Rezekne Higher Education Institution
Latvia

Environment. Technology. Resources

Proceedings of the 1-st International Conference

June 18 - 20
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Zinātnisko rakstu krājumā ietverti referāti, kuri tika nolasīti I Starptautiskajā konferencē "Vide. Tehnoloģija. Resursi" 1997.g. 18. - 20.jūnijā Rēzeknē angļu valodā.

Referātu tēmas saistītas ar līdzsvarotās attīstības poblēmām, vides aizsardzības jautājumiem, dabas resursu racionālu izmantošanu, vides zinātnes speciālistu sagatavošanu, jauno informācijas apstrādes programmēšanas līdzekļu izveidi un izmantošanu, neironu tīkliem un to izmantošanu.

Proceedings include papers presented at the I-st International conference "Environment. Technology. Resources." at 18-20 June, 1997 in Rezekne, Latvia.

The themes at the papers are: the problems of Sustainable development, Environmental protection issues, Natural resources and their exploiting and processing problems, environmental education, computer sciences, indeterminate and discharged data processing, neuron networks and their application.

Atbildīgais par izdevumu Gotfrīds Noviks (konferences orgkomitejas priekšsēdētājs).

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PRIEKŠVĀRDS

1997.g. 18. - 20.jūnijā Rēzeknē notika I Starptautiskā zinātniski praktiskā konference "Vide. Tehnoloģija. Resursi". Tās ietvaros strādāja divi semināri. Pirmajā seminārā attiecīgajās sekcijās tika nolasīti ap 30 referāti, kas saistīti ar vides aizsardzības teorētiskajiem, praktiskajiem, tehnoloģiskajiem jautājumiem, dabas resursu racionālu izmantošanu, vides izglītības un vides zinātnes speciālistu sagatavošanas problēmām.

Otrā semināra tēmas bija veltītas datorzinātņu problēmu pētīšanai: jaunu informācijas apstrādes programmēšanas līdzekļu izmantošana, t.sk. vides zinātnēs, ekspertsistēmu un mākslīgā intelekta teorija un prakse, neironu tīkli un to izmantošana un citi jautājumi.

Konferencē ar referātiem uzstājās Latvijas, Krievijas, Polijas, Igaunijas, Lietuvas, Baltkrievijas zinātnieki.

Konferences materiālu krājuma I sējumā izanalizēti līdzsvarotās koncepcijas realizācijas jautājumi (dokt. Raivo Vilu, Tiina Randla, Igaunija), kalnrūpniecības rezultātā degradēto teritoriju atjaunošanas problēmas (prof. Tadeušs Hržans, Henriks Greinerts, Polija), teritoriju un iežu masīvu stabilitātes kontroles metodes un rezultāti (Jüri - Rivaldo Pastarus, Igaunija), Igaunijas degslānekļu izmantošanas un pētīšanas problēmas (prof. H.Arikula, Igaunija), minerālresursu kompleksās izmantošanas teorētiskie pētījumi un praktiskie rezultāti (dokt. V.Isajevs, N.Orešņikova, Krievija), vides aizsardzības speciālistu sagatavošanas principi Rēzeknes Augstskolā (prof. G.Noviks, Latvija).

Datorzinātņu virzienu krājumā pārstāv A.Molotova, A.Borisova, K.Savčenko, R.Grekova, P.Grabusta referāti (Latvija).

Otrais konferences materiālu krājums ietvers referātus latviešu valodā un tiks publicēts 1999.gadā.

PREFACE

The Ist International Conference on Environment, Technology, Resources was held at 18 - 20 June, 1997 in Rezekne, Latvia. The conference was attended by 60 scientists from Latvia, Poland, Estonia, Lithuania, Russia, Belorussia, there were presented over 30 papers on different issues in Environmental Sciences, rational methods in Natural resources exploiting, environmental education, computer sciences.

The first volume of the Proceedings includes selected basic reports on the conference topics in English.

The papers discuss sustainable development problems (Raivo Vilu, Tiina Randla, Estonia), recultivation and reclamation of lands destroyed by mining (Tadeusz Chrzan, Henryk Greinert, Poland), stability analysing in roeks (Jüri-Rivaldo Pastarus, Estonia), Complex and rational methods in mineral processing (V.Issaev, N.Oreshnikova, Russia, Heino Aruküla, Estonia), Environmental education and training of specialists in environmental sciences (G.Novik, Latvia), modern computer science problems (A.Molotov, A.Borisov, C.Savchenko, R.Grekov, A.Borisov, P.Grabusts, Latvia).

The second volume of conference proceedings will include another group of papers in Latvian and will be published in 1999.

SUSTAINABLE DEVELOPMENT - PROBLEMS OF MEASUREMENT AND POSSIBILITIES OF REALISATION (CASE STUDY OF NORTH - EASTERN ESTONIA)

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In the middle of the century the exponentially growing mankind lived according to the popular slogan of the Mitchurin - do not ask, take from the Nature everything you need. However, environmental problems we currently encounter indicate that the carrying capacity of the Earth might be soon exhausted. Our environmental consciousness has developed from the "silent spring" through the "Limits of the Growth" to the present concept of the sustainable development. If in 70-ies the main problem seemed to be the limitation of the resources, then now reasonable management of the Earth, the development of harmonious existence of the manking in the Nature is in the focus. It means that much attention is paid to defining in quantitative terms what kind of management, resource use, style of life is sustainable. Long lists of quantitative parameters, indicators of sustainability have been proposed (1, 2). Generally speaking the use of indicators should make complicated systems understandable and predictable, to show to the society, where we are, where we are going and how to intergrate different subsystems of noosphere into a sustainable wholeness. The development of adequate set of indicators is feasible only if the noosphere is described using well-founded and syncretic system of models. One of the main goals in the nearest future would probably be formulation and analysis of the hierarchical set of models of the sustainably developing Earth, models where the "climate engine" of the planet and global economy are considered as one integrated system.

The indicators of sustainability are usually divided into four main classes - economic, environment, social sphere and government. The main difference between the indicators of sustainable development and traditional indicators of the state of environment, social welfare etc. is

the complex nature of the new indicators - they are "normalized" and "calibrated". New indicators are based as a rule on instrumental measurements or stastical analysis what makes them objective. We should not forget also that they must be very practical - indicators of no practical use have no practical value. They must help in our turning towards the trajectory of sustainable development. The indicators should be applicable globally but at the same time they should take into account the local (national) peculiarities. For example - the increasing birth rate is negative at the global scale but an attractive goal for Europe and especially Estonia. Some of the indicators are based on the use of the notion of "balanse" - exploitation of resources and the self - regenerative processes. Emission of pollutants should not exceed the adsorption capacity of environment etc. In some cases we act globally, for example we all use oxygen and produce CO_2 which are parts of one global reservoir - atmosphere. In these cases introduction of the notion "global environmental space" is well justified. At the same time fresh water is considerably more local resource (which, however, depends on the functioning of global "climate engine"), and the water use should be balanced locally (appropriate parameter "calibrated" on the local "space"). Problem of calibration is very complicated in some cases due to the need to take into account also "social justification". For example, in what extent the greater use of energy in the cold climate of North-Europe in comparison with Africa, living in the conditions of eternal summer, is "socially" (rationally?) justifiable.

Principles of the sustainable development of Estonia are legitimised by the "Law of sustainable development" (adopted by the Parliament February 22nd, 1995). However, the law is too declarative and needs to be amended in the near future. It is quite difficult to make practical amendments without taking into account logins of indicators of sustainability.

A very interesting separate problem is associated with making industry (industrial areas) more sustainable. These problems have been considered recently in the framework of industrial ecology. A reasonable solution here is the creation of so called eco-industrial parks, where the members of the consortia are effectively using wastes generated by the others which enables to increase the economic efficiency of the complex and to decrease the total production of wastes (3).

However, development of such symbiotic structures is currently not automatically profitable and leads frequently to economic losses. Our

economic system with the set of taxes and prices is not taking into account the principles of sustainability. Another problem which should be pointed out is that engineers are not yet accustomed to think in categories of industrial ecology. The symbiotic relationship can be developed only in the eco-industrial parks, associations of closely connected enterprises-taking these considerations into account would mean adoption of new principles of regional planning. It is not easy.

As is well-known, various large enterprises are concentrated in Northeast of Estonia-oil shale mines, power stations, chemical enterprises etc. Production of these enterprises is extremely important from the point of view oe the economic welfare of the republic - 100% of electrical power used in Estonia is produced in power plants of the region. Unfortunately the powerful industrial complex is also a huge polluter. In 1995, for example, 74 thousand tons of SO_2, 12 thousand tons of CO_2 and 68,3 thousand tons of solid wastes were generated by the power plants (4). There are specialists who think that the sustainable management and development of the Estonian oil shale industry is impossible and the only reasonable decision would be the planned (controlled) liquidation of this industry. At the same time, as far as we know, nobody had studied the opportunities for the development of symbiotic consortia of the enterprises in the region, where the maximum economic benefit would be obtained with the minimal amount of wastes. Just the opposite could be said. As an example it should be reminded that the use of the ashes produced by the combustion of oil shale in thermal power plants in agriculture and production of building materials was stopped in 1993 in the result of the collapse of the former economic system. In 1990 the amount of ashes used for these purposes was about 2,5 million tons. (5).

The aim of the present study is the analysis of the "meaning" and applicability of different indicators of sustainability and problems associated with their "calibration". An attempt to develop system of indicators and to explore the possibilities for the decrease of the iosses of resources and pollution in the result of the integration of enterprises of north-eastern Estonia (already existing and new ones) into a symbiotic eco-industrial park to attain the sustainable development of Estonia will be made.

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INNOVATION IN ENVIRONMENTAL ENGINEERING EDUCATION AT REZEKNE HIGHER EDUCATION INSTITUTION

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ABSTRACT

The paper discusses the elaboration of new study program and curricula in Environmental Engineering at the Rezekne University (RU).

The main goal of the Program is to prepare new formation of Environmental specialists - Ecotehnologists, who are able not only to control pollution of Enviroment, but to prevent it on the early stages by applying in industry ecologically safe technologies.

INTRODUCTION

The integration of Latvia's educational system into European and International systems touches upon a whole string of problems, whose effective resolution could recognizably intensity the process.

At the same time Latvia and its Eastern region - Latgale especially has national and local pecualirities. The Rezekne University has worked out a concept, which could best satisfy regional conditions and on the other side correspond to the standards of higher education accepted in other countries.

The analysis revealed that presently exist various and totally different approaches to the functioning of higher education not only between countries, but also within the borders of one country. Right now

it is difficult to determine higher education criteria that are constant and acceptable to all countries.

The question is often discussed: what is the importance of the bachelor's degree and what is a professional person with higher education? Is a baccalaureate less educated than, let's say, an engineer? In general, where is the need for one kind of person where for the other, where are their jobs, will their be a demand for their skills in the economic branches? Answers to these questions are determined by the amount and depth of acquired knowledge in all training systems.

Considering this situation and based on materials about the work of higher educational institutions in the Republic of Latvia, RU tried to formulate the basic theses of its concept.

THE PRINCIPLES OF RU CONCEPT

The following presumptions were made. First of all, higher education is a complex system of knowledge in a particular field of science containing such a level of development and range that provides the possibility for the acquirers of this knowledge to directly incorporate it into the highest level activities of the field.

Secondly, the bachelor and graduate of the professional school are completely equal specialists with higher education. The only difference is that of theoretical or practical orientation. The bachelor is a person, who has gained higher education in a particular field with emphasis on its theoretical base, mastered scientific research methods, learned fundamental sciences in in-depth courses, and can perform scientific research and theoretical work in his field. The academic degree of the baccalaureate is certified by the bachelor's diploma, which is issued after the successful acquisition of the bachelor's study program, passing of the baccalaureate exam and defense of the dissertation. The baccalaureate's possible work places: scientific research institutions, company laboratories and analytical canters, experimental and theoretical research, and teaching institutions.

A specialist - professional with higher qualification is a person who has gained higher education in a particular field with emphasis on its practical work, deeply understands the organization and methodology, modern machinery and technology of work in this field, and is able to satisfy the demands of this field's development and improvement. The qualification of the specialist-professional is certified by the higher

education specialist diploma, which is issued after the successful completion of the professional study program and defense of a qualification dissertation. The possible work places of a specialist-professional: companies, the production and service sphere, institutions, firms, banks, school, secondary educational institutions.

This definition for us fully renders concrete the essentials and differences of the baccalaureate and the professional and specifies the range of knowledge and work places of each specialist. Of course there could be other views on this subject, but if we keep to this definition, then it is clear that the learning process has to be organized in a particular way. First of all, it is clear that professional training is not the subsequent stages after the acquisition of the bachelor's degree. The training has to take place parallely. The ideal situation would be that each orientation would have totally its own study program beginning with the first year. In our conditions, this is, on one hand, practically difficult to carry out, and on the other hand, not so attractive to the students, because it narrows the choices.

That is why the RU concept states that the acquisition of higher education takes place in parallel fashion with both theoretical (baccalaureate) and practical (specialist - professional) orientations. The study plan for each particular field is unified, but all courses are divided into three groups:

F: fundamental, general education courses, which have to be taken by both baccalaureate and professional candidates;

B: academic educational courses, which are obligatory for all B.A. candidates;

P: professional educational courses, which are obligatory for all candidates seeking specialist qualification.

Any student during the first semester can decide upon his desires and abilities and choose either B or P or take courses in both groups at the same time. In the first instance, the student in the last semester of studies takes the baccalaureate exam and defends his dissertation.

In the second instance, the student completes at least an 8-week internship during the study program and prepares and defends his specialist dissertation.

THE DEVELOPMENT OF ENVIRONMENTAL ENGINEERING

In Latvia as in the whole world the industrial pressure on the nature is increasing continuosly from year to year. And there is relatively little effect from all efforts applied by Environmental professionals and scientists in protection nature from pollution and destruction.

Such situation is due to division specialists activity in numerous considerable isolated parts with no very tight bonds between them such as environmental control and monitoring, treatment, renovation, etc. At the same time it is very important to unite all efforts in solving key problem - to work out scientifically based principles and methods of innovative and alternative technologies, which do not destroy ecosystems and are ecologically balanced (we name it "ecotechnologies").

It is the motive why on the basis of considered concept the Rezekne University started to prepare specialists in Environmental Sciences and Technology (Bachelor's and Master's degree and Engineers). We have created a new original study program and curricula for students. The program consists of 3 main blocks of subjects: Fundamental Sciences and Humanitaes (F), General Environmental and Engineering Sciences (F), Special Environmental Sciences (B) the teaching of Modern Technology (P).

The main goal of the program is to prepare specialists, who are able to control pollution of Environment as well as to work out, apply in industry and agriculture and exploit new ecologically safe technologies.

In the curricula "F" courses include at first Mathematics, Physics, Chemistry, Computer Sciences, Economics, Foreign Languages and at second - Ecology, Nature Resurces, The Chemistry of Environment, Anthropogenetic Processes, Ecotoxicology, the Quality of Environment and some others - total 60 credit points.

"B" courses include Demecology, Synecology, Experimental Ecology, Biogeochemistry, Radiobiology, Limnology and other special courses - total 40 credit points.

"P" courses include Ecology, Sozotechnics, Environment protection technology, Systems of Ecological Monitoring etc. (40 c.p.)

During the last three semesters students are able to choose special profilization courses in one of the next branches: the Industry of Foods, Forest Industry, Civil Engineering, Mining Engineering, the Industry of Tourism. (60 c.p.)

The students are able to choose next schemes of studies: a) 3 year Bachelor's programm + 1 year professional studies; b) 4 year intensive

paralelly Bachelor's and Engineer's studies; c) 3 year Bachelor's programm and 2 year Master's degree programm.

