass spectrometer has allowed to identify different substances in the ambient air, such as NH_3, HNO_3, H_2SO_4, which are essential for the formation of atmospheric aerosols and heavy air ions (for example [8, 9, 10]). The spectrometry of cluster ion mobility is widely used in detection of various impurities in the atmospheric air [11, 12]; the most important substance classes of these impurities are the following: exhaust gases, poisonous chemical gases, military and explosive gases. The total air pollution also affects the mobility and size of air ions [13, 14].

Balance of air ions in the atmosphere depends on various and rather complex ion generation and ion loss physical mechanisms, therefore outdoor studies of air ions is a difficult, but necessary step to acquire new knowledge on atmospheric pollution and its interaction with the ecosystem. The results are often difficult to interpret.

Serious problem for analysis of air pollution and interaction of air ions is caused by multicollinearity of parameters (see the Figure 1). It is particularly important when dealing with the urban environment

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.241

that is characterized by a high level of anthropogenic pollution. Many atmospheric chemical and physical contamination components have a common source such as industrial emissions, transport, energy, etc., therefore there is a strong correlation among them, which causes problems in the classical regression analysis. The study aims to determine and apply a mathematical model of regression analysis that would minimize the negative impact of the multicollinearity on interpretation of the results and help to explain the concentration of air ions by changes of environmental factors.

II MATERIALS AND METHODS

In order to assess the impact of the anthropogenic air pollution on air ion concentrations, measurements of chemical air pollution, meteorological parameters and air ion concentrations are needed. Further analysis was based on data derived from the air monitoring station in Estonia (Tartu, Karlova residential district). Concentration of naturally charged air ions according to their mobility was measured using the Neutral Cluster and Air Ions Spectrometer "NAIS" [20]. Devices for measuring meteorological and chemical parameters are certified.

Measurements were carried out in different seasons in a period of less than a year. Average half-hour values of the measured parameters were analyzed. In order to obtain an overall picture of the effects of atmospheric pollution on basic air ion classes, all air ion sub-classes measured with the NAIS were summed up in the following ion classes with the following ion size ranges:

1. Cluster ions (0.75 – 1.54 nm)
2. Middle ions (1.54 – 7.50 nm)
3. Heavy ions (7.50 – 36.6 nm)
4. Total range of ions (0.75 – 36.6 nm).

Overall, 13756 records were subjected to statistical analysis.

Due to the strongly expressed multicollinearity among the measured parameters, it was not possible to apply the classical regression method of analysis. As an adequate solution to this problem the method of Multivariate Regression was chosen. The purpose of the principal component regression (PCR) is to estimate the values of a response variable at the basis of selected principal components (PCs) of the explanatory variables. There are two main reasons for regressing the response variable on the PCs rather than directly on the explanatory variables. Firstly, the explanatory variables are often highly correlated (multicollinearity) which may cause inaccurate estimations of the least squares (LS) regression coefficients. This can be avoided by using the PCs in place of the original variables since the PCs are uncorrelated. Secondly, the dimensionality of the regressors is reduced by taking only a subset of PCs for prediction.

Multivariate regression methods, such as principal component regression (PCR), enjoy are very popular in a wide range of fields, including the natural sciences. The main reason is that they have been designed to confront the situation that there are many correlated, predictor variables, and relatively few samples - *a* situation that is common, especially in chemistry where developments in spectroscopy since the seventies have revolutionised chemical analysis.

In the context of usual multiple linear regression (MLR), the least-squares solution for

$$Y = XB + \varepsilon \tag{1}$$

is given by

$$B = \left(X^T X\right)^{-1} X^T Y \tag{2}$$

Often the problem is that $X^T X$ is singular, either because the number of variables (columns) in ***X*** exceeds the number of objects (rows), or because of collinearities. PCR circumvent this by decomposing ***X*** into orthogonal scores ***T*** and loadings ***P***

$$X = TP \tag{3}$$

and regressing ***Y*** not on ***X*** itself but on the first columns of the scores ***T***. In PCR, the scores are given by the left singular vectors of ***X***, multiplied with the corresponding singular values, and the loadings are the right singular vectors of ***X***. This, however, only takes into account information about X, and therefore may be suboptimal for prediction purposes.

In PCR, we approximate the ***X*** matrix by the first *a* principal components (PCs), usually obtained from the singular value decomposition (SVD):

$$X = \widetilde{X}_{(a)} + \varepsilon_X = \left(U_{(a)} D_{(a)}\right) V_{(a)}^T + \varepsilon_X = \\ = T_{(a)} P_{(a)}^T + \varepsilon_X \tag{4}$$

Then we regress ***Y*** on the scores, which leads to regression coefficients

$$B = P\left(T^T T\right)^{-1} T^T Y = V D^{-1} U^T Y \tag{5}$$

where the subscripts *a* have been dropped for clarity.

Choosing the number of extracted factors, one subset (the training set) is used to fit the model, and the other subset (the test set) is offered to measure how well the model fits. The number of factor chosen is usually the one which shall minimize the square root of the mean squared error of prediction (RMSEP) [15, 16, 17].

$$e_i = y_i - \hat{y}_i \tag{6}$$

$$RMSEP = \sqrt{\frac{1}{n}\sum_{i=1}^{n} y_i^2} \tag{7}$$

The R^2 values returned by '"R2"' are calculated as

$$R^2 = 1 - \frac{SSE}{SST}, \tag{8}$$

where SST is the (corrected) total sum of squares of the response, and SSE is the sum of squared errors for either the fitted values (i.e., the residual sum of squares), test set predictions or cross-validated predictions [17, 18, 19].

III RESULTS AND DISCUSSION

In general, the air ion concentration correlates with air pollution and meteorological conditions (See Fig. 1. Correlation coefficients above 0.3 are colored light gray). For different air ion classes, this correlation is manifested in different ways. For example, correlation of cluster ions with the chemical air pollution is relatively weak, while correlation with the temperature is moderately strong. In the area of middle air ions this correlation is even weaker. It would be necessary to mention the nature itself of the middle air ions, i.e. they constitute a transition from cluster ions to heavy ions or aerosol ions, and their concentration, under natural conditions, is usually very low, perhaps only a few or a few dozen ions per 1cm^3 of air . This is the fact which leads to a relatively weak correlation. In the area of heavy ions (especially positive ones), there is a strong correlation with the chemical and physical (PM 10) air pollution. Heavy ions contain aerosol particles as condensation nuclei. Not only air ions can stick to neutral aerosol particles, but air-polluting gas molecules can also absorb on them.

	CO	NO	NO	NOx	O3	PM10	PM2,5	SO2	Rel. Hum.	Temp.	Wind Dir.	Wind Sp.	Cluster "-"	Cluster "+"	Middle "-"	Middle "+"	Heavy "-"	Heavy "+"	Total "-"	Total "+"
CO, mg/m3	1																			
NO, ug/m3	0,75	1																		
NO2, ug/m3	0,83	0,66	1																	
Nox,ug/m3	0,84	0,96	0,84	1																
O3, ug/m3	-0,52	-0,38	-0,64	-0,50	1															
PM10, ug/m3	0,48	0,35	0,48	0,43	-0,24	1														
PM2,5, ug/m3	0,15	0,09	0,15	0,12	-0,12	0,20	1													
SO2, ug/m3	0,41	0,31	0,40	0,37	-0,21	0,29	0,09	1												
Rel. Humidity, %	0,05	-0,01	0,05	0,01	-0,55	-0,20	-0,01	-0,07	1											
Temperature, °C	-0,44	-0,33	-0,45	-0,40	0,55	-0,12	-0,12	-0,39	-0,36	1										
Wind Dir., deg.	-0,15	-0,12	-0,15	-0,14	0,12	-0,21	-0,07	-0,11	0,06	0,05	1									
Wind Speed, m/s	-0,24	-0,18	-0,33	-0,25	0,32	-0,23	-0,02	-0,07	-0,08	0,01	0,03	1								
Cluster Ions "-"	-0,13	-0,07	-0,16	-0,10	0,11	-0,02	-0,03	-0,04	-0,10	0,32	0,02	-0,03	1							
Cluster Ions "+"	-0,11	0,01	-0,17	-0,05	0,10	0,00	-0,03	-0,11	-0,10	0,49	0,01	-0,09	0,80	1						
Middle Ions "-"	-0,08	-0,02	-0,07	-0,04	0,15	-0,03	-0,03	-0,02	-0,20	0,09	0,03	0,12	0,18	0,05	1					
Middle Ions "+"	-0,02	0,04	-0,02	0,02	0,12	0,02	-0,02	0,00	-0,23	0,08	0,03	0,09	0,11	0,08	0,41	1				
Heavy Ions "-"	0,16	0,19	0,18	0,20	-0,09	0,15	0,03	0,07	-0,06	0,02	-0,06	-0,08	0,08	0,10	0,14	0,10	1			
Heavy Ions "+"	0,48	0,49	0,49	0,53	-0,27	0,33	0,08	0,25	-0,09	-0,21	-0,09	-0,15	0,13	0,09	0,11	0,21	0,41	1		
Ions (Total) "-"	0,15	0,18	0,17	0,19	-0,08	0,14	0,02	0,07	-0,08	0,03	-0,05	-0,08	0,13	0,13	0,20	0,12	1,00	0,41	1	
Ions (Total) "+"	0,45	0,48	0,46	0,51	-0,24	0,32	0,08	0,23	-0,11	-0,16	-0,08	-0,15	0,19	0,17	0,15	0,31	0,41	0,99	0,42	1

Fig. 1. Matrix of correlation of data used in calculations

As shown in Fig. 1, among different air ion classes there are different correlations. The correlation matrix demonstrates the above-mentioned problem of multicollinearity: correlation of the components of chemical and physical air pollution is strong or moderately strong.

The principal component regression was used to solve the problem of multicollinearity without excluding any of parameters from the analysis.

For further analysis we will use a number of principal components where R^2 reaches its highest level, but the RMSEP is at the lowest level (See table 2 and table 3).

Regression equation coefficients obtained with a help of the principal component regression were summarized in the table 1. The sign and value of the coefficient show the influence of each variable on the concentration of air ions of each specific class.

Regression equation highlights the profound impact of CO on the air ion concentration which increases when air ions become bigger. In the area of cluster ions, the impact is lower, while in the area of heavy ions there is the highest impact, which also influences the air ion concentration in general. Both in the area of cluster ions and heavy ions, the presence of CO reduces the concentration of negative ions and increases the concentration of positive ones. This effect could explain the lack of negative air ions which is often observed in a polluted atmospheric environment.

TABLE 1

MULTIVARIATE REGRESSION COEFFICIENTS (ROUNDED)

Parameter / Ion Class	Cluster Ions		Middle Ions		Heavy Ions		Ions (Total)	
	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive
CO	-2.67	6.64	-24.61	-22.74	-164.92	58.20	-192.20	42.10
NO	0.94	6.58	-2.68	-2.84	3.73	6.96	1.99	10.70
NO_2	-0.29	2.06	-1.77	-2.02	5.87	8.38	3.81	8.42
NO_X	-0.45	-3.72	1.89	2.11	3.30	2.90	4.75	1.28
O_3	-0.43	-1.01	-0.05	-0.23	-3.24	-2.14	-3.72	-3.38
PM10	0.03	0.10	-0.10	-0.07	3.46	3.83	3.40	3.86
PM2,5	0.01	0.03	-0.04	-0.04	-0.06	-0.05	-0.08	-0.06
SO_2	3.31	4.04	-0.14	-0.61	10.71	11.06	13.88	14.48
Rel. Humidity	-0.14	-0.14	-0.86	-1.29	-3.16	-5.82	-4.16	-7.25
Temp.	2.08	4.61	0.06	0.12	17.32	-0.49	19.46	4.23
Wind Direction	0.01	0.01	0.03	0.04	-0.23	0.11	-0.19	0.16
Wind Speed	-1.57	-3.68	9.45	9.33	-10.64	1.02	-2.76	6.67

TABLE 2

R^2 VALUES OF PRC REGRESSION FOR PRINCIPAL COMPONENTS

Number of principal components.	R^2, Cluster Ions		R^2, Middle Ions		R^2, Heavy Ions		R^2, Ions (Total)	
	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive
1	0.0005702	0.0002741	0.001516	0.0006379	0.005258	0.01706	0.004701	0.01502
2	0.0134813	0.0053189	0.004933	0.0006494	0.038530	0.27499	0.034487	0.25070
3	0.0136028	0.0054994	0.005181	0.0011777	0.040145	0.28353	0.036093	0.25925
4	0.0233351	0.0242611	0.036738	0.0414312	0.044579	0.29319	0.042324	0.27463
5	0.0235593	0.0242821	0.036755	0.0418616	0.047670	0.30272	0.045371	0.28382
6	0.0241145	0.0301941	0.044522	0.0549076	0.048119	0.30615	0.045983	0.28758
7	0.1154693	0.3157421	0.045134	0.0572499	0.054510	0.30637	0.054367	0.28854
8	0.1218842	0.3364217	0.047814	0.0611757	0.058017	0.30637	0.057809	0.28855
9	0.1359462	0.3497774	0.047884	0.0614623	0.058209	0.30688	0.058121	0.28939
10	0.1363843	0.3510621	0.055531	0.0671997	0.058244	0.30688	0.058125	0.28942
11	0.1364403	0.3512581	0.057873	0.0687347	0.058552	0.30697	0.058533	0.28947
12	0.1364405	0.3512681	0.057875	0.0687366	0.058552	0.30697	0.058533	0.28947

TABLE 3

RMSEP VALUES OF PRC REGRESSION FOR PRINCIPAL COMPONENTS

Number of principal components.	RMSEP, Cluster Ions		RMSEP, Middle Ions		RMSEP, Heavy Ions		RMSEP,Ions (Total)	
	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive
1	50.80	67.77	72.45	82.74	1331	852.4	1350	883.3
2	50.47	67.60	72.33	82.74	1309	732.0	1329	770.4
3	50.47	67.59	72.32	82.72	1308	727.7	1328	766.0
4	50.22	66.95	71.16	81.04	1305	722.8	1324	758.0
5	50.21	66.95	71.16	81.02	1303	717.9	1322	753.2
6	50.20	66.74	70.87	80.46	1302	716.1	1321	751.2
7	47.79	56.06	70.85	80.37	1298	716.0	1316	750.7
8	47.62	55.21	70.75	80.20	1296	716.0	1313	750.7
9	47.24	54.65	70.75	80.19	1295	715.8	1313	750.3
10	47.22	54.60	70.46	79.94	1295	715.8	1313	750.3
11	47.22	54.59	70.38	79.87	1295	715.7	1313	750.2
12	47.22	54.59	70.38	79.87	1295	715.7	1313	750.2

In general, nitrogen oxides show a slightly weaker trend. They are cause a moderate increase of the number of heavy air ions, but it should be noted that NO and NO_2 slightly increases the concentration of positive cluster ions. NOx is the sum of these nitrogen oxides, but the regression analysis shows that the total effect is ambiguous - NOx slightly reduces the concentration of cluster ions.

The impact of ozone is not very strong, but it should be noted that in all air ion classes it manifests itself negatively. It is considered that O_3 as a strong oxidant can quickly reduce the number of air ions, but this effect is weak in low ozone concentrations in the atmospheric boundary layer under normal conditions.

SO_2 is associated with a moderate increase in air ion concentrations, except middle-sized ions.

Impact of dustiness on air ions manifests itself mainly in the increase of the number of heavy or aerosol ions, or in increase in the number of aerosols, because aerosols form a part of large ions as nuclei. Contrary to expectations that aerosols would cause decrease of cluster ion concentrations because, when a cluster ion collides with an aerosol, it gives its charge to this aerosol thus forming a large ion, relations of dustiness and air ions were found to be almost neutral.

Relative humidity of the air, which is basically the relative content of water vapor in the air, influences negatively the air ion concentration. Water vapor molecules are good condensation nuclei in the atmosphere, and air ions, when connecting with these molecules, give away their charge and cease to exist. Besides, the bigger air ion, the greater possibility for it to come into contact with a water molecule in the air.

Temperature slightly increases the concentration of all air ions, because, when the temperature rises, the intensity of the movement of molecules in the air increases as well, which contributes to mutual collisions of molecules and ions, resulting in possible recombination of ions with opposite signs or in formation of new ions due to such collisions.

Similarly, when the wind speed increases, it enhances the mixing of atmospheric layers and spread of pollution, which may result in decrease of concentration of individual ion groups. On the other hand, the wind also contributes to the raise of radioactive isotopes above the earth's surface at a height of several meters, where they serve as atmospheric ionizers.

Wind direction in the city is important, as it determines whether polluted air from industrial districts and transport nodes, or clean and fresh air from suburban areas, seaside, etc. shall be brought to the monitoring point. For precise interpretation of the impact of wind direction on air ions, location of pollution emission points in each specific city should be analyzed.

IV CONCLUSION

By using the principal component regression, a positive result has been achieved, i.e. the problem of multicollinearity has been solved, which was the main problem in analyzing such type of data. A significant advantage of this method is that all data can be analyzed without excluding any of them because of multicollinearity. When using the classical regression, the excluded data may turn out to be significant.

The linear regression applied to value R^2 is not very high, only in 2 cases it exceeds 0.3, the RMSEP is also relatively high. It means that the data contain errors, and the selected 12 variables are not sufficient to explain air ion concentration and its fluctuations.

In further studies, it would be necessary to expand the range of the measured parameters to find new factors that affect air ion concentration significantly. In further statistical analysis, it would be helpful to use non linear regression and method of cross-validation.

Basing on the obtained regression coefficients of the regression equation, the following conclusions can be made. Anthropogenic atmospheric pollution is one of the factors influencing the air ion concentration, charge and size.

In general, there is a trend that air pollution contributes to increase of concentration of positively charged air ions; concentration of heavy air ions or aerosol ions raises as well. This effect creates environment unfavorable for human health with increased air pollution, because the human health needs sufficient concentration of negative cluster ions in the inhaled air [21].

Air ion concentration, charge, chemical composition and structure are important factors for assessing the air quality. Their role and interaction with other components of the atmospheric air has not been adequately studied yet and requires further researches in the future.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 280-283

Determining the Isotopic Composition of Nitrate in the River Daugava and Loads of Nitrogen to the Gulf of Riga

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Abstract. **The Daugava or Zapadnaya (Western) Dvina River belongs to the Baltic Sea basin. The length of the river is 1,005 km with a drainage area of 87,900 km^2. It crosses three countries: Russia (323 km and 18,500 km^2), Belarus (328 km and 33,100 km^2) and Latvia (352 km and 24,700 km^2). Water samples were collected at three points with the following coordinates: Kraslava, Daugavpils, and Riga and distance from the river mouth 320, 255, and 20 km respectively. Discharge measurements by use of acoustic Doppler current profiler (ADCP) from a moving boat were also performed in the locations indicated above. Nitrates were extracted from water samples using the 'ion-exchange resin method', which involves extracting NO_3^- from freshwater and converting it into solid silver nitrate, which is then analysed for $^{15}N/^{14}N$ and $^{18}O/^{16}O$ ratios by IRMS. Prior to passing water through an anion-exchange resin precipitation of O-bearing contaminants (mainly sulphate and phosphate) with barium chloride was carried out. The $\delta^{15}N_{NO3}$ values of riverine samples varied from 7.1 to 8.6 ‰ in Kraslava, from 7.2 to 8.3 ‰ in Daugavpils, and from 8.1 to 9.0 ‰ in Riga and displayed significant differences between the three sampling points.**

Keywords: **nitrates; stable isotopes; ion exchange.**

I INTRODUCTION

Like the Earth's water, nitrogen compounds cycle through the air, aquatic systems, and soil. However, unlike water, these compounds are being injected into the environment in ever increasing quantities. In doing so, humans alter the global nitrogen cycle, causing possible grave impacts on biodiversity, global warming, water quality, human health, and even the rate of population growth in developing nations. In natural environments, the availability of nitrogen is often limited by the rate of N-fixation. Nitrogen availability is one of the main controls on productivity and is an important factor regulating biodiversity [1]. Presently, N input from human sources, chiefly N-fixing crops, synthetic fertilizers, and burning of fossil fuels, approximately equals the input from natural nitrogen fixation [2]. The increased N input from anthropogenic sources causes eutrophication of lakes, streams, and coastal waterways, acidification of susceptible environments, and degradation of drinking water quality [3].

Nitrogen and oxygen isotope ratios of nitrate provide a powerful tool to investigate nitrate sources and cycling mechanisms. The analysis of nitrate for both $\delta^{15}N$ and $\delta^{18}O$ allows improved discrimination among potential sources and reaction mechanisms [4, 5].

In our time, $\delta^{15}N–NO_3^-$ and $\delta^{18}O–NO_3^-$ in nitrate can be measured according to three analytical methods [6]: two 'denitrifier methods' requiring Isotope Ratio Mass Spectrometry (IRMS) analysis of N_2O gas generated by bacterial or chemical means, and a procedure known as the 'ion-exchange resin method' whereby NO_3^- is extracted from freshwater and converted into solid silver nitrate ($AgNO_3$) that is analysed by IRMS [7]. Minor modifications have been adopted by some to ease the sample preparation [8], one of the most significant changes being the precipitation of O-bearing contaminants (mainly sulphate and phosphate) with barium chloride ($BaCl_2$) prior to passing water through an anion-exchange resin so that $AgNO_3$ is ready for both $\delta^{15}N$ and $\delta^{18}O$ analyses [9].

The objectives of the research proposal are to use isotope data for nitrate as a tool for determining nitrate sources in river systems, while also evaluating how natural variation in water discharge can influence seasonal changes of nutrient loads and isotopic values.

II MATERIALS AND METHODS

A. Sample preparation

The Daugava or Zapadnaya (Western) Dvina River belongs to the Baltic Sea basin. The length of the river

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.249

is 1,005 km with a drainage area of 87,900 km^2. It crosses three countries: Russia (323 km and 18,500 km^2), Belarus (328 km and 33,100 km^2) and Latvia (352 km and 24,700 km^2). Mean annual Daugava River water runoff is 710 m^3 s^{-1}. Mean annual riverine loads of N–NO_3^- is 27.4 thousand tons per year at discharge 23.27 km^3 yr^{-1} [10, 11].

Water samples were collected at three points with the following coordinates: Kraslava (55°53'22"N; 27°09'59"E), Daugavpils (55°51'41"N; 26°31'16"E), Riga (56°54'18"N; 24°11'01"E) and distance from the river mouth 320, 255, and 20 km respectively. Discharge measurements by use of acoustic Doppler current profiler (ADCP) from a moving boat were also performed in the locations indicated above. Samples were collected with 2 litres HDPE bottles in the middle of the river at 1 m depth, the parallel were collected three samples.

In first, NO_3^- concentrations are measured to determine how much water needs to be processed to retain 100–200 μmol of nitrate (i.e. 6.2–12.4 mg NO_3^-) on the anion exchange resin. The sample water is then filtered through a 0.45 μm nylon membrane to remove particles that might clog the resin. In reference method [7] for the removal of O-bearing contaminants to the sample added of 4 mL of 1 M $BaCl_2$ (large excess) to precipitate sulphate (up to 4000 μmol) and phosphate to a lesser extent (levels typically low in sub-surface water), stored at 4°C overnight, filtered through a 0.2 μm nylon membrane. Sulphate removal is crucial because sulphate has a higher affinity for the resin than nitrate (according to the resin manufacturer). We modified method and added $BaCl_2$ after NO_3^- was stripped from the columns.

Sample passed through the anion exchange resin column (2 mL Bio-Rad AG1-X8, 200–400 mesh in Cl^- form, capacity of 1200 μeq mL^{-1}, pre-conditioned by dripping through 4 mL of 1 M HCl and rinsed) at a flow rate of 500–1000 mL h^{-1} is achieved by adjusting the stopcock on the separatory funnel. Resin is then rinsed and column is filled with deionized water, and stored at 4°C until later elution. The resin was kept wet at all times. This steps completed in the laboratory within 48 hours of collection [7].

The NO_3^- is stripped from the columns by five 3 mL increments of 3 M HCl passed through the column (elutant kept chilled to minimise volatilisation of HNO_3), each increment kept in the column for 30 seconds before slowly blowing the column dry, rinsing (whole step carried out in the dark) [9]. Elutant immediately neutralised by slow addition of about 6 g of silver oxide (three different batches of high-grade Ag_2O heavily contaminated with nitrate were previously washed [7]) until pH reached 5–6 (checked with pH-paper), filtration through a 0.2 μm nylon membrane to remove excess Ag_2O and silver chloride (AgCl), rinsing (whole step carried out in the dark). $AgNO_3$ solutions (about 40 mL) frozen at -75°C, then freeze-dried in the dark (and stored in amber vials in a desiccator).

B. IRMS measurements

For oxygen isotope analysis an aliquots of the samples (1.0 ± 0.1 mg amounts) were weighed into silver capsules (8 x 5 mm). Oxygen isotope analysis was conducted by total conversion at 1080°C in a quartz reactor tube lined with a glassy carbon film, filled to a height of 170 mm with glassy carbon chips and topped with a layer of 50% nickelized carbon (10 mm deep). Carbon monoxide and nitrogen were separated on a GC column packed with molecular sieve 5A at a temperature of 60°C. The IRMS used was a Europa Scientific 20-20 with triple Faraday cup collector array to monitor the masses 28, 29 and 30.

For nitrogen isotope analysis an aliquots of the samples (2.0 ± 0.3 mg amounts) were weighed into tin capsules (8 x 5 mm). Analysis was undertaken by EA-IRMS (Elemental Analyser Isotope Ratio Mass Spectrometry). Tin capsules containing sample or reference material wereu loaded into an automatic sampler on a Europa Scientific RoboPrep-CN elemental analyser, from where they are dropped in sequence into a furnace held at 1000°C and combusted in an oxygen rich environment. The tin capsules flash combust, raising the temperature in the region of the sample to ca. 1700°C. The gases produced on combustion are swept in a helium stream over combustion catalyst (Cr_2O_3), copper oxide wires (to oxidize hydrocarbons), and silver wool to remove sulphur and halides. For nitrogen-15 analysis, CO_2 is removed using a Carbosorb chemical trap and the nitrogen focused on packed column gas chromatograph held at a constant temperature of 100°C. The resultant N_2 chromatographic peak enters the ion source of a Europa Scientific 20-20 IRMS where it is ionized and accelerated. Gas species of different mass are separated in a magnetic field then simultaneously measured using a Faraday cup collector array set to monitor masses 28, 29 and 30.

III RESULTS AND DISCUSSION

A. Compositions of river water samples

Nitrate concentration was determined by flow analysis (FIA) and spectrometric detection method. Analysis was undertaken by FIALab-2500. Levels of nitrate nitrogen in first sampling point – Kraslava is ranged between 0.15 and 1.58 mg L^{-1}, in second point – Daugavpils is ranged between 0.43 and 1.75 mg L^{-1}, and at the third location – Riga it is in the range between 0.79 and 2.23 mg L^{-1} (Fig. 1).

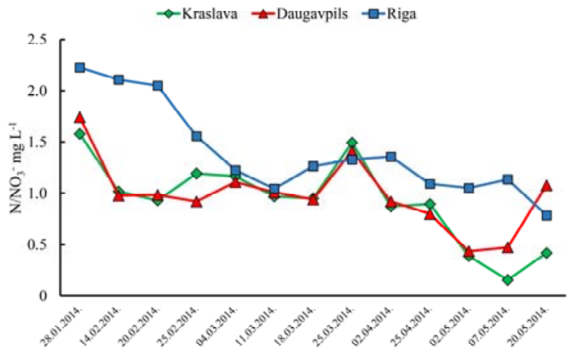

Fig. 1. Changes in N/NO$_3$ at the depth of 1 m in Daugava river over the period between January 28 and May 20, 2014 in Kraslava, Daugavpils, and Riga.

% N measured in AgNO$_3$ prepared from field water samples ranged from 1.5 to 8.1 (median of 7.5), with 90 % of these samples showing % N between 6.9 and 8.1. % O measured in AgNO$_3$ ranged from 20.1 to 28.7 (median of 28.2), with 90 % of these samples showing % O between 27.7 and 28.7.

In winter, the largest differences were observed in the hydrological regime between sampling points. The $\delta^{15}N_{NO3}$ values of riverine samples taken in winter varied from 7.1 to 8.6 ‰ in Kraslava, from 7.2 to 8.3 ‰ in Daugavpils, and from 8.1 to 9.0 ‰ in Riga (Fig. 2) and displayed significant differences between the three sampling points.

The data obtained for Kraslava, Daugavpils, and Riga for $\delta^{15}N_{NO3}$ values and $\delta^{18}O_{NO3}$ values are given in Table 1.