Presented programm guarantee that our Bachelors and Engineers will be educated in the next fields of Environmental Science and Technology.

- The general principles of the ecologically balanced technologies (ecotechnologies).
- The environment control systems in industrial and agricultural plants.
- Pollution prevents systems in plants.
- Remediation and treatment of water, soil and air.
- Utilization of refuse and recycling of materials in industry.
- Environmental quality parametres and their determination.
- The problem of ecologically pure products.

At the same time they will complete full course of special technology and will be able to work as Engineers and Technologists in the concrete area of industry.

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RECULTIVATION OF THE DUMPING AREAS AND WATER MANAGEMENT ON THE EXAMPLE OF BROWN COAL OPEN-PIT "KONIN"

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In the paper is presented the characteristics of the brown coal open-pits Konin's, and characteristics of the outerdumps and terminal dumps in these open-pits with methods of their development.

The two methods of recultivation, using in the open-pits areas are described.

The quantities of pumped out from open-pits water, and a ways of ground waters level monitoring are shown. Also are described the ways of pit-water treatment and counteraction to the effects of the grounds drainage by pits.

1. INTRODUCTION

Poland is a country with reach brown coal deposits. 14 billion Mg of resources are in the documentary evidence, and 70 billion Mg of resources are estimated in perspective. For today and in the future the main use of the brown coal is burning it for the electric energy generating. The brown coal can be used also in agriculture, for the devastated and polluted soils recultivation, and to the water and waste treatment.

The excavations after brown coal exploitation are making the water basins for recreation, fish breeding and ashes and wastes disposals.

The brown coal deposits, which are located in the Konin locality, were known as early as 20 th years of our century. Only in 1945 was started the exploitation of Morzysław open-pit, for the new builded briquetting plant.

After the ending of this deposit exploitation, in the year of 1953 was started the exploitation of Niesłusz open-pit.

Basing oneself on the brown coal resources in the documentary evidence, was builded in the year of 1958 the power station in Gosławice with 583 MW plant rating, and in the year of 1969 was commited to exploitation the power station Pątnów with 1200 MW plant rating.

The builded power stations, based on the brown coal burning, caused increase of coal demand and starting of the new open-pits exploitation: Gosławice - 1958, Pątnów - 1962, Kazimierz Płd. - 1965, Juzwin - 1971, Lubstów - 1982.

2. CHARACTERISTICS OF THE WORKING OPEN-PITS OF KONIN MINE PLANT

For today are still working four open - pits: Pątnów, Kazimierz Płd., Juzwin, Lubstów. Coal year-output is on the level about 13 mln t, and a quantity of removed cover materials is about 74 mln m^3. The average coal calorific value is 9400 kJ/kg, average sulfur content in the coal is 0,8%.

During 50 - year's exploitation was extracted out 374.536 mln t of coal and was removed to the new places 1.855.417 mln m^3 of cover materials. The quantities of removed ground masses and start-point of terminal excavations recultivation is shown in the table 1.

The exploitation of brown coal with the open-pit method caused the new areas occupied with outer-dumps and excavations. From the beginning of mining activity to the end of the year 1994 was occupied for the mine plants needs the area 9194 ha. To the 1994 was given to the local administration 4164 ha of recultivated and developed areas.

Table 1

Open-pits characteristics (2)

	Meas. units	Pątnów	Kazimierz Płd.	Juzwin	Lubstów
Start of exploitation	year	1962	1965	1971	1982
End of exploitation Start of terminal excavations recultivation	year	2000	1997	1999	2007
Coal resources	mln t	17,7	4,2	18,3	64,6
Depth of cover (average)	m	50,5	47,5	47,9	46,1
Depth of coal deposit (average)	m	8,8	6,6	9,0	28,8
Year - output	mln t	3,2	1,7	2,9	5,6
Removed cover materials masses value (yearly)	mln m^3	17,0	8,2	24,0	6,0

3. OUTER-DUMPS AND TERMINAL EXCAVATIONS

As a result of hitherto existing mining activity, are formed many outer-dumps and terminal excavations. The dumping areas are successive recultivated and prepared for the developing. The outer-dumps slopes are developing in the forestry-direction and top-area of dumps first of all in the agricultural direction. The previous outer-dumps are developed, as shows the table 2.

Table 2

Outer-dumps characteristics (2)

O. n.	Dump's name	Height [m]	Plane [ha]	Development direction
1	Morzysław	8 - 20	25	individual houses building
2	Niesłusz Niesłusz	12 20	60 43	allotments forestry
3	Gosławice	40	70	forestry
4	Juzwin	70	340	forestry
5	Kazimierz	45	203	agricultural
6	Lubstów	40	193+215	forestry + agricultural

Dumping of the cover material, which is founded above the brown coal level is performed this way, that to the top of the dump are located heavy and dense clays - the most useful for the process of biological recultivation.

The recultivation works include:

1. The forming of the lateral slopes and top areas of outer- and inter-dumps.
2. The leveling of the adjacent areas.
3. The forming of the water basins slopes.
4. The biological covering of the dumps and terminal excavations slopes.
5. The making of the access roads.
6. The agrotechnical treatments.
7. The geodesic measurements and soil classification.

During the 50 years of brown coal exploitation were formed the after-exploitation terminal excavations in the open-pits, which were developed as follows (tab. 3.).

Table 3

Terminal excavations development (2)

O.n.	Open-pit's name	Plane (ha)	Excavation's development
1.	Morzysław	2,5	water basin for allotments
	Morzusław	4,0	communal wastes dump
2.	Niesłusz	18,5	water basin, fish breeding basin
3.	Gosławice	32,0	ashes dump for power station
	Gosławice	32,5	water basin in the briquetting plant's closed cycle
4.	Pątnów	57,7	mine-waters decanter
	Pątnów	332,0	ashes dump for power station
5.	Kazimierz	65,0	recreation water-basin
		35,0	fish breeding basin

As a result of Prof. Bender's long-term experiments on the dumping areas in Konin locality, the new model of after-mining areas recultivation was created. It is consist in biochemical transformations, which are occurred in top layer of dump's ground. To achieve this effect the following conditions must to be fulfilled:

1. Correctly forming of the slopes and top area of the dump in the limits of mining works, building of a new hydrogeological net and the access roads.

2. Renovation of the chemizm in the top layer of the ground through mineral fertilization in correct rates and compounds relations, which are depended on recultivated ground's properties and applied plants requirements.
3. Renovation of physical properties of the after-mining ground through mechanical cultivation which has stimulated the ground weathering processes and ground's homogenization.
4. After the making all of the mentioned above points, the including of plants to soil-forming process and the increase of the ground fertility is possible.

On the part dumping area, where the chemizm renovation was not done, the yields of rape even after 10 years are almost zero, and the yields of corns not exceed 0,3 Mg/ha.

On the dumps, where this renovation was done, the yields are higher than average yields obtained in the Konin locality.

The yields of the plants growing on the dumps fertilized with mineral fertilizers are setting together in the table 4.

Table 4

Yields of the plants under mineral fertilization (1)

Plant species	Fertilization's combination	Year				Average
		1980	1985	1991	1993	
Winter rape	0 NPK	0,0	0,0	0,0	0,0	0,0
	1 NPK	2,4	1,8	2,0	0,9	1,3
	2 NPK	2,9	2,3	2,1	1,2	1,8
Bread wheat	0 NPK	0,0	0,2	0,6	0,0	0,3
	1 NPK	1,9	2,4	3,2	2,1	2,7
	2 NPK	2,3	3,0	3,0	2,5	3,0

With the yields quantity is connected the amount of organic matter putting in the ground as a crop residues, straw and roots. It is an energetic and building material for soil's microorganisms.

After 20 years, the soil created from after-mining ground secured stable production on the 2,0 Mg/ha yield's level (without fertilization) and on the 4,0 Mg/ha yield's level (with fertilization).

For the agricultural direction of recultivation 3 models are worked out: a) rape-corn - consist in the alternating growing of rape and wheat;

b) feed - consist in the alternating 5-year's growing of lucerne and 2-year's growing of wheat;
c) feed - only lucerne growing.

The recultivated area amounted 4164 ha. On the 300 ha area of agricultural recultivation was made the soil classification. It was noticed, that after 15 years of growing the soil has higher class, than before mine building.

In the Bełchatów mine, cause the higher dumps and bigger areas, was made the sawing of grass and liquid fertilization using agricultural aviation. But these operations are many times more expensive, than traditional and costs from 600 to 650 USD/ha. It is not the best dissolution also because the grass influences not good on the later growing trees; the grass has taking away the water with nutrients.

The dumps slopes are planted with forest-creating plant species, as maple, great maple, ash, oak, larch, beech.

The slopes are fertilized every 4 years, with mineral fertilizer in amount 1 t/ha.

4. TERRAIN DRAINAGE AND COUNTERACTION TO IT'S EFFECTS

The brown coal exploitation is connected with drainage of the deposit and adjacent terrain, because of pumping out the big amount of water. As a result of open-pits Pątnów, Kazimierz and Juzwin drainage was created the depression funnel in the underground waters level (which were located in the Tertiary grounds) with an area about 260 km^2. The depression funnels in Quaternary grounds comprise the areas located in the near of excavations - to the several hundred meters from it's edge.

On the all area located around the open-pits Kazimierz, Pątnów and Juzwin were making 194 of sight-holes for the underground water level observing. Similar in the Lubstôw open-pit, the ground water level is monitored using 135 sight-holes.

In the depression funnel's range are making quarterly measurements of ground water level in 1039 local farm-wells.

Because the ground drainage in many villages lacked the water in the wells. To secure the water supply for these people, the mine has

builded about 700 km of water supply system, 31 hydrophore stations and deep bored wells.

The deposit drainage is making with two methods. First - using deep bored wells, which caused the underground water level decrease under the coal deposit's deepness. These waters are pure and their physic-chemical composition is near to drink-water. These waters are using for the mine - workers supply and their overflow is draining to the nearby lakes.

In the year of 1994 were pumped out the underground waters in quantities (2):

Pątnów open-pit	55,49 m^3/min.
Kazimierz open-pit	52,98 m^3/min.
Juzwin open-pit	51,83 m^3/min.
Lubstów open-pit	22,47 m^3/min.

All of the open-pits have pumped out, using deep bored wells in the year of 1994, water in the amount 95.804.000 m^3.

The second method of drainage comprise the surface waters intakes from mine area and effluents of the underground waters to the excavation. These waters are mechanical polluted with coal suspension and clay particles. For the decreasing of suspension amount to the normative quantities these waters are purificated using settling ponds. For the Pątnów, Kazimierz and Juzwin open-pits were used as many-chamber settlings the inter-dumps, located in the part of mine-excavation, where coal was yet taking away. In the Lubstôw open-pit polluted waters are purificated in 6-chamber settling with 19.700 m^3 value. Each of the chambers have an additional plant filter. After the purification these waters are draining to the Warta river. In the year of 1994 were draining 64.681.000 m^3 of waters drainaged with the second method.

5. SUGGESTIONS

1. Konin mine-plant as a first in Poland has used the recultivation model based on biochemical transformation processes in dumping ground, on which were achieved higher yields, than adjacent soil.
2. The outer-dumps slopes were recultivated in forestry direction and flat areas in agricultural direction.

3. The excavations of terminal pits were used as the communal wastes dumps, power station's ashes dumps, and water basins for recreation and fish breeding.
4. On the inter-dumps were located the settlings for the mechanical polluted water purification.
5. The water from the deep bored wells, which draining the open-pits can be useful for man water supply.

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CONCEPTIONS OF LAND RECLAMATION IN THE POLISH OPENCAST MINING

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In the paper the influence of surface mining on the environment is presented. The sizes of mining areas and depression funnels has been shown. Also are presented the amount of cover materials and the quantity of water pumped out from the mines in five regions of brown coal mining in Poland.

Various conceptions of land reclamation are discussed, from the method of pioneer vegetation in the years of 1950 - 1970, trough selective excavation of the humus soil in the years 1970 - 1980, to conception of the direct introduction of the final type of vegetation.

In the lost part of the paper three models of agricultural land remediation are discussed, as well as the yields of the cultivated plants on recultivated former mining areas.

1. INTRODUCTION

In the years 1950 - 1960 the mineral rock materials open-pits mines were small and because that their interference in the each elements of the natural environment was not so big (consider to their character and scale of changes). The biggest one from these changes referred to the water relations disturbance and landscape changes, caused by digged out excavations and wastes and cover materials coning. In many cases, in spite of the less of conscious activity, fast following natural succession has cover mine-exploitation's damages. Only the building of the big brown-coal open-pits in the years 1960 - 1980, with the deepness to

60 m, which required a cover materials removal in amounts to 20 mln m^3 per year and storing these materials caused, that the influence of the brown coal mining on the environment was very big and some effects of this influence have a long-term character. Sweeping changes are observed in terrain morphology and landscape, natural conditions and terrain's utilization. The most visible for the outside observer are the changes connected with deposit work-out - the big empty excavation and cover material dump.

The additional negative factor for the agricultural - forestal cultivation also causing less of water in the intakes and wells is the rock mass drainage (of the grounds and rocks under and upper the coal bed).

The areas under open-casts are using for the making of excavation, dump areas and mine's back-up facilities. The using of the terrain is time-limited and against payment. It is including the time needed for cover material remove, coal output, after-exploitation areas recultivation and delivery of the area to the commune (territorial division) or selling for the individual farmers. The recultivation is leaded in agricultural- , forestal- or water-development direction.

The duty of the mine during recultivation works is restoration of hydrographical and communication systems. Because of this, that all of the mine-grounds are bought, is taken as a rule that the amount of bought terrain hectares shall be equal with hectares amount of the terrains delivered to the communes or sold after recultivation.

In the table 1 are collected the areas occupied by brown coal mines (in hectares). From the table it appears, that almost half of the occupied terrains by mines is already recultivated and delivered to the other users.

To make it possible to realize the mine working, the ground water level is drawed down by the drainage wells, what caused the creation of depression funnel around the mine. The depression funnel's size is depended from filtration coefficient of the aquifers. At present the depression funnel's size [2] expressed in ha amounts for the mines:

Adamów	20,0 tys. ha
Bełchatów	63,0 tys. ha
Konin	35,2 tys. ha
Turów	2,5 tys. ha

Table 1

Territorial balance of the areas occupied by brown coal mines (2) on the 01.01.1995.

Mine	Area (ha)			
	occupied from the beginning of mine existence	recultivated and delivered to the other users	under exploitation	after exploitation - and recultivation-ending
Adamów	4260	2117	1214	280
Bełchatów	6339	2085	2684	230
Konin	8257	4015	2664	832
Turów	4753	850	3803	34
TOTAL	23609	9067	10365	1376

On the area like this is following the vanishing of the water in the shallow farmers wells in the villages. The mines have builded at theirs own charge about 2050 km of water-pipe network [4] and 65 water intakes.

On the area depression funnel is also noticed decrease of the grasses and corns yields, but it is referred to the 10% of funnel's area.

2. CHARACTERISTICS OF THE POLISH BROWN-COAL OPEN-PITS

The open-pit brown coal exploitation is localized in Poland in four regions, and is leaded through following national firms:

1) Konin mine with 4 open-casts, winding efficiency about 14 mln Mg/year, fuel supply for Konin power station with 583 MW plant rating and Pątnowo power station with 1200 MW plant rating. Characteristics of the Konin-mine open-costs are shown in table 2.

From the table appears the necessary of the developing as soon as possible not only cover materials dumping areas, but also terminal excavations of brown-coal open-costs.

Table 2

Open - casts characteristics [3]

	Unit	Pątnów	Kazimierz	Jóźwin	Lubstów
Building's beginning	year	1957	1962	1965	1979
Delivering to the exploitation	year	1962	1965	1971	1982
Exploitation's ending	year	2000	1997	1999	2007
Developed reserves	mln Mg	17,7	4,2	18,3	64,6
Overlay thickness	mln Mg	50,5	47,5	47,9	46,1
Coal bed thickness	mln Mg	8,8	6,6	9,0	28,8
Sulphur content	%	0,9	1,2	0,7	0,4
Coal uptake	mln Mg	3,2	1,7	2,9	5,6
Stripings remove	mln m^3	17,0	8,2	24,0	6,0
Excavation's deepness	m	59,3	54,1	56,9	74,9

In the table are shown the average values.

2) Adamów-mine with 3 open-casts: Władysławów, Adamów and Koźmin, winding efficiency about 5 mln Mg/year. Fuel supply for Adamów power station with 600 MW plant rating. Developed reserves are about 120 mln Mg.

3) Turów-mine with 1 open-cast, winding efficiency about 15 mln Mg/year. Fuel supply for Turow power station with 2000 MW plant rating. Developed reserves are about 568 mln Mg.

4) Bełchatów mine with open-cast, winding efficiency 38,5 mln Mg/year. Fuel supply for Bełchatów power station with 4320 MW plant rating. Developed reserves are about 568 mln Mg.

The mines mentioned above in 1994 have been taking up the coal and removing the cover material in amount, which are shown in the table 3.

From the table appears, that enormous amounts of the stripping needs dumping process and next recultivation in agricultural or forestry direction.

Table 3

The productivity indices of the mines 1, 2, 3, 4

Specification	Unit	1	2	3	4	Total
Coal uptake	tys. Mg	13380	4772	14852	33650	66654
Strippings remove	tys. m^3	74170	34212	45497	99740	253619
Water pumping	tys. m^3	96525	76851	22539	192822	388737
El. energy consumtion	MWh	344717	162466	490495	757605	1755243

3. RECULTIVATION CONCEPTIONS FORMATION IN POLAND (1)

In 1953 the Polish Academy of Science (PAN) has brought into being the Scientifical Committee for Upper-Silesia Industrial Region (GOP), which have been engaged in natural environment degradation's scale recognition and in degradation process inhibit-methods elaborating.

In 1961, in connection with rising up the importance of ecological problems, instead of Committee was created the Department of Scientifical Researches of Upper-Silesia Industrial Region of Polish Academy of Science in Zabrze-city, which next in 1970 has changed the name in the Department of Industrial of Industrial Areas Environment Restoration of Polish Ac. of Sc. During this period the recultivation's problems were for the first time serious elaborated, specially natural environment formation in regions with mining industry, which produced the big amounts of wastes and translocated the enormous amounts of ground masses.

In 1970 was created in the Konin-mine the Research Station of Polish Ac. of Sc., which finally was converted in the Department of Recultivation of Agricultural Academy in Poznań.

Their task was the elaboration and practical application of biological methods of recultivation of the after-mining areas at a lowest charge.

3. 1. CONCEPTION OF THE TECHNICAL RE-CREATION OF THE SOILS (1)

The author of this conception was Prof. Świętochowski from Wrocław. He says, that only one and effective solution, which makes possible to restoration of after-mines areas with dumped rocks from cover layers, is selective dumping of the soil's humus horizon and after exploitation covering with this material the barren rocks on the dumps. The costs connected with this recultivation technology amounts in this period about 1000 q of rye per hectare. The author excluded the possibility of returning dumping, barren grounds for the agricultural utilization.

Prof. Świętochowski says, that afforestation of the incoherently formed areas after deposit's exploitation with open-pit method will be enough big attainment.

This conception was right for the recultivation of the wastes and dumping areas of the firmrocks open-pits, where soil is not presented, but only rock fractions with different mechanical composition. It would not refer to the brown coal open-pits, where we can cover the dumped cover material with clays.

However selective dumping of the humus horizon of the soil for the fertilizing of the barren grounds excavating during exploitation of the all arts deposits and big industrial building is included to the polish law regulations and is in force in Poland till now.

3. 2. CONCEPTION OF THE PIONEER PLANTS (1)

The author of this conception was Prof. Skawina from Kraków. He says, that quality of humus horizons, which are located upper the brown-coal deposits, in compare with chernozems is very low, so collected of these humic grounds for the dumps fertilizing is groundless and very expensive.

He admits as more rational the covering of dumping areas with covering rocks layer more suitable for the future soil formation. In described time period the selective getting of this layer costs 1600 - 2300 q of the corn per ha, what has limiting use of this method.

For the decrease of costs, author has elaborated the conception of pioneer plants for two directions of after-mining areas use - agricultural

and forestal. As the main purpose of the biological transformation, he appreciates rock-ground transformation into soil with lowest valuation class. This transformation of after-mining grounds properties in the soil direction is following as a result of pioneer plants growing, mainly Melilot, or afforestation with False Acacia, Black Alder and Gray Alder.

The transformation process takes 4 to 7 years for the agricultural recultivation direction and 10 to 15 years for the forestal recultivation direction. After this period the aplantation reconstruction is needed, which consist in the replacement of pioneer plants with economically useful plants.

He admits, that this recultivation method is cheapest and minimal arduous for the mines. It has an effect in National Commission of Surface Protection against Mine-Damages decision, that main recultivation direction in Poland should be the forestal one.

The dumps afforestation is making in Bełchatów- and Tarnów-mines on the outer-dumps.

3. 3. CONCEPTION OF FINAL APLANTATION (1)

The professor's Skawina conception has leaded the recultivation process to the one engineer-agrotechnical treatment. But, as Prof. Bender admits the main-point of the recultivation process lies not in the treatment, but in biogenic processes. According to the Bender thesises, recultivation is a "organized joint action of abiotic and biotic factors, which making possible in a short time and at the lowest charge, creation from rock-ground the productive soil".

The biochemical transformations, which are occurred in the dumped rock, are under the anthropogenical influence. The Prof. Bender's conception lies on the following rules, using:

1 - correctly making mining works connected with slopes and top-areas of the dumps forming and the dumps themselves, and hydrogeological net of after-mining area forming;

2 - creation of the right conditions for the plants growing or afforestation, through rock-ground chemizm renovation with mineral fertilizers using;

3 - renovation of the after-mining grounds physical conditions, as a result of mechanical cultivation, which has stimulated the rock weathering processes;

4 - including of the flora to the soil-creation process and soil productivity formation.

4. RESULTS OF THE FINAL APLANTATION CONCEPTION USING (1)

On the experimental fields, where the soil's chemizm renovation was not done, the corn yields are not exceed 0,3 Mg/ha.

On the fields, after mineral fertilization the rape yields, a early as in the first year amounts (in average) 2,5 Mg/ha and the wheat yields 3,0 Mg/ha. These yields are higher, than average yields obtained on the other soils near the mine.

For the agricultural development of the dumps top-areas 3 recultivation models are worked out:

a) rape-corn - consist in the alternating growing of rape and wheat,

b) feed - consist in the 5-years growing of lucerne with grasses, and next 2-years growing of wheat,

c) lucerne - many-years lucerne growing.

On the dumps slopes after making all works, as for the agricultural development, are planted maple, great maple, ash, oak, larch, beech.

The ground chemizm renovation is leaded first 4 years from the aplantation beginning, and plants density is increased to the 5000 trees per hectare and 2500 shrubs per hectare. This amount of the trees and bushes secured effective protection of the slopes surface against water erosion and good wood-production.

SUGGESTIONS

1. The technical soils restoration conception and the pioneer plants conception are right, when recultivation of the dumps and excavations of the rock row-materials open-pits is leaded.
2. The final aplantation conception is a good method of cover material dumps and terminal excavations in the brown coal open-pits, where the top layer of the soil can be created from the clay material.

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EXTRACTION OF CRISTOBALITE FROM MILKY–WHITE FORMS OF QUARTZ STUFF[1]

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1. INTRODUCTION

Natural quartz is one of the main sources of getting a unique material - quartz glass. Wide application of quartz glass in chemical and electronic industry, aviation and cosmonautics, fibre optics and computer techniques makes it absolutely indispensable. However, industrial reserves of rock-chrystal lodes, that is the most pure source of quartz stuff with minimal mineral admixturer, are practically exhausted everywhere. All this results in usage of low quality stuff and, thus, to significant complication of technological schemes of quartz processing and concentration, to high energy waste, high waste of inorganic acids, significant increase of industrial waste. Quartz concentrate output according to traditional technologies of lode quartz processing on Urals deposits is not more then 35%. In this turn the part of defectless transparent quartz glass when smelting from granular quartz is not more then 30%. It is evident that low efficiency of quartz industry call to new scale technological decisions.

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2. MAIN MODERN TECHNOLOGICAL TRENDS IN PRODUCTION OF PURE SILICA

Pure silica is mainly used in production of transparent and multicomponent quartz glass, the most deficient in volumes and quality of the used quartz. Nowadays, the main technological trends in this field come to processing of various natural types of quartz (rock crystal, crystalline, glassy, granulated and milky-white) and to synthesis of silica tetrachloride ($SiCl_4$).

Modern technological schemes of natural lode quartz processing are based on a complex of concentration processes: hand and automatic sorting, crushing, chemical processing in inorganic acids, pounding, flotation, electroseparation, magnetic separation. There are two traditional trends: the first one is making of industrial production on concentrating mills with their further retreating on glass plants; the second one is making of quartz concentrates on ore mining and processing enterprises suitable for smelting of quartz glass.

Now the resources of piezoquartz (rock crystal formations) in Russia are practically exhausted, there is also significant shortage of tykoquartz (quartz with concentration of SiO_2 not less then 99,98 %) suitable for smelting of transparent quartz glass. Thus, other types of quartz stuff are being processed: glassy, granulated, milky-white. However, traditional technological processes of preparation and processing these types of quartz do not provide the final product of high degree of purity, so that the sum of impurities would not be more then 10^{-4}%. So, in our practice making of transparent quartz glass out of natural quartz for the needs of cosmonautics, aviation, laser, nuclear, satellite technique, electronic and chemical industry, fibre optics remains rather problematic.

Basically different source for making of quartz glass is silica volatile components - mainly $SiCl_4$. Chemical technologies of making quartz glass are based on high temperature vapourphase synthesis from silica tetrachloride ($SiCl_4$) in hydrogenic-oxygenic flame by reaction:

$$SiCl_4 + H_2O \rightarrow SiO_2 + 4HCl \qquad (1)$$

or by oxidizing of silica tetrachloride in oxygenic low temperature plasma by reaction:

$$SiCl_4 + O_2 \rightarrow SiO_2 + Cl_2 \qquad (2)$$

Ecological problems bound with such production are due to harmful effects of the large emitted volumes of chloride combinations HCl and Cl_2 and the necessity to trap them. In particular, 5 - 6 kg HCl (!) are being emitted for each kilogram of the smelt glass, the losses of silica tetrachloride being 50% (!) (V. P. Pryanyshnikov, 1971).

But for the enumerated drawbacks presenting certain ecological threat, tetrachloride technologies are not perfect as far as the quality of the end product is concerned. The smelt glass has significant amount of hydroxyl groups (OH) which provoke an intense range of absorption 2720 nm, and the reduced heat-resistance. Glass obtained by means of hydroxyl-free technology has considerable amount of Cl (up to 0,05 %), common demands to the sum of impurities being $\leq 1{,}10^4$ % (V. K. Leko, O. V. Mazurin, 1985).

So, chemical methods of making artifical silica could not be accounted as satisfactory and optimal for the development of quartz production. They aggravate ecological problems and only to a certain extent solve the problem of providing the quartz stuff for glass industry. In essence, there was "frozen" large production resources bound with extraction and processing of quartz (in particular, deposits and concentrating mills of the Urals), and aggravated the problems of employment.

3. TECHNOLOGICAL PRINCIPLES OF DEEP PURIFICATION OF MILK-WHITE QUARTZ OFF GAS-LIQUID IMPURITIES

Among various types of crystalline quartz stuff the most promising for the high-quality transparent quartz glass are milk-white modifications of quartz (for example, from deposits "Dodo", "Mountain Krustalnaya", "Novotroitskoye" - Russia, "Aktas" - Kazakhstan). The content of mineral admixtures in some of milk-white quartz varieties is not less than in rock-glass (Table 1) (V.I.Yakshin, 1976).

Table 1

Main physical parameters of various types of quartz

No	Type of quartz	Light transmitting T, %	Calcination losses, %	The amount of gas-liquid impurities (cm^3 for each 1000 grains of quartz)	Water parameter H_2O, CO_2	The amount of mineral impurities (n-sing for each 1000 grains of quartz)	The elementary cell volume (A^3)	The rate of solution in HF (%/hour)	Absorption in IRS (q)
1.	Rock crystal	60 - 95	0,001 - 0,02	1 - 10	1 - 4	0 - 10	112,913	0,08	0,13
2.	Milky-white	10 - 30	0,03 - 0,05	35 - 60	4 - 10	0 - 5	112,950	1,5	no information
3.	Glassy	20 - 60	0,02 - 0,04	10 - 30	2 - 5	2 - 25	112,949	0,68	0,36
4.	Granulated	50 - 90	0,02 - 0,05	4 - 10	1 - 2	3 - 20	112,923	0,16	0,15

It might be well pointed that milk-white quartz supplies in Russia (the Urals), Kazakhstan (Aktas), Brasilia (Mimoso, Shiki-Shiki, Cety-Lagoas, Cristallina), Madagascar (Manakara, Itermo), Angola (Pokarisa) are practically unlimited and add up to billion tons. The only technological limit to wide milk-white quartz deposits exploitation is high content of gas-liquid impurities in them (GLI), the disposal of which by traditional means is not effective.

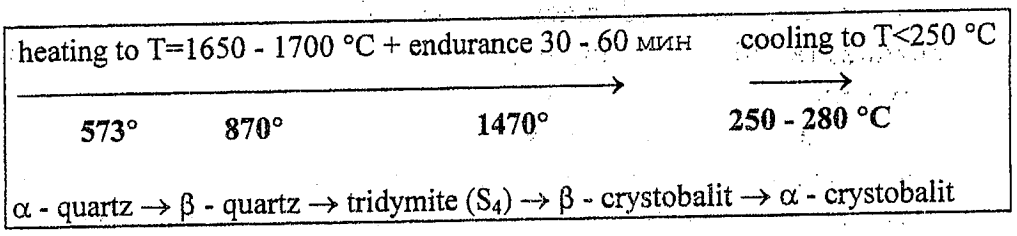
The known methods of GLI disposal from quartz are as follows: mechanical - that is grinding providing breakdown of caverns, channels and pores; and thermal - that is thermoprocessing of line-grained and mean-grained quartz fractions in the range of temperatures 440 - 600 °C (deposits of the Middle Urals and Bashkiria), or 900 - 1100 °C (deposits of the Middle Urals). However, the investigations of the milk-white quartz varieties has shown that they are characterized by ultra small dimensions of GLI, mean area of which varies from 2,6 up to 30,0 x 10^{-6} mm^2 depending on a deposit (V. A. Issaev, V. T. Dubinchook, 1997). Such impurities could not be revealed by common thermoprocessing.

New approach of the extraction of GLI from quartz (Author's certificate N 1818309) is based on the process of its modified

transmitting into low-temperature crystobalite (α - crystobalite) according to the scheme (Fig.1).

Fig. 1

The scheme of polymorphous transfer of quartz into low - temperature crystobalite



The stated consequence of polymorphous conversion for each pair of the neighboring quartz modifications in this row is followed by significant change of elementary cell volume by 0,6% (K. S. Filatov, 1990). β - quartz → tridymite - by 4%, tridymite → β - crystobalite - by 5 - 6%, and, correspondingly, conversion of β → α - crystobalite is attended by the decrease of elementary cell volume by 5,6% (V. P. Pryanashnikov, 1971). So, modified thermoprocessing of quartz up to α - crystobalite through multiple meaning changes of elementary cell volume leads to revelation of even small GLI.