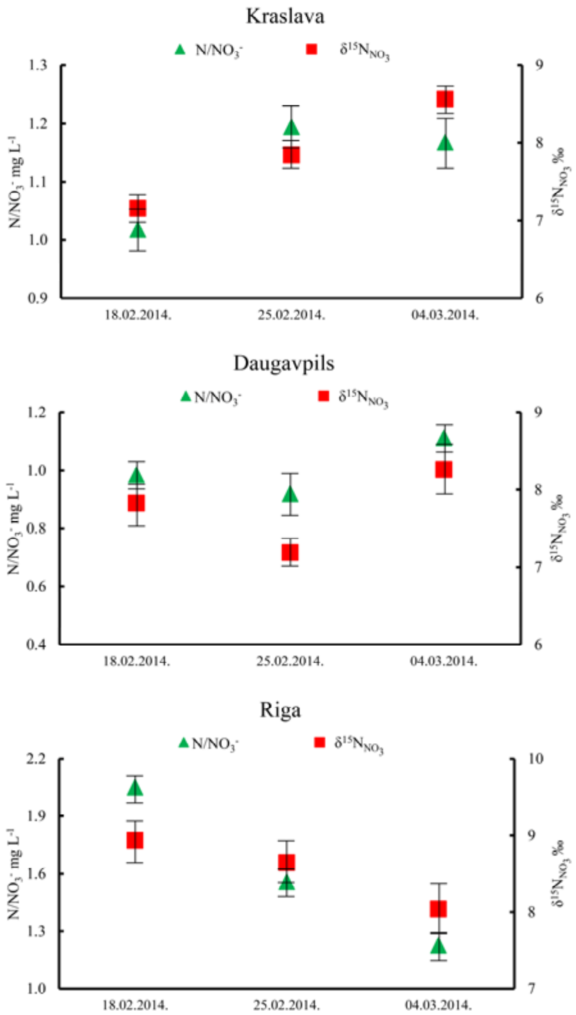

Fig. 2. Nitrate nitrogen concentration and isotopic composition of N in Kraslava, Daugavpils, and Riga.

TABLE I

SUMMARY OF THE CHARACTERISTICS OF RIVER DAUGAVA. AVERAGE VALUES AND STANDARD DEVIATIONS ARE GIVEN FOR THREE REPLICATE RUNS

Date	Sampling point	N/NO_3^- [mg L^{-1}]	$\delta^{15}N_{NO3}$ [‰]	$\delta^{18}O_{NO3}$ [‰]
18.02.2014.	Kraslava	1.02±0.07	7.16±0.38	3.65±0.17
	Daugavpils	0.98±0.09	7.83±0.23	5.89±0.21
	Riga	2.05±0.17	8.94±0.22	5.07±0.19
25.02.2014.	Kraslava	1.19±0.09	7.84±0.28	3.99±0.09
	Daugavpils	0.92±0.03	7.19±0.12	5.40±0.11
	Riga	1.56±0.04	8.65±0.24	6.19±0.15
04.03.2014.	Kraslava	1.17±0.11	8.56±0.19	5.49±0.18
	Daugavpils	1.11±0.12	8.26±0.15	5.42±0.14
	Riga	1.23±0.06	8.04±0.27	5.58±0.12

Nitrate nitrogen concentrations were significantly positively correlated with $\delta^{15}N_{NO3}$ values in Kraslava, Daugavpils, and Riga (R=0.8). The liner equation describe the correlation between Isotopic tracers and nitrates with linear regression coefficient (R^2=0.62) (Fig. 3). The relation of $\delta^{15}N_{NO3}$ used to distinguish between sources of nitrates. The first source could be related to NO_3^- leaching from non-fertilized soils usually having $\delta^{15}N_{NO3}$ values in the range from -3 to 5 ‰. The second nitrate source with a higher NO_3^-

concentration and $\delta^{15}N_{NO3}$ value could be related to nitrate N leaching from manured agricultural areas and/or to nitrate N derived from sewage. NO_3^- originating from animal manure and sewage generally shows $\delta^{15}N_{NO3}$ value >7 ‰.

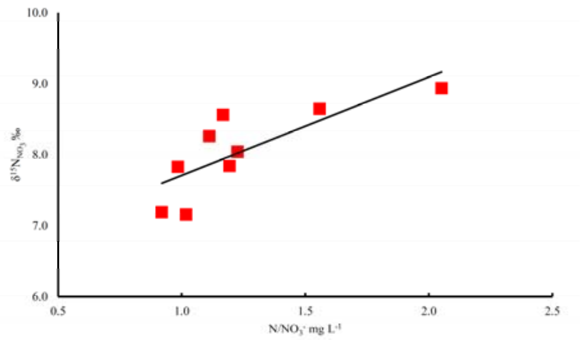

Fig. 3. The relation between $\delta^{15}N_{NO3}$ values and NO_3^- concentrations in the Daugava River

IV CONCLUSIONS

The results suggesting that 62 % of variability in the $\delta^{15}N_{NO3}$ values could be attributed to mixing of NO_3^- from two sources: from non-fertilized soils and from manured agricultural areas.

V ACKNOWLEDGMENTS

This study was supported by Cohesion Fund (KF) project "Seasonal changes of nutrient load in the catchment area of Gulf of Riga" No. L-KC-11-0005.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 284-288

Co-digestion of algae biomass for production of biogas and fertilizer: Life Cycle Cost Analysis

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Abstract. **The purpose of this article is to determine and assess Life Cycle Costs of biogas and fertilizer produced in anaerobic digestion of biomass. General Cost Breakdown Structure for anaerobic digestion plant is described for better understanding of the system. Main cost categories discussed in this study are: Investments; Design, construction and dismantling costs; Maintenance, Operation and Transportation costs. Results showed that Design, construction and dismantling costs have the biggest share in Total Life Cycle Cost (TLCC) per cubic meter of biogas. This category also has the biggest influence on TLCC of fertilizer. Investment costs are the second most significant cost category.**

Keywords**: algae co-digestion, anaerobic digestion, Life Cycle Costing.**

I INTRODUCTION

European Commissions Renewable Energy Directive sets targets for energy sector up to 2020. The main objectives are to cover at least 20% of EU energy demand with renewable resources and to ensure that 10% of vehicle fuel used in EU also comes from renewable sources. To achieve this directive, more specified targets were set for each country. These targets are included in National action plans for energy sector. At the time when EU Renewable Energy Directive was developed, Latvia was one of the leader countries with 29.9 % renewable energy share in total final energy consumption, in large part due to an extensive use of hydro energy for power and wood biomass in district heating sector. National action plan dictates that this position must be maintained and sets a target of 40% share of renewable energy sources (RES) by 2020. Year 2020 draws nearer and nearer. EU wide progress report shows that in 2010 the total share of RES had reached 12.5 % in total and 4.7% in transport sector. Without serious improvements the annual growth rate of renewable energy share would stay the same and EU will fail to reach the target. The latest available progress report from Latvia is written in 2013. It describes progress Latvia has made towards the targets up to year 2012. Total renewable energy share in 2012 was 35.78%. Situation in transport sector is worse. According to the Directive renewable energy share in transportation sector in each country should be at least 10% by 2020. In 2012 RES share in Latvian transportation sector was only 3.10% [1].

Biomass has been used as energy source from ancient times, and it provides around 14% of worlds energy supply [2].Traditionally wood fuel is used for cooking and heating through direct combustion. There are other methods that can be used to convert biomass into energy. One of them is anaerobic digestion. Biogas that contains methane (biomethane) is produced as the end product of this process. [3] The first experimental biogas production plant in Latvia was designed in 1983.Technology development from then has been quite slow. In 2008 there were only 3 operating biogas production plants. Two of them used municipal waste that is collected in landfill. Several biogas production plants have been built since then. They use different feedstock, such as, manure, straw and other agricultural wastes. Collection and utilization of biogas reduces greenhouse gas emissions. Carbon dioxide, methane and other gases from landfill, which, otherwise, would be released to the atmosphere, are collected and dealt with or utilized in a useful manner. Development of biogas technologies provides opportunities to increase Latvian independence in the energy sector and strengthen the economy of rural areas. Several studies discuss the possible use of algae as a feedstock in Latvian conditions [4]. Pastare et. al. evaluates sustainability of biogas production from algae [5].

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.627

This paper focuses on the economical aspects of biogas production, where algae is one of the feedstocks, using Life Cycle Costing (LCC) methodology described and used by [6] and [7].

II METHODOLOGY

According to European Commission, Life Cycle Costing is a tool which evaluates the costs of an asset throughout its life-cycle. LCC costing is widely used in industry, especially with products that have long life time or ones that require special treatment at end-of–life stages. For example, hazardous wastes like batteries or medicine. Both the producers and consumers of the product are interested in its Life Cycle Costs. For the user price of the product is only a part of expenses related to its purchase and use. The use of some product may constitute the majority of costs related to it, for example, electricity consumption for electrical oven or coffee and filters for a coffee machine. LCC allows user to make informed and smart selection when purchasing the product. For the producers, LCC allows seeing if the production costs "pay off" and indicates opportunities to optimize costs and increase profits. [8] LCC can be based on Cost Breakdown Structure, which defines main cost categories and sub-costs from products design stage to its eventual disposal. Cost Breakdown Structure can help to justify the price charged to a client and determine which cost component has the highest impact [7].

Main focus for this LCC study is Internal Life Cycle Costs of fertilizer and biogas produced in pilot project anaerobic digestion plan, externalities are not taken into account.

A. Life Cycle Cost Assessment

Total Life Cycle Cost consists of the following components: Investments (C1), Design, construction and dismantling costs (C2), maintenance (C3), operation (C4) and transportation costs (C5). Total life Cycle costs for the plant are the sum of all these costs:

$$LCC = C1 + C2 + C3 + C4 + C5 \tag{1}$$

However the goal of our study is calculation of LCC of fertilizer from digestate obtained as by-product from biogas production in pilot plant. Therefore it is necessary to allocate the total life cycle costs of the plant between biogas and fertilizer. Allocation of costs was performed on the basis of the benefits gained from each end product.

$$A_F = \frac{Q_{Fe} \times C_{Fe}}{B_{Total}} \tag{2}$$

$$A_B = \frac{Q_{el} \times C_{el} + Q_{th} \times C_{th}}{B_{Total}} \tag{3}$$

Where:
A_F – allocation to fertilizer, %
A_B – allocation to biogas, %
Q_{Fe} – the amount of fertiliser produced, kg
C_{Fe} – fertilizer price in the market, euro/kg
Q_{el} – the amount of electricity produced, kWh
C_{El} – electricity price in the market, euro/kWh
Q_{th} – amount of thermal energy, kWh
C_{th} – thermal energy price in the market, euro/kWh
B_{total}l – total income in the time period, euro

As you can see from equation (3) benefits from biogas is a sum of benefits from electricity and thermal energy, because, in this specific plant, biogas is used in CHP to produce both electrical and thermal energy. Allocated costs for fertilizer and biogas can be calculated as follows:

$$BG_{Total} = PlantTC \times A_B \tag{4}$$

$$F_{Total} = PlantTC \times A_F \tag{5}$$

Cost Breakdown Structure in this case is selected as shown in equation (1). It consists of five already mentioned categories: Investments (C1), Design, construction and dismantling costs (C2), Maintenance (C3), Operation (C4) and Transportation costs (C5). Description of each category is given in the next section.

B. Cost Breakdown Structure

Category "investment costs" include all costs related to the equipment and materials used to construct the plant. This includes the costs of anaerobic digester, equipment for algae ponds, CHP station and different supportive buildings and instruments.

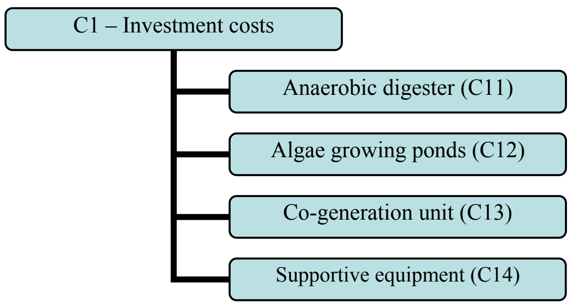

Fig.1. Cost breakdown structure of investment costs

Investment costs do not include human or energy resources necessary for the construction of biogas plant complex.

Design, construction and dismantling costs are the widest category. These costs are assumed to be mainly dependent on the capacity of the plant and are calculated as fractions of total income and investment costs. Cost breakdown structure for this category is displayed in figure below.

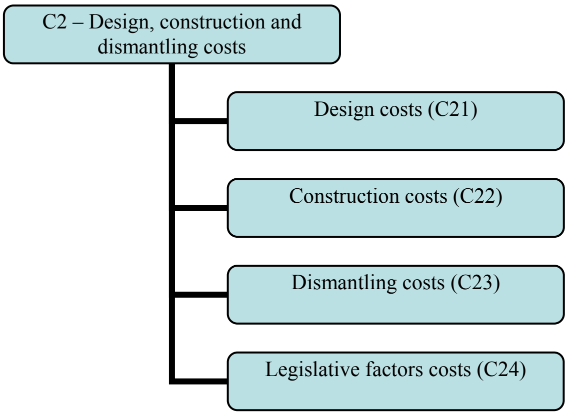

Fig.2. CBS of design construction and dismantling costs

Design costs include research and development, design of the plant and market analysis.

Maintenance cost category (See. Fig.3.) includes all repair costs as well as regular maintenance works, such as, cleaning, oiling and others.

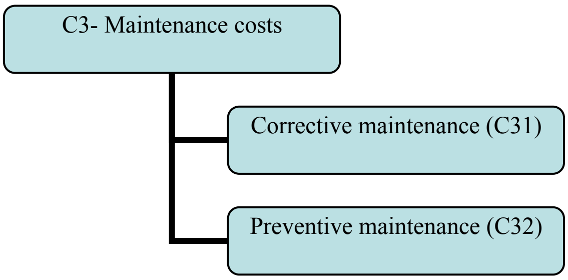

Fig.3. Maintenance cost breakdown

Next category is operational costs (C4), which include all expenses related to the operation of plants equipment and feedstock storage facilities – consumed electrical and thermal energy. In this case electricity and thermal energy consumption for the operation of the plant is covered by energy produced on site; therefore operational costs are kept to minimum.

Transportation costs (C5) are all expenses related to transportation of feedstock's to the plant. Full Cost Breakdown Structure is displayed in equation (1).

C. Description of scenarios

LCC calculation was performed for 4 scenarios. Tree of the scenarios are for Italian conditions using different mixes of biomass. Data used in these scenarios were obtained from pilot plant described by (E. Gili) but the last one is adapted to conditions (mandatory procurement component, transport, biomass mix and others) characteristic to Latvia.

Several parameters are the same in all scenarios. **Scenario 0 (base scenario)**: Biomass mix of Poultry manure, Citrus pulp, Olive Mill waste water (OMWW) obtained from respective industries, where they are wastes, and algae biomass cultivated on site. Transportation of biomass is assumed based on the average distance between the plant and possible suppliers. Biomass is transported using small truck (capacity 3.5 tons, with expanses 0.12 euro/km. The amount of biomass and total transportation distance in 1 year is displayed in Table 1.

TABLE 1

Biomass	Amount, t/year	Dry matter(DM), %	Volatile solids % of DM	Total transportation distance, km/year
Poultry manure	365	25	75	2520
OMWW	365	3	86	312
Citrus pulp	365	20	85	2340
Algae	37	10	85	-

Scenario 1: meet leftovers and kinder garden canteens leftovers are added to the biomass mix. Proportions of the kinds of biomass that were used in previous scenario have been changed as well, see Table 2.

TABLE 2

Biomass	Amount, t/year	Dry matter (DM), %	Volatile solids % of DM	Total transportation distance, km/year
Poultry manure	17.80	25	75	2520
OMWW	303.80	3	86	312
Citrus pulp	365.00	20	85	2340
Algae	49.70	10	85	-
Meet leftovers	365.00			3120
kindergarten canteens leftovers	30.02			165

Scenario 2: Scenario 2 uses the same kinds of biomass as in Scenario 1, however the proportions are changed (see Table 3.)

TABLE 3

	Amount [t/year]
Poultry manure [t*]	280.40
OMWW	365.00
Citrus pulp	329.00
Algae	49.70
Meet left.	77.10
Kinder garden canteens left.	30.02

Scenario 3 (Latvian case scenario). Basic parameters such as electricity, thermal energy and fertilizer procurement price in this scenario are set

according to real life values in Latvia. Algae and sewage sludge are used as biomass mix; the capacity of the plant is the same as in previous scenarios. Biomass mix in Scenario 3 is displayed in Table 4.

TABLE 4

Biomass	Amount, t/year	Dry matter (DM), %	Volatile solids % of DM	Total transportation distance, km/year
Algae	50	10	85	-
Sewage sludge	365	0.05	0.75	2000

III RESULTS AND DISCUSSION

Allocation of LCC of biogas and fertilizer separately are calculated and summarised in bar graphs.

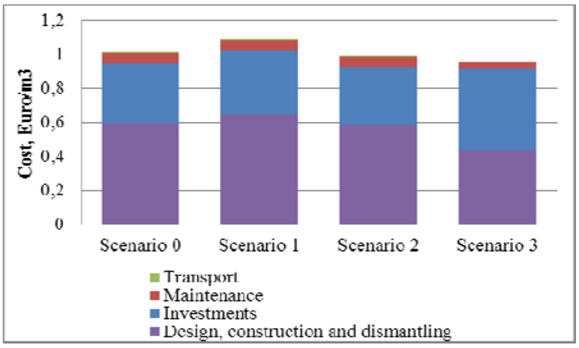

Fig.4.TLCC of biogas

TLCC of biogas are summarised in Fig.4. As you can see calculated TLCC of biogass are around 1 euro/m$^{3\cdot}$These results are similar to the ones obtained by Gili [6]. TLCC allocated to fertilizer are displayed in Fig.5.

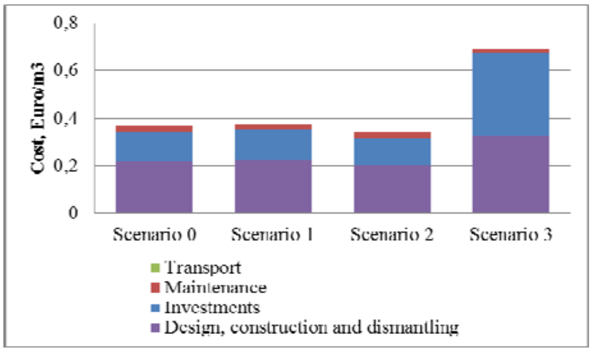

Fig.5. TLCC of fertiliser

There is significant difference between LCC of fertiliser in scenario 3 and all other scenarious. This can be partly explaind with utilization of sewadge sludge, which has considerably lower dry matter content and as a result can produce less fertilizer.

Sensitivity analysis was performed in order to determine which cost category has the highest impact on total life cycle costs. Scenario 0 (base scenario) was taken as the basis for sensitivity analysis. Figures below displays the impact on total life cycle costs per unit of fertilizer with 5%, 10%, 15%, -5%, -10% and -15% changes in certain cost categories.

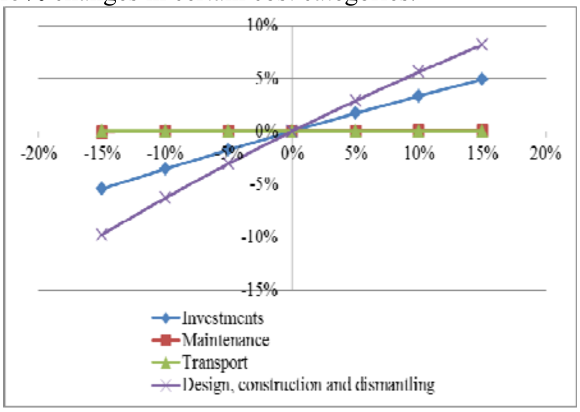

Fig.6. Changes in TLCC of fertilizer in percents depending on 5%, 10%, 15%, -5%, -10% and -15% changes different cost categories

As you can see in Figures above the most drastic change in LCC of fertilizer is in case of changes in "Design, construction and dismantling costs". This is very fortunate, because design costs will naturally decrease for other plants built by the example of this pilot plant.

This is, also one of the reasons why life cycle cost of biogas is smaller in Scenario 3. Another sensitivity test was performed in order to gain better understanding of the components and their impact on LCC of fertilizer and biogas. In this test costs in two categories were increased by 10 % at the same time. Resulting changes in LCC of fertilizer in percents are displayed in Table 5.

TABLE 5

	Investments	Maintenance	Transportation	Design, construction and dismantling	Market price(thermal energy & electricity)	Market price (fertilizer)
Investments	3%	3%	3%	9%	9%	8%
Maintenance	3%	0%	0%	6%	-6%	5%
Transportation	3%	0%	0.00%	5%	-6%	3%
Design, construction and dismantling	9%	6%	5%	6%	0%	11%
Market price(thermal energy & electricity)	-2%	-6%	-6%	0%	6%	0%
Market price (fertilizer)	8%	5%	3%	11%	0%	3%

IV CONCLUSIONS

Life Cycle costs for digestate use as fertilizer can be divided into five main categories: Investments, Design, construction and dismantling costs, Maintenance, Operation and Transportation costs. Four biogas production scenarios were compared in this study. Design, construction and dismantling had the most impact on Life Cycle Cost of fertilizer in scenarios 0 to 2. In the last scenario, which was assumed to operate under Latvian conditions, Investment category had the highest share of Life Cycle Costs. This was to be expected, because biogas plant in Latvia can be built following Italian example and, therefore, design costs for the plant can be reduced. Transportation share in Life Cycle Costs are very small, and this is also the narrowest category as it includes only fuel expenses for the transportation of different kinds of biomass. Sensitivity analysis also confirmed that the total Life Cycle costs are most influenced by Design, construction and dismantling cost category. There are also good opportunities to reduce costs in this category for other plants that would be constructed following this example.

V ACKNOWLEDGEMENT

This work has been supported by the European Social Fund project "Involvement of Human Resources for Development of Integrated Renewable Energy Resources Energy Production System" (project No. 2013/0014/1DP/1.1.1.2.0/13/APIA/VIAA/026).

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 289-296

Soil erosion risk assessment at small catchments scale: comparison of GIS-based modelling and field survey data and its implication for environmental maintenance of rivers

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Abstract. **One of the limitations to implementation of effective measures to mitigate negative environmental and economic effects associated with soil erosion is the lack of data on the geographic distribution of erosion risk and potential erosion hotspots. Hence, experts and policy makers in many cases have no spatially referenced information on which to base their decisions. There is a trend approved by EU institutions and agencies to use soil erosion models which can be integrated into geographic information systems (GIS) environment in order to obtain data at different spatial scales and to assist such decision-making. Despite that, until now in Latvia only some studies on the GIS-based modelling of potential soil losses have been conducted. Considering that, in the study presented in this paper soil erosion risk assessment has been performed by the widely used Revised Universal Soil Loss Equation (RUSLE) model over five selected small catchments of the river Daugava valley. In order to validate the results of modelling and to assess if theory accords with a real situation, the theoretical data were compared with information gained from the field survey of the same catchments. Modelled potential soil loss from each of five catchments under study totals 0.25; 0.26; 0.42; 0.51 and 0.58 t ha^{-1} y^{-1} in average. However, results of the comparison indicate the discrepancies between modelled and measured values, i.e. the used empirical model underestimates the soil erosion risk. The recognition of this fact raises implication for appropriate environmental maintenance of rivers, due to possible underestimation of eroded material delivery to receiving streams and, subsequently, under-prediction of water pollution..**

Keywords: **GIS, headwater gully catchments, RUSLE model, soil erosion.**

I INTRODUCTION

The soil erosion, including the soil erosion by water, is one of the most widespread forms of soil degradation thorough the world [1]. At the same time, this process is associated with reducing of area of agricultural lands and diminishing of soil fertility, hence in many countries soil erosion is ranked among other environmental problems [2]. Moreover, soil erosion simultaneously has negative off-site impacts due to transfer of agrochemicals and eroded material from headwater catchments to receiving streams and lakes, where it intensifies processes of silting up and eutrophication [3], [4]. Thereby it is essential to carry out studies focused on these issues in order to obtain reliable data in terms of both scientific and applied aims, e.g. environmental protection and sustainable management of soils as well as water resources.

The water quality and protection of soils are some of the major concerns in the European Union member states. Considering the key objectives of the EU Water and draft Soil Framework Directives [5], [6], during the past decade attention of scientific community and policy makers has understandably focused on matters of soil erosion in respect of environmental maintenance of rivers and streams and reduction of their pollution. The rationale for such approach is obvious – the data reported by researchers suggest that the main part of sediment inputs to permanent water bodies like rivers and lakes relates to transferring of soil erosion products from adjacent landscape [7] – [9]. In order to implement effective measures to mitigate water pollution and other negative environmental and economic effects associated with soil erosion, representatives of development and planning departments of local authorities and other specialists need information on which to base their decisions. There is a trend approved by EU institutions and agencies [10], [11] to use soil erosion models which can be incorporated into geographic information systems (GIS) environment to assist such decision-making, aimed to provide sustainable management of soil resources and environmentally

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.233

wise planning of land-use. Despite that, until now in Latvia only some studies on the GIS-based modelling of potential soil losses have been conducted [12], [13]. Considering that is difficult to carry out direct measurement of soil erosion rates at large scales [14], erosion modelling is significant tool for estimation or erosion risk at local, regional and European levels.

The models developed for the purposes of assessment of soil losses caused by water erosion (for reviews, see e.g. [15] – [17]) can be divided into three groups, i.e. (1) qualitative models; (2) semi-empirical or semi-quantitative models and (3) quantitative models.

Qualitative models include those ones which are based on geomorphological approach, i.e. the direct identification and estimation of erosion features and eroded areas from satellite images or aerial photos and the preparing of thematic geomorphological maps [18], [19].

Semi-empirical or semi-quantitative models are based on simplified methods, hence allowing to employ these models on territories characterised by high complexity of physiogeographic conditions or where input data for erosion modelling is insufficient [20], [21].

According to the quantitative approach of soil erosion modelling, potential soil loss is estimated by application of empirical equations, which as input data require several numerically parameterized factors. Several quantitative models have been developed since the 70ties of the 20th century for soil loss quantification, e.g. USLE [22], RUSLE [23], ANSWERS [24], WEPP [25], EUROSEM [26], PESERA [27]. Considering the manner for describing the erosion process representation, quantitative models are classified as empirical, conceptual and physics-based [28]. Despite all these models provide information on erosion and water quality processes, they differ in terms of their mathematical complexity, input data, spatial scale and the type and the reliability of output information [16]. However, the empirical Universal Soil Loss Equation (USLE) [22], and its more recent version, Revised Universal Soil Loss Equation (RUSLE) [23], which quantifies the mean area-specific annual soil loss caused by formation of runoff on the slopes, is most frequently used worldwide at various spatial scales and different environmental contexts [29] – [31].

Considering that, the aim of the research presented in this paper was to assess soil erosion risk in the river Daugava valley by application RUSLE model and ArcGIS software.

II MATERIALS AND METHODS

The methodology followed in this research can be subdivided into three major stages: (1) input data collection, processing and computation; (2) integration of data in RUSLE model and modelling of mean soil loss by GIS tools; and (3) validation of modelling data through field assessment of soil erosion rates.

The input data for modelling were obtained from orthophoto maps, field survey, published sources of information and from high-resolution digital elevation model (DEM), which was compiled both from topographic maps and airborne laser scanning (LiDAR) data. Subsequently the results of modelling were validated through comparison of GIS-computed values and field survey data. The latter was obtained from the estimation of suspended sediment load directly during episodic runoff events in selected gully catchments.

For research purposes, five small catchments drained by gullies were chosen as model territories. Such small catchments constitute the upper part of the hydrographic network in hummocky post-glacial landscape in SE Latvia and play an important role as sources of eroded soil material. The local names of gullies which drain the corresponding catchments are Baznīcas grāvis, Pesčanij ručej, Moģiļnij ručej, Eitvinišku strauts and Ververu strauts, hence model territories were named BG, PR, MR, ES and VS respectively. All the research procedures described below were performed for each catchment.

According to Renard et al. [23] the potential soil erosion risk within the defined area, in this case – within the small catchment can be predicted by the RUSLE model, which has the following expression:

$$A = R \cdot K \cdot L \cdot S \cdot C \cdot P \qquad (1)$$

where A is the mean soil loss per year (t ha^{-1}y^{-1}); R is the rainfall erosivity factor (MJ mm ha^{-1}h^{-1}y^{-1}); K is soil-erodibility factor (t h MJ^{-1} mm^{-1}); L is the slope length factor and S is the slope steepness factor (both dimensionless); C is the cover management factor (dimensionless); and P is the support practice factor (dimensionless).