However, it is necessary to state that polymorphous transfers of quartz into tridymite and of β - crystobalite are effective only if there are modifying admixtures. Modifying admixture are mainly alkaline elements, their sum being not less than 10^{-3}%. For quartz stuff of milk-white variety of the Middle and SubPolar Urals deposits the content of admixture elements varies within the limits of $(70 \div 350)10^{-4}$%, the alkaline elements admixture Na and K is $(10 \div 80) \cdot 10^{-4}$%. The mentioned types of the quartz stuff are suitable for modification thermoprocessing aimed at production of GLI-free silica in the form of α - crystobalite.

4. EXPERIMENTAL STUDIES OF QUARTZ CRYSTOBALIZATION

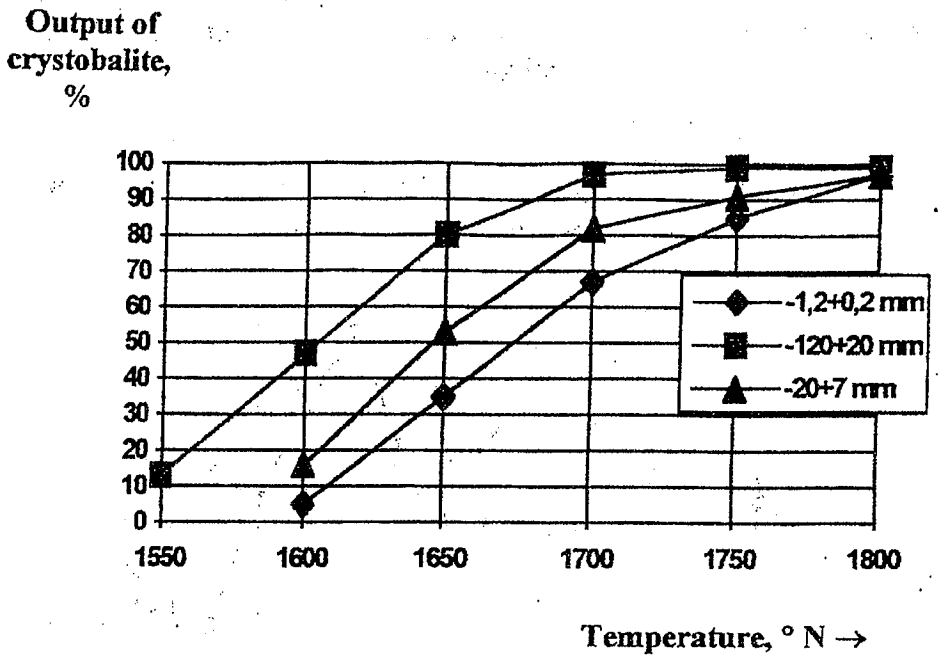
The carried out investigations of various milk-white varieties have shown that traditional thermoprocessing do not provide effective results of GLI purification irrespective of temperature and rate of heating. There

are several reasons to it, first, because of the quartz granules smelting while GLI are being removed. Second, the temperature of quartz granules treatment under the known technologies conditions (USA patent N. 3565595, 1971) varies in a wide range from 1500°C and up to temperature higher than the point of phase transfer of α - quartz into β - crystobalite. All this do not allow to count on a full removal of GLI. Purification of milk-white quartz from GLI is conditioned by revelation of both microscopic and macrocavities filled by gaseous and liquid admixtures resulting from the transfer of α - quartz into β - crystobalite in temperature interval of 1470 up to 1723°C according to Day-Sorsman scale. It was experimentally stated that the crystobalite content in thermoprocessing of quartz stuff grows quicker, the higher is temperature. For example, the time of heating being 0,5 hour and temperature 1600, 1650 and 1700°C the output of crystobalite is 0, 50 and 80% correspondingly for the quartz stuff with mean grains diameter 0,5 mm. The dimension of grains of thermoprocessed material is an important factor influencing the effectivity of quartz-crystobalization process. It was stated that the diameter of grains being increased up to 70 mm, the yield of crystobalite also increases when compared with the previous experiments and is 48,82 and 98% correspondingly. The analysis of the results of twenty experiments on crystobalization of quartz of various granulometric composition has shown that the maximum yield of crystobalite is not more than 80% for grains less than 2,5 mm at various temperature-temporal regimes.

Fig. 2 shows the dependence of the influence of grain size of the initial quartz (deposit "Aktas", III generation) upon the yield of crystobalite depending on temperature of thermoprocessing.

The experiments have shown that thermoprocessing of milk-white quartz at 1600°C has low output of crystobalite (not more than 45%), and the increase of the time of heating sharply decreases the capacity of the process and is not profitable. The most optimal temperature interval for quartz stuff processing is 1650 - 1700°C. The rate of crystobalization at such temperatures is maximum, the time of heating is not more than 1 hour.

The influence of grain size of milk-white quartz upon the yield of crystobalit depending on temperature processing



(Time of thermal treatment 0,5 h)

Fig. 2

The increase of temperature of thermoprocessing of the quartz stuff for more than 1700°C is not expedient, because of crystobalite melting down which disturbs the quality of the product and hinders its further dressing off mineral impurities. The temperature at which crystobalite fully transfers into fusion is 1723°C. It was experimentally stated that the larger is the grain, the higher is crystallite content in the processed quartz stuff, and, consequently, the more effective in the process of GLI removal.

Fig. 3 shows the ratio of the influence of mean diameter of grains upon the glass phase formation. These ration testifies to the decrease of temperature of crystobalite smelting with the decrease of grains dimensions.

It was stated that the influence of grain size upon intensification of crystobalization process is due to the character of GLI spreading in the mass of quartz stuff on different preliminary stages. Thus, the crushed

and fractured quartz granules (grain diameter: 0,1 - 0,4 mm) is partly released from those gas and liquid impurities which concentrate along the surface of the healed cracks of crystals and, consequently, the amount of impurities containing mainly Na^+ and K^+ ions lessens, which in its part decreases the rate of crystobalization.

The influence of grain size of milk-white quartz upon the amount of the glass phase

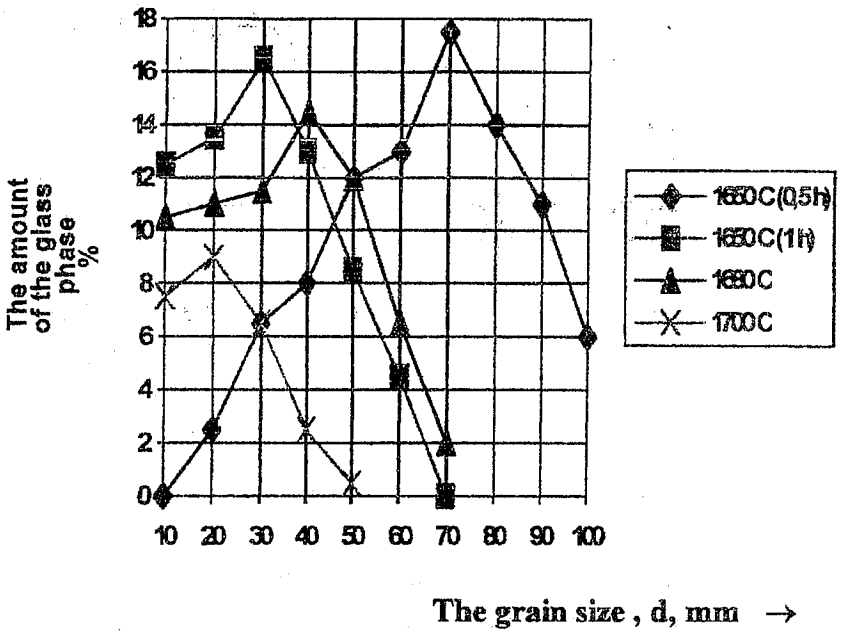


Fig. 3

With the growth of mean dimensions of grains especially of the uncrushed and unconcentrated ones, the rate of crystobalization considerably increases, even minute traces of alkaline impurities on the surface of crystals lead to the transfer quartz into crystobalite.

Theoretical and experimental studies allowed to develop method of purification of milk-white quartz gas-liquid impurities (**1**).

In Table 2 the results are presented of milk-white quartz crystobalization depending on thermoprocessing conditions, grain size and ratio of $\varnothing_{max}/\varnothing_{min}$ fractures diameter.

5. TECHNOLOGICAL SCHEME OF MILK-WHITE QUARTZ PROCESSING BY MEANS OF MODIFICATIONAL THERMOPROCESSING

On the base of the developed method of milk-white quartz purification from GLI there was developed technological scheme of this type of the stuff processing. It provides production of especially pure silica in a form of crystobalite (Fig. 4). The scheme is based on modified thermoprocessing of the preliminary fractured initial stuff. The peculiarities of this method are as follows:

- The main technological operation is special thermoprocessing of lump or coarse-grain milk-white quartz at 1650 - 1700°C temperatures. The process may be performed in induction or HF-kilns.
- Depending on the amount of the initial product types it may be produced in powder, large-grain or lump crystobalite forms. Powder crystobalite provides making new types of commodities after crushing, preliminary pressing and further transfer into glass.
- Chemical processing is applied only in case of necessity, of the initial stuff do not meet technical requirements (TR).
- Considering chemical processing this method allows to unify all types of quartz stuff.

6. CONCLUSIONS

The analysis of literary data and studies of peculiarities of milk-white quartz stuff varieties under high-temperature processing conditions allowed to justify new method of intransparent varieties of quartz processing. The method allows to produce very pure silica in the form of crystobalite for transparent glass melting.

The proposed method presupposes new means of preparing the initial quartz stuff for the processing, in particular, the application of large and superlarge grain size material (up to 120 mm) (according to traditional technologies the final product-quartz concentrate - should be 0,1 - 0,4 mm which finally leads to considerable decrease of industrial energy losses.

Crystobalite obtained in the result of polymorphous quartz transformation is highly porous and its deep purification may be achieved with better results when compared with quartz granules.

The proposed method makes it possible to develop technological version of obtaining quartz glass from milk-white quartz during one cycle, that is to combine processing of the inital quartz stuff with quartz glass production.

Table 2

The results of crystobalization of milk-white quartz depending on thermoprocessing conditions, grain size and ratio of fracture diameters

NN experi-ments	Fraction, mm	Φ_{max}/Φ_{min}	Conditions of thermoprocessing		The yield of product after thermoprocessing, %			The degree of gas-liquid impurities disposal
			T, °C	Time, hour	quartz	crysto-balit	the glass phase	
1	-1,2 + 0,2	6	1600	0,5	70	-	30	31,3
2	-1,2 + 0,2	6	1600	1,0	15	48	47	45,8
3	-1,2 + 0,2	6	1700	0,5	5	80	15	84,2
4	-3 + 0,5	6	1680	0,5	7	83	10	81,1
5	-6 + 3	2	1680	0,5	2,0	97	1,0	96,9
6	-9 + 3	3	1680	0,5	2,5	96	1,5	96,61
7	-12 + 3	4	1680	0,5	3,0	95	2,0	94,36
8	-18 + 3	6	1680	0,5	6,0	90,5	3,5	90,4
9	-20 +7	2,8	1650	1,0	8	87	5	89,27
10	-20 + 7	2,8	1680	0,5	2	98	-	97,2
11	-20 + 7	2,8	1730	0,5	-	88	12	96,04
12	-21 + 3	7	1680	0,5	7	88	5	87.0
13	-120 + 20	6	1600	0,5	48	52	-	43,4
14	-120 + 20	6	1650	1,0	4	96	-	94,92
15	-120 + 20	6	1680	0,25	10	85	5	87,57
16	-120 + 20	6	1680	0,5	2	98	-	96,62
17	-120 + 20	6	1680	0,75	3	97	-	97,46
18	-120 + 20	6	1680	1,25	-	96	4	98,3
19	-120 + 20	6	1700	0,5	-	100	-	97,9
20	-120 + 20	6	1700	1,25	-	92	8	96,61

PRINCIPLE TECHNOLOGICAL SCHEME OF MILK-WHITE QUARTZ PROCESSING

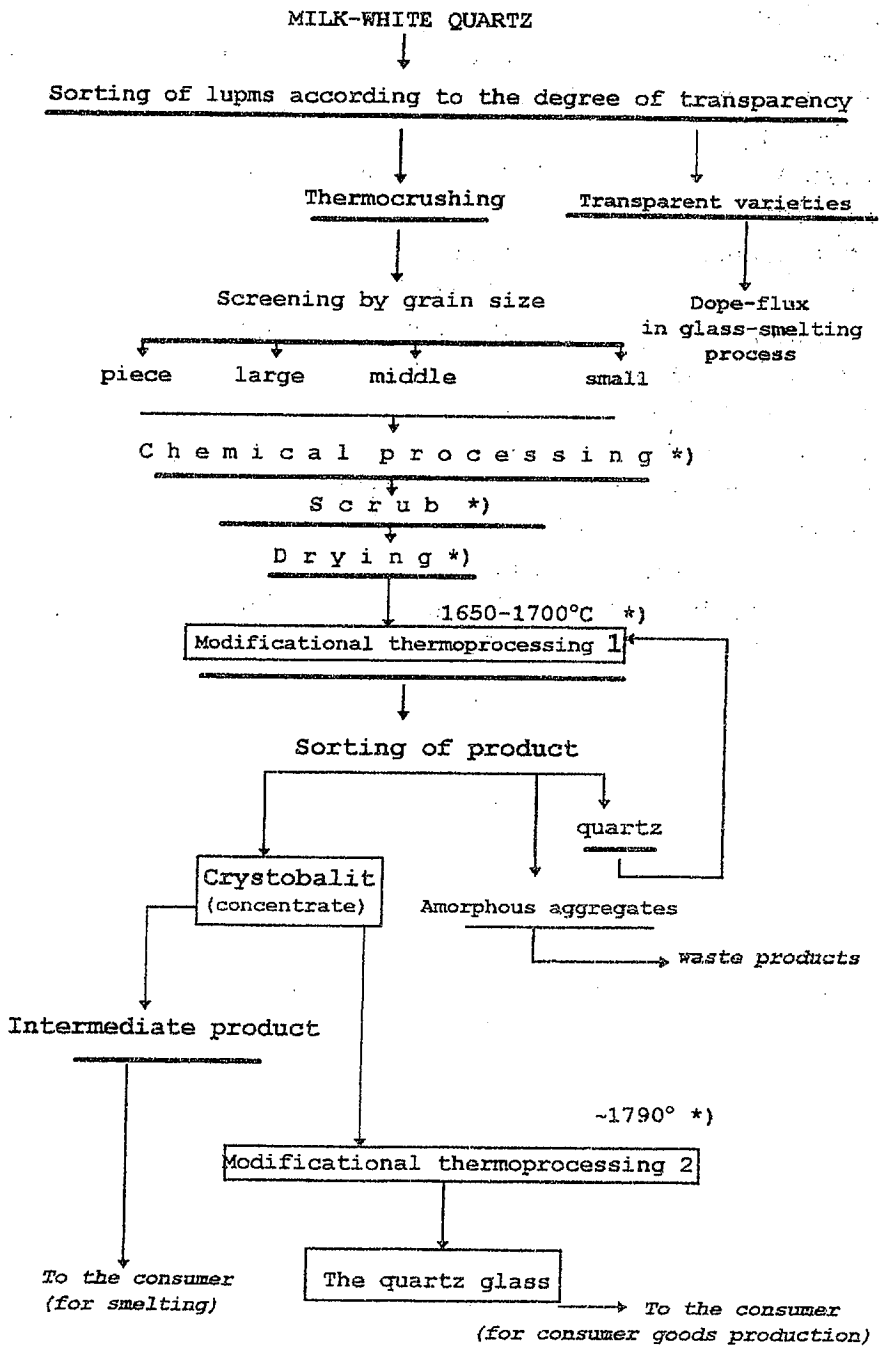


Fig. 4

*) Technological operations are perfomed separately for each class

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EVALUATION AND STANDARDIZATION OF ESTONIAN OIL SHALE QUALITY CHARACTERISTICS

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GENERAL

The most important mineral wealth of Estonia is oil shale, which is used as fuel for generating electricity, thermal energy, for producing the shale oil, impregnation oil, cement, concrete and other products.

Estonian oil shale (Kukersite) deposit occupies an extensive territory (about of 1830 square km). Proved reserves in this deposit were estimated about 4 billions tons of oil shale. (Fig. 1). The industrial oil shale seam (thickness 2,5 - 3,2 m) contains 6 oil shale layers (A - F2) which are separated from one other by limestone intercalation poor in kerogene. The calorific value of oil shale layers ranges between 7 - 15 MJ/kg. The bedding depth of oil shale deposit is from a few meters up to 150 m, now maximum depth in mines are about 70 m. At present oil shale mining is carried out in 6 mines and 3 opencast, oil shale output was 14,6 million tons in 1996.

The most important quality characteristics of oil shale are: calorific value Q, moisture W, ash content A, carbonic acid content CO_2, which have influence on efficiency of using oil shale in power and thermal processing plants and construction materials production. Therefore it is important to elaborate standards of oil shale quality, characteristics and investigate how to guarantine the required for consumers stable quality of oil shale. Checking necessary number of samples from mines, opencasts, power plants and other consumers, evaluating precision of sampling and determination of quality characteristics is also important.

STANDARDS

Standards for moisture and ash content have been worked out by Estonian Oil Shale Corporation management (K.Koitmets) and verified as Estonian republican standards in 1995. Investigating methods for determination averages and primary increment variance of testing gross samples the coefficients of variance for moisture content W did not exceed 1,5% and results determining ash content A were:

for shortened method 52,38 ± 0,03%;

for key method 50,40 ± 0,04%.

The shortened method had bias (systematic deviation) and therefore was not included in verified standard.

Standard of oil shale sampling and calorific value is now in work. All these standards are necessary and corresponding to ISO standards, creating systems of quality for satisfying consumers needs and security, increasing efficience of quality politics.

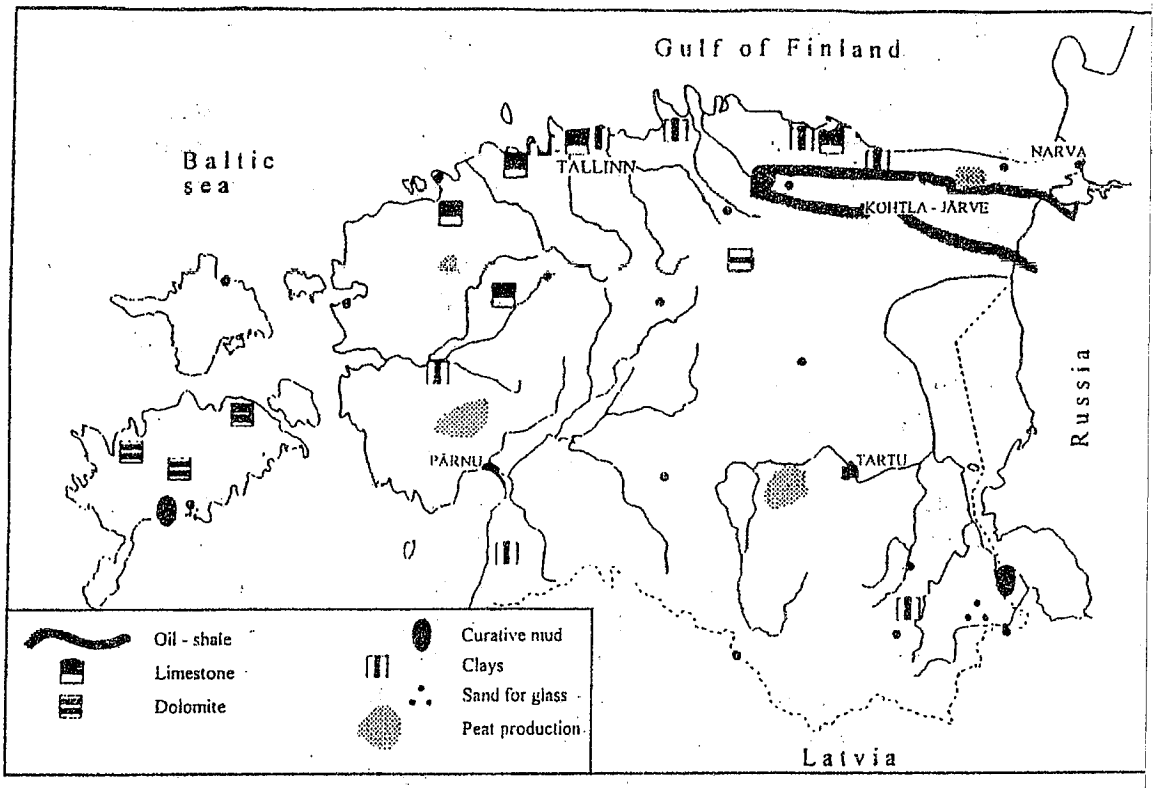
EVALUATION OF OIL SHALE QUALITY

Research work staff members of Mining Institute Tallinn Technical University investigating these problems with experiments of sampling in mines, opencasts and power plants, statistical analyses of the samples and data from mining and power enterprises, the degree of variability oil shale quality characteristics in space and time had following key results:

1. Comparing coefficients of variance V and correlation matrix the Estonian oil shale quality characteristics may be ordered in following row by significance: low and high calorific value Q_S^d and Q_i^r, V<16%; moisture content W_t^r, V<12%; carbonic acid content $(CO_2)_M^d$ V<10%; ash content A^d V<8% (1).

2. Standard deviation of oil shale quality characteristics depends from size of delivered oil shale quantity, number of primary increments and time between taking it. Therefore it is necessary besides evaluating the common statistics of oil shale quality: average, variance, standard deviation, skewness and kurtosis to have information about conditions of sampling: time, place, apparatures and preparation.

3. Experiments of sampling in mining enterprises and power plants indicated that coefficient of variance calorific value in small portions of oil shale (100 - 200t) was 7,5 - 16%, what means that the precision of



Deposits of mineral resources in Estonia

MINERAL RESOURCES Resource	Unit	Explored resorces 01.01.1997.	Mined in 1996
Oil - shale	million tons	3972	14,6
Limestone, dolomite	million m^3	271	1,125
Sand, gravel	million m^3	426	0,703
Peat	million tons	1547	1,124
Currative mund	million m^3	3	0,001

Figure 1

indicating data from samples in power plants is 180 - 300 KJ/kg. All quality characteristics of oil shale samples showed, that statistics had normal distribution and time series random variability.

4. Analysis distribution tables of sold oil shale quantities (lots) and qualities Q in 1994 - 1997 (Table1, Figures 2, 3) indicated, that statistics of lots were stable and coefficients of variance special low calorific value did not exceed 8 %.

Note: For all oil shale classes, excerpt class P2 (0 - 125 mm) coefficients of variance Q did not exceed 5%.

5. To guarantee that the uncertainity (precision) of sampling determining Q for lots do not exceed:

class K - 550 KJ/kg;

class P - 630 KJ/kg,

it is necessary to take no less as 25 and 20 increments for gross sample. In this case uncertainity of determining $CO2 < 1\%$ and $A < 2{,}3\%$.

6. Detailed checking the variances of sample preparation and testing (Fig.4) gave results that variances were (K. Koitmets):

at the first stage of sample division V1=1225 KJ/kg;

at the second stage of sample division V2=101 KJ/kg;

at the analysis V3=216 KJ/kg;

at whole sample preparation and testing V=1541 KJ/kg.

The uncertainity of sample preparation and testing was evaluated as 177 KJ/kg and did not exceed 20% of whole uncertainity by sampling, sample preparation and analyzing.

Therefore, it is more important do investigate carefully procedures of taking increments for gross sample to guarantee representative and reability sampling. It consists methods checking random and normal distribution of increments statistics, statistical hypothesis comparision of means and of variances.

7. Analyses indicated that the low calorific value Q as the main quality index possesses high and significant coefficient of correlation with all other quality indexes and therefore it is recommended to base this index for classification and determining price scale for selling oil shale to consumers (1).

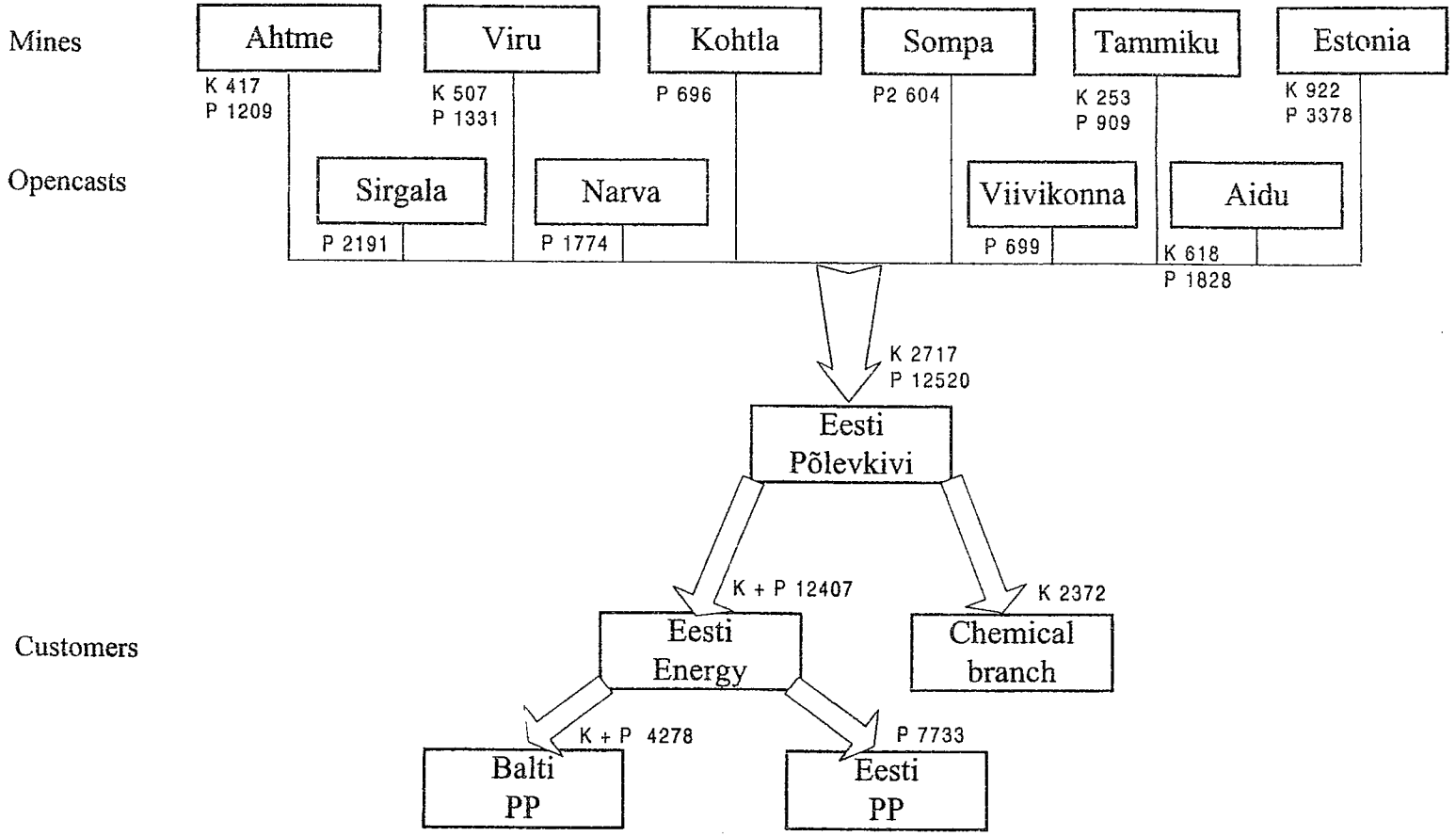
8. Experiments showed that the stability of oil shale quality can be considerable increased by storing oil shale in depots of opencasts and power plants. Decreasing standard deviation of oil shale calorific value for power plant boilers, it decreased specific quantity of oil shale for production electricity.

Table 1

Average specific low calorific value MJ/kg for lots of oil - shale

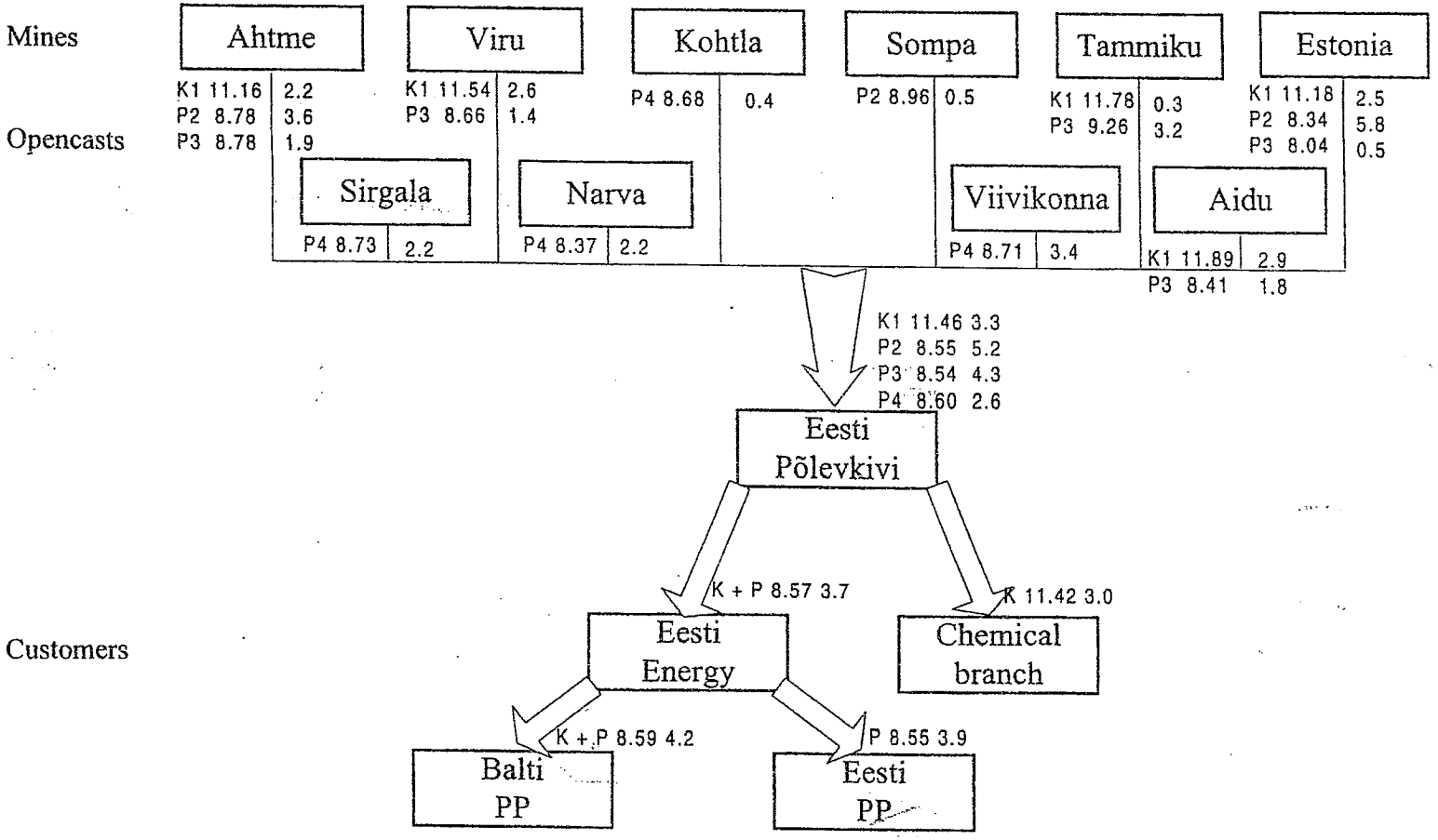
Enterprise	Oil - shale class	1994	1995	1996	1997 *
Mines:					
Ahtme	K	11.27	11.25	11.16	11.08
	P	9.04	9.13	8.78	8.78
Viru	K	11.48	11.54	11.54	11.56
	P	8.99	8.71	8.66	8.47
Kohtla	K				
	P		8.84	8.68	8.68
Sompa	K				
	P		8.88	8.96	9.02
Tammiku	K	11.85	11.90	11.78	11.75
	P	9.51	9.59	9.26	8.94
Estonia	K	11.20	11.20	11.18	11.20
	P	8.67	8.45	8.34	8.26
Opencats:					
Sirgala	K				
	P	8.72	8.75	8.73	8.71
Narva	K				
	P	8.42	8.34	8.37	8.41
Viivikonna	K				
	P		8.69	8.71	8.70
Aidu	K	11.44	12.13	11.89	11.49
	P	8.29	8.26	8.41	8.61
Eesti Põlevkivi	K	11.48	11.51	11.46	11.34
	P	8.65	8.64	8.57	8.58

* only January and February;
K - concentrate oil - shale 25 - 125 mm;
P - oil - shale 0 - 300 mm



K - class concentrate 25 - 125 mm sized from preparation plants;
P - class 0 - 300 mm from opencasts and mines.