Firstly, in order to perform modelling procedures, input data have been collected and the factors to be included in the RUSLE model have been computed. For this purpose literature review and survey of topographic maps and orthophoto maps was carried out, hence obtaining basic data collection.

The R factor which quantifies the effects of rainfall impact and reflects the rates of interrill erosion is not measured at meteorological stations in south-eastern Latvia. Thereby the value of this factor has been inferred from the literature [32], from the closest location where estimations of R factor is available, i.e. north-east Lithuania. Considering the close geographic location of the river Daugava valley to the mentioned region, and as result minor differences in annual amount of precipitation and its seasonal distribution, the R factor was set to value 461.2 (MJ mm ha^{-1}h^{-1}y^{-1}).

The K factor is an empirical measure of soil erodibility and depends on soil properties. For the modelling purposes K factor values were obtained in two steps: (1) deriving soil texture type from large-scale geological survey data [33] and (2) assigning values given in literature [22] for soils with corresponding texture type. In addition conformance of *K* factor values were verified with the most recent published data on the distribution of soil erodibility factor values in Europe [14].

For the obtaining of *L* and *S* values, high-resolution DEM was developed, which was compiled both from topographic maps and airborne LiDAR data. For that contour lines and spot heights were digitised from the topographic maps at scale 1:10,000 with contour interval 2 m, and subsequently ESRI Grid raster DEM was generated by ArcGIS extension Spatial Analyst tool *Topo To Raster*. In order to improve the quality and spatial resolution of DEM, raster data generated from topographic maps were combined with the LiDAR data of the same catchments by ArcGIS tool *Mosaic to New Raster*.

Considering the slope length *L* and the slope steepness *S* are topographic dimensionless factors, usually they are combined in RUSLE model and represented as integrated *LS* factor. Therefore, the *LS* factor was calculated with the previously developed DEM according to the following expressions of McCool et al. [34] used in RUSLE:

$$L = (\lambda / 22.13)^m \tag{2}$$

$$m = \beta / (1+\beta) \tag{3}$$

$$\beta = (\sin\theta) / (3 \cdot (\sin\theta)^{0.8} + 0.56) \tag{4}$$

$$S = 10.8 \cdot \sin\theta + 0.03 \quad \text{if slope gradient} < 9\% \tag{5}$$

$$S = 16.8 \cdot \sin\theta - 0.5 \quad \text{if slope gradient} > 9\% \tag{6}$$

where λ is the length of the slope; m is a variable length-slope exponent; β is a factor that varies with slope gradient, and θ slope inclination angle.

For further modelling purposes, *S* factor was derived from DEM by raster processing tool *Slope*, and *L* factor was derived by combination of two raster processing tools – *Flow Direction* and *Flow Length*. Then formulas (2); (3); (4); (5) and (6) were used to obtain the *LS* factor values.

The *C* factor values were obtained from identification of land cover types on the basis of analysis of orthophoto maps. In addition, field survey of this factor was performed, allowing to distinguish the following land cover classes in the catchments under study: grassland and rangeland, arable land, garden, orchard, forest, scrub and pond. Then *C* factor was parameterised by assigning a uniform value given in the literature [22] to each land cover class.

Finally, the support practice *P* factor (dimensionless) was set to value '1' because there are no specific erosion control practices in the studied catchments, hence this factor has no impact on the resulting soil losses.

Because RUSLE model deals with input data which have geographic reference to their location, i.e. these data are geospatial data, the availability of GIS instruments facilitated the automatization of calculation procedures. Therefore the mean annual soil loss for the each of five catchments were calculated for a 1 × 1 m cell grid by ArcGIS tool *Raster Calculator* according to the following SQL codes developed by Grišanovs [35] for application in GIS:

```
L=Pow(([FlowLength]/22.13),(((Sin([Slope]·3.14159/180)/0.0896)/(3·Pow(Sin([Slope]·3.14159/180),0.8)+0.56))/((Sin([Slope]·3.14159/180)/0.0896)/(3·Pow(Sin([Slope]·3.14159/180),0.8)+0.56)+1)))

S=(10.8·Sin([Slope]·3.14159/180)+0.03)+(16.8·Sin([Slope]·3.14159/180)-0.5)

A=461.2·[K]·[L]·[S]·[C]
```

This procedure allowed to obtain data at high spatial resolution because potential mean annual soil loss values were calculated for each cell of 1 × 1 m regular grid.

The results of modelling were compared with the data on sediment load from gully catchments carried by temporary streams. To do that, first of all, measurements of discharge Q ($m^3\ s^{-1}$) and sediment concentration C_S ($mg\ l^{-1}$) were carried out during the formation of runoff in gullies which drain corresponding catchments. Than sediment load Q_S ($kg\ s^{-1}$) was estimated applying the relationship (7) given in the literature [36]:

$$Q_{SS} = Q \cdot C_S \tag{7}$$

After that, in order to get comparable values of suspended sediment load from gully catchments that differ in size, an area-specific daily sediment yield SY_D ($kg\ ha^{-1}\ day^{-1}$) was derived by formula (8). Namely, the area-specific daily sediment yield SY_D can be expressed as the established ratio between the corresponding sediment load Q_S ($kg\ s^{-1}$) multiplied by the time span equal to one day expressed in seconds and the contributing area of catchment C_A (ha), hence SY_D can be calculated from:

$$SY_D = Q_S \cdot 86400 / C_A \tag{8}$$

Finally, the reasons why the modelled and measured assessments of erosion rates differ are discussed hereinafter in the paper.

III RESULTS AND DISCUSSION

A. Characteristics of catchments

Considering their topography, all five catchments have a similar structure, i.e. the drainage area could be subdivided into two parts. The (1) upper part or gully channel contributing surface are represented by morainic slightly undulated plain with rather gentle slopes, whilst the (2) lower part are represented by river valley slope dissected by gully and with steeper slope gradient. This can be distinguished in a digital elevation model of catchment BG in Fig. 1. Typically the upper parts of catchments stretch at elevations above 140 m a.s.l., but their lower parts are located at elevations from 90 to 92 m a.s.l. Thus, high vertical difference between contributing areas and local base level creates favourable conditions for soil erosion process.

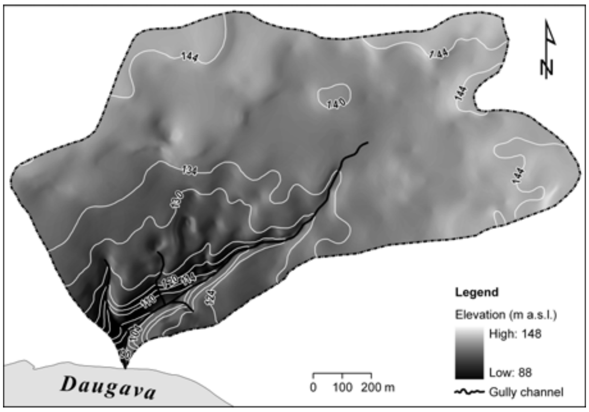

Fig. 1. Topography typical for gully catchments under study: an example of BG catchment, showing relief by a shaded DEM in the background.

Considering a lithological diversity of Quaternary deposits combined with intricate topography, a variety of soils can be identified within model territories. However, Stagnic Albeluvisols, Albic Rubic Arenosols and Albic Stagnic Podzols are dominant types of soils. Despite the variety of soils, the selected gully catchments have similar properties in respect of erodibility because glacial till derived stony loamy – clayey diamicton sand textures prevail in the selected catchments. Hence, values of erodibility *K* factor of the top-layer are more or less similar.

Comparison of the gully catchments under study which is given in Table I indicates, that the most significant differences can be distinguished concerning morphological features, i.e. catchments area and gully network drainage density, as well as vegetation and land cover.

These factors namely determine the difference in a formation and rate of runoff and, thus, control the soil erosion. That reflects the notable variation in the susceptibility of small catchments to mobilization and transferring of soil erosion products due to spatial alteration of controlling factors.

Theoretically, considering the morphology of gully catchments, particularly the mean slope of gully channel contributing surface (Table I) which is one of the main erosion controlling geomorphological factors [37], the ES and VS catchments are the most prone to soil erosion, and hence should present the highest values of soil losses. Both aforementioned catchments also are characterised by comparatively high drainage density (3.71 km km^{-2} and 3.45 km km^{-2} respectively) and as a result more rapid draining of water and subsequently, higher transporting capacity of eroded sediments and their transferring it to the receiving stream.

TABLE I

MAIN MORPHOLOGICAL CHARACTERISTICS OF GULLY CATCHMENTS UNDER STUDY

Characteristic	Catchment				
	BG	PR	MR	ES	VS
C_A (ha)	139.06	74.67	124.44	68.93	59.06
WLR	0.59	0.28	0.48	0.65	0.39
LB (m)	58	72	56	87	84
DD (km km^{-2})	1.16	1.72	0.88	3.71	3.45
S_m (m m^{-1})	0.029	0.034	0.025	0.058	0.064
GL (m)	1230	1160	860	1010	860
GG_m (m m^{-1})	0.043	0.044	0.040	0.063	0.056
PVC (%)	11.10	9.64	81.20	44.35	42.95

Note: C_A = catchment area; *WLR* = width-length ratio of catchment; *LB* = local base level equal to max. difference in local topography within catchment; *DD* = drainage density of gully network (including side branches) within catchment; S_m= mean slope of gully channel contributing surface; *GL* = gully length; GG_m = gully thalweg mean gradient; *PVC* = proportion of area under protective canopy vegetation cover (forest and scrub) within catchment.

Review of literature indicates [38] that besides the geomorphological factors, the protective canopy vegetation cover and land use also are significant factors affecting soil erosion rates. Therefore, the spatial analysis of land cover patterns and calculation of a specific area for each landscape mosaic element was carried out. In Fig. 2, the calculated ratio among different land cover classes for each of the studied gully catchments, obtained from aerial photographs by GIS analysis, are shown.

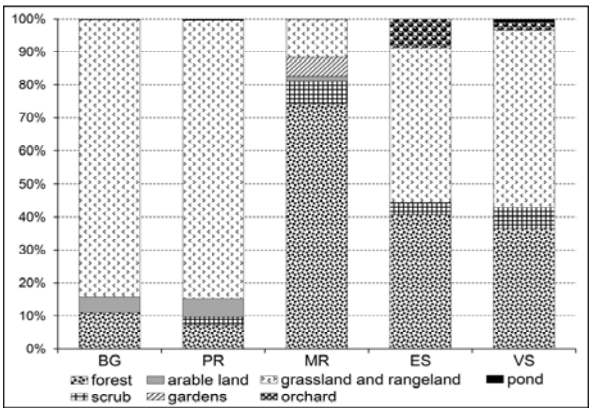

Fig. 2. Land cover classes and their proportion in each gully catchment under study.

The arable land in the territory under study constitutes less than 5% of the total gully catchments BG, PR and MR area (e.g. 4.74%, 5.67% and 1.41% respectively), while in catchments ES and VS this type of land cover is not presented at all. At the same time, forest canopy vegetation covers more than 40% of the area of three of these catchments, i.e. MR, ES and VS. Hence, it can be anticipated less erosion rates and associated eroded material delivery from these model territories.

B. Results of RUSLE modelling

The potential mean annual soil loss A under present land use in the gully catchments BG, PR, MR, ES and VS modelled by RUSLE was 0.51; 0.58; 0.26; 0.25 and 0.42 t $ha^{-1}y^{-1}$ respectively (Table II). Within catchments the modelled values of soil loss are characterised by high deviation and variation – statistics indicates that these indices can reach values up to 527%. Such a high dispersion can be explained by high spatial variability and physical entity of input data used in RUSLE model – these data represent independent phenomena or values, which are non-correlated each other.

TABLE II

RESULTS OF MODELLING OF ANNUAL SOIL LOSSES FROM GULLY CATCHMENTS

Catch-ment	N	Potential mean annual soil loss (t $ha^{-1}y^{-1}$)			$STDV$ σ	V (%)
		A_{min}	A_{max}	A_{avg}		
BG	1 390,581	0.0	62.91	0.51	1.558	305
PR	746,747	0.0	150.62	0.58	2.165	373
MR	1 244,375	0.0	62.83	0.26	1.369	527
ES	689,346	0.0	8.99	0.25	0.376	150
VS	590,590	0.0	8.93	0.42	0.598	142

Note: N = number of grid cells used for calculations of statistics; A_{min} = minimal modelled potential mean annual soil loss at catchment; A_{max} = maximal modelled potential mean annual soil loss at catchment; A_{avg} = average modelled potential mean annual soil loss at catchment; $STDV$ = standard deviation of the modelled A values; V = variation index.

However, at the catchment scale average A values varies greatly depending on land cover type, corresponding to 5.59 t $ha^{-1}y^{-1}$ for cropland and arable land, 0.27 t $ha^{-1}y^{-1}$ for grassland and rangeland, and 0.12 t $ha^{-1}y^{-1}$ for forestland. The average soil loss modelled rates of cropland was about 20.7 times that of grassland, and 46.5 times that of forested land. The spatial distribution of the soil erosion risk is uneven and differs both among the catchments and at the each catchment.

The spatial distribution of the erosion risk represented by potential soil loss, as shown on example of BG catchment in Fig. 3, was divided into five categories: Category 1, very low risk (potential soil loss 0 – 0.3 t $ha^{-1}y^{-1}$); Category 2, low erosion risk (potential soil loss 0.3 – 1.0 t $ha^{-1}y^{-1}$); Category 3, moderate erosion risk (potential soil loss 1.0 – 3.0 t $ha^{-1}y^{-1}$); Category 4, high erosion risk (potential soil loss 3.0 – 10 t $ha^{-1}y^{-1}$); and Category 5, very high erosion (potential soil loss >10 t $ha^{-1}y^{-1}$).

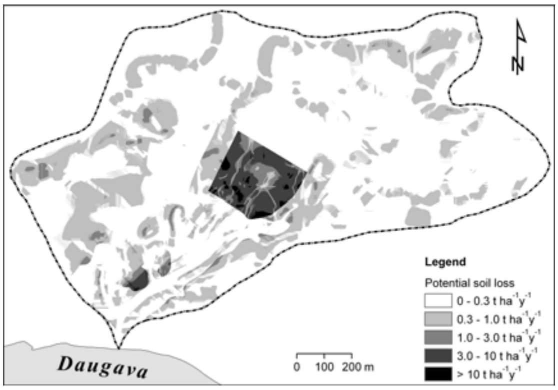

Fig. 3. Spatial distribution of modelled soil erosion risk represented by potential soil loss (t $ha^{-1}y^{-1}$): an example of BG catchment.

The regularity elucidated during analysis of data indicates that the lowest soil erosion risk Category 1 included mostly forested areas, whilst the higher soil erosion risk categories, i.e. Category 4 and Category 5 geographically coincide with arable land.

The data obtained on potential soil loss indicate, that despite the ES and VS catchments are characterized by the highest mean values of contributing surface slope and theoretically both catchments are most prone to soil erosion, the modelled A values are comparatively small, contrary to anticipated results. This fact can be explained by the highest proportion of area under the protective canopy vegetation cover within both these catchments.

C. Results of field assessment of soil erosion rates

Area-specific daily sediment yield SY_D (kg ha^{-1} day^{-1}) as eroded material output from catchments was calculated for short measuring periods, using the methods described in the section "Materials and methods". Calculation of the mean annual load was not performed because such an approach is incorrect if the measurements of input data have been carried out *in situ* only during runoff causative weather events. The obtained results on SY_D are summarized in Fig. 4.

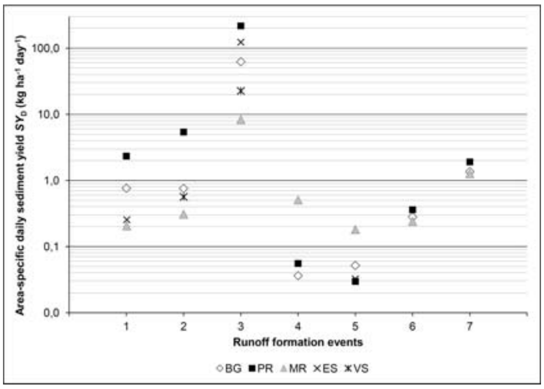

Fig. 4. Comparison of area-specific daily sediment yield SY_D of catchments under study for different runoff events

The highest area-specific daily sediment yield SY_D occur for the PR catchment, which is possibly associated with the lowest percentage of canopy vegetation cover and the highest percentage of agricultural land.

For the reasons of comparison, the modelled potential soil loss A values were downscaled at temporal scale to obtain it daily values, which, in fact, correspond to SY_D. Comparison of modelled versus measured values indicates that the applied RUSLE model underestimates real sediment delivery, which shortly can reach values 217.63 kg ha^{-1} day^{-1} during intense snow melting in spring. Hence, in fact, the ‘theory’ does not reflect ‘reality’. This discrepancy why the two assessments of erosion obtained from GIS-based modelling and field survey data differ can be associated with several reasons. First of all, RUSLE model doesn’t take into consideration possible influence of high-intensity hydro-meteorological extremes as well as the impact of rill and gully erosion on sediment production from catchments. Consequently, these errors are not included in calculations of mean values, leading to inadequate evaluation of erosion risk. This fact is also indicated in the literature [40]. Secondly, the field observations indicate that the most of the eroded material is supplied from the erosion of cohesive gully sidewalls and rewashing of material replaced downslope into gully channels by mass movement processes; less the eroded material is supplied from the surface erosion in the catchment area by such processes as overland flow. This demonstrates that gullies certainly contribute to the sediment yield from a catchment even if a process of downcutting does not occur. This also indicates that suspended sediment comes from two different sources, i.e. soil erosion of the catchment surface, and lateral erosion of the channel banks, when fine material is thrown into suspension by the temporary stream after a bank collapse, however, quantifying this effect is difficult. Finally, the presence of boulders and very coarse material in glacial till-derived soil, which is not taken into consideration in calculations of K factor values, enhances turbulence of the stream and, consequently, the associated erosivity.

Summarizing the results obtained in this research, as well as above discussed issues, it is possible to conclude that the applied modelling underestimates real values of sediment delivery from headwater catchments, hence causing implications for development of appropriate erosion risk reduction practices and adequate measures to maintain environmental quality of the river. Nevertheless, results of GIS modelling can be reasonably used to estimate the spatial distribution of soil erosion risk and to identify potential erosion hotspots.

IV CONCLUSIONS

The application of RUSLE model, originally developed for application in the farming sector at local scale, if applied to a catchment scale in different landscapes and various environmental and climate conditions, must take into account some limitations. The obtained values of potential soil loss and corresponding erosion risk must be employed adequately, only for indicative or comparative purposes, and not considered in absolute terms.

The analysis of data carried out in this study has showed that the current approach of RUSLE erosion model underestimates the proportion of the sediment load which is transferred from erosion sources associated with contributing surfaces of headwater catchments.

Field observations indicate that important factors affecting sediment mobilization and delivery to receiving rivers are erosion and mass movement processes within gully channels. Hence, a major limitation for the soil erosion risk assessment by RUSLE is that accelerated erosion by streams, mass movements and gully sidewalls erosion most often are not considered in calculations. In addition eroded material output is very responsive to extreme runoff events, leading to a strong underestimation of loads when using empirical models like RUSLE based on the mean values of factors.

Although the results of RUSLE modelling, in general, can be used as a basis for management and environmental maintenance of rivers, until better models will be implemented and adapted, policy makers and decision taking institutions should treat the results of soil erosion risk assessment with some caution.

The GIS-based RUSLE modelling enables scientists, experts of local authorities and other specialists to identify erosion risk areas and potential erosion hotspots and to implement mitigation and control measures with a respect of limiting environmental damages and related costs. According to Glymph [41], ‘It costs less to keep soil on the land than dredge it from waterbodies’, hence the approach ‘control at source to prevent water pollution by sediment’ should be implemented wider by local authorities and responsible experts for environmental maintenance of rivers, in particular given the situation of limited resources for developing and implementing erosion mitigation measures.

ACKNOWLEDGMENTS

Research reported in this paper was financially supported by the ESF project No. 2013/0020/1DP/1.1.1.2.0./13/APIA/VIAA/066 „Interdisciplinary Team of Young Scientists for Assessment and Restoration of Soil Quality and Usage Potential in Latvia”.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 297-302

Yield development of flax varieties and lines within variable environment in Latvia

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Abstract. **Flax is the multiple purpose crop cultivated in temperate region. Seeds of oil flax recently became important constituent for many industrial applications, such as pharmacy, medicine, food production *etc.* and have high prospective for use in Latvia. Understanding the underlying processes that limit seed yield in flax is major with respect to enhancing the breeding of flax for yield improvements. The aim of study was evaluated 29 flax varieties and lines (including 20 Latvian origins) plasticity of seed yield production in changeable environmental conditions. The experiment was carried out in the Agricultural Scientific Centre of Latgale on field trials over the period 2010-2013. According to 4 years results was to establish the nature of relation between seed yield and hydrothermal coefficient (HTC), and seed yield and another yield components of flax. Apart from the changing conditions highest seed yield were produced from a varieties 'Lirina' (2.54 h $^{-1}$t), high seed oil content from variety 'Amon' (53.03%). Positive and significant relationships were found between seed yield and HTC 'T30-28-6-94'(r=+0.98*), 'German Serenade' (r=+0.95*) and 'Scorpion' (r =+0.95*).**

***Keywords*: flax, genetic resource, seed yield.**

I INTRODUCTION

Flax (*Linum usitatissimum* L.) is a good example of a multiple purpose crop being utilized for oil and fiber. It was one of the eight "founder crops" of agriculture, was a principal source of oil and fiber from prehistoric times until the early 20th century, and still remains a crop of consider able economic importance [1], [2].

The seed of flax (i.e. linseed) produces oil that is rich in unsaturated fatty acids, especially a-linolenic acid (C18:3), polymers of which are used in linoleum, paints and other finishes. Consumption of the oil or seed has been reported to have beneficial effects on cardiovascular health and in the treatment of certain cancers and inflammatory diseases [3]. Health benefits are derived from both the a-linolenic acid, rich supply of soluble dietary fiberand and other components of the seed, including lignans such as secoisolariciresinol diglucoside (SDG), which is an antioxidant and the precursor of several phytoestrogens [4], [5]. Flax seed is also used in animal feed to increase levels of a-linolenic acid in meat or eggs [6]. A 100 g portion of flaxseed provide 1890 kJ and 450 kcal energy and contains approximately about 41% oil, 20% protein, 8% moisture, 4% ash and 27% total dietary fiber. Also, flaxseed is known to be nature's best source of omega-3 oil [7].

In recent years, the food and pharmaceutical industries have paid attention to the properties of flax mucilage. Due to its specific biological activities, seed mucilage (SM) can be used as a thickening agent [8], as a substitute to chemical additives for food preservation [9] and as an excipient in drug formulations [10]. In contrast to the human food industry, the animal feed sector requires flax cultivars with low mucilage content to prevent negative effects on animals' digestion [11].

Yield is a quantitative characters and it is influenced by both genetics and environmental condition [12]. As environmental factors exert a major role in determining yield potential it is important to understand environmental effects on yield. Weather patterns and soil types affect seed yield in flax, but plant density has little effect because flax compensates for reduced stand densities mainly through increasing the number of boils per plant [13]. Temperature affects the rate of crop development however; excessively high temperatures during flowering limit flax seed production due to reduced seed set and boil numbers [14].

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.276

Crop yield is a polygenic trait that is greatly affected by environment and gene-environment interactions. Yield related genes are affected to a different degree by environment in any given year; therefore, selection based on yield per se is not always effective in the long term [15]. Indirect selection through yield components is likely to be more effective than focusing on grain yield (a trait generally knows to be highly influenced by the environment with low heritability) because the components of yield are less environmentally sensitive and have higher heritability [16], [17]. Taking in account the facultative cross-pollination, the development of genetically stabile lines could take more than 15 years [18], [19].

Yield is the most important and complex trait in crops that shows correlations with other traits [20]. In linseed, yield and its components such as 1000 seed weight (TSW), seeds per boll (SPB), and bolls per area (BPA), are quantitatively inherited and controlled by many genes affected by multiple interactions with other genes and the environment [21]-[23]. An understanding of impact of environmental influence on yield-related traits is of practical value to breeders because such information assists in the design of efficient breeding strategies and for farmers in the choice of variety for cultivation.

Accordingly the aim of this study was evaluated plasticity of seed yield production in changeable environmental conditions for 29 flax varieties and lines (including 20 Latvian origins).

II MATERIALS AND METHODS

Field experiments

This study was carried in four consecutive growing seasons (2010 - 2013) out at the field trial in the Agricultural Science Centre of Latgale in Latvia. Experimental material for the present study consisted of 29 flax varieties and lines (including 20 Latvian origins) [24]. Flax varieties and lines were compared with the standard varieties ‘Lirina’ and ‘Vega 2’.

Evaluated flax varieties and lines

- ‘Lirina’, ‘Scorpion’, ‘German Serenade’ (Germany origin varieties).
- ‘Bildstar’, ‘Amon’ (Czech Republic origin varieties).
- ‘Princess’, ‘Duchess’ (France origin varieties). ‘Flanders’ (Canada origin varieties).
- ‘ST Vega2’ (Lithuania origin variety).
- ‘TVR 03’, ‘T VR02’,’T 36-26/4-8-94’, ‘T 31-42-94’, ‘T 30-28-6-94’, ‘K 47-17/11-1-95’, ‘T 30-15/4-3-94’, ‘K 30-14/14-18-94’, ‘K 30-14/14-11-94’, ‘T 29-14/4-2-94’, ‘38’, ‘37-50’, ‘37-49’, ‘37-34’, ‘37-28’, ‘37-10/1’, ‘37-9/1’, ‘37-5’, ‘37-2’, ‘37-1’ (Latvia origin lines).

Seed yield and 1000 seed weight was determined in each harvested parcel area. Number of seed-vessel per plant and seed number per seed-vessel were determined by randomly selected 10 plants in each parcel. Oil content of each variety and line was determined by grain quality analyzer "Infratec 1241". Each variety and line was noted the vegetation period.

Agrochemical properties of the soil were determined four experimental years.

Meteorological conditions

Agro-meteorological conditions determined by ADCON installed meteorological stations which are connected to the computer program Dacom Plant Plus. Facility provides information in direct nearby field trials.

This study was calculated hydrothermal coefficient (HTC) of each month during the growing season (are presented on Fig. 1). Hydrothermal coefficient has been calculated by applying formula (1) of G.Selyaninov [25]:

$$HTC= \Sigma x / \Sigma t \times 10; \qquad (1)$$

where Σ x and Σ t –accordingly sum of precipitations and temperatures in the period, when the temperature has not been lower than 10^{o} C.

Criteria:

HTC $\leq$ 0.5 – strong, very strong drought;

HTC = 0.6 – weak drought;

HTC $\leq$ 0.7 – dry conditions;

HTC $\geq$ 1.0 – characterizes the sufficient moistening.

Data analysis

Microsoft Excel program was used for data statistical processing. Used data analysis tools Descriptive Statistics and Correlation tests. This study was carried out to determine the effect of significant and not significant relationship between seed yield and yield components, and between seed yield and HTC.

III RESULTS AND DISCUSSION

Weather conditions in 2010 - 2013 seasons of vegetation periods were different and varied impact on flax growth and development. Basically during the growing season of flax lasts from May to the end of August.

During the 2010 in the first period of flax growing seasons were characterized by the sufficient moistening HTC range from 1.12 to 1.64 and second period with strong, very strong drought HTC range from 0.34 to 0.37. The weather conditions for flax in the vegetation period have been favorable for the flax yield development because from “fir-tree” stages to flowering stages are wet and in maturation stage of the hot, dry weather [26]. The year 2011 is characterized as the driest year HTC range from 0.42 to 0.84 only in May was sufficient moistening HTC was 1.11. And year 2012 characterized by the highest moisture content HTC ranged from 1.73 to 2.86. During the 2013 at the beginning of the season is a very large amount of moisture in April, HTC was 4.75. Excess moisture content adversely affects the germination of flax in May. Throughout the growing season HTC is characterized the sufficient moistening range from 0.92 to 1.27, except June with weak drought, HTC was 0.56.