Fig. 2. Oil - shale consumption and production 1996 10^3 tonns



Classes: K1 - concentrate 25 - 125 mm;
P2 - oil - shale 0 - 125 mm;
P3 - oil - shale 0 - 25 mm;
P4 - oil - shale 0 - 300 mm.

Fig. 3. Average low specific calorific value Q_M^i MJ/kg and coefficient of variance V% lots of oil - shale from mines and opencasts, for consumers in 1996

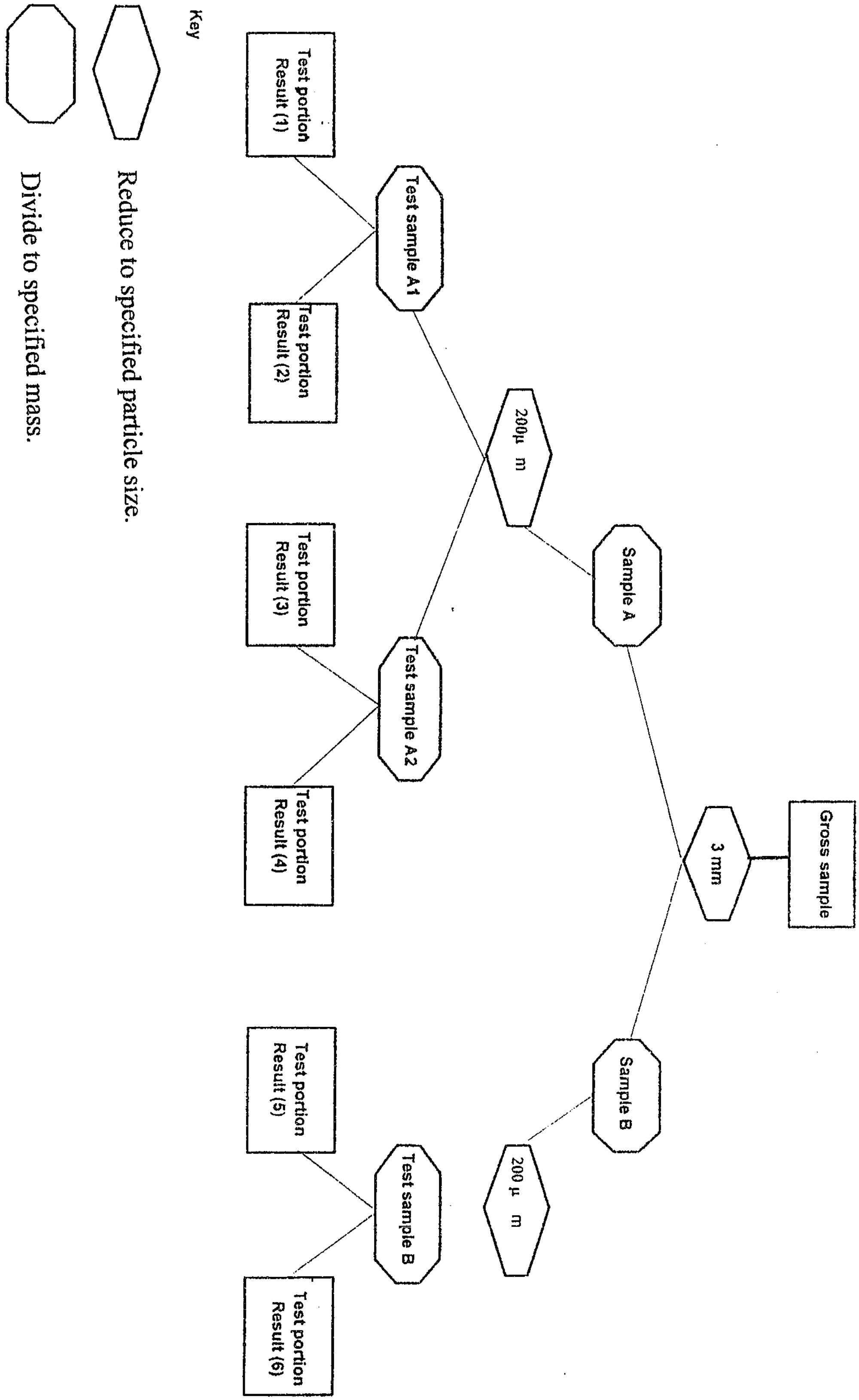


Fig. 4. Detailed check of sample preparation.

9. Predicting relationship between boiler performance and oil shale quality needed to be developed to predict the costs and price of producing electricity.

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TOOMPEA HILL STABILITY ANALYSIS

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INTRODUCTION

On Toompea Hill situated in the center of Tallinn there are several natural, ancient architectural and historical monuments. It has become apparent that the processes in the rock mass caused an unfavorable environmental side effect accompanied by significant subsidence of the Toompea Hill.

Identification of the reasons of the Toompea Hill's subsidence and opening the physical substance of these processes is the main aim of the present work. For the feasibility study stability problems were investigated. Accordingly, it was decided to perform numerical modeling analysis using two-dimensional Fast Lagrangian Analysis of Continua (FLAC - program) (1). It is suitable for stability analysis, for parametric and sensitivity studies.

For the first time, preliminary calculations before the modeling have been proposed. This method enabled to simplify and quicken the further modeling. It was made by means of conventional calculation methods, using theoretical formulas. The utility of preliminary calculations was clearlyproved.

At first, little field information was available to estimate the rock mass properties. For this estimation, geological data were used. The rock mass properties were selected, based on Bieniawski's rock mass rating (RMR) (2).

GEOLOGY

Precambrian crystalline igneous and metamorphic rocks form the base of the area of Tallinn. Lower Paleozoic sedimentary rocks lie on the crystalline base rock, which is covered with Quaternary clastic

rocks (Fig.1). During the Pre-Quaternary period, ancient valleys were incised through Cambrian clays and the underlying sandstones. Later the ancient valleys was filled by fluvio-glacial sand - and - gravel deposits, Quaternary lacustrine-glacial flowing and plastic clays, loams.

Consolidated Cambrian clays form a waterproof roof for the confined Cambrian-Vendian aquifer of the thickness about 50 m. It is one of water sources for Tallinn. Owing to strong underground pumping in the center of cone of depression the lowering of the potentiometric surface (about 30 m) attains.

Unconfined Ordovician-Cambrian aquiter-aquitard system is separated from Cambrian-Vendian system by 85 - 90 m thick Cambrian clays. 18-22 m thick sandstone layer represents the aquifer. The water table of this layer fluctuates from 0,4 to 1,0 m.

The waters in the ancient buried valleys are hydraulically connected with the aquifereous strata.

Toompea Hill is situated between two ancient buried valleys (see Fig. 1.A). The height of Toompea Hill is 24 m (47 m above sea level) and the dimensions in different directions are: NE - SW - 300 m, NW - SE - 200 m. It is represented by Quaternary, Ordovician and Cambrian sediments (Fig.2). Field investigations of Toompea Hill were carried out by means of a boring program. The number of boring holes was 6 bored at different depth from 26 to 68 m. Several laboratory tests of the rock samples have been carried out.

Surface water is situated in the cracked Ordovician limestones and dolomites. The argellite clay layer form a waterproof bottom. It is feed on the water from rain and snow, which infiltrates into terrain and dissolves carbonate rocks to saturation level. Abovementioned process may influence on the stability of the Toompea Hill and consequently, demands the supplementary investigations.

THEORETICAL MODEL

On the bases of the investigations by L. Vallner and R. Lutsar, the total subsidence of the territory of Tallinn can be calculated by following formula (3, 4):

$$N(t) = -A(t) + B(p) + C(p) + D(t) + E(t) + F(t) + G(p) + K(t) + S(t) \quad (1)$$

where N(t), total subsidence of the territory of Tallinn; A(t), surface displacement, caused by the tectonic processes; B(p), surface displacement caused by the atmospheric pressure; C(p), unconfined aquifer elastic deformation, caused by the decrease of the water table; D(t), unconfined aquitard plastic deformation, caused by the decrease of the water table; E(t), soil compaction, caused by the buildings; F(t), soil compaction, caused by the vibrations; G(p), confined aquifer plastic deformation, caused by the decrease of the potentiometric surface; K(t), confined aquitard plastic deformation, caused by the decrease of the potentiometric surface; S(t), clays compaction in ancient buried valleys.

The influence of the different factors on the surface subsidence in the territory of Tallinn is represented in Table 1. (3). Analysis showed that the subsidence mainly depends on the behavior of Ordovician-Cambrian and Cambrian-Vendian aquifer-aquitard systems. As is known, the process of aquitard drainage leads to compaction of the aquitards just the process of aquifer drainage leads to compaction of the aquifer. The deformations of the aquitard are seemly inconsiderable, owing to the rather great density of the Cambrian clays (4). Accordingly, for the first stage of the project, only the Ordovician-Cambrian and Cambrian-Vendian aquifer compaction was investigated.

If the weight of overlying material remains constant and the potentiometric surface in the confined aquifer or the water table in the unconfined aquifer is decreased, the stratum compaction is (4, 5):

$$db = \alpha\, b\, \Delta p \qquad (2)$$

where db, the change in the thickness of the stratum; α, compressibility; b, thickness of the saturated zone; Δp, the increase of the effective pressure.

The increase of the effective pressure is calculated by following formulas (5):

$$\Delta p = \gamma\, \Delta h \quad \text{or} \quad \Delta p = (\gamma_2 - \gamma_1)\, \Delta H \qquad (3)$$

where γ, the weight density of water; Δh, the decrease of the hydraulic head in the aquifer; γ_2, the weight density of rocks in the unsaturated zone; γ_1, the weight density of rocks in the saturated zone; ΔH, the decrease of the water table.

NUMERICAL MODELING

For the evaluation, the two-dimensional Fast Lagrangian Analysis of Continua (FLAC) was used (1). FLAC is an explicit finite difference code which utilizes the "Lagrangian" calculation scheme and explicit time stepping algorithm. It has several built in material behavior models. In addition it contains groundwater and consolidation (fully coupled) models.

The problems assumes isotropic Darcy flow for fluid transport. The soil grain skeleton is assumed to behave elastically. The water is assumed to flow in the vertical direction only, and there is no horizontal strain (one-dimensional problem) (see Fig.3). The applicability of the one-dimensional models depends on the physical substance of the modeled processes and was demonstrated by spetial investigations (4). Here, the methodology for rock mechanics modeling in data limited conditions was used (6). Two different models regarding the behavior of the aquifer-aquitard system have been presented here: a) for the confined Cambrian-Vendian aquifer; b) for the unconfined Ordovician-Cambrian aquifer.

The resulting rock mass responses are presented in terms of induced principal stress and displacement contours.

MODEL PROPERTIES

During the first stage of the project, when relatively little field information is available, it is reasonable to estimate the rock mass properties from geological data. The selection of all rock properties was based on Bieniawski's rock mass rating (RMR) (2). The elasticity and compressibility parameters for the aquifer was precised by using the special investigations (3, 4). By combining the field observations, laboratory tests and the RMR - system, a good approximation for rock mass properties was constructed (Table 2).

RESULTS

Analysis showed that the Toompea Hill stability is connected with the subsidence of the territory of Tallinn and Ordovician aquifer-aquitard

system. Surface subsidence is caused by Cambrian-Vendian and Ordovician-Cambrian aquifer. Owing to the rather great density of the aquitard, the deformation one are seemly inconsiderable.

The decrease of the water table in the unconfined Ordovician-Cambrian aquifer by 1 m gives the deformation of this layer from 1,0 to 2,5 mm and respectively for confined Cambrian-Vendian aquifer from 0,05 to 0,1 mm.

The results of the modeling and measuring of the deep-seated ground bench-mark are in the same magnitude.

CONCLUSIONS

As a result of the study, the following conclusions and recommendations can be made.

1. The Toompea Hill stability is connected with the subsidence of the territory of Tallinn. For the most part, the surface subsidence is caused by Ordovician-Cambrian and Cambrian-Vendian aquifers-aquitard systems.

2. The preliminary calculations enabled to simplify and quicken the further modeling. The method for rock mechanics modeling in data limited conditions improves the quality of the investigations.

3. Investigations show that the deformation of the aquifer-aquitard systems by the results of the modeling and deep-seated ground bench-mark are in the same magnitude.

4. This study was based on assumed properties of the rock mass and aquifer-aquitard systems. Other combinations of these parameters may give different results. Therefore, a sensitivity study is recommended to be performed.

ACKNOWLEDGMENTS

I am very grateful to Ph. D. Leo Vallner of Geological Survey of Estonia for his great help and valuable comments.