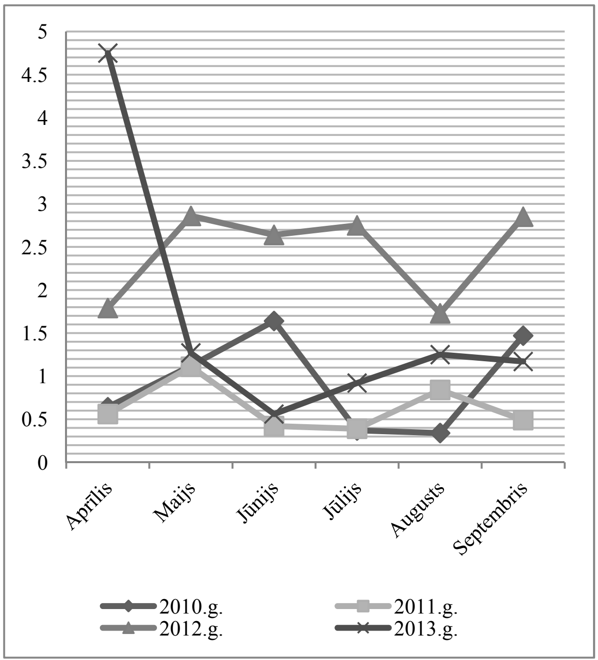

Fig.1. Comparison HTC in 2010-2013 growing seasons of flax

Fertilization and agrochemical actions for all flax varieties and lines was equivalent. Soil agrochemical characteristics of the four experimental years were not significantly different: organic matter content of the soil is 6.5%, pH - 6.4 to 7.0, phosphorus contents P_20_5 - 130 to 145 mg kg^{-1} soil, potassium K_2O - 118 to 124 mg kg^{-1} soil.

During the 2010 – 2013 seasons were harvested seed yields from flax varieties and lines are presented on Fig. 2. The all studied years highest yield obtained from a variety 'Lirina' (average seed yield 2.54 t ha^{-1} with variations coefficient V= 8%). This variety by genetic composition is the most valuable, because unable to give a high yield at different temperatures and humidity. Only in the 2012 higher harvesting is carried out from varieties 'Flanders' (average seed yield 2.10 t ha^{-1}, with variations coefficient V = 15%), 'Scorpion' (average seed yield 1.88 t ha^{-1}, with variations coefficient V = 16%), 'German Serenade' (average seed yield 1.49 t ha^{-1}, with variations coefficient V = 24%), 'Duches' (average seed yield 1.97 t ha^{-1}, with variations coefficient V = 11%) and 'Amon' (average seed yield 1.85 t ha^{-1}, with variations coefficient V = 17%). High seed yield for these varieties explaining by high moisture content in vegetation period. The genetic resource permits the production of high yields under certain weather conditions.

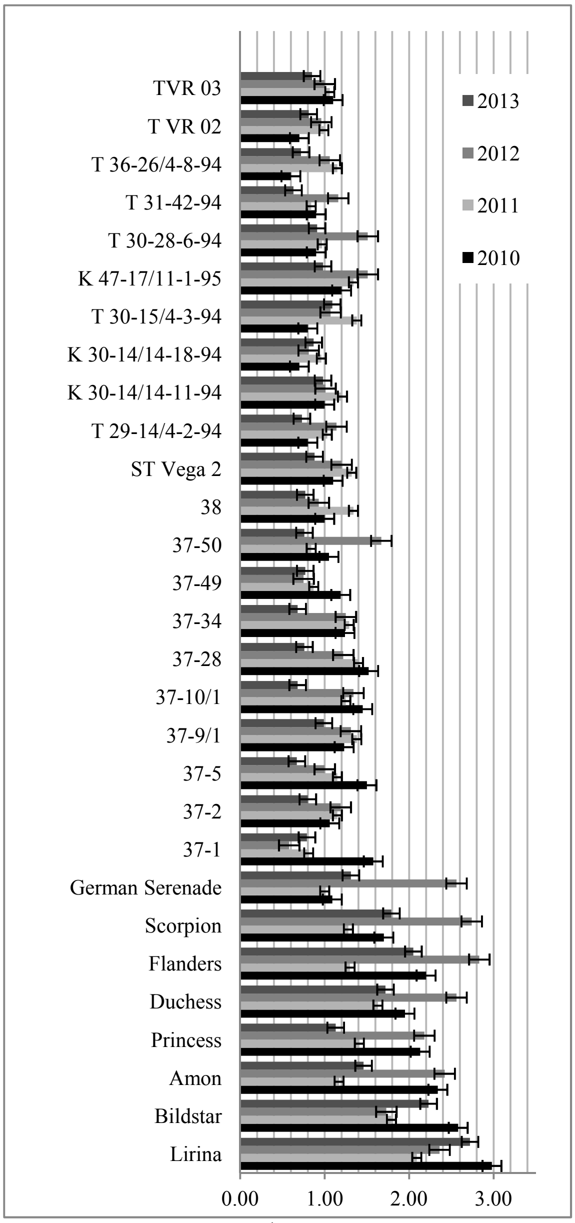

Fig.2. Seed yield (t ha^{-1}) of flax varieties and lines

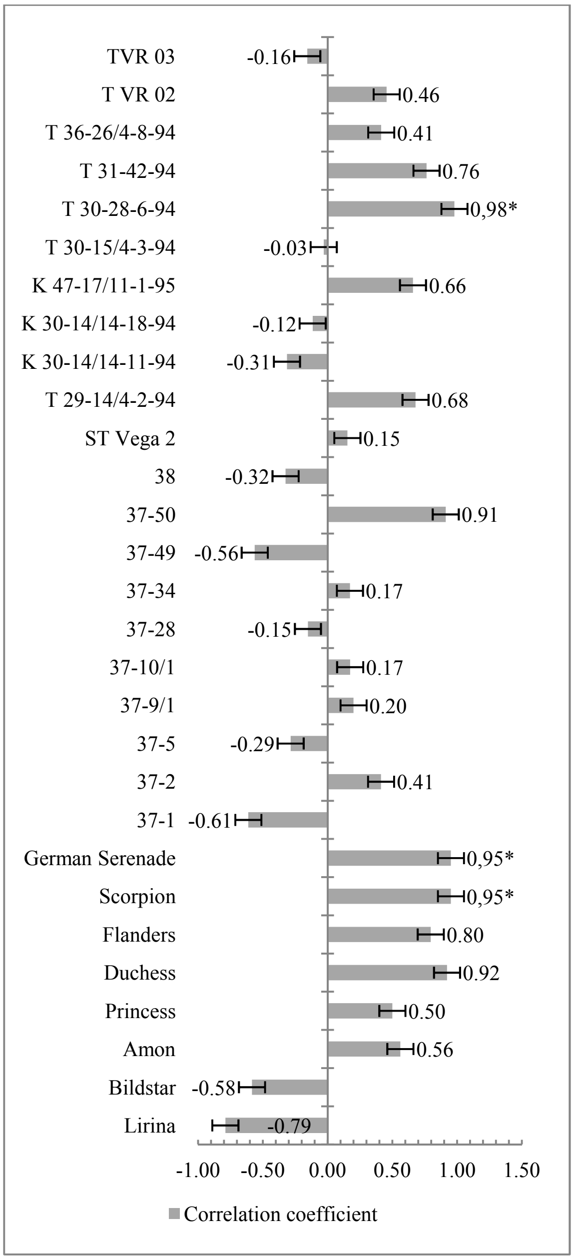

Fig.3. Correlation coefficient between seed yield and HTC in flax varieties and lines (* − correlation significant at p≤0.05)

Correlation coefficients are displayed between each flax varieties/lines of seed yield and HTC in Fig. 3. Positive and significant relationships were found 'T30-28-6-94' (r=+0.98*), 'German Serenade' (r=+0.95*) and 'Scorpion' (r =+0.95*). In this case, the yield formation significantly was influenced by environmental conditions. Major negative, but no significant coefficient was found 'Lirina' (r=-0.79).

Multiple correlation coefficients among the characters investigated in the experiments presented in Table1.

Positive and significant relationships were found between seed yield and 1000 seed weight (r=+0.59**), number of seed vessels per plant (r=+0.77**), number of seed per vessels (r=+0.40*) and vegetation period (r=+0.85**). The effects are related to environmental condition and genotypic reason. [12], [27] - [34] working on flax also found similar results. The research shows these indicators as are important to obtaining high seed yield.

As it is seen from Table 1 positive and significant correlation was found between 1000 seed weight and number of seed-vessels per plant (r=+0.68**) and vegetation period (r=+0.53**).

TABLE 1

Investigated characters	SY	OC	1000SW	NSVP	NSV
OC	-0,03				
1000SW	0,59**	-0,36			
NSVP	0,77**	-0,39*	0,68**		
NSV	0,40*	-0,28	0,14	0,42*	
VP	0,85**	-0,09	0,53**	0,73**	0,26

SY: Seed Yield, OC: Oil Content, 1000SW: 1000 Seed Weight, NSVP: Number of Seed Vessel per Plant, NSV: Number of Seed per Vessel, VP: Vegetation Period, * − correlation significant at p≤0.05, ** − correlation significant at p≤0.01

IV CORRELATION COEFFICIENT OF SEED YIELD AND COMPONENTS IN FLAX

As also number seed vessels per plant positive and significant correlated between number of seed per vessel (r=+0.42*) and vegetation period (r=+0.73**).

Negative and significant relationships were found between oil contents and number of seed vessel per plant (r=-0.39*). In this case, results were showed that on the development of the oil content high influence have genotypes. Oil contents in seed of flax varieties and lines are showed in Fig. 4. Apart from the seed yield the high oil content derived from variety 'Amon' with average 53.03%. All investigated years oil content ranged from 42.8 to 53.03%.

The relative contribution of yield components to the yield varied largely depending upon the environment, which was supported by the previous work [34] - [36].

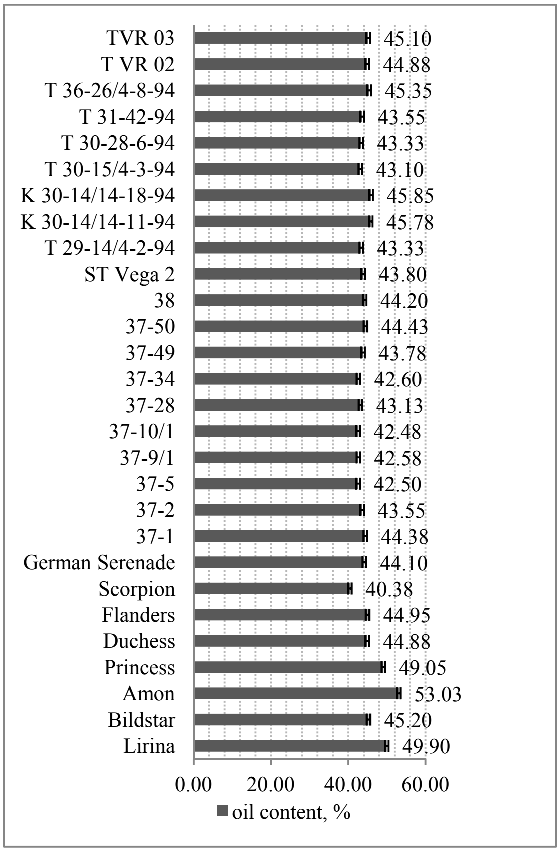

Fig.4. Oil content (%) in seeds of flax varieties and lines

V CONCLUSIONS

The best stability in changeable environmental conditions and higher seed yield was showed variety 'Lirina' (average seed yield 2.54 t ha^{-1} with variations coefficient V= 8% and r=-0.79).

The study was proved that for the some varieties and lines rainfall and temperature averages significantly affect the vegetative and reproductive stages of development of flax. Positive and significant relationships were found 'T30-28-6-94'(r=+0.98*), 'German Serenade' (r=+0.95*) and 'Scorpion' (r =+0.95*). May recognized that these varieties at high humidity quantity during the season are directly or indirectly affected by positive yield increase.

They are of particular interest for the further collecting of genetic resources and show a wide spectrum of agronomic variability among the varieties investigated. The results obtained have shown that the agronomic parameters are very useful for the initial description.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 303-306

Anthropogenic Impact on the Macrophytes of Pskov Region Alkalitrophic Lakes

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Abstract. **In 2007 a research of the macrophytes species composition in three alkalitrophic lakes of Pskov region was conducted with the aim to reveal human impact of experimental activities on Fishery transformation, which were conducted in 1969-1972. The study displayed small changes in higher aquatic plants' composition: the number of macrophytes species almost haven't changed, dominant species of emergent vegetation belt maintained their positions, and locations of species listed in the Red Data Book were unchanged. The strong negative impact fishery activities made only on *Charophyta* stretches, which has disappeared or their areas were much reduced in studied lakes. One of the reasons of small changes is that the lakes belong to macrophyte type, which are more resistant to anthropogenic influences.**

Keywords: **alkalitrophic lakes, *Charophyta*, macrophytes.**

I INTRODUCTION

Alkalitrophic (alkaline) lakes in Pskov Region were discovered and studied by V.N. Abrosov [1], [2] in the river Velikaya basin (lakes Beloe, Ostrovito, Sinovino et al.).

These lakes are characterized by the following features: the presence of silt containing $CaCO_3$, high transparency of water (4-8m), an alkaline reaction of environ, low quantities of oxidation and phytoplankton production. V.N. Abrosov highlights characteristics of alkalitrophic lakes, and emphasizes that "their alkalitrophy is not autochthonous, inherent (by E. Nauman) for lakes located in the limestone basins, but nutrient - the result of *Charophyta* mass development" [1, p. 308].

Charophyta occupy a relatively small niche in nature, but in areas where the plants exist they have a significant impact on the hydrological regime of water bodies [8], [1]. These algae are able to absorb the water soluble calcium bicarbonate, and insoluble compounds of calcium bicarbonate settle on the algae cell surface. When development of *Charophyta* is intense these compounds are deposited not only on plants, but also to the bottom of the lake, forming powerful silts [2].

Charophyta are the largest representatives of all freshwater multicellular algae. Their usual height is 20-30 cm, but some plants reach 1-2 m in height [10]. Partly based on this thesis, *Charophyta,* as well as aquatic higher plants living in water bodies, are considered to be aquatic macrophytes.

Lakes with a high degree of overgrowing macrophytes are separated into a special type – macrophyte lakes. Eutrophication of such lakes are determined not by production of phytoplankton, but macrophytes production, which are rivals for nutrients, and which accumulate it and hold it in their tissues for a long time during growth process. Phytoplankton in such conditions cannot activate its production functioning [16].

This lakes have been subject to intense human influence since 1968 to 1972, when there have been conducted the experimental fishery activities, which included applying fertilizers and agrochemicals to increase nutrition base and feed supply and "to bring a century character to eutrophy" [3], reduction of native fish species, and planting of valuable fish species juveniles in polyculture [18].

In order to assess the human impact on this rare type of lakes in Pskov Region we examined aquatic plants of lakes Ostrovito, Beloe and Krivoe.

II MATERIALS AND METHODS

Three examined alkalitrophic (macrophytes) lakes (Lake Beloe, Lake Krivoe and Lake Ostrovito) are located in the Alolskaya volost of Pustoshkinsky District.

The lakes are small in size of their surface area (67.5 - 177.3 ha), with an average depth 6.1 - 9.5 m, with high transparency of water (4 - 6 m), with medium mineralization, with moderately hard water belonging to hydrocarbonate class of type II calcium group [5]. The lakes are slowly flowing, and are connected into unified hydrological system. Trophic status of these lakes is determined ambiguously: on the basis of hydrochemical parameters they were classified as oligotrophic [5], on the basis of

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.248

phytoplankton – as mesotrophic [13], on the basis of zoobenthos and zooplankton biomass - as eutrophic type [19].

For studying aquatic plants the technique, common in hydrobotany [11] was used.

For assessment of common reed stretches' condition there were used such characteristics as: fertile shoots height, diameter and above-ground shoots biomass.

III RESULTS AND DISCUSSION

The flora and plants of these lakes were first studied in 1966-1968 [6], [7]. In the composition of aquatic plants were identified 54 species of macrophytes, of which *Magnoliophyta* - 45, *Polypdiophyta* - 1, *Equisetophyta* -1, *Bryophyta* - 2 species, and 5 species of *Charophyta*: *Chara rudis* A. Br, *Ch. tomentosa* L., *Ch. jubata* A. Br., *Chara sp., Nitellopsis obtusa* (Desv.) J. Grov. The largest number of macrophyte species was found in Lake Ostrovito - 34, the minimal (21) – in Lake Krivoe, in Lake Beloe were found 30 species [6], [7].

The most prevalent species, which were encountered in all examined lakes, were the following: *Phragmites australis* (Cav.) Trin. et Steud., *Carex rostrata* Stokes, *C. lasiocarpa* Ehrh., *Equisetum fluviatile* L., *Potamogeton natans* L., *Nuphar lutea* (L.) Sibth. et Smith, *Nymphaea candida* C. Presl, *Elodea canadensis* (Rich.) Michaux, *Chara rudis*. They were dominant or co-dominant aquatic plants in studied lakes.

The dominated plants among macrophytes were *Charophyta* (projective cover degree 90-100%). They grew to a depth of 6 m (Lake Ostrovito) and 9 m (Lake Beloe). Especially prominent role *Charophyta* played in Lake Ostrovito, where they occupied about 65% of the macrophytes total area.

In all these lakes aquatic plants were located in zones or belts. There were two dominated belts: the emergent vegetation and submerged vegetation. Among the emergent vegetation open pure stands of *Phragmites australis* (Lake Ostrovito and Lake Krivoe) or mixed communities of *Phragmites* and *Carex* (Lake Beloe) were prominent. Submerged vegetation belt in lakes Beloe and Ostrovito was formed by *Charophyta*. Air-dry phytomass of macrophytes in Lake Beloe reached 655 g / m3, in Lake Ostrovito - 607.3 g / m3, which is more than 50% of the organic matter produced by aquatic plants.

Charophyta were not detected in Lake Krivoe, although earlier *Charophyta* were found in all lakes, including Lake Krivoe, where "all the bends and bays slopes are covered with stonewort meadows" [4].

In all these lakes in 1969-1972 experimental activities on Fishery transformation were carried out, which includes: destruction of aboriginal and introduction of new fish species, intensive fertilization and artificial eutrophication.

It should be noted that in the early year's fishery measures gave good results. Phytoplankton biomass increased by 5-10 times [14]. Fish production in fertilized lakes increased from 5-15 kg / ha to 300 kg / ha. At the same time, negative phenomena have been identified: the deterioration of hydrological cycle and hydrochemical regime, the aquatic organisms' productivity reduction after fertilization cessation et al. [18].

Later, a comprehensive analysis of fertilize lakes data showed that "fertilized lakes' artificial ecosystem existed only as long as the measures were taken" [15]. After the cessation of human impact, as noted D.W. Schindler et al., "the lake slowly or fairly quickly returns to its original state" [20].

From 80-th years of XX century all experimental activities were stopped.

During our research in examined lakes there were discovered 50 species of macrophytes belonging to 29 families. Of these, 1 species was *Equisetophyta*, 1 *Polypdiophyta*, 3 species of *Bryophyta*, 4 species of *Charophyta*, the rest species (41) were *Magnoliophyta*.

Comparison with previous researches has shown that number of macrophytes species almost had not changed: as before the first rank in biodiversity has Lake Ostrovito (31), last rank – Lake Krivoe (21), in Lake Beloe there were revealed 28 species.

Dominant species of emergent vegetation belt maintained their positions. Locations of species listed in the Red Data Book *Cladium mariscus* (L.) Pohl in lakes Ostrovito and Krivoe were unchanged. We discovered another kind of aquatic higher plants from Pskov Region Red Data Book - *Najas marina* L., which was found in Lake Beloe in *Charophyta* coenosis.

Some changes in aquatic plants of Lake Ostrovito are associated with a decrease of *Elodea sanadensis* role, with the emergence of *Potamogeton lucens* and *Potamogeton perfoliatus* among dominants, which are forming a small monocoenosis far from the shore, and distribution of *Myriophyllum spicatum* in the lake. Above-mentioned species was found in the 60s only in the Bay Hodchische, which was separated by dam. In 2007 in this bay *Myriophyllum spicatum* was almost the only dominant. This species was found in the other two lakes. Propagation of *Myriophyllum spicatum* usually indicates an increase in the trophic status of the water body [9].

In lakes Krivoe and Ostrovito there was registered a slight expansion of the plants with floating leaves stretches (*Nuphar lutea, Nymphaea candida* and *Potamogeton natans*), which may be explained by the presence of a significant number of sites with soils enriched by organic compounds. Typically, these species form mixed communities, which are exposed along the shoreline in stripes or in spots (in Lake Ostrovito its width amounts up to 40 m).

In Lake Krivoe deep-water station (6 m) *Drepanocladus lycopdioides* (Schwag.) Warnst. of *Bryophyta* was detected, whereas it was absent in this lake previously. Mosses tangle also survived in Lake Beloe. According to literature *Bryophyta* communities fall out from the vegetation composition when water body trophic level is rising. The same happens with the communities in which the main dominant is *Potamogeton lucens* L. [9]. In the studied lakes this species exists as a co-dominant in submerged plants communities, and in Lake Ostrovito it sometimes forms pure stands at a depth of 1-2.5 m.

Belt type of vegetation arrangement continues to exist in all the lakes. As before two belts dominate: the emersed and submerged vegetation. In 2007, in lakes Ostrovito and Krivoe a belt of coastal aquatic plants consisting of hygrophytes - plants of wetland habitats stood out. In addition to *Carex* species in the lakes coastal zone were found *Agrostis stolonifera* L, *Lycopus europeus* L., *Scutellaria galericulata* L. et al., apparently caused by decreasing lakes water level in the dry summer in 2006-2007.

The most common overgrowing profiles in 2007 in the studied lakes were: *Phragmites australis* → *Nuphar lutea* + *Nymphaea candida* → *Potamogeton natans; Phragmites australis* + *Schoenoplectus lacustris* → *Nuphar lutea* + *Potamogeton natans* (lakes Ostrovito and Krivoe); *Phragmites australis* → *Schoenoplectus lacustris* + *Equsetum fluviatile* → *Potamogeton natans* → *Chara rudis* (Lake Beloe).

TABLE I

STRUCTURAL INDICATORS *PHRAGMITES AUSTRALIS* IN AUGUST 2007 (AVERAGE OF 10)

Lakes	Shoots height (cm)	Diameter (cm)	Shoots biomass, g
Beloe	135.7	0.48	12.8
Krivoe	142.8	0.28	34.8
Ostrovito	166.0	0.53	46.3

The most important dominant of emersed aquatic plant in the studied lakes is *Phragmites australis*. Literature data and our observations on Lake Peipsi show that with increasing trophic level the structural indicators of this species increase [21]. Previous researchers noted predominance of open, very low yielding common reed, especially in Lake Beloe. Such a situation remains until the present time. *Phragmites australis* communities in 2007 consisted of thin low yielding reed stands - 4-7 samples/0.25 m2, except Lake Krivoe, where they reached up to 33 / 0.25 m2) (Table. 1)

As it is known, the increase of the water body trophic status via natural or anthropogenic factors leads to changes in species composition and structure of plant communities, to overgrowth areas enlargement.

Absence of significant changes in the higher aquatic plants composition and structure in the studied lakes under artificial eutrophication measures probably is caused by the fact that they belong to the macrophyte type lakes. According to T.N. Pokrovskaya [17], production-functional organization of macrophyte lakes is very stable. “It not only withstands the sharp fluctuations of natural environmental conditions, but also can survive for quite a long time in a conditions markedly disturbed by human impact, when a flow of nutrients into the water greatly increased” [17, p.17].

The specificity of lakes Beloe, Ostrovito and Krivoe is that they are not just macrophyte lakes, but alkalitrophic ones, where the main cenosis role play stonewort algae, which lost this role after anthropogenic interference. In Lake Krivoe, which was subjected to the most severe impact, stonewort algae disappeared even before fertilizer application, immediately after the fishery alteration measures. In Lake Beloe, which was fertilized only once, and fertilizers were applied beyond macrophyte stands, stonewort algae survived better, but only in the coastal area (depth 1-3 m). In Lake Ostrovito fishery activities were not carried out, except for the Bay Hodchische, which is separated by a wooden dam. Eutrophication of this lake occurred as a result of fertilized Lake Beresovoe water discharge via the stream connecting these two lakes. In 2007 in this lake we have revealed only some fragments of stonewort algae in the coastal zone.

IV CONCLUSIONS

The study displayed small changes in higher aquatic plants’ composition: the number of macrophytes species almost haven’t changed, dominant species of emergent vegetation belt maintained their positions, and locations of species listed in the Red Data Book were unchanged.

The strong negative impact fishery activities made only on *Charophyta*, which has disappeared or their areas were much reduced in studied lakes: in alkalitrophic lakes overgrown area decreased during trophic level increase, and not enlarged. Thus, our research confirms the literature data that lakes eutrophication affects Charophyta development negatively.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 307-311

Analysis of emergency situations on the process of thermal power plants using mathematical apparatus of Petri nets

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Abstract. **Article is dedicated to the issues of accident scenarios analysis on the process of thermal power plants. The theoretical foundations of the graphical and analytical representation of Petri nets are shown. The article describes the steam cycle process and listing of its technology protections. A state model for power unit equipment and technological protections under the influence of changes in critical process parameters (steam's temperature, pressure, level) is presented. Conclusions about the plans for further work in this direction are proposed.**

Keywords: **thermal power plants, risk analysis, Petri nets, technological protections.**

I INTRODUCTION

Thermal power plants are the basis of the generating industry in Russia and many other countries. Serious failures and accidents at thermal power plants not only lead to an aggravation of the electric power system operation, a possible deterioration in the quality and electricity shortage. Also power plant permanent equipment and ancillary equipment of thermal power plant can be damaged; building structures can be destroyed; staff can suffer. The process of electricity production at thermal power plants is a complex technology for energy conversion. This process is associated with a variety of potential hazards - burning fuel, using high-pressure steam; there are mechanisms with a large supply of mechanical energy, using grids and equipment from different voltage levels and others.

Over the past 40 years in the Soviet Union and the CIS 30 major accidents occurred with the failure of more than one power unit [1]. Over 90 % accidence occurred due to failure of the main and auxiliary equipment. Such accidents do not bear the consequences of such accidents at nuclear power plants, but cause damage to millions of dollars.

Power plants are designed with a large reliability margin, enough to withstand a single failure of equipment or personnel, but we can see that serious accidents still occur. Causes of accidents on the thermal power plants are usually not single negative factor, but a combination of several of them. A careful study of all important, but low probability negative factors that can lead to damage and loss of human life is the basis of modern approaches to the safety management in the industry. Risk analysis is a component of safety management. Hazards are identified, risks and risk mitigation requirements are established, technical and organizational solutions for reducing the risk are found out during the procedure of risk analysis.

There are several quantitative and qualitative risk assessment methods that that are applied to designed and already operated facilities. It is usually difficult to quantify the risk of a complex system such as a process of power generation at the thermal power plant, consisting of hundreds of items. Even qualitative analysis is complicated by the structural complexity that cannot be reduced to the serial and parallel structures. Mathematical apparatus of modeling Petri nets is suitable for such systems. Petri nets are widely used in the simulation of dynamic discrete systems. Graphical programming language for controllers SFC (Sequential Function Chart) was created and is based on the formalism of Petri nets. Stochastic and fuzzy Petri net modifications allow to model systems with high levels of uncertainty.

The main system to counter the development of accidents is the emergency control schemes (technological protections). It is a complex control automatics, consisting of monitoring the critical parameters sensors, the logical unit controller and final elements that affect the process and prevent an accident.

This article is dedicated to the possibility of using Petri nets for modeling of emergencies on the process of thermal power plants.

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ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.258

II MATERIALS AND METHODS

A. Description of Petri net's formalism

Petri nets are bipartite directed multigraphs with two types of nodes (places and transitions). Petri nets are described by a mathematical expression

$$C = (P, T, F, W, M_0) \quad (1)$$

where P ={p_1, p_2,…p_n} is a set of places; T={t_1, t_2, t_m} is a set of transitions; F is a set of arcs; W is an incidence-function; M_0 is the initial marking. Arcs connect only nodes of different types

$$F \subset (P \times T) \cup (T \times P) \quad (2)$$

Arcs (and places) are input if ones connect places with transitions (I ⊆ P×T) and are output if vice versa(O ⊆ T×P). One couple of nodes can be connected by more than one arc with different directions.

Graphically places are pictured by circles and transitions are pictured by rectangles. Places, transitions and arcs form the static structure of Petri nets.

Marking is responsible for the dynamic component of models based on Petri nets. It is a vector M=(m_1, m_2,…m_k), where m_i=M(p_i). Marking changes discretely from the state M_0 to the state M by the rules described below. Graphically marking are pictured by dots inside appropriate places. These dots are named "tokens". Each place can contain zero, one or few tokens.