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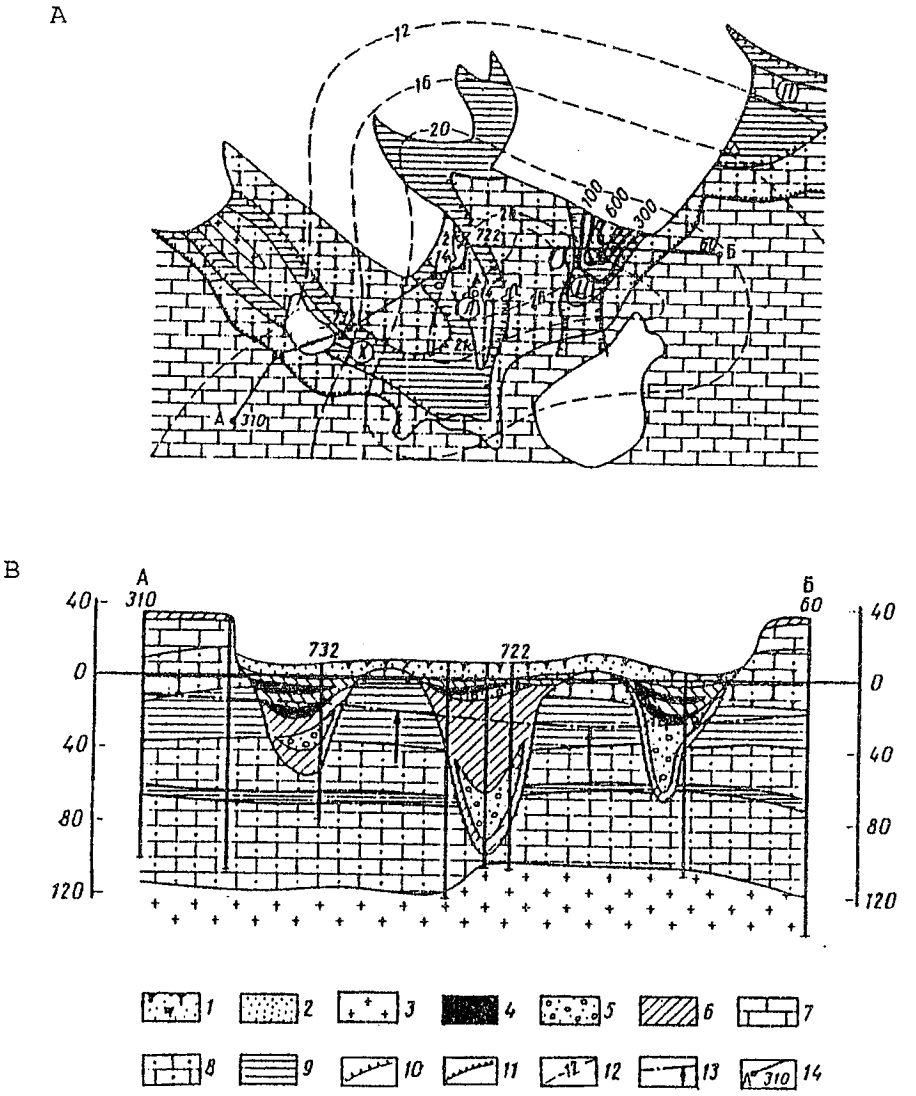
ABSTRACT

This paper analyses the stability of the Toompea Hill, using the theoretical and numerical modeling. Calculation were performed by the FLAC-program. Rock properties were estimated from geological data by Bieniawski's rock mass rating. The results demonstrate that Toompea Hill stability is connected with the subsidence of the territory of Tallinn, where the compaction of Ordovician-Cambrian and Cambrian-Vendian aquifer-aquitard systems cause the surface subsidence.

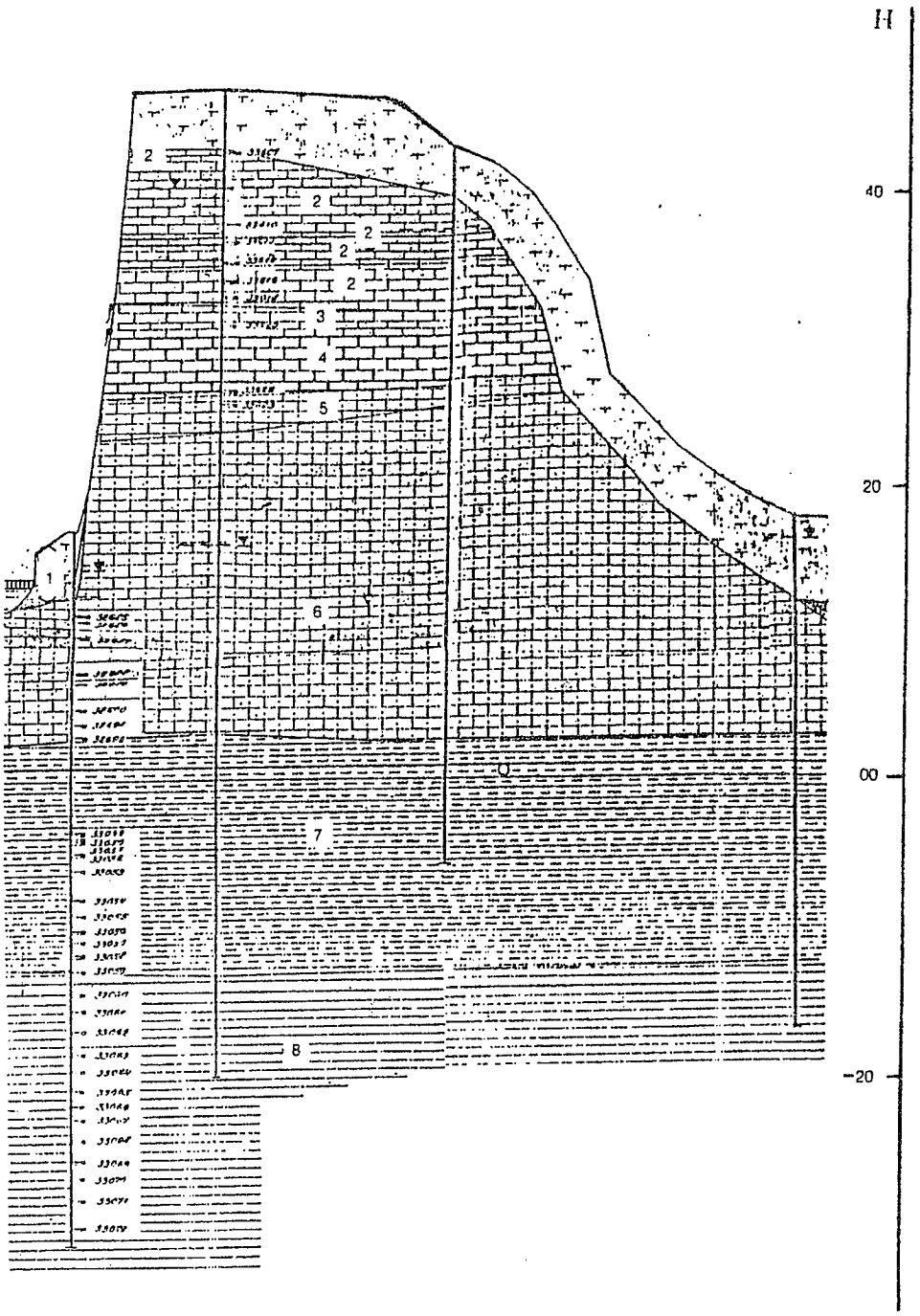
KEY WORDS: stability, rock mass, model, weight density, aquifer-aquitard system, hydraulic head, water table, surface subsidence.

FIGURES



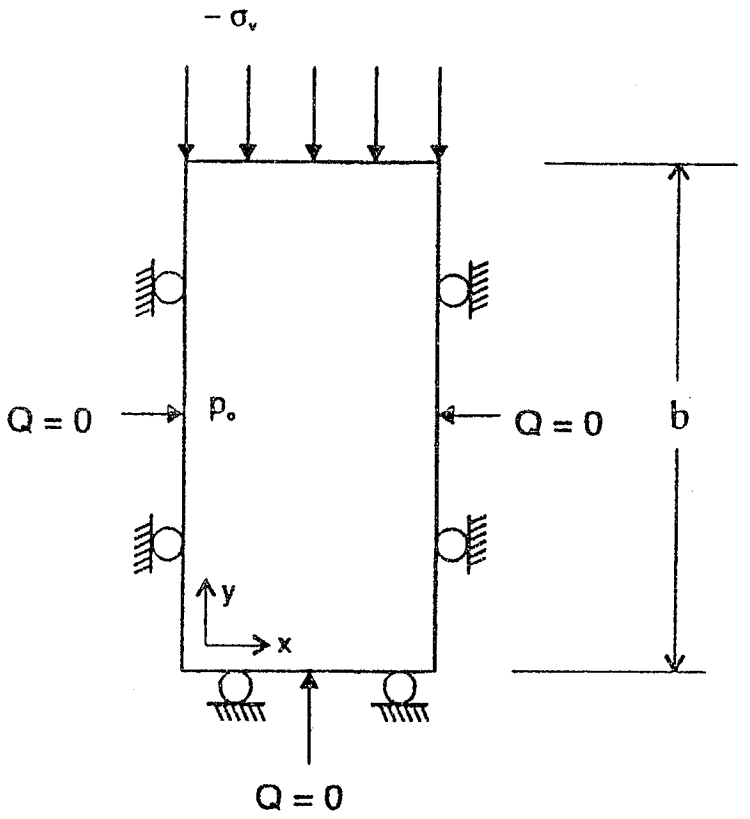
1 - soil; 2 - sand; 3 - crystalline rocks; 4 - flowing-plastic clay; 5 - sand and gravel; 6 - morainic loam; 7 - hard limestone; 8 - solid sandstone; 9 - solid clay; 10 - contours of ancient buried valleys; 11 - Baltic Klint; 12 - isopiezes of Cambrian-Vendian aquifer stratum; 13 - piezometrical surface of Cambrian-Vendian aquifer stratum; 14 - profile.

Fig. 1. Schematic geological map (A) and section (B) of the Tallinn area (3, 4).



1 - Quaternary sediments; 2 - limestone; 3 - soft sandstone; 4 - argillite; 5 and 6 - sandstone; 7 - clay and siltstone; 8 - clay.

Fig. 2. Geological section of the Toompea Hill



σv - applied vertical pressure; p_o - initial excess pore pressure; Q - outflow (inflow) rate of water; b - thickness of the stratum.

Fig. 3. Conceptual model

TABLES

Table 1

Influence of the different factors on the total subsidence of the territory of Tallinn between the buried valleys (by Vallner, L et al.)

Parameter	Value	Observation
A(t) - surface displacement, caused by the tectonic processes, mm/year	-1.7	from 1911 to 1980 < 0.1 m
B(p) - surface displacement, caused by the atmospheric pressure, mm	0.1 -0.2	max <0.5 mm
C(p) - Ordovician-Cambrian aquifer elastic deformation, mm	0.5 -1.0	by Δh = 0.4 - 1.0 m
D(t) - Ordovecian-Cambrian aquitard plastic deformation, mm/yar	< 0.1	by Δh = 0.4 - 1.0 m
E(t) - soil compaction, caused by buildings, mm	100	p = 0.1 - -0.15 MN/m^2
F(t) - soil compaction, caused by vibrations, mm	-	unknown
G(p) - Cambrian-Vendian aqufer elastic deformation, mm	1 - 2	from 1900 Δh = 30 m
K(t) - Cambrian-Vendian aquitard plastic deformation, mm	30 -50	from 1900 Δh = 30 m

Note: Δh - decrease of the water table or hydraulic head in the aquiter; p - pressure, caused by the foundation.

Table 2

Rock mass and hydraulic properties used for modeling

Parameter	Ordovician--Cambrian	Cambrian--Vendian
Density (saturated), kg/m^3	2020	2200
Bulk modulus (dry), Pa	$1.3\ 10^8$	$1.1\ 10^{10}$
Shear modulus (dry), Pa	$8\ 10^7$	$6.8\ 10^9$
Bulk modulus, fluid, Pa	$2\ 10^9$	$2\ 10^9$
Permeability, (m/sec)/(Pa/m)	$5\ 10^{-7}$	$1\ 10^{-9}$
Porosity	0.33	0.29

TRANSFORMATION OF AN INFERENCE TREE TO A LOGICALLY EQUIVALENT NEURAL NETWORK

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1. INTRODUCTION

Ill-formalized situations can easily be represented by means of conditional rules. Heuristics that are represented through rules well describe the relationships among the factors of the process or event to be examined.

In such a situation two tasks should usually be solved. The first deals with constructing the logical structure of a set of rules which properly represent the described process. The second task is the adjustment of this structure on the level of quantitative evaluations which characterize the described relationships. A logically full, consistent and non-exhaustive set of rules is adjusted through learning procedures taken from the apparatus of artificial neural networks (Zurada 1992).

When implementing this approch, the following tasks arise that are considered in the present:

(i) construction of the adequate neuronlike structure,

(ii) choice and implementation of a learning algorithm for training the above structure.

Other investigations are also known that have used a neural network as an element of an expert system. Gallant (1986) proposes the

methodology of artificial neural network application for the task of knowledge acquisition task.

2. INITAL REQUIREMENTS TO THE REPRESENTATION OF A KNOWLEDGE BASE

A knowledge base should meet the requirements that follow:
(1) An inference tree, on the basis of which a logical neural network is being constructed, implements *a straightforward reasoning chain (straightforward inference)* (Harmon and King, 1985).
(2) Presence of the consistent rule base. For example, a rule base should not contain the rules of the form:

- IF A and B THEN C
- IF A and B THEN not C.

(3) All the rules should be reduced to the following form (Li Min Fu, 1993):

$$\text{If } \alpha_1 \text{ and } \alpha_2 \text{ and } \ldots \alpha_n \text{ Then } \beta,$$

where α_1, I=1, ..., n are attributes contained in condition part of the rule, β is the consequence of the rule.

If rules are of another format, they should be changed by means of the following equivalent transformations:

- "If P Then Q and R" $\Leftrightarrow$ "If P Then Q" and "If P Then R"
- "If P or Q Then R" $\Leftrightarrow$ "If P Then R" and " If Q Then R"
- "If P and (Q or R) Then S" $\Leftrightarrow$ "If P and Q Then S" and "If P and R Then S"

3. CONSTRUCTION OF AN ADEQUATE NEURAL NETWORK

The process of network construction is implemented through three stages.
1. *Construction of a global neural network.* At this stage, a neural network based on the inference tree structure, the so-called global neural network, is constructed. The number of network layers, the number of neurons in each layer, as well as the structure of relationships among separate neurons of the network are determined.

2. *Decomposition of the global neural network into local 2-level nets.* At this stage, the network constructed on the basis of an inference tree is decomposed into as many 2-level networks (local neural networks) as many levels of inference the corresponding inference tree has. If the global neural net has no hidden layers, i.e. an inference tree has a single inference level, this stage is not performed. The necessity for the global neural network decomposition could be explained as follows. First, local neural networks enable making intermediate (local) inferences which precede the main, global inference. To obtain intermediate inferences in the global neural network, is either very difficult or impossible. Second, it easier to train local networks than to train global ones.

3. *Inclusion of additional hidden layers into local neural networks.* Depending on the number of input neurons and the similarity of input and output patterns, one or more hidden layers are included into each local neural network. Additional hidden layers enable successful training of local neural networks.

Local logical neural networks created and trained at the preceding stages enable emulation of the inference engine of a knowledge-based system, which implements a straightforward reasoning chain. By obtaining numerical input data that are the facts about the problem domain coded in the numerical form, each local neural network should represent such numerical values in its outputs after decoding of which the same conclusions could be obtained as the ones produced by the knowledge-based system inference engine on the basis of analogous facts.

The rule base underlying logic is transformed to a neural network by means of network training. The network trained through the examples taken from the rules truth table enables implementation of any logical operation laid down in this truth table.

4. ANALYSIS OF THE EXPERIMENTS

To check the equivalence of the conventional inference tree based approach to the implementation of logical inference engine and the proposed, artificial neural net based approach, a number of experiments were performed.

Before the experiments are made, a logically equivalent neural net is constructed and trained. Each experiment passes through several stages:

- generation of input network values;

- computation of output network values;
- matching of obtained values with the required values from the truth table on the basis of which the present neural network has been trained.

A set of rules proposed in (Harmon and King, 1985), known as theatre knowledge base, was used as a knowledge base in this paper.

On the basis of an inference tree, a global neural networks was constructed which was later decomposed into two local neural networks. The first local neural network that has one hidden layer of three neurons, implements logical inference equivalent to the first inference level in the inference tree. The second local neural network which has two hidden layers of nine neurons in each, implements logical inference equivalent to the second inference level in the inference tree.