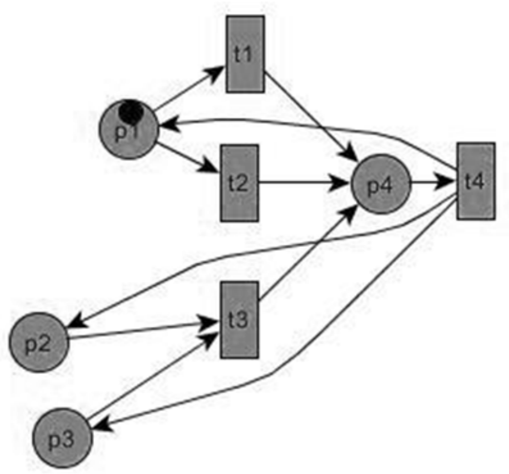
The presence of tokens in places is a condition to make transition enabled. All places which are connected with arcs that lead to transition must have enough tokens to make it enabled. After that transition can be fired. Then transition is firing number of tokens equal number of input arcs disappears from appropriate places and tokens appear in places connected with firing transition equal number of output arcs. After transition had fired the Petri net got a new marking. Example of graphical presentation is shown on Fig.1.

There is one token in place p1. This token makes enabled at once two transitions (t1 and t2) but only one of them will fire. After firing transition t1 or t2 transition t4 will be enabled because place p4 will have a token. Firing of transition t4 will lead to situation when each of places p1, p2, p3 will get one token. Transitions t1, t2, t3 will be enabled. Transition t3 become enabled only because both of places p2 and p3 got tokens.

There is an analytic presentation of Petri net in addition to the graphical representation. In Fig. 1 Petri net has 4 transitions and 4 places. Transitions have mapping on sets of input and output places:

$$I(t1) = \{p1\} \qquad O(t1) = \{p4\}$$

$$I(t2) = \{p1\} \qquad O(t2) = \{p4\}$$



$$I(t3) = \{p2, p3\} \qquad O(t3) = \{p4\} \quad (3)$$

$$I(t4) = \{p4\} \qquad O(t4) = \{p1, p2, p3\}$$

The incidence matrix can be contracted on the basis of mapping.

The incidence matrix has number of rows that equals the number of transitions and number of columns that equals the number of places. Every position in matrix places value -1, 0 or 1. If place p_i is input to transition t_j that position [j, i] places value -1. 1 is placed in the position in the case of place is output to transitions. 0 is placed in the position if there is no any connection between transition and place.

Incidence matrix for Petri net from Fig. 1 is shown in (4). Incidence matrix describes structure of Petri net. Dynamic changes are described by transition matrix (5) and marking matrix (6). Transition matrix shows transition which will fire next. Every position in transition matrix represents transition. In (5) t1 will fire and will change initial marking M_0 (6) to marking M_1.

Fig.1. Petri net example

$$W = \begin{bmatrix} -1 & 0 & 0 & 1 \\ -1 & 0 & 0 & 1 \\ 0 & -1 & -1 & 1 \\ 1 & 1 & 1 & -1 \end{bmatrix} \quad (4)$$

$$Tr_1 = [1 \quad 0 \quad 0 \quad 0] \quad (5)$$

$$M_0 = [1 \quad 0 \quad 0 \quad 0] \quad (6)$$

Marking change and state change of Petri net from Fig. 1 are determined by (7).

$$Tr_1 \times W + M_0 = M_1 \quad (7)$$

$$M_1 = [1 \quad 0 \quad 0 \quad 0] \times \begin{bmatrix} -1 & 0 & 0 & 1 \\ -1 & 0 & 0 & 1 \\ 0 & -1 & -1 & 1 \\ 1 & 1 & 1 & -1 \end{bmatrix} +$$

$$+[1 \quad 0 \quad 0 \quad 0] = [0 \quad 0 \quad 0 \quad 1]$$

B. Description of process of thermal power plant

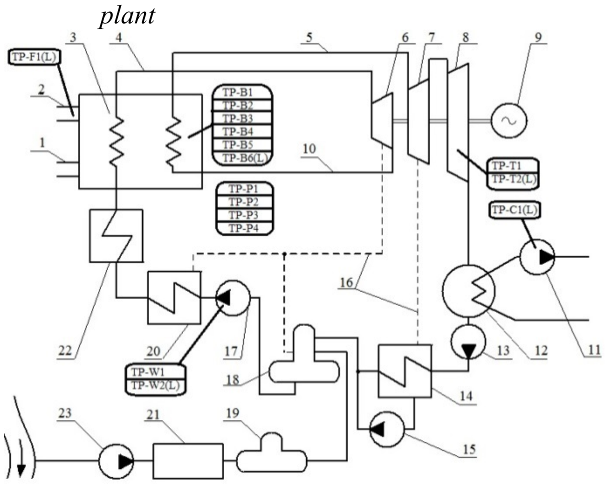


Fig. 2 A simplified diagram of an oil-gas fueled thermal power plant steam circuit

The same type equipment is shown once in the figure. Also there are not shown valves in the Fig. 2.

Fuel 1 and air 2 are supplied into steam generator (boiler) 3. Heated steam enters into turbine by steam pipes 4. Turbine at Fig. 2 consists of three cylinders (high pressure cylinder 6, medium pressure cylinder 7 and low pressure cylinder 8) that differ from each other by sizes and numbers of blades. There are also encountered turbines with one or two cylinders. Turbine rotates synchronous generator 9. Steam is partly taken for reheating by “cold” reheating pipe system 10 and then it is returned into turbine by “hot” reheating pipe system 5. Condensate comes into condenser 12 after turbine. Cooling water pumps 11 provide enough flow of cooling water from cooling tower or special pond (not shown at Fig. 2) to effectively take excess heat and convert steam into water. Group of condensate pumps 13 create head of water that is required to overcome the low-pressure heater 14 and get to deaerator 18. Deaerator removes dissolved gases out of water and gets water prepared to new cycle of heating. Moreover there is a system of pumps 23, chemical water treatment 22 and deaerator 19 that serves to compensate for the loss of water. Then feed water pumps 17 supplies feed water to the boiler through the medium-pressure heater 20 and high pressure heater 22. Also there are drain pump 15 and pipes of process steam extraction 16.

Safety and effective work of such complex system as power plant steam circuit provides by SCADA-systems that control station-service auxiliaries and regulate parameters of process. For supplying safety of equipment ant health of station staff emergency control schemes (also named technological protections) are responsible. Technological protections react to significant changes of parameters and carry out shutdown of equipment or load rejection. Parameters that are controlled by protections are:

- temperature, pressure, level of steam and water in boiler, turbine, condenser, deaerator;
- temperature, pressure, level of oil in lubrication system that deliver oil to bearings of electric motors and synchronous generator, turbine;
- vibration rate of turbine bearings;
- water and hydrogen consumption in cooling system of generator;
- operational condition of generator, pumps, induced fans, turbine;
- condition of control keys on emergency control panel.

There are list of groups of protections for Fig. 2.

- Protections of power unit:
  - TP-P1 – protections that shutdown power unit;
  - TP-P2 – protections that reject load of power unit to 50% of the nominal power;
  - TP-P3 – protections that reject load of power unit to 30% of the nominal power or to idling;
  - TP-P4 (L) P3 – local protections that regulate important parameters by opening and closing valves without changing behavior of power unit.
- Protections of boiler:
  - TP-B1 – protections that shutdown boiler;
  - TP-B2 – protections that reject load of boiler to 50% of the nominal power;
  - TP-B3 – protections that reject load of boiler to 30% of the nominal power;
  - TP-B4 – protections that shutdown fuel delivery to the boiler;
  - TP-B5 (L) – local protections of boiler.
- Protections of steam turbine:
  - TP-T1 – protections that shutdown turbine;
  - TP-T2 (L) – local protections of turbine.
- Protections of feed water pumps:

- TP-W1 – protections that shutdown feed water pumps; TP-W2 (L) – local protections of feed water pumps.

- Protections of fuel delivery system:
    - TP-F1 (L) – local protections.
- Protections of cooling water delivery system:
    - TP-C1 (L) – local protections.

Structure and operating principle of the protections described in the operating instructions and other documents. But such description is not clear and does not allow to structure and study them from different positions. The next section presents a state model for power unit equipment and technological protections under the influence of changes in critical process parameters. The model is implemented in the form of Petri net.

III RESULTS AND DISCUSSION

Information that was given above has been systematized into and processed in the Petri net (Fig. 3). The network presents several structural blocks. Left block represents the initiation of an emergency caused by a significant deviation from the parameters controlled by technological protections. Values of temperature, pressure and level of steam (water) can become less or more than allowable limits. It leads to changes in the right block.

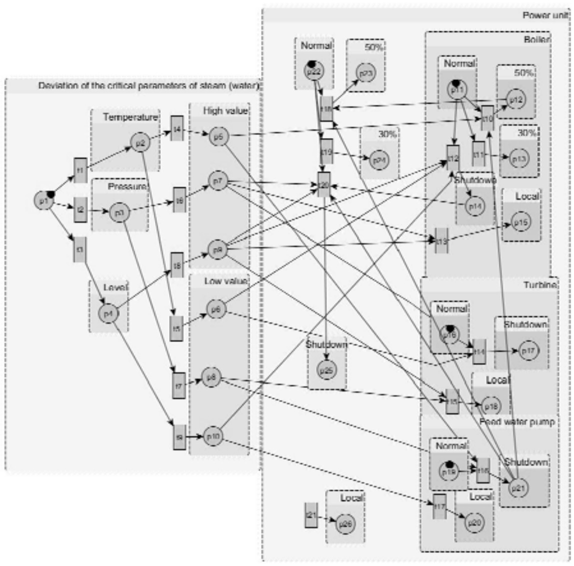


Fig. 3. Petri net of states of power unit equipment in an emergency change of parameters of steam (water).

Right block describes the equipment (boiler, turbine and feed water pump) set of states under the control of technological protections. Such states as normal state, loading by 50%, loading by 30%, safety shutdown the equipment and triggering of the local protections were identified for this model.

Normal states each component of equipment in initial marking have token. Another initial token is in place p1. Depending on what transition will fire deviation occurs with one of the three parameters.

The models for other critical characteristics (parameters of oil, vibration rate, operational condition of equipment and others) can be made in the same way. In addition to the visibility of the graphical representation of Petri nets analytical representation is interesting by enabling of creation software programs based on them. It was drawn incidence matrix with dimension 26×21 and initial marking for Petri net. Accident scenarios obtained in the form of sequence of firing transitions.

IV CONCLUSIONS

Energy companies applied great efforts for the creation of a modern safe and reliable electricity. But application of advanced technologies in the field of automation and informatization without the prior risk analysis does not always leads to effective safety improvement on the process. Using structures based on Petri nets allows to present sets of external events and internal states of the equipment as a dynamic multilevel model.

Currently, authors are developing a software package for the analysis of the risk of accidents at thermal power plants on the basis of these models.

V ACKNOWLEDGMENTS

This study is supported by the Foundation for Assistance to Small Innovative Enterprises in the scientific and technical field (FASIE).

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 312-316

The Visualizations Methods of Geometrical Forms in teaching of Civil Engineering Students

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Abstract. **Development of spatial representation (the ability to imagine three-dimensional objects using flat pictures or drawings), skills of the intuitive decision of spatial problems and more meaningful use of CAD software are essential for qualified education of students. Visualization of geometric problems helps students to understand and to solve the given geometric tasks. The paper describes types of visualization of geometrical objects from graphic exercises of compulsory subject “Civil Engineering Graphics”. This course is specified for Civil engineering undergraduate 2nd year students of Riga Technical university.**

Performance of a breadboard model, creation of the given model using ArchiCAD and using augmented reality (AR) software are included in the course "Civil Engineering Graphics” assignments. The examples of the tasks of 3D modeling in learning process are presented in this article. AR application allows faster understanding of complicated spatial problems and relationships and was used to entertain the students during the studies. Before mentioned approach was enabled to develop spatial skills of students, facilitate the students to obtain more practical experience in solving graphic exercises and was supposed enhance the quality of graphic education.

Keywords: **augmented Reality, Engineering Education, Spatial Skills, CAD, 3D models.**

I INTRODUCTION

The modern world is changing more and more rapidly. It is the reality of our times. So, the knowledge becomes obsolete very quickly and needs correction. Learning outcomes in the conception of the ability to learn are becoming more and more popular. New social needs determine the goals of education as a cultural, personal and informative evolution, providing the education as a competence "learning to learn". Various branches of learning theory are used to improve and accelerate the learning process.

The need to intensify training explains the use of visualization in educational process. Visualization improves the efficiency of the information; it's used as the way how it is represented for students, as a teaching method and as one of the most progressive educational technologies.

The visualization means any way to provide observability of the reality, and the result of visualization means any visually perceptible image that simulates the essence of the object of knowledge. Hence, it is especially important to develop the spatial ability of the students. The development of this ability is one of the graphical subjects’ aims. Spatial ability and visualization skills, as component of this ability, may be developed with help of different training tools and methodologies: graphics courses using traditional drafting method (pencil and drawing board) [1], [2], [4], Augmented Reality (AR) based application [3], [4], 3D CAD modeling[5], [6], Web-based graphics applications and a sketchbased modelling system[7].

Following to modern psychology metavisualization is a process to monitor and regulate the internal representation of the individual [8], [9]. Psychologists say that visualization is central in the thinking process. Considering the spatial intelligence, regarding the ability to perceive the visual world and all the intelligences at basic level can be developed. Therefore, the development of skills such as the ability to visualize and abstract thinking go beyond technical subjects, but connected with the concept of education and training of the technical intelligentsia.

The psychologists of the 20th century have argued that human’s impellent activity and formation of his mental faculties have a direct link [10]. Movement of the hand, the development of eye estimation in the process of human development, leads to the formation of spatial representations, creating external space that is the basis of internal cognitive activity. In this regard, we believe that it is important to have exercises are performed manually and as a basic sketch. To realize these problems we offer students perform some tasks on the theme “Roof Construction”. The first step of visualization of given

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.254

task is the performance of the cardboard model of the roof slopes intersection.

Currently in RTU there is a shortage of lecture hours in the engineering curricula for the subjects related to engineering graphics. The higher rate of learning process is relevant as ever.

In this article we would show the examples of graphical exercise with 3D models and represent content of subject “Civil Engineering Graphics”. We share our experience of the use of 3D CAD software’s, such as ArchiCAD and Revit Architecture, following to BIM (Building Information Modelling) conception. Visualization of 3D models applying Augmented Reality Technologies is given. The new generation, which grown up in the modern technology environment surrounded by computers, videogames and smart phones, prefers to get necessary information quickly and feels good in augmented reality space. The use of the different types of the visualization are necessary for qualitative and faster training of graphical skills, understanding of geometric problems and to make the educational process more attractive and positive.

II COURSE CONTENT

Subject “Civil Engineering Graphics” of Computer Aided Engineering Graphics Department is a compulsory for RTU Civil engineering second-year students. Course is related to the theoretical knowledge and standards used for representation of civil engineering constructions onto the plane. Methods of projections with level marks are able produce the cut and fill design for appropriate urban project. Descriptive geometry and engineering graphics background on surfaces intersection theme is developed by determining the roof slopes intersection line. Main principles of creation of civil engineering projects using Computer Aided Drafting and Computer Aided Design aspects are given.

The course structure has four modules: “Projections with level marks”, “Roof construction”, “Civil engineering drawing” and “Geometric modelling using ArchiCAD or Revit Architecture”.

The “Civil Engineering Graphics” course duration is 32 academic hours (spring semester, 2 hours per a week). Course consists of graphical exercises and practical training (10 hours) using ArchiCAD or Revit software. The aim of this training is to acquire a basic knowledge about possibilities of given software. During this training the students perform one variant of architectural model and individual exercise “Roof construction”. The kind of evaluation of the training tasks is pass/fail. Students perform exam at the end of the course. Graphical exercises and exam are evaluated at 10 point rating system.

A. Projections with level marks

The first part of the course consists in a 4 lessons where the principles of objects creation using method of projections with level marks are presented. Students perform individual assignment where it is required to locate given building site at a topographical surface and determinate the limits both cut and fill areas with given angle of repose for cuts and fills. Students carry out this task applying traditional way of creation drawing - by pencil and drawing board.

B. Roof construction

Module “Roof construction” concerning problems nearly related to determination of the roof slopes intersection. Module consists of following parts: construction of the plan and a front elevation of roof, finding of full size of roof slopes, performance of a breadboard model of roof, construction of roof model using 3D CAD software.

Students perform the first part as a sketch using handout material prepared by staff on separate A4 format sheets. Task concerning definition of full size of slopes may be performed by computer aided drafting (AutoCAD). It provides an opportunity to increase production of drawing, realize the construction more precisely and improve skills of AutoCAD use. Essential skills of AutoCAD drawing preparation students got on course “Interactive computer graphics”.

The breadboard model is visualization of task performed manually and may be constructed from cardboard, wood or plastic (Fig. 1). For students it is a quick and effective process to independently evaluate correctness and accuracy of construction of roof slopes intersection and determination of full size of slopes. Right constructed outcome model it is not only correct determination of polygons intersection but also correct selected dip direction. Given exercise improves spatial skills of students and develops ability of intuitive solution of spatial problems.

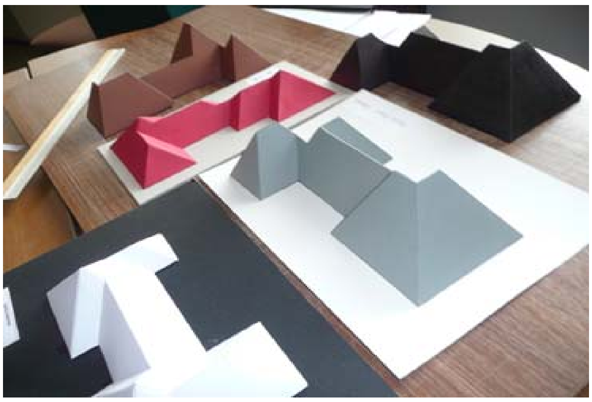

Fig. 1. Visualization of task “Roof Construction” performed in the form of cardboard model

Another kind of visualization of given task is creation of digital model of roof using ArchiCAD. Experience obtained from performance of previous exercises allows avoiding possible mistakes that might arise during construction of this model.

C. Civil engineering drawing

Third module of course provides knowledge about kinds and methods of creation of civil engineering drawings and also acquaints with ISO standards of drawing preparation. Students perform following civil engineering drawings: building plan, building section and front elevation. Students can choose method of drawing creation – traditional drafting or computer aided drafting.

Compared to drafting by pencil, CAD is faster, but computer is only a powerful tool to create correct drawings in the minimum term. Trained students who know engineering drawing very well are able to manipulate the CAD systems. After learning drawing by traditional drafting methods, one can use CAD software to develop the skill and speed for excellent performance.

It will be observed significant difference between making drawings on the computer and making it by hand and pencil. Creation drawing by traditional drafting instruments requires to imagine the various views of object while you develop the drawing. This technique develops the spatial representation of students and ability to analyze the shape and design of real objects. These skills are essential qualities for engineers and necessary requirement for successful work with 3D CAD software [11], [12].

Unfortunately we take note that in drawings performed by CAD method there are appreciable quantity of mistakes, which are linked with insufficient CAD background. Many of students perform drawings not autonomously by simple copy-pasting of drawing performed by other students.

D. Geometric modelling with BIM software

The high rate of technological and science-based innovation is requiring the implementation of new knowledge in education process. Engineering Graphics today has to consider BIM concept in Architecture and Civil Engineering [13]. BIM is a process of creating and managing building data from planning and design phase of the project, expanding throughout the building life cycle, on out to construction and cost management and facility operation. BIM software is three-dimensional, real-time and dynamic that allows increasing effectiveness and productivity [14].

Module number 4 of the subject "Civil Engineering Graphics" deals with an introductory level of BIM. Students perform small individual task using ArchiCAD or Revit Architecture BIM software. The aim of this task is to develop the ability of geometric modelling applying BIM supporting software. After lecture the students create the 3D digital model of a building and study how to manipulate the model, types of basic construction components (doors, windows, panels, columns and stars) and their behavior. Using 3D model students have to create the basic supporting architectural documentation – plans, elevations, sections.

Visualization of 3D building model is realized by creation of axonometric projection using exterior and interior rendering. Figure 2 demonstrates example of individual task used in the introductory level of BIM concept study.

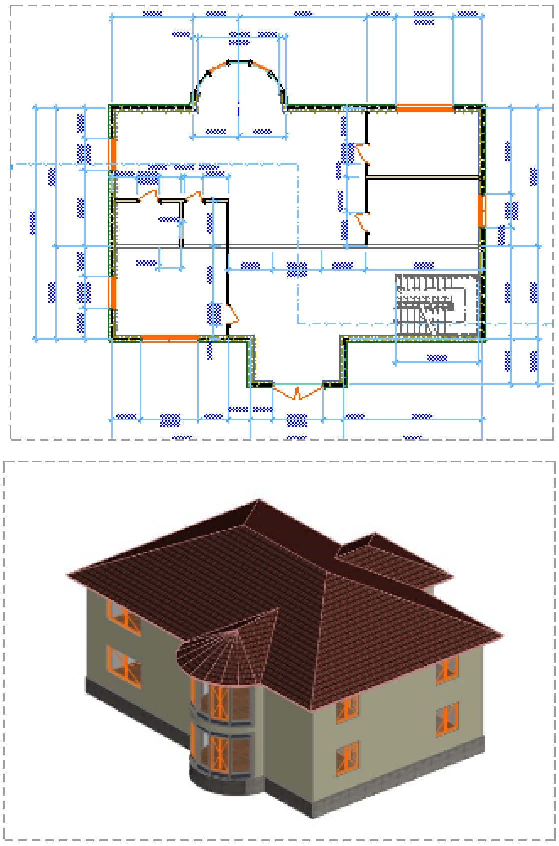

Fig. 2. Plan and visualization of two story building performed by civil engineering student for course "Civil Engineering Graphics"

BIM concept is introduced in different limited and free choice subjects of Computer Aided Engineering Graphics Department. Students can enhance skill level concerning BIM concept and continue study selecting corresponded subject. Using BIM supporting software, students perform project related to creation of their own „dream house"

E. Use of Augmented Reality application for visualization

The introduction of Augmented Reality technologies in the educational process brings new perspectives for civil engineering and architectural students. For example, by means of interaction of 3D digital models with real environment, the all operational sequence of building construction in time and space can be simulated for better understanding of students.

AR application allows to place created 3D model of building in defined geographical location. This kind of project visualization helps to assess compatibility of building with real environment quickly and without resort to extra cost.

Advanced students visualize own building models, created with help of ArchiCAD, using AR technology. This visualization method is not obligatory for described course. For generation of AR scenes the BuildAR software is exploited. In software the marker-based method is realized, that requires associating the 3D model and physically printed marker. The virtual 3D model appears as part of the surrounding environment on computer monitor when the marker is picked up by the web camera (Fig. 3).

Fig. 3. Three-dimensional virtual model of building in Augmented Reality environment.

Students use AR application also during the studies of “Descriptive Geometry and Engineering Graphics” subject. In this case 3D models of engineering objects from the graphic assignments attached in Augmented Reality environment promote understanding of spatial problems and illustrate the relationship between the 3D geometry of object and 2D projections [4].

The students’ feedback on use of AR model in the Engineering Graphics courses of our department was very positive. The visualization of tasks using AR technologies is helpful in solving graphic exercises, makes learning process more attractive and interesting and supports learning activities.

Fast development of computer technology and creating an augmented reality browser that allows viewing computer generated elements superimposed on the live camera view of Smartphone [15]. Such AR application simplifies comprehension of complex spatial mutual relation between objects, motivates students to study Engineering Graphics subjects. Unfortunately, the nonsufficient financial resources at the current economic situation at RTU prevent continued expansion and more extensive use of this technology in the engineering education process.

III CONCLUSIONS

- The use of different visualization methods in the educational process is a good way to get more sustainable knowledge, cognitions, and understanding in a variety of natural subjects of engineering education;
- Introduction of the modern BIM software in education process will allow to be competitive and flexible in a rapidly changing information technology environment;
- A certain number of drawings and models carried out manually is necessary for the development of spatial skills and understanding of the shape and objects geometry;
- The students apply AR technology with pleasure and great interest, consequently, such important components of cognition as motivation and wish, will be enhanced.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 317-322

Analysis of Energy Consumption for Biomass Drying Process

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Abstract. **This study is dedicated to the analysis of the drying process energy consumption. In order to evaluate the main energetic processes that consume the most energy, the energy consumption of each individual drying process with and without air recirculation was modelled. The model shows that drying agent (air) recirculation is not an energy-saving operation, since it increases the total electricity and heat consumption. Recirculation of the drying agent increases the moisture content of the drying agent at the dryer entrance, which increases the need for fresh air in the dryer so that it can absorb the evaporating moisture from the dried material. An increased flow of the drying agent in the dryer increases the heat and electricity consumption.**

Keywords: **biomass, dryer, energy consumption, moisture content.**

I INTRODUCTION

Biomass drying is an energy-intensive process that consumes heat energy and electric energy. The principles and parameters of the drying process operations that influence a dryer's energy use are listed below [1]:

1. Type of heat supply, or heat transfer, in the dryer. Heat is transferred in the surrounding environment via thermal conduction, convection or radiation, and these principles are exploited in the dryer. Specific dryer variations include the use of an electrical field, microwaves, solar energy and freeze drying;
2. Temperature and pressure of the drying environment, which, in turn, influences the drying time;
3. The movement of materials around in the dryer is a key factor in drying materials of a certain size;
4. The type of drying operation, which can be continual or periodical (batch-type), which, in turn, influences the productivity of the dryer and its energy consumption;
5. The efficiency of the drying process is also influence by the direction of flow for the drying agent and the dried material.

The above-listed factors are the technological parameters for various dryers, but the most important factor is to evaluate the characteristics of the particular material to be dried and thereby choose the most appropriate drying method and dryer type. The dryer's basic goal is to supply heat to the materials that need to be dried in order to evaporate the moisture in those materials. There are three types of dryer:

- Convection-type dryers. The evaporation of the moisture content in the material by applying heat from the surrounding atmosphere or the covering the material with a drying agent is called convection drying. Convection drying is the most popular method used when drying fine material such as wood chips. During convection drying, the most common drying agent is heated outdoor air; other agents include flue gases and superheated steam or other inert gases (N2) that ensure evaporation. The drying agent absorbs the evaporated moisture, which is then usually released in the atmosphere. Convection-type dryers operate at atmospheric pressure, and they can operate in a very broad range of temperatures (80–600 °C). Dryers using convection heat transfer are called direct dryers. Belt, tunnel, rotation, pneumatic, spray and also fluidised-bed dryers use convection heat transfer. Drying times in such dryers are very variable. Pneumatic dryers and spray-type dryers have drying times of less than one minute, while drying in belt, tunnel and rotation dryers can take more than an hour [2].
- Indirect dryers. Dryers in which the dried material receives the necessary heat by coming into contact with a hot surface, which is heated by a drying agent, are called indirect dryers. In such dryers, superheated steam or high-temperature flue gases are used as the drying agent to heat the surface. Heat is supplied in a heat supply method, and such dryers are used to dry very moist material as well as heat-resistant material. Often, the drying process can be performed in a vacuum. Contact drying can be used as a pre-drying method for a convection-type dryer in

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.625

order to ensure an even drying process, or both processes can be combined to ensure more effective drying; for example, the pipes through which the hot drying agent flows can be placed in a rotation or fluidised-bed dryer that uses convection drying, thereby lowering energy consumption. The contact drying process is used in drum, pipe rotation and fluidised-bed as well as spray dryers [3].

• Radiation dryers. Heat supply to a dryer can also be accomplished through the radiation process. In radiation dryers, more heat is transferred to the material than convection or contact dryers. They are used to dry materials that are difficult to dry in order to noticeably lessen the drying time, because infra-red radiation enters the material deeper, thereby ensuring better evaporation of moisture from the inner layers of the material. Such a drying method requires a heat source, such as natural gas or flue gases that heat the surface (a metal or ceramic screen) that generates the infra-red radiation [4]. Radiation heat transfer can be performed in a belt dryer, in which a screen generating infra-red radiation is located above the moving belt.

When drying a specific type of material, it is important to evaluate the suitability of the dryer to the material and the movement of the material during the drying process, because this influences the total energy consumption of the drying process. Small-sized materials (sawdust or wood chips) are appropriate for rotation, tunnel, belt, fluidised-bed and pneumatic dryers. In such dryers (except rotation dryers, where the material is moved by gravitation), supplemental energy is required to move the material during the drying process. The electricity consumption needed to move belts or trolleys, as well as the blowing of air, depends on the volume of dried material, or flow. Of the above-mentioned methods, belt dryers consume the smallest amount of electricity [1].

In evaluating the characteristics of the dried material and the dryer's technological parameters, it is concluded that the most appropriate dryer for the drying of sawdust is a continuous convection dryer, which results in the lowest operational costs. Belt and rotation dryers, as well as pneumatic dryers, are the most commonly dryers used for sawdust [5].

Drying is a process that consumes considerable amounts of energy and for which it would be very important to implement energy-saving measures, thereby reducing energy consumption during the drying process. This paper focusses on energy consumption during a single drying cycle and over the course of a year. It therefore provides a description of a model of the drying process with and without drying agent recirculation over the course of a year.

II MODEL OF THE DRYING PROCESS

A simplified mass and energy flow of the model are shown in the diagram in Figure 1. The diagram shows all the elements of the process needed to successfully model the drying process.

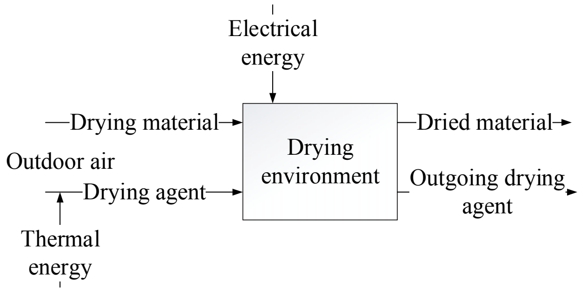

Fig. 1. Simplified mass and energy flow of the model

Figure 1 shows all the elements that are necessary to successfully simulate the drying process.

Outdoor air is heated in heat exchangers. The heat exchangers are powered by the outgoing heat of the heat carrier from the cogeneration unit, which is at the temperature of 90 °C. The outdoor air is drawn into the dryer with fans. By creating a perpendicular flow of air, heat is added to the outdoor air, and the air heats up, thereby becoming a drying agent. The drying agent is heated to 80 °C, thereby cooling the cogeneration heat carrier to 50 °C. The drying agent enters the drying chamber, or drying environment, in which the moveable belt is located. The dried material is spread out to a specific depth on the belt. The relative moisture content of the input material may vary, but the moisture content of the outgoing material is 25 %, which is a constant parameter value. The fact that the outgoing moisture content of the material is defined in turn influences other drying parameters, such as drying time and the volume of supplied energy.

The main drying process parameter values – drying time and the required amount of heat – are obtained by the dryer calculations. To simplify, the drying process is the supply of heat to the material in order to obtain good-quality, dry material in as short time as much as possible, which can then be sold on the market for a profit. Thus, one of the most important parameters characterising the drying process is the drying time. The second most important parameter is the amount of heat needed to successfully implement the drying process, which in turn directly influences the drying costs.

The first calculation parameter characterising the drying environment is the equilibrium moisture content of the material (wood). The equilibrium moisture content of wood is the moisture level towards which the drying wood naturally tends while standing in a constant drying environment (at the temperature and moisture content of the drying agent). This means that at this point the material no longer gains nor loses moisture; it is in equilibrium with the surrounding environment and parameters. As the drying environment's parameters change, the equilibrium moisture content also changes. This means that if damp wood is placed in an environment with high temperature and low moisture content, the moisture content of the wood will gradually decrease as the result of desorption. However, if dry wood is placed in an environment where the air is highly saturated, the wood will gain moisture by way of adsorption. By standing in an environment with constant parameters for an extended amount of time, the moisture content of the wood also becomes constant; in other words, it reaches the equilibrium moisture content value. The equilibrium moisture content of wood increases as the relative moisture of the environment increases and the temperature of the drying environment decreases [6].

Equilibrium moisture content is usually not reached when drying wood, but it would be possible to reach it by noticeably increasing the drying time. At the end of the drying process, the outgoing moisture content of the dried material falls between the boundaries of equilibrium moisture content and outgoing moisture content. In any case, it is impossible to reach the material's equilibrium moisture content by drying it at a high temperature and low relative moisture – and this is also not desirable – because as soon as the dried material would be taken out of the drying chamber, it would begin to absorb moisture from the outdoor environment by means of adsorption, because the relative moisture content would increase and the temperature would decrease, and the material's equilibrium moisture content value would increase [3].

It is important to calculate the equilibrium moisture content of wood in the model of the drying process, because it influences the drying time at specific drying environment parameters such as temperature and relative moisture. The equilibrium moisture content of wood can be determined by diagrams, but for simplicity's sake it will be calculated here using the formulas listed below.

To calculate the equilibrium moisture content of wood at constant drying environment parameters (X_e) [6], Formula 1 needs to be used:

$$X_e = \frac{1800}{W}\left[\frac{Kh}{1-Kh} + \frac{K_1Kh + 2K_1K_2K^2h^2}{1+K_1Kh+K_1K_2K^2h^2}\right] \tag{1}$$

where

k, k_1, k_2 – empirical coefficients;

h – parameter;

W – drying rate, tonne/h.

The following formulas (in which *T* = drying environment temperature, °C) are used to calculate the parameters included in the formula that describe the adsorption processes in wood:

$$W = 349 + 1.29T + 0.0135T^2 \tag{2}$$

$$K = 0.805 + 0.000736T - 0.00000273T^2 \tag{3}$$

$$K_1 = 6.27 - 0.00938T - 0.000303T^2 \tag{4}$$

$$K_2 = 1.91 + 0.0407T - 0.000293T^2 \tag{5}$$

The relative moisture of the drying environment, which is in turn dependant on the moisture content of the outdoor air, is used to obtain the parameter:

$$h = \frac{\varphi}{100} \tag{6}$$

where

φ – relative humidity, %.

In order to calculate the drying time, it is important to understand what the drying material is like and what are its characterising parameters. The drying time constant expresses the features of the specific material to be dried, which in turn influences the total drying time.

The drying time constant is influenced by the temperature of the drying environment and the size and density of the material. In general, the drying time constant is influenced by the species of wood. Denser woods, such as oak, require a longer drying time. As mentioned above, sawdust and wood chip density is influenced by their relative moisture content, which is in turn influenced by various parameters: weather conditions, time of year, amount of precipitation. The following formula is used to calculate the drying time constant (t_c) [7, 8]:

$$t_c = \frac{d^{1.83}}{0.0878 + 0.00143 \cdot P_s} \cdot \frac{\rho_r}{\rho_{ref}} \tag{7}$$

where

ρ_{ref} - wood density, kg/m^3;

d – particle size, m;

P_s – vapour pressure at drying conditions, bar.

The partial pressure of the water vapour of the drying environment, which depends on the moisture content of the outdoor air, is also an influencing factor in the drying process. It can thereby be stated that the outdoor air parameters, such as temperature and moisture content, are influencing factors in the length of the drying process. The drying time (*t*) is calculated thus [9]:

$$t = -t_c \ln\left[\frac{(X - X_e)}{(X_o - X_e)}\right] \tag{8}$$

where

X – final moisture content, kg/kg $_{\text{dry basis}}$;

X_o – initial moisture content, kg/kg $_{\text{dry basis}}$;

X_e – equilibrium moisture content, kg/kg $_{\text{dry basis}}$.

In order to calculate the amount of heat and electricity needed to ensure the drying process, it is important to determine the flow of outdoor air necessary to reach a specific moisture content for the outgoing material. As mentioned above, the drying agent (or, heated outdoor air) absorbs the evaporated moisture from the material. In order to determine the amount of fresh air needed to absorb the evaporated moisture from the material, it must be determined what amount of moisture must be evaporated from the material in order to reach the indicated outgoing moisture content. The amount of moisture to be evaporated from the material (*W*) is calculated thus [9]:

$$W = F(X_o - X) \tag{9}$$

where
F – feed flow rate, tonne/h.

So, the flow of evaporated moisture in the material is determined by the flow and moisture content of the material before and after drying. Actually, the formula is the moisture mass balance of the material in the dryer. As the moisture content of the material decreases before drying, the evaporated moisture mass would also decrease, which would in turn shorten the drying time and amount of energy consumed.

In order for the drying process to take place, the drying agent must absorb the moisture evaporated by the material and remove it from the drying chamber. The following formula is used to determine the amount of air needed for it to be able to absorb the moisture evaporated from the dried material (F_a) [45]:

$$F_a = \frac{W}{(Y - Y_o)} \tag{10}$$

where
Y – drying air humidity, kg/kg $_{\text{dry basis}}$;
Y_o – ambient air humidity, kg/kg $_{\text{dry basis}}$.

The amount of outdoor air to be heated is influenced by the air temperature and moisture content as well as the moisture content of the material before drying. The amount of drying agent in the dryer influences the total energy consumption needed to operate the suction fans as well as the heat consumption needed to heat the specific amount of air. This means that there is a direct correlation between the moisture content of the outdoor air and the amount of drying agent in the dryer. The moisture content of the outdoor air is thereby one of the most important parameters influencing the energy consumption of the drying process.

The formulas listed below are used to calculate the heat consumption needed to ensure an effective drying process. Heat is needed for the drying process in order to promote the evaporation of moisture and to heat the material and outdoor air. The total heat consumption is obtained by adding up all of the above-mentioned heat consumers.

The amount of heat needed to evaporate the moisture from the material is (Q_m) calculated thus [9]:

$$Q_m = F(X_o - X)\left[r_o - (C_{pw} - C_{pv})T\right] \cdot t \tag{11}$$

where
r_o – latent heat, kJ/kg;
C_{pw} - specific heat of water, kJ/kg K;
C_{pv} - specific heat of water vapor, kJ/kg K.

The amount of heat needed to evaporate the moisture from the material is dependent on the moisture content of the material before drying and the temperature of the drying agent as well as the length of the drying process.

The heat consumption needed to heat wood chips (dried material) (Q_{dw}) is calculated thus:

$$Q_{dw} = F\left[C_{ps} + X_o C_{pw}\right](t_m - T_o) \cdot t \tag{12}$$

where
C_{ps} – specific heat of dry material, kJ/kg K;
t_m – drying air temperature, °C;
T_o – ambient temperature, °C.

The amount of heat needed to heat wood chips depends on the moisture content of the material before drying, the outdoor air temperature and the drying agent's wet-bulb temperature as well as the length of the drying process. The temperature of the dried wood chips is equal to the drying agent's wet-bulb temperature, which in turn depends on the heat content of the drying agent, which is calculated using the moisture content of the outdoor air. As the temperature of the outdoor air increases, its moisture content increases as well, which in turn increases the drying agent's wet-bulb temperature. Therefore, in the summer, when the outdoor air temperature is higher, the amount of heat needed to heat the wood chips will be lower.

The heat consumption needed to heat the air (Q_a) is calculated thus [9]:

$$Q_a = F_a\left[C_{pa} + Y_o C_{pv}\right](T - T_o) \cdot t \tag{13}$$

where
C_{pa} – specific heat of air, kJ/kg K.

The amount of heat needed to heat the air depends on the temperature and moisture content of the outdoor air as well as the length of the drying process. Over the course of a year, the heat consumption needed to heat the air will decrease, because the temperature of the outdoor air will be higher, so the difference between the outdoor air and the temperature to which the drying agent needs to be heated will be smaller and less heat will have to be supplied to the air to reach the appropriate drying environment temperature.

The following formula is used to calculate the total amount of heat needed (Q_{tot}):

$$Q_{tot} = Q_m + Q_{dw} + Q_a \qquad (14)$$

The following correlation is used to evaluate the efficiency of the dryer's operations (n_q) [9]:

$$n_q = \frac{Q_m}{Q_{tot}} \qquad (15)$$

The main task of the drying process is to evaporate moisture from the material, and it is therefore important to evaluate how much of the supplied heat is used for its intended purpose, which in turn shows how efficient the system's operations are in ensuring the drying process. This parameter depends on the moisture content of the material before drying. In addition, if the total amount of heat consumed is noticeably larger than the heat needed to evaporate the moisture, this could indicate excessive heat loss or less-than-optimal operation of the dryer.

III RESULTS

In order to evaluate the main energetic process that consumes more energy, the energy consumption needs of each separate drying process were calculated. A detailed description of the heat and electricity consumption (y – axis, in kWh) is shown in the graphs in Figure 2.

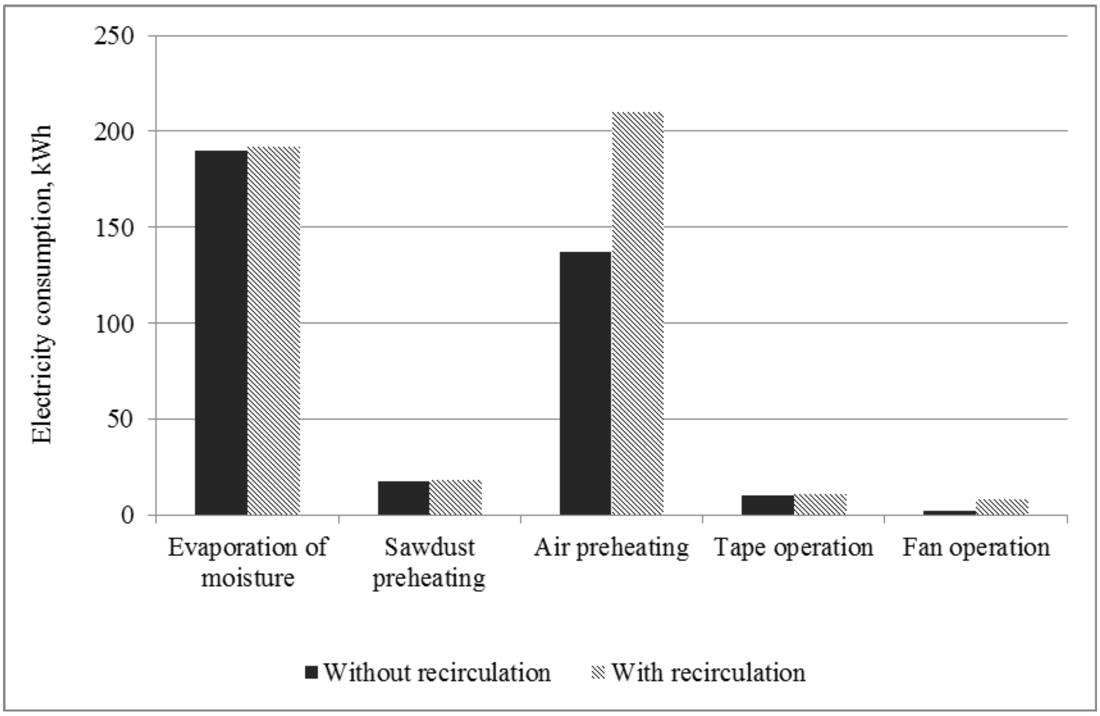

Fig. 2. Energy consumption with and without recirculation of the drying agent

As seen in Figure 2, when compared with drying without air recirculation, the greatest increase in heat consumption is for the heating of the air. This can be explained by the fact that during the drying process with air recirculation the moisture content of the outgoing drying agent increases, which in turn increases the amount of fresh air needed in the dryer to absorb the evaporated moisture from the material to be dried. If the recirculation of the drying agent is increased by 50 %, the amount of heat needed to heat the air increases by 53 %. As the flow of air needed to ensure the drying process with air recirculation increases, the amount of outgoing drying agent increases, which in turn substantially increases the amount of electricity needed to operate the fan. In a drying process with 50 % air recirculation, the amount of electricity needed to move the drying agent is approximately 2.5 times greater than it is for drying an equal amount of material using a drying process without air recirculation.

IV CONCLUSIONS

1. Recirculation of a drying agent (air) does not minimise energy use, because it increases the total consumption of electricity and heat.

2. Recirculation of a drying agent influences an increase in the moisture content of the drying agent at the dryer's entry point, which increases the need for fresh air in the dryer so that it can absorb the evaporated moisture from the dried material. An increased drying agent flow in the dryer increases the consumption of heat and electricity.

V ACKNOWLEDGEMENT

This work was supported by the project "Development of Innovative Biomass Gasification Technology for Syngas Production" (the European Economic Area (EEA) Financial Mechanism 2009-2014 Programme's "National Climate Policy" open call "Emission reduction technologies including renewable energy, sustainable buildings and technology development".)

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 323-328

The Nutrient Concentration in Drainage Water in Fertilizer Experiments in Skriveri

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Abstract. **The paper describes the influence of long term (more than 30 years) fertilizer application to nitrogen, phosphorus, potassium, calcium and magnesium leaching through subsurface drainage in small experimental catchment. The effect of crop and cultivation practice on nutrient concentrations in drainage water is analyzed. This paper presents leaching data during 2011-2013 when spring oilseed rape (OSR), spring barley (SB) and perennial grasses (GC) were grown.**

The research has been carried out at the Research Institute of Agriculture of Latvian University of Agriculture in the long-term subsurface drainage field established in Skrīveri in 1981 under the guidance of professor J. Štikāns. The long-term drainage field was established in the uncultivated gleyic sod-podzolic *Hypostagnic Endogleyic Albeluvisol (Hypereutric), stw-ng-AB(he)* loam that had not been used in agriculture for 20 years before. The experimental field was established with four rates of mineral fertilizers: without fertilizers, N45P30K45; N90P60K90 N135P90K135 calculated in form of P_2O_5 and K_2O. Since 1994 a seven-year crop rotation has been organized: 1) winter triticale, 2) potatoes, 3) spring wheat, 4) spring oilseed rape, 5) spring barley + perennial grasses (red clover, timothy), 6) perennial grasses, 1st year of using, and 7) perennial grasses 2nd year of using. The total area (1.6 ha) of the experimental field was divided into 16 plots (15x50 m). Each plot was supplied with a seepage tile drain at the depth of 80-100 cm and an inspection well for drain water sampling and measurement of total water amount.

The nitrate nitrogen content in subsurface drain water was significantly affected by fertilizer rate and crop species. The concentration of nitrogen in drain water was significantly lower from non-fertilised plots than from other treatments and was considerably lower growing grass without autumn soil tillage than with conventional ploughing. Different fertilizer rates (applying 30, 60 or 90 kg ha^{-1} of phosphorus and no fertilizer) had no significant effect on phosphorus concentration in drain water. However, concentration of potassium in drain water depended remarkably (p<0.001) on fertilization rate and was lower from non-fertilized plots. Without autumn ploughing and providing vegetation potassium leaching was significantly lower. The use of fertilizers increased the subsurface water concentration of calcium and magnesium considerably.

Keywords: **drainage water, nitrogen, phosphorus, potassium, calcium, magnesium.**

I INTRODUCTION

The results of many scientific findings from the long-term monitoring show large differences in the levels of plant nutrient losses between the catchments and fields with different farming intensity, large annual and interannual variability due to climate impact and soil conditions [9,11,19].

Fresh applications of phosphorus (P) may cause losses of dissolved and particulate P forms in land runoff when rainfall interacts directly with fertilizers and manures which are spread onto the soil surface. Rates of P loss are temporally and spatially very variable (< 1 to 25 % of total P applied) depending on the amount of P applied; the P release properties of the materials applied (% P extractable in water), the timing of storm events after application and the amounts of runoff generated. Large P applications left on the surface of wet, frozen, compacted, and intensively under-drained soils in high rainfall areas are particularly vulnerable to leaching. Concentrations of P in runoff are often the greatest during the first storm event following P application, but can remain high for several weeks, or even months after application [26].

Long-term fertilisation experiments have shown that important processes in the large-scale turnover of nitrogen operate on a time scale of decades up to at least a century [6].

The group of scientists [21] from the Baltic Sea region have determined that for the time period 1970–93 there had been substantial changes in land use, atmospheric deposition and wastewater treatment in many parts of the study area. But the total riverine

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.277

loads of nitrogen (N) and phosphorus (P) to the Baltic Sea have been fairly constant since 1980, and most likely also since 1970. Moreover, the interannual variation was clearly correlated to the runoff. The average annual loads to the Baltic Sea for the time period 1980–93 were found to be about 825 000 tonnes N and 41 000 tonnes P, respectively. The total annual riverine load from the 117 basins to the Baltic Sea for the years 1994–2006 was estimated to 570000t of N. The results show that around 380000t of N are annually retained in surface waters draining to the Baltic Sea [20].

The aim of research – to analyze the influence of long term (more than 30 years) fertilizer application to nitrogen, phosphorus, potassium, calcium and magnesium leaching through subsurface drainage.

The hypothesis – the long term fertilizer application influence the nutrient concentration in drainage water.

The paper describes the influence of long term (more than 30 years) fertilizer application to nitrogen, phosphorus, potassium, calcium and magnesium leaching through subsurface drainage in small experimental catchment. The effect of crop and cultivation practice on nutrient concentrations in drainage water is analyzed.

II MATERIALS AND METHODS

Field site

The research has been carried out at the Research Institute of Agriculture of Latvian University of Agriculture in the long-term subsurface drainage field established in Skrīveri in 1981 under the guidance of professor J. Štikāns.

The long-term drainage field was established in the uncultivated gleyic sod-podzolic Hypostagnic Endogleyic Albeluvisol (Hypereutric), stw-ng-AB(he) (IUSS Working Group WRB, 2007) loam that had not been used in agriculture for 20 years before. After 32 years similar soil parameters showed significantly different content of all nutrients (phosphorus, potassium) related to the different level of fertilizer application (table 1).

TABLE 1
THE NUTRIENT CONTENT IN SOIL

Fertilizing rate	Content, mg kg^{-1}				Organic matter, g kg^{-1}
	P	K	Ca	Mg	
Without	14	29	670	68	22
N45P30K45	30	74	1016	128	23
N90P60K90	78	108	574	41	24
N135P90K135	181	174	877	78	24

The study site is located in the central part of Latvia (56°38′N; 025°08′E) with warm temperate climate. The precipitation amount is normally 670 mm a year. The annual air temperature is + 5.7ºC. The winter average air temperature is - 4.3ºC. The duration of vegetation period proceeds 180-210 days.

The meteorological conditions were different during research period (Fig.1, Fig. 2.)

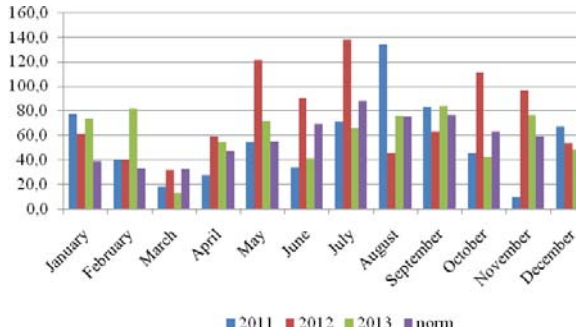

Fig.1. The amount of precipitation, 2011-2013 (Skriveri)

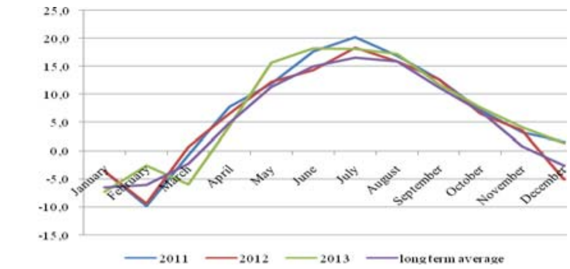

Fig.2. The average temperature of air, 2011-2013 (Skriveri)

Experimental treatments

The experimental factors were mineral fertilizers, termed 'F'. The experimental field was established with four rates of mineral fertilizers: F0 – without fertilizers, F1 – N45P30K45; F2 – N90P60K90 and F3 – N135P90K135 calculated in form of P_2O_5 and K_2O or F1 – N45P13K37; F2 – N90P26K74 and F3 – N135P39K112 calculated as elemental P and K kg ha^{-1}. Mineral fertilizers were applied according to the anticipated rates of plant nutrient elements annually during the cultivation of soil before sowing. For winter cultivars the phosphorus as superphosphate and potassium as potassium chloride fertilizers were cultivated before the sowing in autumn and nitrogen in form of ammonium nitrate was applied the next spring at the beginning of vegetation and at the stage of tillering.

The total area (1.6 ha) of the experimental field was divided into 16 plots (15x50 m). Each plot was supplied with a seepage tile drain at the depth of 80-100 cm and an inspection well for drain water sampling and measurement of total water amount.

Crop management

This paper presents leaching data during 2011-2013 when spring oilseed rape (OSR), spring barley (SB) and perennial grasses (GC) were grown.

OSR variety Clipper was used in 2011. Soil was ploughed in the autumn before growing OSR. OSR was sown at the depth of 1.5 -2 cm and at the row distance of 12-12.5 cm. The sowing was done on the 28th of April for a target density of 90 plants m^{-2}. For weed control the mixture of herbicides lontrel *72 SG* (*clopiralid* 720 g kg^{-1}) 0.4 l ha^{-1} + pantera (*quisalophop tephuril* 40 g l^{-1}) 1.5 l ha^{-1} was used at the end of May.

SB variety Anakin was used in 2012. Spring barley was sown at the depth of 2-4 cm and at the row distance of 12-12.5 cm. The sowing was done on the 8th of May. A day later, the mixture of GC was sown under spring barley. The components of mix include red clover Jancis, timothy Varis, meadow fescue Silva and festulolium Vizule with sowing rate of mix 30 kg ha^{-1}.

Measurements and calculations

The intensity of drain water flow was measured and water samples were taken. The water sampling was done manually every time the water ran through drains at the start, at maximal and at the end of flow. Since 2010 to measure drain water flow pendulum type automatic water counters with data loggers were installed. Nitrate nitrogen content in drain water was determined by applying LVS ISO 7890-3:2002, phosphorus content – by LVS EN ISO 6878:2005, potassium – by LVS ISO 9964-3:2000, calcium – by LVS ISO 6058:1984 and magnesium – by ISO 6059:1984.

The obtained data mathematical processing was performed using analysis of variance (ANOVA).

III RESULTS AND DISCUSSION

The nitrate nitrogen content in subsurface drain water was significantly affected by fertilizer rate and crop species (Table 2; Table 3). Significant differences were noted when comparing three-year average N-NO_3 concentrations between the highest rate (F3), the lowest rates (F1 and F2) and plots with no applied fertilizer (F0) ($P<0.001$; Table 2). The spring OSR (2011) and spring barley (2012) resulted high nitrate content in subsurface water 11.94 and 12.32 mg N-NO_3 l^{-1} respectively (Table 2). Growing grass- clover mix (2013) the concentration of nitrate nitrogen in drain water was low and ranged from 4.98 mg N-NO_3 l^{-1} (F2) to 5.51 mg N-NO_3 l^{-1} (F1) except highest fertilization rate (F3) where was 11.03 mg N-NO_3 l^{-1} drain water nitrate content found and it was near to spring cultivars. There was found no interaction between fertilizer and crop species ($P=0.128>0.05$; Table 3).

Ingrid Wesström, Ingmar Messing [25] write that the high-risk periods for N losses through drains coincided with periods of high outflow rates and high mineral N content in soil. The changes in mineral N content in soil, NO_3-N loading in drain outflow, N fertiliser application, N uptake in crops showed a surplus during autumn in all plots.

TABLE 2
NUTRIENT CONCENTRATION IN DRAIN WATER 2011-2013 RELATED TO CULTIVATION REGIME AND LONG-TERM FERTILIZATION RATE, MG L^{-1}

Param.	Rates of fertilizers				
	F0	F1	F2	F3	average
NO3, mg l^{-1}					
OSR (2011)	10.95	11.70	11.43	13.68	11.94
SB (2012)	10.92	11.47	12.33	14.54	12.32
GC (2013)	5.39	5.51	4.98	11.03	6.73
Average	9.09	9.56	9.58	13.08	
P_2O_5, mg l^{-1}					
OSR (2011)	0.004	0.005	0.004	0.003	0.004
SB (2012)	0.004	0.005	0.004	0.004	0.004
GC (2013)	0.008	0.008	0.009	0.010	0.009
Average	0.005	0.006	0.006	0.006	
K_2O, mg l^{-1}					
OSR (2011)	0.13	0.23	0.30	0.25	0.23
SB (2012)	0.10	0.18	0.28	0.31	0.22
GC (2013)	0.10	0.13	0.13	0.18	0.13
Average	0.11	0.18	0.24	0.25	
Ca, mg l^{-1}					
OSR (2011)	58.50	49.00	63.75	66.00	59.31
SB (2012)	63.94	88.38	73.25	98.88	81.11
GC (2013)	72.25	87.00	77.25	99.75	84.06
Average	64.90	74.79	71.42	88.21	
Mg, mg l^{-1}					
OSR (2011)	11.50	18.75	12.50	20.50	15.81
SB (2012)	13.94	19.69	14.81	23.56	18.00
GC (2013)	15.25	22.25	14.00	21.50	18.25
Average	13.56	20.23	13.77	21.85	

Rates of fertilizers: F0 - N0P0K0, F1 - N45P30K45, F2 - N90P60K90 and F3 - N135P90K135

OSR – spring oilseed rape; SB – spring barley ; GC – grasses-red clover

During the winter season, a surplus in measured net changes of N was found in common drainage system in all years. The nitrogen is leached from agricultural soils, even with no N application By N application similar to that removed with yields, N leaching losses amounting to 40 – 50 kg ha^{-1} [24] and 25 – 30 kg ha^{-1} [13] are found [2]. The N losses were the highest for fields with excessive N application [3]. Our trials show even after 30 years of experiment from plots with no nitrogen fertilisation the nitrogen is leached by drain water and excessive N application resulted highest nitrogen concentration in drain water. In Latvia the maximal nitrogen rate for spring barley (at predicted yield 3- 5 t ha^{-1}) is limited to 100 kg N ha^{-1} but for spring oilseed rape (predicted yield 2 – 4 t ha^{-1}) is limited to 120 kg N ha^{-1}.

The content of phosphorus in subsurface drain water was relatively low and average yearly concentration ranged from 0.003 mg P l^{-1} (at F3, OSR, 2011) to 0.010 mg P l^{-1} (at F3, GC, 2013) of water (Table 2). Statistical differences of P concentrations in subsurface drainage are presented in Table 2. There were no statistically remarkable differences of phosphorus content in drain water among different fertilizer application rates (p=0.759>0.05; Table 3). When comparing phosphorus concentrations between OSR or SB (0.004 mg P l^{-1}) and GC (0.009 mg P l^{-1}) in average by fertilizer rates, significant differences were noted (P=0.008<0.05; Table 3).

TABLE 3
ANALYSIS OF VARIANCE P-VALUES FROM CULTIVARS AND FERTILIZER RATES 2011-2013

Source of variation	ANOVA values	
	F_{act}	P
NO3, mg l^{-1}		
Effect of cultivar (A)	**	<0.001
Effect of fertilizer rates (B)	**	<0.001
AxB	n.s.	0.128
P, mg l^{-1}		
Effect of cultivar (A)	**	0.008
Effect of fertilizer rates (B)	n.s.	0.759
AxB	n.s.	0.489
K, mg l^{-1}		
Effect of cultivar (A)	*	0.001
Effect of fertilizer rates (B)	*	0.000
AxB	n.s.	0.216
Ca, mg l^{-1}		
Effect of cultivar (A)	**	<0.001
Effect of fertilizer rates (B)	**	<0.001
AxB	*	0.017
Mg, mg l^{-1}		
Effect of cultivar (A)	*	0.008
Effect of fertilizer rates (B)	**	<0.001
AxB	n.s.	0.506

*:P ≤0.05; **: P ≤ 0.01; n.s.: not significant

In long-term grassland trials there was no significant change in total soil P between any of the treatments, although there was a significant decrease in total inorganic P on two of the sites accompanied by an increase in the organic P pool, suggesting that over time P was becoming occluded within organic matter, reducing the plant availability [5]. This could be one of the ways for phosphorus accumulation in soil and limited leaching through drains.

In Italian soils long-term factors influencing the mobility of P within the soil profile are due not only to excessive P inputs, but also the forms of P fertilizer applied [17]. Some results suggest enhanced P losses through subsurface runoff on heavy soils, once a certain plow layer concentration of critical level is exceeded [7,8]. Probably in our experiment in 30 years there is still no critical P concentration in plow layer reached. The results of Norwegian scientists illustrated that losses of phosphorus (P) and nitrogen (N) had often different critical source areas. The P losses were highest for fields with manure application and/or high soil P status or with autumn ploughing [3]. Reduced nutrient application and stubble during autumn and winter led to the largest decrease in nutrient losses, and it was also apparent that management changes in high-risk areas had the greatest impact on the indices [3] and our results show similar trend especially for nitrogen and potassium. Marianne E. Bechmann and Johannes Deelstra [1] say that soil phosphorus status in addition to soil erosion is an important factor for phosphorus transfer. High-risk periods of phosphorus losses from common drainage system did not exclusively occur in months with highest outflow rates. In 3 out of 4 years, peak P loads occurred in late winter and P concentrations were positively correlated to soil temperature [25].

The results of water sample analysis showed remarkable (P=0.001<0.05, Table 3) influence of fertilization rate on content of potassium in leaching drain water. The highest content of potassium in drain water was observed in the catchment area with high rate (F3) of fertilizers and it had statistically significant (p<0.05) difference. The highest leaching of potassium was noted in spring OSR plots, where the content of potassium in subsurface drain water rose considerably: from 0.10 in plots with no fertilizer to 0.31 mg K l^{-1} in plots fertilized with rate F3 (P<0.05).

Perennial grasses (GC) in average resulted lowest potassium leaching through drains where the content of potassium in water ranged from 0.10 mg l^{-1} without fertilizer (F0) to 0.18 mg K l^{-1} in the catchment area with the highest fertilizer rate (F3) with calculated average 0.13 mg K l^{-1} of drain water (Table 3).

The content of calcium in leaching water was variable (p<0.05; Table 3). On average by fertilizer rates the lowest content of calcium in drain water was observed in 2011 growing spring OSR: 59.31 mg Ca l^{-1} and this was significantly lower (p>0.05) than 81.11 mg Ca l^{-1} at SB and 84.06 mg Ca l^{-1} at GC. The content of calcium in leaching water in average ranged from 64.90 mg Ca l^{-1} without treatment of fertilizers to - 88.21 mg Ca l^{-1} (Table 2) and its mean that fertilization rates considerably increased content of calcium in drainage water (P<0.001, Table 2).

The content of magnesium in drain water significantly variated by the different fertilizer rates (P<0.05; Table 3). The content of magnesium varied within the range on average from 11.50 to 22.25 mg l^{-1} Mg (Table 3). Variation of magnesium concentration in drain water was more influenced by fertilizer rate than growing year or cultivar what was still significant with statistically significant impact (P=0.008, Table 3).

Calcium and magnesium cations are leached from the soil most intensively. The succession of vertical migration intensity of soil elements is as follows: Na > Ca > Mg > K [13]. The results obtained from the long-term (1972–1995) lysimetric experiments conducted in Lithuania suggest that the amounts of calcium and magnesium leached from the soil depend not on the amount of water moving through the soil, but on the level of calcium and magnesium content in the soil, therefore the largest amounts of these elements are leached from heavy-textured calcareous soils [23]. Fertilisation increased the migration of magnesium in soil as well, but the concentrations of magnesium in lysimetre water were lower, since magnesium is retained by soil particles more strongly than calcium [22].

Our results show that fertilization rates considerably increased content of calcium in drain water. The reason for that could be the high Ca-release within the process of higher soil organic matter mineralization. Higher fertilization rates resulted higher crop residues returned to the soil. It is consistent with report of the data obtained from the long-term (1992–2003) experiments conducted in Western Lithuania suggest that the largest annual amounts (on average 112.7 kg ha^{-1}) of calcium were leached from the limed experimental plots treated with mineral and organic fertilisers. The amounts of calcium leached from these plots were larger by 21.3% than those of calcium leached from the not limed and not fertilised experimental plots [12]. Nitrogen fertilizer at rate of 150 kg N ha^{-1} results significantly in the highest value of calcium leaching [15]. Soil pH had a strong influence on $Ca^{2+}$and Mg^{2+} concentrations in the leaching water [4,18]. Monaghan et al. [15] found that N fertilizer application significantly increased losses of nitrate-N and Ca in drainage but had no significant effect on K, Mg, Na, sulfate-S, Cl, and P drainage losses. Our results show significant increase of content of calcium and magnesium in drain water with fertilizer use.

The inputs of nutrients should be based on realistic crop yield expectations that vary with soil properties. Proper management helps avoid excessive levels of elements such as nitrogen and phosphorus that then become harmful.

IV CONCLUSIONS

The concentration of nitrogen in leached drain water was significantly lower from non-fertilised plots than from other treatments and was considerably lower growing grass without autumn soil tillage than with conventional ploughing.

The content of phosphorus in drain water was more influenced by crops and agricultural practice including climatic condition of the year than used fertilizer rate.

Exchangeable potassium in soil has increased more than 4 times (from 64 till 223 mg K_2O kg^{-1}) and significantly affected drain water content of potassium.

V ACKNOWLEDGEMENTS

This work was supported by the European Regional Development Fund within the project Development of Technology of Reduction of Environmental Pollution Using Mineral Fertilizers (No. 2010/0232/2DP/2.1.1.1.0/10/APIA/VIAA/097).

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 329-332

The Changes of Nutrient Content in Soil in Long-term Fertilizer Experiments

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Abstract. **The paper describes the influence of long term (more than 30 years) fertilizer application to the changes of soil properties and identifies the influence of different fertilization rates to phosphorus, potassium, calcium and magnesium accumulation in soil.**

The research has been carried out at the Research Institute of Agriculture of Latvian University of Agriculture in the long-term subsurface drainage field established in Skrīveri in 1981 under the guidance of professor J. Štikāns. The long-term drainage field was established in the uncultivated gleyic sod-podzolic *Hypostagnic Endogleyic Albeluvisol (Hypereutric), stw-ng-AB(he)* loam that had not been used in agriculture for 20 years before. The experimental field was established with four rates of mineral fertilizers: without fertilizers, N45P30K45; N90P60K90 N135P90K135 calculated in form of P_2O_5 and K_2O. Since 1994 a seven-year crop rotation has been organized: 1) winter triticale, 2) potatoes, 3) spring wheat, 4) spring oilseed rape, 5) spring barley + perennial grasses (red clover, timothy), 6) perennial grasses, 1st year of using, and 7) perennial grasses 2nd year of using. Mineral fertilizers were applied according to the anticipated rates of plant nutrient elements annually during the cultivation of soil before sowing. For winter cultivars the phosphorus as superphosphate and potassium as potassium chloride fertilizers were cultivated before the sowing in autumn and nitrogen in form of ammonium nitrate was applied the next spring at the beginning of vegetation and at the stage of tillering. During the vegetation period all the required common agro-technical measures were taken – treatment with herbicides, fungicides and insecticides.

After 32 years of trial similar soil parameters showed significantly different content of nutrients related to the different level of fertilizer application. On a low background of fertilizers (N45P30K45) a small increase of mobile phosphorus in soil has only been observed in recent years. At the fertilizer rate N90P60K90 the content of available phosphorus and potassium in soil gradually begins to grow. Fertilization norm N135P90K135 caused a constant accumulation of nutrients in soil. In 30 years' time the content of exchangeable phosphorus (calcium lactate – extractable) has increased more than 20 times (from 9 till 184 mg P_2O_5 kg^{-1}) and exchangeable potassium (calcium lactate – extractable) has increased more than 4 times (from 64 till 223 mg K_2O kg^{-1}). There were no relation between different fertilizing rates and calcium and magnesium content in soil observed.

Keywords: **mineral fertilizers, phosphorus, potassium, nutrient content, soil.**

I INTRODUCTION

In the recent years in the Baltic Sea region there is an increasing attention to the research of the agricultural impact on the environment. The losses of plant nutrients (nitrogen and phosphorus) in agricultural soils are extremely complex and are affected by a number of factors such as soil type, climate, crop rotations and the use of manure and fertilizer. The factors vary in time and space both at field, farm and regional level causing uncertainties in the estimates of leaching. [5,6,11].

Currently, there is general acceptance that soils should contain a certain amount of plant-available phosphorus (P), together with other nutrients, to ensure optimum yields of crops and the efficient use of other annual inputs, especially nitrogen (N) fertilizers [10].

Reducing P fertilisation did not decrease P leaching, but the yields decreased [12]. Other similar experiments demonstrated a yield response to P fertilisation [2].

Calcium and magnesium are vitally important elements. These base elements (cations) are very important not only as plant nutrients. Agrochemical and physical properties of soil depend on the base cations as well. Calcium improves soil properties and thus has a tremendous effect on the growth and development of plants as well as on soil microbial activity. Even in acid soils its amount is 2–3 times larger than that of potassium or phosphorus. Like calcium, magnesium improves the properties of soil, yet high levels of magnesium content impairs soil water regime [1,8].

The paper describes the influence of long term (more than 30 years) fertilizer application to the

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.624

changes of soil properties and identifies the influence of different fertilization rates to nitrogen, phosphorus, potassium, calcium and magnesium accumulation in soil.

II MATERIAL AND METHODS

Field site

The research has been carried out at the Research Institute of Agriculture of Latvian University of Agriculture in the long-term subsurface drainage field established in Skrīveri in 1981 under the guidance of professor J. Štikāns.

The long-term drainage field was established in the uncultivated gleyic sod-podzolic *Hypostagnic Endogleyic Albeluvisol (Hypereutric), stw-ng-AB(he)* (IUSS Working Group WRB, 2007) loam that had not been used in agriculture for 20 years before.

The study site is located in the central part of Latvia (56°38′N; 025°08′E) with warm temperate climate. The precipitation amount is normally 670 mm a year. The annual air temperature is + 5.7ºC. The winter average air temperature is - 4.3ºC. The duration of vegetation period proceeds 180-210 days.

The experimental factors were mineral fertilizers, termed ‘F’. The experimental field was established with four rates of mineral fertilizers: F0 – without fertilizers, F1 – N45P30K45; F2 – N90P60K90 and F3 – N135P90K135 calculated in form of P_2O_5 and K_2O or F1 – N45P13K37; F2 – N90P26K74 and F3 – N135P39K112 calculated as elemental P and K kg ha^{-1}. Mineral fertilizers were applied according to the anticipated rates of plant nutrient elements annually during the cultivation of soil before sowing. For winter cultivars the phosphorus as superphosphate and potassium as potassium chloride fertilizers were cultivated before the sowing in autumn and nitrogen in form of ammonium nitrate was applied the next spring at the beginning of vegetation and at the stage of tillering.

The total area (1.6 ha) of the experimental field was divided into 16 plots (15x50 m). Each plot was supplied with a seepage tile drain at the depth of 80-100 cm and an inspection well for drain water sampling and measurement of total water amount.

Crop management

In the long-term site in Skrīveri winter rye, winter triticale, winter and spring wheat, spring barley, oat pure stand and mixed with peas as well as potatoes, spring oil rape (OSR) and perennial grass (biennial clover and timothy mix) have been grown since 1982. Since 1994 a seven-year crop rotation has been organized: 1) winter triticale, 2) potatoes, 3) spring wheat, 4) spring oilseed rape, 5) spring barley + perennial grasses (red clover, timothy), 6) perennial grasses, 1st year of using, and 7) perennial grasses 2nd year of using. The crop was the same on all plots. During the vegetation period all the required common agro-technical measures were taken – treatment with herbicides, fungicides and insecticides.

Measurements and calculations

The area of harvested plot composed 23.2 m^2 (1.7 x 13.6 m) for growing grain and OSR. The yield was harvested by direct combining. The straw and other harvest residues were incorporated into the soil. The perennial grass was cut two times during the growing season. The harvested grass-clover (GC) biomass was removed from the plots.

The soil samples were taken in autumn for the analysis of P, K, Mg and Ca. Forty soil samples were taken in each plot at 25 cm depth using a 12 mm diameter steel auger, and the samples from each plot were mixed, dried and sieved. Phosphorus and potassium content in soil was extracted from acid calcium lactate, calcium and magnesium– in the 1M KCl extract by atomic absorption method.

The obtained data mathematical processing was performed using analysis of variance (*ANOVA*).

III RESULTS AND DISCUSSION

At the beginning (1981) of the experiment soil properties were pH (KCl) 4.7-4.9; available phosphorus (DL-method) 10-20 mg P_2O_5 kg^{-1}; exchangeable potassium (DL-method) 40-60 mg K_2O kg^{-1}and soil organic matter 19-21 g kg^{-1} (Tyurin's method). After 32 years similar soil parameters showed significantly different content of all nutrients (phosphorus, potassium) related to the different level of fertilizer application.

In variant without fertilizers (F0) available phosphorus and potassium both did not change significantly during the experiment (Figure 1). In 2012 (Table 2) phosphorus content in soil was only 12 mg P_2O_5 kg^{-1} and characterized as very low. Potassium content was 60 mg K_2O kg^{-1} and characterized as average.

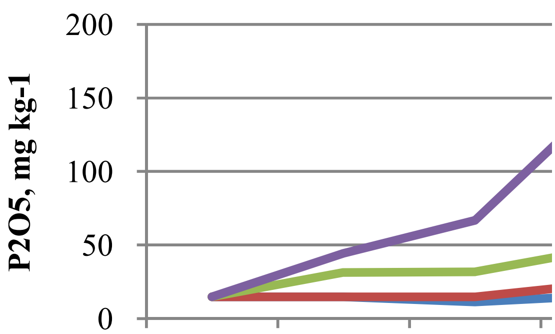

Fig.1. The changes in phosphorus content (mg P_2O_5 kg^{-1}) in soil, 1981-2012

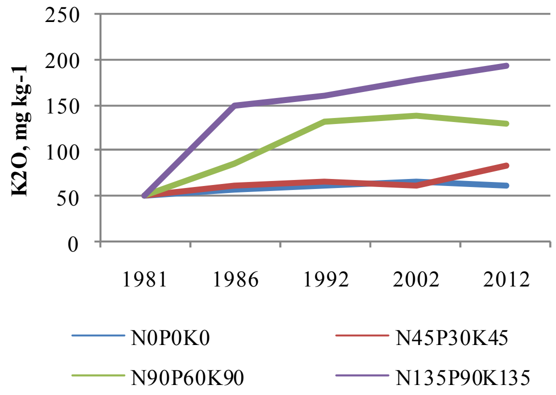

Fig. 2. The changes in potassium content (mg P_2O_5 kg^{-1}) in soil, 1981-2012

At fertilizer rate F1, available P only started increasing 20 years after the establishment of the experiment. The rise was insignificant and in 2012 the content of available P was 29.8 mg P_2O_5 kg^{-1}. Available K only started increasing in 2002. The content of available K in case of F1 variant was 74.8 mg K_2O kg^{-1} in soil after 30 years of the experiment.

In variant with fertilizer rate F2, the available P increased slowly yet gradually and in 2012 reached 75.0 mg P_2O_5 kg^{-1} (Table 1). Available K enhanced rapidly and in 1992 stabilized, but during the last ten years the content of K started decreasing (Figure 1). The level of available K in 2012 was 108.0 mg K_2O kg^{-1} and characterized as average.

In variant with fertilizer rate F3, the growth of available P was faster than in variants with lower fertilizer rates. During first 10 years the content of P reached 67 mg P_2O_5 kg^{-1} (high level). The following ten years, available P increased very rapidly and reached 151 mg P_2O kg^{-1}. In recent years the available P continued to increase to 174 mg P_2O kg^{-1} (Table 1). There was a slight rise. Available K intensified very rapidly and reached a high level within five years. During the next period, the plant available K increased slightly but gradually (Figure 1).

Long-term application of mineral fertilizers to agricultural soils can lead to accumulation of plant nutrients in soil. The proper amount of fertilizers is determined by the soil properties and crop needs.

There is a gradual decrease of stock of mobile phosphorus if phosphorus fertilizer is not used. On a low background of fertilizers (N45P30K45) a small decrease of mobile phosphorus in soil has only been observed in the recent years. At the rate of phosphorus P60 in soil the content gradually begins to grow and at the fertilizer rate P90 there is already a constant accumulation of mobile phosphorus in soil.

Exchangeable K content on non-fertilized plots declined slightly over the experimental period, but without reaching levels expected from nutrient balance estimates. Annual applications of K equal to average off take in yield were adequate to maintain available soil K content at its initial value. Potassium release kinetics for the exchangeable fraction, clearly discriminated between fertilized and non-fertilized treatments. These results highlight the role of K reserves readily available in soils and demonstrate the importance of cultural residues in K fertility management [7]. Exchangeable K leaching in the K225 treatment at 0–100cm soil depth was the result of excessive K application or non-synchrony between K application and crop K demand. However, exchangeable K and non-exchangeable K at different soil depths are controlled by different physical, chemical and biological factors [9] like it is stated in our experiments about significant importance of fertilizer rate and factor of cultivar.

After 32 years the content of organic matter increased from 19-21 g kg^{-1} till 22-23 g kg^{-1} and there are no significant differences among fertilizing rates (Table 1).

TABLE 1
NUTRIENT CONTENT IN SOIL, 2012

	Organic matter, g kg^{-1}	Ca, mg kg^{-1}	Mg, mg kg^{-1}
F0	22	670	68
F1	23	1016	128
F2	24	574	41
F3	24	877	78

There were no relation between different fertilizing rates and calcium and magnesium content in soil observed.

IV CONCLUSIONS

Long-term application of mineral fertilizers to agricultural soils can lead to accumulation of plant nutrients in soil.

The use of NPK fertilizers in 30 years' time resulted increase of content of exchangeable phosphorus in soil arable layer more than 20 times (from 9 till 184 mg P_2O_5 kg^{-1}).

Exchangeable potassium in soil has increased more than 4 times (from 64 till 223 mg K_2O kg^{-1}).

There were no relation between different fertilizing rates and calcium and magnesium content in soil observed

V ACKNOWLEDGEMENTS

This work was supported by the European Regional Development Fund within the project Development of Technology of Reduction of Environmental Pollution Using Mineral Fertilizers (No. 2010/0232/2DP/2.1.1.1.0/10/APIA/VIAA/097).

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 333-336

Crop diversification for weed management in organic arable cropping systems

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Abstract. **Within the ERA-net CORE Organic Plus transnational programmes supported project PRODIVA producing of the information required for a better utilization of crop diversification for weed management in North European organic arable cropping systems was started. To fulfill the goal of this project- not to eradicate weed problems, which is unlikely to happen in any arable farming system, but to maintain a diversified and manageable weed flora that can support beneficial organisms- there were data from ongoing long-termed cropping system experiments from Latvia analyzed.**

It is hypothesised that: a) perennial weeds can be suppressed in the post-harvest period by improved cover crop establishment and pertinent selection of cover crop species; b) on-farm practices of crop diversification are related to weed pressure and species composition.

On the bases on data from organic farm and ongoing long-termed cropping system experiment on weed dynamics in six-field crop rotations with cover crop was concluded that red clover as cover crop after the harvest period is effective to manage perennial weeds. In crop rotation with higher proportions of cereals weed infection growth in six-field rotation with 50% share of cereals up to 3.4, but with 33.3 % share-up to 2.1 times.

Keywords: **crop diversification, organic farming, weeds, PRODIVA.**

I INTRODUCTION

Crop productivity in organic cropping systems in Northern Europe is largely constrained by weed infestations [10]. Perennial weeds are usually most detrimental to crop yield and quality, whilst many annual weed species are less harmful. Despite the need for weed management to preserve crop yield, organic cropping systems strongly contribute to maintain and support diverse weed communities on arable fields (with no selection pressure posed by herbicides) [6].

Considerable research has been allocated to develop new and direct weed control methods and strategies to reduce immediate weed problems in the crops [5]. These methods are either mechanical or thermal weeding devices some of which consume considerable fossil energy and may have adverse effects on soil structure and beneficial organisms [1]. Direct control actions are motivated to instantly release the crop from weed interference. However, the reliance on direct tactics could be reduced through careful and pertinent planning of cropping systems that mitigate severe weed problems and create a more balanced and manageable weed flora [6].

Currently, organic cropping systems are mainly planned according to the prevailing commodity prices and the need for nutrient supplies. The potential of diversifying the cropping system, not only by changing the choice of main crops, but also through the introduction of improved methods for catch/cover crops establishment [7,11], has not been exploited in practise. This is mainly because the knowledge is relatively scarce. Careful planning of crop sequences is known to disrupt weed communities, especially of annual weeds [2]. Perennial weeds can also be manipulated through crop choice and by making room for control actions whenever needed [7].

For any practical implementation of crop diversification, farmers need to pay attention to the most severe weed problems. Thus, they need to distinguish between major groups of weed species

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.274

having either high or low noxiousness or being even neutral to positive for the cropping system [3, 9].

Crop diversification methods should focus on the species with high noxiousness, while maintaining diversity within the non-detrimental section of the weed assembly. Crop diversification methods will act on weeds differently, depending on regional conditions.

To fulfill tasks of the ERA-net CORE Organic Plus transnational programs supported project PRODIVA (Crop diversification and weeds) data from organic farm practices and ongoing long-termed cropping system experiments on weed dynamics in crop rotation with cover crop to produce information for weed management in North Europa were summarized from two locations in Latvia.

II MATERIALS AND METHODS

Fields

Weed survey at organic farm 'Kelmeni' (OFK) (57°15'14.57"N, 26° 9'13.01"E) and at State Priekuli Plant Breeding institute (SPPBI) (57˚18'49"N, 25˚20"E) was carried out in 2008 and 1014 in organic crop rotations, characterized by sod-podzolic loamy sand soils both locations (Table 1). Agrochemical parameters were determined by the State Plant Protection Service of Latvia in 2008 and 2014: the soil pHKCl was measured potentiometrically, humus content- Tyurin, and plant available phosphorus and potassium using Egner–Riehm methods.

Table 1.
SOIL CHARACTERISTICS OF EXPERIMENTAL FIELDS

Soil characteristic:	OFK		SPPBI	
	2008	2014	2008	2014
pH_{KCl}	5.8	5.6	5.7	5.6
humus, g kg^{-1}	22	24	25	21
P_2O_5, mg kg^{-1}	159	134	128	126
K_2O, mg kg^{-1}	143	152	135	109

Soil and weed management

Fields have been organically managed since 2003. As the basic soil fertility management measure was green manure (Table 2). Additionally the enriching of soil is achieved by cultivating clover as the improvement through the nitrogen fixation, as well as by turning the plant residues into the soil.

Table 2.
SOIL AND WEED MANAGEMENT

Location:	Amount of N, kg ha^{-1}	Weed management
Organic farm KELMENI *(OFK)*	19.7	No
State Priekuli Plant Breeding Institute *(SPPBI)*	26.5	Harrowing (barley)

Weed assessment

Weed assessment was carried out in fields with winter rye (OFK) and with spring barley (SPPBI) in last week of June in 2008 and 2014. The weed numbers of each individual weed species were recorded using a 0.20 m^{-2} frames (Fig.1). The occurrence of each weed species was recorded as percentage frequency by the method of A. Rasins and M.Taurina [4].

Fig. 1. Frame used for weed inventory *(Photo by LAAPC)*

The species were assigned to weed groups on the basis of life form (annual or perennial) and morphological characters (dicotyledonous or monocotyledonous). Weed numbers were recalculated to per m^2. Weed dynamic after full rotation (six year period) were calculated and expressed as percentage of the total weed number. Dispersion around the average weed number was assessed using the standard error.

To compare weed occurrence and dynamic there was determined the proportion of cereals in rotation that was 33.3% in OFK and 50% in SPPBI, accordingly.

Crop rotation at OFK:

Winter rye with red clower as undersown- red clover (mulch)– red clover (green manure)- winter rye with red clower as undersown- red clower;

Crop rotation at SPPI:

Spring barley- crucifers for green manure (oil radish)- spring barley with clover as undersown- red clover- winter rye- potatoes.

III RESULTS AND DISCUSSION

Density of weeds

The average density of weeds was 94.2 plants m^{-2} (S_{AV}= ±14), ranging from 12 to 165 at OFK and 24 to 231 plants m^{-2} at SPPBI (Fig. 2). 1.8 times less weeds were in field from crop rotation with less proportion of cereals.

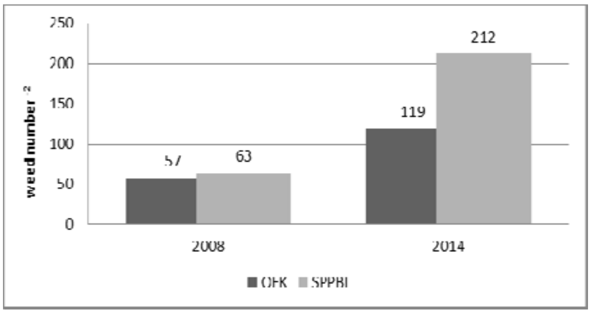

Fig. 2. The average weeds density in the fields, LSD_ 28

The results shows that amount of weeds in both sites in the first survey (in 2008) were comparatively low (in average 60 plants m^2) and similar (difference between locations- 6 plants), whereas after a full rotation (6 years from 2008 till 2014) density of weeds increases and difference between studied crop rotation is significant.

Since fewer weeds in the field from crop rotation where no harrowing which is typical physical weed control method, there is the reason believe that including of red clover in crop rotation as cover and mulch crop is an effective weed management method.

Weed groups

At the weed assessment in winter rye annual dicotyledonous species were dominant both surveys years (Fig.3). Similarly tendency was also in spring barley; however, there were significant differences in proportional distribution.

Fig. 3. Weed groups on the bases of morphological characters WR-A: winter rye- annual dicotyledonous species; WR-P: winter rye- perennial dicotyledonous species, SB-A: spring barley- annual dicotyledonous species; CB-P: spring barley- perennial dicotyledonous species

In average, between the five dominant annual dicotyledonous weed species were *Chenopodium album* L. (20.6 ± 5.1 plants m^2), *Viola arvensis* (Murray; 9.9 ± 3.5 plants m^2), *Capsella-bursa pastoris* (L) (5.4 ± 1.4 plants m^2), *Stellaria media* (L) (2.8 ± 0.8 plants m^2), *Thlaspi arvense* (L) (1.3 ± 0.4 plants m^2), Fig.4.

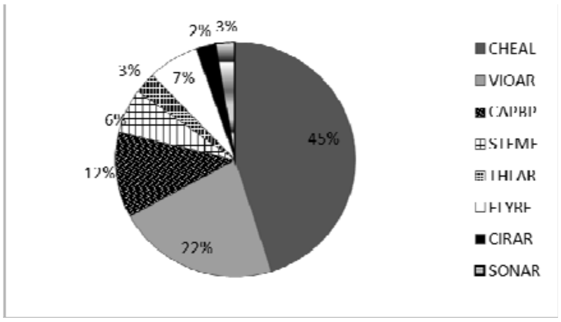

Fig. 4. Share of the dominant annual and perennial weed species, %

CHEAL- *Chenopodium album* L., VIOAR- *Viola arvensis* (Murray, CABP- *Capsella-bursa pastoris* (L) , STEME- *Stellaria media* (L), THLAR- *Thlaspi arvense* (L), ELYRE- *Elymus repens* (L.), CIRAR- *Cirsium arvense* (L) (Scop.), SONAR- *Sonchus arvense* (L).

There were three dominant perennial weeds fixed: *Elymus repens* (L.) (Gould) (3.1 ± 0.8 plants m^{-2}), *Cirsium arvense* (L) Scop.) (1.2 ± 0.5 plants m^{-2}), and *Sonchus arvense* (L) (0.3 ± 0.09 plants m^{-2}). The total amount of perennial weed species at OFK was 5 in both- 2008 and 2014, but at SPPBI- 6 and 7 plants m^{-2}, accordingly that, taking into account results from nine year monitoring in conventional fields same region [10], can be defined as low.

Figure 5 shows that in crop rotation with less diversity of crops is smaller number of weed species.

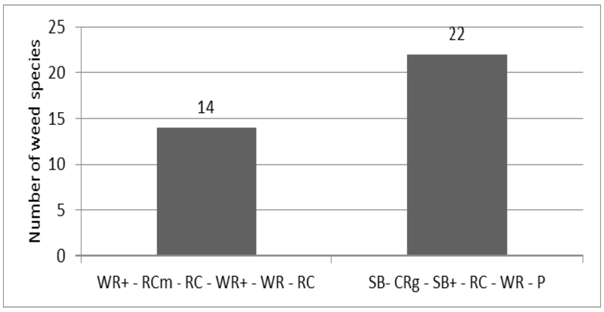

Fig. 5. Average number of weed species depending crop rotation WR+ -winter rye with red clower as undersown, RCm- red clover (mulch), RC– red clover, SB - spring barley, CR - crucifers for green manure (oil radish), SB+ - spring barley with clover as undersown, P - potatoes.

Data summarized from two organic fields in Latvia point on fact that perennial weeds may be cancelled after the harvest period improving the cover crop establishment and the appropriate choice of cover crop species (Fig.6). Red clover used as cover crop in context with weed management justifies itself. Particularly good efficiency is regarding perennial weeds which are in tune with one of the PRODIVA hypothesis.

Fig. 6. Winter rye at OFK in 2011 (there were only some weeds, mainly crop contaminant- buckwheat that was sown after old ley in 2007).

IV CONCLUSION

In crop rotation with higher proportions of cereals weed infection growth:

- in six-field rotation with 50% share of cereals up to 3.4 times;
- in six-field rotation with 33.3% share of cereals up to 2.1 times.

In winter rye annual dicotyledonous weed species are dominant. Similar expressing also in spring barley, but there are significant differences in proportional distribution between annual and perennial dicotyledonous species.

There are no sharp differences in the spectrum of dominant weed species in both experimental sites in general; however, more weed species diversity was in rotation with more crops.

Red clover as cover crop after the harvest period is effective to manage perennial weeds. Also using red clover herbage as mulch in the previous autumn ensures effective weed management for 2-nd year clover yield, both – green mass and seed.

V ACKNOWLEDGMENTS

This study was partly supported by the Ministry of Agriculture of Latvia. Project No 120308/S38.

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Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume II, 337-343

Variability of estimated contamination extent depending on calculation methods

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***Abstract*. The aim of research was to analyse the changes of contamination extent (E, %) estimated using two methods of background calculation by eliminating anomalies outside the interval mean±2σ or median±2MAD (σ is standard deviation, MAD is median absolute deviation) and optional normalisation. Two methods were used for estimation of background values (B) and upper threshold values (T) of Ag, As, Ba, Co, Cr, Cu, Mn, Mo, Ni, Pb, Sn, U, V, Zn and selected major elements according to their contents in topsoil samples from football fields in less contaminated districts of Klaipėda. Then two different sets of B and T values were applied to the whole geochemical data set. After determination of two sets of concentration coefficients (K_k), four sets of enrichment factors were calculated: two simple (EF_1) (normalisation by Al) and two complex (EF_3) (normalisation by Al, K, Ti).**

Estimation of E using T values resulted in lower percentage compared to percentage of sites where K_k>1, EF_1>1 or EF_3>1, because the latter 3 indices depend on B values. Since all T values obtained by median±2MAD method are much lower (by 6-37.1%) than by mean±2σ method, respective E is much higher: for 11 pollutants it is higher by more than 5% (range 6.3-34.2%). Since the absolute difference between B values estimated by two methods is much lower (only for Sn and Mn exceeds 5%) than the difference between T values, the influence of different B values on estimated E is much lower. Higher than 5% absolute difference between two sets of E estimated according to K_k>1 is observed for 5 pollutants, according to EF_3>1 for 4 and according to EF_1>1 only for 3 pollutants. So E estimated according to EF_1>1 is least of all influenced by the method of determination of B values, besides, it usually gives the highest E.

***Keywords*: background value, concentration coefficient, enrichment factor, upper threshold value.**

I INTRODUCTION

Trace element background estimation is one of the fundamental geochemical tasks. It is necessary not only for exploration of mineral resources, but also for assessment of contamination. However, there is no consensus among scientists how to calculate geochemical background in particular area. Different concepts and definitions of the background (natural, ambient, pre-industrial) have been discussed [1], [2]. Some geochemists also use the term “baseline” [3] – [5]. It is a sum of background and anthropogenic contribution [5]. Part of researchers [6], [7] consider that the citation of single values for geochemical background is not useful, because background is a range; besides, they are much more concerned about the upper limit of this range, i.e. the upper threshold value (T) and pay less attention to the mean or median values, i.e. the background values (B). The reason is that they rather use T values for discrimination between the natural and anthropogenic content than calculate various dimensionless indices which depend on B values and reflect contamination by potentially harmful elements (PHE).

The latter indices are different: contamination factor (CF) used by Hakanson [8], geoaccumulation index (Igeo) defined by Muller [9] and concentration coefficient (K_k) [10] are mono-element, meanwhile pollution load index (PLI) [2], enrichment index (EI) [11] and additive contamination index (Z_d) [10] are multi-element. The mentioned indices are without normalisation. The enrichment factor (EF) differs from them, because it is mono-element index which uses normalisation by the content of conservative (or reference) element.

Both T values and mono-element indices can be used for assessment of topsoil contamination extent (E), i.e. the percentage of samples which are considered as contaminated or possibly contaminated. In both cases, location of sites for background

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol2.234

estimation and method of background calculation may influence the results. They may also differ depending on whether normalisation was used or not and which reference element was chosen (the magnitude of EF depends on its content and background value).

There is no consensus among scientists concerning the necessity of normalisation. According to Loringh [13] grain size and provenance are the two most significant parameters which must be compensated for by any normalisation procedure. However, according to Reimann and de Caritat [12] the EF (calculated to either the crust or local background) can be high or low due to multitude of reasons, of which contamination is but one; they are influenced by biogeochemical and other near-surface processes. Since the content of usual reference elements is variable in large areas, they state that distribution pattern of EF much more reflects the distribution pattern of the reference elements than anthropogenic contamination. Still soil texture and major soil taxonomical group have a major influence on trace metal concentrations in soil [14]. So it might be useful to carry out normalisation.

There is also no consensus concerning the reference element. Some of the scientists selected Fe as a proxy for clay fraction content [15]. Chang et al. [16] used Cs because its content tends not to be interfered by anthropogenic sources. Loring [13] stated that normalisation by Li may have an universal application to silicate sediments. In ombrotrophic peat bogs cores, usually Ti is used as conservative element, because its minerals are resistant to chemical weathering [17], sometimes Zr or Sc [18]. However, the most common element to carry out the normalisation is Al [19] – [21]. Sometimes a group of elements is used for this aim, e.g. median of concentration coefficients of Al, K, Ti [22], because it has been shown that these 3 major elements are good indicators of clay content in urban soil [23].

The methods of geochemical background determination were divided into 3 groups [2]: 1) direct (geochemical) which use either historical or contemporary aspect, 2) indirect (statistical) which are based on spatial analysis or statistical frequency analysis; 3) integrated which combine the first two groups of methods.

Some researchers of soil from natural areas prefer direct historical approach (sometimes integrated with statistical methods), i.e. they presume that soil background concentration can be established from parent material samples (C-horizon) below the level of anthropogenic influence of the same region [15]. They express the level of soil contamination with heavy metals in terms of a distribution index (DI) calculated by dividing metal content in the solum horizon by metal content in parent material. However, Reimann and Garret [1] criticised this approach which can lead to misinterpretations if natural biogeochemical soil processes are ignored.

The most widely used indirect statistical methods are based on the assumption of either normal or lognormal distribution of data, however, regional geochemical data almost never follow these distributions, because they are skewed, have outliers and originate from more than one process [24]. Still in most indirect statistical methods for background determination the researchers have to choose one of the two assumptions.

Eight indirect statistical methods to calculate the background have been reviewed by Matschullat et al. [6]. Three of them (4σ-outlier test, iterative 2σ technique (σ is standard deviation) and calculated distribution function method) which are based on presumption of normal distribution were tested by them. The conclusion was done that the second and third methods are appropriate for fast and reliable evaluation of likely T values. Other five procedures were used by previous researchers and are based on graphical analysis of cumulative frequency distribution curves (CFDC) of either non-transformed or log-transformed data, mode analysis of distribution functions using Al-normalised data or regression technique using conservative element. For regional and local studies with soil samples belonging to both uncontaminated and contaminated populations, the CFDC (using log-transformed data) has shown to be a powerful tool to discriminate different populations of samples and define their background trace element levels [25]. The inflexion points of CFDC that separate different classes in the dataset were identified as the end data points for which the resulting population showed a skewness closest to 0 [26].

Later Reimann et al. [7] compared several procedures for identification of outliers, determination of B and T values according to simulated natural (non-transformed) and log-transformed data: 1) mean±2σ; 2) boxplot; 3) median±2MAD (MAD is median absolute deviation); 4) empirical cumulative distribution function.

The aim of the present research was to analyse on example of topsoil from Klaipėda city the variability of estimated contamination extent obtained using two analogous methods of background calculation and optional simple or complex normalisation by selected reference elements.

II MATERIALS AND METHODS

A total of 79 composite topsoil samples was taken in Klaipėda [27]: 51 of them were from the territories of schools and 28 from football fields. Each sample was formed by mixing 20 to 30 sub-samples taken at a depth of 0-10 cm during zigzag crossing the sampling area of school or football field. The samples were dried and sieved to <1 mm, then analysed for real total contents of chemical elements. The contents of 12

PHE (As, Ba, Cr, Cu, Mn, Mo, Ni, Pb, Sn, U, V, Zn) and 3 major elements (Al, K, Ti) were determined by energy-dispersive x-ray fluorescence (EDXRF) equipment Spectro Xepos using TurboQuant for pressed pellets calibration method. The contents of 2 PHE (Ag and Co) were measured by optical atomic emission spectrophotometry (OAES) using spectrograph DFS13.

Basing on previous investigations [27], a subset of 20 football fields which are not in the city centre was chosen for experiments with background estimation, presuming that these sites have only insignificant contamination, though high or low anomalies are possible there. Two methods of elimination of anomalies were applied for the contents of PHE and major elements in this subset. The first method eliminates anomalies outside the interval mean±2σ, the second one outside the interval median±2MAD.

The choice of these methods was determined by their simplicity, lower subjectivity compared to graphical methods of threshold determination and by previous investigations of researchers. Iterative 2σ technique (when omitting values outside the range mean±2σ is repeated until all remaining values lie within this range) was tested by Matschullat et al. [6]. It was based on presumption of normal distribution. The procedure similar to iterative mean±2σ was used by Zinkutė [28] for log-transformed data; from 6 iterations the version was selected for which the average square deviation of CFDC on the probability paper from the approximating line determined by the least squares method was the lowest.

Both methods selected for experiments were among 4 procedures tested by Reimann et al. [7] according to simulated natural (non-transformed) and log-transformed data. On their opinion, the continued use of the mean±2σ rule is based on misunderstanding and median±2MAD procedure is more suitable than mean±2σ, but the choice between 3 from 4 tested procedures depends on the percentage of outliers. Besides, on their opinion data should approach a symmetrical distribution before any T estimations are applied. To find out this, they recommend to calculate the coefficient of variation (CV%). If CV>100%, plots on logarithmic scale should be prepared, if 70%<CV<100%, the inspection of such plots is also informative.

Since the CV values of all PHE in subset from Klaipėda were below 70%, experiments were done only for non-transformed data. Taking into account the above mentioned recommendation not to use iterations, the estimated B (median) and T values were taken after the first elimination of anomalies. These values were used for calculation of K_k, simple enrichment factor (EF_1) (K_k of PHE divided by K_k of Al) and complex enrichment factors (EF_3) (K_k of PHE divided by the weighted average of K_k of Al, K and Ti where weights are proportional to the share of their B values). The values of 3 mono-element indices were used for calculation of respective 3 additive contamination indices (Z_d).

Then different B and T values were applied to the whole data set to find out the contamination extent (E, %) by several ways. The first way was to estimate the percentage of sites where the content of PHE exceeds T (index ET). The second way was to calculate the percentage of sites where K_k>1 using B values of PHE (index EK). The third and the fourth ways were to calculate the percentage of sites where EF_1>1 (index EE_1) or EF_3>1 (index EE_3), respectively, using B values of PHE and conservative elements.

Median values of the indices and of 3 additive contamination indices gave additional information.

III RESULTS AND DISCUSSION

Though subset used for background estimation was rather homogeneous, anomalies were found for each PHE by both methods (Table I). The mean±2σ method detected only one anomaly for each PHE, it was usually related to high contents, except Ba, Mo and Mn which had anomalies related to low contents. For all PHE, except As, the median±2MAD method revealed more anomalies (from 3 to 7), besides, for 8 PHE, the number of high anomalies exceeded the number of low anomalies, for 4 PHE these numbers were the same and only for Ba and Ni the number of high anomalies was lower than of low anomalies. The prevalence of high anomalies indicates than the sites selected for background estimation are partly influenced by contamination. However, the fact that for Ag, Ni and Mo both estimates of B values are the same and do not differ from median in subset without any elimination of anomalies points that the influence of pollution on these sites is insignificant.

Due to higher (or at least the same) number of eliminated positive anomalies, the T values of all PHE obtained by median±2MAD method are much lower (by 6-37.1%) than obtained by mean±2σ method, i.e. T(2)<T(1). This result corresponds to findings from simulation by Reimann et al. [7] showing that median±2MAD procedure always results in the lowest T value, the boxplot in the second lowest and the classical rule mean±2σ in the highest. Earlier results of Matschullat et al. [6] showed that in most cases 4σ-outlier test resulted in highest T values, calculated distribution function method in lower and iterative mean±2σ technique in the lowest T values. Both ET(2) and ET(1) values enable to reveal the extent of obvious contamination. Due to lower T(2) than T(1), the respective ET(2) is much higher than ET(1) estimated according to T(1) (Table II): for 11 PHE it is higher by more than 5% (range 6.3-34.2%).

So in comparison with many other methods of the background estimation, the median±2MAD method enables to attribute more sites to the category "contaminated".

Unlike ET index, the other 3 indices (EK, EE_1 and EE_3) which are related to B values enable to reveal the percentage of sites which can be attributed not only to the category "contaminated", but also to category "possibly contaminated" and therefore are much higher than ET percentages. The difference between B values estimated by two methods is much lower (only for Sn and Mn exceeds 5%) than the difference between T values (Table I). Similarity of medians obtained by both methods does not correspond to the statement of Matschullat et al. [6] that the medians may differ strongly depending on the chosen technique, especially for the mean±2σ approach. The reason of disagreement is that these researchers were comparing mean±2σ approach not with median±2MAD, but with other methods, besides, their datasets included much more data.

Lower differences between B values explain greater closeness between estimated EK values: >5% absolute difference is observed only for 5 PHE (Table II). For Ag, As, Ni and U, the estimated B(1) and B(2) values are the same, for Ba, Cr and V, B(2) values are slightly higher than B(1), but for other 7 elements they are slightly lower than B(1). So the median±2MAD method shows a tendency to give also lower B values. As a result, EK(2)>EK(1) for 7 PHE. However, for 2 PHE (V and Ba), on the contrary, EK(2)<EK(1), because due to low anomalies their B(2) exceeds B(1).

The values of indices EE_1 and EE_3 depend on B values not only of PHE, but also of major elements: EE_1 on Al, EE_3 on Al, K and Ti. Like for PHE, the mean±2σ method eliminated lower number of their anomalies than median±2MAD method (Table I). For Al and K it has even not found anomalies, so B(1) values of Al and K are the same as in experimental subset. The main feature of major elements is that they have more low anomalies than high anomalies. Therefore elimination of anomalies results in higher B(1) value of Ti and higher B(2) values of Al, K, Ti in comparison with medians in experimental subset.

TABLE I

COMPARISON OF BACKGROUND ESTIMATION RESULTS OBTAINED BY TWO METHODS

NOTES. ChE, CHEMICAL ELEMENT, Med, MEDIAN VALUE (MG/KG) IN SUBSET FOR BACKGROUND ESTIMATION WITHOUT ELIMINATION OF ANOMALIES. PARAMETERS OR THEIR CHANGE: B (MG/KG), BACKGROUND; T (MG/KG), UPPER THRESHOLD; AH, NUMBER OF ELIMINATED HIGH ANOMALIES IN SUBSET; AL, NUMBER OF ELIMINATED LOW ANOMALIES IN SUBSET. THE VALUE IN PARENTHESES: 1, PARAMETER WAS OBTAINED USING MEAN ±2σ METHOD; 2, PARAMETER WAS OBTAINED USING MEDIAN±2MAD METHOD; %, THE PERCENTAGE OF THE DIFFERENCE BETWEEN THE VALUE OBTAINED BY MEDIAN±2MAD METHOD AND BY MEAN ±2σ METHOD FROM THE VALUE OBTAINED BY MEAN ±2σ METHOD.

ChE	Med	B(1)	B(2)	B(%)	T(1)	T(2)	T(%)	AH(1)	AL(1)	AH(2)	AL(2)
Ag	0.066	0.066	0.066	0.0	0.090	0.076	-16.1	1	0	3	2
As	3.47	3.28	3.28	0.0	5.63	5.16	-8.3	1	0	1	0
Ni	11.1	11.0	11.0	0.0	16.1	14.0	-13.0	1	0	1	2
U	0.94	0.91	0.91	0.0	1.67	1.33	-20.5	1	0	3	0
Ba	338	342	345	0.8	377	355	-6.0	0	1	1	6
Cr	35.2	34.9	35.2	0.8	50.6	44.5	-11.9	1	0	2	2
V	28.0	26.9	28.0	4.2	42.7	38.1	-10.9	1	0	2	2
Mo	0.68	0.68	0.68	-0.3	0.79	0.73	-8.0	0	1	3	3
Cu	11.0	10.8	10.7	-0.5	16.6	12.8	-23.1	1	0	4	1
Zn	63.8	63.5	62.6	-1.5	90.9	79.6	-12.5	1	0	**3**	0
Co	4.55	4.47	4.38	-2.1	5.61	4.62	-17.6	1	0	**5**	0
Pb	22.1	22.1	21.1	-4.6	37.1	23.6	-36.4	1	0	**6**	0
Mn	297	305	289	-5.2	386	333	-13.7	0	1	**2**	1
Sn	2.92	2.79	2.58	**-7.5**	5.17	3.25	-37.1	1	0	**5**	0
Al	34966	34966	35340	1.1	45161	43895	-2.8	0	0	0	1
K	18118	18118	18309	1.1	22490	21121	-6.1	0	0	0	2
Ti	2024	2033	2033	0.0	2584	2343	-9.3	0	1	2	3

TABLE II

INFLUENCE OF CALCULATION METHOD ON ESTIMATED CONTAMINATION EXTENT

NOTES. PHE, POTENTIALLY HARMFUL ELEMENT; ET, PERCENTAGE OF SITES WHERE THE CONTENT OF PHE EXCEEDS T; EK, PERCENTAGE OF SITES WHERE K_k>1; EE_3, PERCENTAGE OF SITES WHERE EF_3>1; EE_1, PERCENTAGE OF SITES WHERE EF_1>1. THE VALUE IN PARENTHESES: 1, PARAMETER FOR CALCULATION WAS OBTAINED USING MEAN ±2σ METHOD; 2, PARAMETER FOR CALCULATION WAS OBTAINED USING MEDIAN±2MAD METHOD; D, THE DIFFERENCE BETWEEN THE PERCENTAGE WHEN PARAMETER FOR CALCULATION WAS OBTAINED BY MEDIAN±2MAD METHOD AND WHEN IT WAS OBTAINED BY MEAN ±2σ METHOD.

PHE	ET(1)	ET(2)	ET(D)	EK(1)	EK(2)	EK(D)	EE_3(1)	EE_3(2)	EE_3(D)	EE_1(1)	EE_1(2)	EE_1(D)
Ag	40.5	50.6	10.1	65.8	65.8	0.0	73.4	74.7	1.3	74.7	74.7	0.0
As	3.8	6.3	2.5	40.5	40.5	0.0	46.8	50.6	2.5	50.6	51.9	1.3
Ni	5.1	15.2	10.1	59.5	59.5	0.0	77.2	78.5	1.3	78.5	78.5	0.0
U	3.8	10.1	6.3	40.5	40.5	0.0	60.8	60.8	0.0	62.0	63.3	1.3
Ba	12.7	38.0	25.3	50.6	46.8	-3.8	75.9	75.9	0.0	77.2	78.5	1.3
Cr	30.4	32.9	2.5	57.0	57.0	0.0	65.8	65.8	0.0	68.4	68.4	0.0
V	1.3	2.5	1.3	40.5	34.2	-6.3	59.5	54.4	-6.3	60.8	58.2	-2.5
Mo	16.5	30.4	13.9	43.0	45.6	2.5	70.9	70.9	0.0	69.6	72.2	2.5
Cu	36.7	57.0	20.3	79.7	81.0	1.3	78.5	79.7	1.3	79.7	79.7	0.0
Zn	59.5	68.4	8.9	87.3	88.6	1.3	83.5	88.6	5.1	83.5	86.1	2.5
Co	1.3	29.1	27.8	39.2	54.4	15.2	73.4	77.2	3.8	74.7	79.7	5.1
Pb	40.5	74.7	34.2	82.3	88.6	6.3	83.5	86.1	2.5	83.5	86.1	2.5
Mn	6.3	19.0	12.7	36.7	54.4	17.7	67.1	81.0	13.9	69.6	82.3	12.7
Sn	17.7	45.6	27.8	65.8	73.4	7.6	69.6	79.7	10.1	72.2	79.7	7.6

Besides, unlike PHE, B(2) values of reference elements are mainly higher (for Al and K) than respective B(1) values or at least equal to them (for Ti). Higher background of Al decreases its K_k, so during normalisation by Al the EF_1 values of PHE can often be higher than respective K_k values. This regularity is reflected in median values of respective indices of all PHE (Table III). The EF_3 values should also be usually higher than K_k values, the explanation is given below. The weights of K and Ti obtained by both methods are the same (0.329 and 0.037, respectively), of Al almost the same (0.634 by mean±2σ method and 0.635 by median±2MAD method). The highest share of K_k of Al compared to K_k of other 2 major elements determines the highest influence of its K_k on the value of EF_3. For both methods of background estimation, median values of EF_3 of all PHE are higher than median K_k, but lower than median EF_1 values (Table III). The median values of additive contamination index (Z_d) calculated according to EF_3 are also higher than median Z_d values calculated according to K_k, but lower than median Z_d values calculated according to EF_1 (Fig. 1).

For most PHE, except V, the EE_3(1) and EE_3(2) values are closer to each other than EK(1) and EK(2) values, because >5% absolute difference is observed only for 4 PHE (Table II). The values of EE_1(1) and EE_1(2) are even closer, because >5% absolute difference is observed only for 3 PHE. The tendency of EE_3(2)>EE_3(1) and EE_1(2)>EE_1(1) is observed for 9 PHE, while for V there is the opposite relationship.

TABLE III

MEDIAN VALUES OF MONO-ELEMENT INDICES IN THE WHOLE DATA SET. NOTES. PHE, POTENTIALLY HARMFUL ELEMENT; VALUE IN PARENTHESES: 1, B VALUES WERE OBTAINED USING MEAN ±2σ METHOD; 2, B VALUES WERE OBTAINED USING MEDIAN±2MAD METHOD. HIGHER OF TWO VALUES OF EACH INDEX IS IN BOLD.

PHE	K_k(1)	EF_3(1)	EF_1(1)	K_k(2)	EF_3(2)	EF_1(2)
Zn	1.56	1.93	1.97	**1.58**	**1.98**	**2.02**
Pb	1.51	1.72	1.73	**1.58**	**1.82**	**1.83**
Cu	1.30	1.44	1.49	1.30	**1.47**	**1.51**
Ag	1.18	1.32	1.33	1.18	**1.33**	**1.35**
Sn	1.13	1.17	1.22	**1.22**	**1.27**	**1.33**
Ni	1.05	1.14	1.18	1.05	**1.15**	**1.19**
Co	0.99	1.10	1.13	**1.01**	**1.13**	**1.16**
Cr	**1.06**	1.10	1.11	1.05	1.10	**1.12**
Mo	0.98	1.10	1.13	0.98	**1.11**	**1.14**
Ba	**1.00**	1.10	1.15	0.99	1.10	1.15
Mn	0.96	1.07	1.11	**1.02**	**1.15**	**1.18**
U	0.94	1.07	1.10	0.94	**1.08**	**1.11**
V	**0.97**	**1.06**	**1.07**	0.93	1.02	1.04
As	0.89	0.99	1.02	0.89	**1.00**	**1.03**

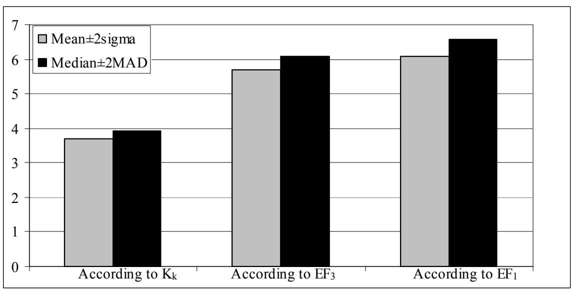

Fig. 1. Median values of the additive contamination index calculated according to different mono-element indices of Ag, As, Ba, Co, Cr, Cu, Mn, Mo, Ni, Pb, Sn, U, V, Zn.

IV CONCLUSIONS

The method of background calculation (either mean±2σ or median±2MAD) most of all influences the contamination extent which is estimated according to the upper threshold values (T) and reveals the percentage of contaminated sites. The median±2MAD gives much lower T values compared to mean±2σ method and many other methods, so for most potentially harmful elements (PHE) it results in much higher (by >5%) percentage of contaminated sites.

The method of background calculation has much lower influence on contamination extent which reflects the joint percentage of contaminated and possibly contaminated sites and which is estimated according to higher than unit mono-element indices: concentration coefficients (K_k), simple enrichment factors (EF_1) or complex enrichment factors (EF_3). The reason is that these indices depend on the background values (B) which differ less than T values. According to decreasing influence of the method of background calculation on the estimated contamination extent the mono-element indices can be arranged as follows: K_k, EF_3, EF_1.

Optional normalisation has much higher influence on the contamination extent than the method of background calculation. Normalisation usually increases the values of mono-element indices and enables to better reveal the areas presumably affected by pollution sources. The results partly depend on the choice of the reference elements. The arrangement of mono-element indices according to increase of the estimated contamination extent is as follows: K_k, EF_3, EF_1. The same arrangement is according to increase of the median values of mono-element indices and median values of multi-element additive contamination indices calculated by summing up respective mono-element indices.

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