For all possible combinations of attributes contained in conditional parts of rules the truth table was constructed. For each combination of attributes in the truth table a chain of local and global inferences obtained from the inference tree is shown. The truth table for the first local neural network contains 9 examples, where as the table for the second local neural network contains 24 examples.

In order to cover all possible combinations of attributes, 24 experiments were performed. In each experiment, the set output values of the 1st and 2nd neural networks was equivalent to the logical inference chain obtained on the basis of the inference tree.

5. CONCLUSIONS

The paper proposes a method for implementing a logical inference engine based on artificial neural networks. To that end, on the basis of the inference tree structure of the corresponding knowledge base, an artificial neural network is constructed that is trained by the corresponding algorithm intended for this architecture.

A number of experiments were performed to examine the equivalence of two approaches to the implementation of an inference engine, i.e. the conventional, inference tree based approach, and the proposed, neural networks based one. Experimental data have shown the efficiency of the proposed method for the implementation of artificial neural network based inference engine.

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LOGISTICS CHAIN ANALYSIS BASED ON A BELIEF NETWORK

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1. STATEMENT OF THE PROBLEM

In the present paper, the concept of logistics is used to construct a decision making system for choosing the best logistics chain. In principle, the logistic approach to the management of material flows differs from the conventional one in following: it integrates separate elements into the common system that is able to react adequately to the perturbation of the environment (Coyle, Bardi et al. 1992).

Logistics operations on the way of material flow movement from the initial source of raw materials to the terminal consumer are mostly fulfilled by using various transport vehicles. Costs for performing these operations constitute 50% of the total amount of logistics costs.

Logistics chain is a linearly ordered set of participants of the logistic process that implement logistics operations on transportation of the external material flow from one logistics system to another (see Figure.1).

The presence of an uncertain decision making situation, probabilistic data changing as the time changes, complex relationships among the variables and the subjectivity of task perception in the given problem make it necessary to use an influence diagram (Moravski 1989) as a model of decision making problem.

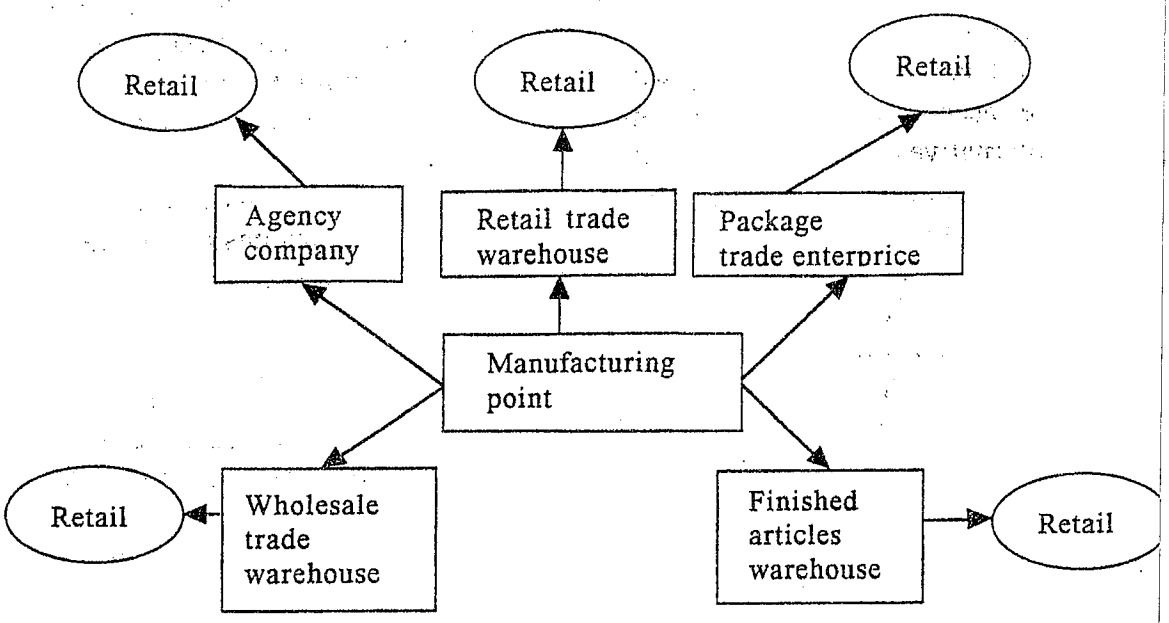

Fig. 1. Various consumer goods distribution channels.

2. INFLUENCE DIAGRAM GENERATION

To construct an influence diagram, let us use the goal-oriented influence diagram generation. First, it is necessary to determine possible values of a decision note. The complexity of a logistics chain depends essentially on goods transportation modes. Given own access roads, necessary transports and loading / unloading means, a logistics chain consists of two participants only, i.e. the seller and the customer.

In the problem under consideration, in order to deliver goods from the manufacturer to the customer, it is necessary to apply to a forwarding firm, since the customer, has no his own transport. With this, it should be taken into account that transportation by two transports complicates the logistics chain significantly as automobile transport is often involved in such transportations and sometimes an intermediary, the warehouse owner, is drawn in. Goods transportation is simplified essentially when direct relationship between the manufacturer-seller and the customers is broken by a transportation intermediary. Such a chain is average in complexity, easy arrangable and easy implementable.

To solve the problem under consideration, let us apply a logistics chain consisting of three participants: a manufacturer-seller, a forwarding

intermediary and a wholesale base-customer. A manufacturer-seller and a wholesale base-customer are constant elements of the chain, whereas several forwarding firms can stand for a forwarding intermediary. Thus, the forwarder-intermediary will figure as a decision node. Then it should be ascertained for which aim the decision is made and how the alternatives available will be evaluated.

Since the problem is to choose a logistics chain, let us ascertain for which aim the chain is created. Any activity in logistics has a finite goal that was called *six logistics rules.* They are: (1) *cargo* is reqired cargo, (2) *quality* is the required quality, (3) *quantity* is necessary amount, (4) *time* is required time, (5) *destination* is the required destination, (6) *costs* are minimal. The aim of a logistics chain is considered to be achieved if all the six conditions are met. Let us call the degree of fulfilling those six conditions *the efficiency of a logistics chain.* Assume that the manufacture-seller and the customer do not influence the increase of the logistics chain efficiency as they are constant elements of a logistics chain. The efficiency of a logistics chain will depend on the forwarding firm's activity. That is, the estimation of a forwarding firm activity's efficiency will be used as the evaluation of available alternatives and will be regarded as a value node.

Since a decision node and a value node are determined, the minimal influence diagram could be constructed (see Fig. 2).

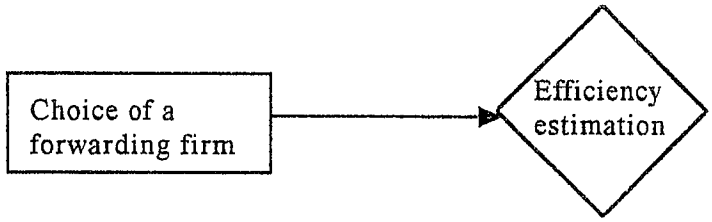

Fig. 2. An influence diagram for choosing a forwarding firm.

At the next stage, it should be determined which chance nodes are necessary for the estimation of the value node.

Since the efficiency of a logistics chain depends on the above six logistics rules fulfillment, the influence diagram should then be supplemented with following chance nodes: goods, quality, quantity, full delivery time, destination and costs. Let us determine values of generated

chance nodes. Chance node "Required goods" can assume two values: "yes" or "no" that depend on the possibility to transport necessary goods by a forwarding firm's transport.

Chance node "Destination" can also assume two values: "yes" or "no" which depend on the possibility to deliver goods by a forwarding firm to the required place. A chance node "Costs" can assume several values measured in monetary units depending on the distance, quantity of transported goods and transportation rate.

Values of a chance node "Full delivery time" measured in hours depend on transportation time and transport delays. Values of a chance node "Quantity", measured in per cents of the shipped cargo, depend on the goods safety on the way. Values of a chance node "Quality" depend on the quality of spoiled goods and are also measured in per cents. An influence diagram should now be supplemented with new chance nodes. Chance nodes "Possibility to transport" and "Possibility to deliver" can assume two values: "yes" and "no" and are determined depending on the chosen transport.

A chance node "Delay on the way" is measured in days and has some prior probability for cargo delay on the way, however this probability could be ascertained given information on the weather for the planned period. Transport delay can be also caused by an accident. A chance node "Delay on the way" is decomposed into two nodes: "Accident" and "Weather". The chance of an accident, in its turn, depends on the technical state of transport. It can be unsatisfactory, satisfactory, normal and excellent.

As goods shipment frequency is an important factor when choosing a transport vehicle, the influence diagram is supplemented with a chance node "Shipment frequency" that is measured in shipment times per week. The choice of shipment type is influenced by convenient goods delivery from manufacturing point to the starting point and from destination point to the wholesale base. Then one more chance node, "Convenient delivery", is incorporated, the qualitative characteristic for which could be evaluated in points. It should also be taken into account that delivery time depends on the transportation distance. Taking into account that delivery time depends on the distance but spoiling of goods depends on the accident, nodes "Delivery time" and "Transportation distance" should be connected by directed in pairs arcs. All boundary nodes of such influence diagram are of deterministic or probabilistic nature. Thus there is no need to incorporate any new nodes, since the influence diagram is

complete and finished. Generation of an influence diagram for the choice of a forwarding firm is considered to be completed.

3. DETERMINATION OF POSSIBLE DECISION OPTIONS

Two decisions should be made in the problem under consideration. They are: to choose a forwarding firm and to choose goods transportation type. Since both decisions are interconnected, combinations of forwarding firm choice options and transportation types could be regarded as decision options.

Let us find an allowable set of alternative combinations of decisions about the choice of a forwarding firm and transportation form taking into account that the goods to be shipped are washing machines, i.e. a big cargo that can be shipped both in containers and in small packages according to the total goods weight. Then, an assumption will be made for the present problem that between the starting point and the destination point there exist all kinds of transport communications. Transportation can be made by several firms dealing with cargo transportations. Among them there could be: a) a firm transporting goods by motor transport (forwarder 1), b) a firm transporting goods by rail (forwarder 2), c) a firm transporting goods by air (forwarder 3), and d) a firm transporting goods by over water (forwarder 4). A transportation contract will be concluded with a single firm. An option of transport vehicles combination is not considered in order to avoid problems of coordinated operation of two intermediary firms and due to additional loading / unloading costs.

4. INFLUENCE DIAGRAM REDUCTION

Let us analyse the obtained influence diagram for the choice of a forwarding firm. The possibility of delivering required goods to the required destination point is the necessary condition during construcing a logistics chain. In case if eithe of Variables "Transportation possibility" or "Delivery possibility" is equal to zero, the efficiency of the logistics chain will also equal zero. Values of those variables are known to the decision maker before a decision is made. All this influences the choice of an alternative decision option. Thus the dependence of a value node on

variables "Transportation possibility" and "Delivery possibility" can be taken off. With this, limitations on the choice of alternatives should placed. There should exist a possibility of delivering goods from the starting point to the destination point by using transport that a forwarding firm, which is a possible alternative decision, possesses. Besides, this kind of transport is to be adjusted for transporting the goods mentioned in the contract.

In the obtained influence diagram, variables "Convenient delivery", "Theft of cargo" and "Shipment frequency" have constant values for each decision option. Calculations for variables "Costs" and "Full delivery time" are given above. It is necessary to determine probability distributions for nodes "Spoiling of cargo" and "Delay on the way" only. To find them, a belief network (see Figure 3) is used that is transformed from an influence diagram by extracting value and decision nodes. Deterministic chance nodes "Convenient delivery", "Theft of cargo", "Shipment frequency" and "Costs" were not included into the belief network.

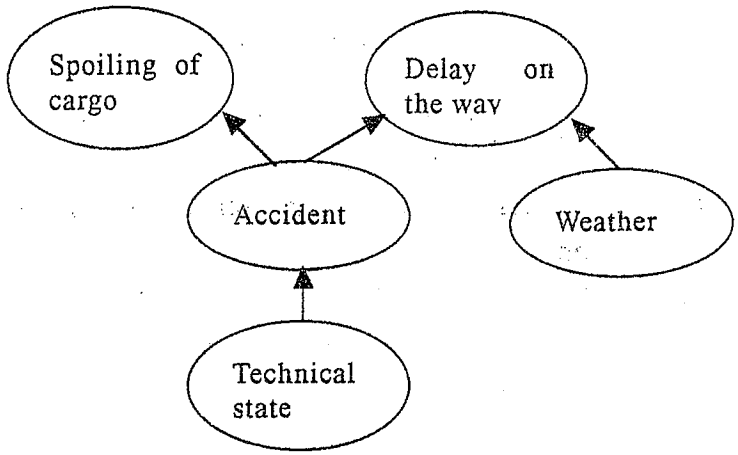

Fig.3. A belief network for the choice of a forwarding firm.

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CHARACTERIZATION OF THE EFFICIENCY OF THE FEATURES AGGREGATE IN FUZZY PATTERN RECOGNITION TASK

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1. INTRODUCTION

Let a set of objects exist each of which is described by N features X_1, ..., X_N, where each feature X_i is a real number. So each object is set by N-dimensional vector (X_1, ..., X_N) and represents a point in the space of object descriptions, R^N.

There are also set objects for which degrees of membership in either class are unknown. A decision rule should be determined that could enable estimation of the membership of either object with unknown degrees of membership in the given classes (Ozols and Borisov, 1996). To determine the decision rule, such features should be found which give a possibility to distinguish objects belonging to different classes, i.e. features that are specific for each class. That is why a subtask of estimation of the efficiency of features should be solved. A function δ should be determined which could enable estimation of the efficiency of both separate features and of features groups.

Thus, the task is reduced to the determination of a number of features from set N that will best describe groups of objects and will enable possibly correct recognition of the object's membership in a class.

2. CHARACTERIZATION OF THE EFFICIENCY OF A SINGLE FEATURE IN COMBINATION WITH TWO OTHER FEATURES

Let there exist a space of features X×Y×Z×K. The efficiency of the aggregate of either of two features could be estimated through the composition of binary relations. For example, by taking compositions

$$XZ \circ ZY \quad \text{and} \quad XZ \circ ZK$$

it is possible to ascertain the influence of features Y and K in combinatioin with feature Z. In this case definitions that follow are valid:

- *negative synergy*: importance of feature Z in combination with feature Y is not greater than that of feature Z in combination with feature K. In other words, replacement of feature K with feature Y, in combination with feature Z, will not improve recognition quality;
- *positive synergy*: importance of feature Z in combination with feature Y is greater than that of feature Z in combination with feature K. In other words, the quality of recognition could be improved by substituting feature Y for feature K, in combination with feature Z;
- *independence*: the middle case when there is no difference either feature K or feature Y is used. Recognition quality does not change.

3. CHARACTERIZATION OF THE EFFICIENCY OF A PAIR OF FEATURES IN COMBINATION WITH TWO OTHER FEATURES

Assume that a space of features X×Y×Z×K exists. By taking compositions of binary relations it is possible to characterize the efficiency of the aggregate of any features. For example, compositions of features

$$XZ \circ ZY \quad \text{and} \quad XZ \circ ZK$$

will enable us to ascertain the influence of the aggregate of features Z and K on the quality of recognition. Here, three definitions are valid:

- *negative synergy*: importance of a pair of features Z and K, if they are taken in combination, is not greater than the sum of their individual importances. In other words, we will not be able to improve recognition quality by combining features;
- *positive synergy:* importance of a pair of features Z and K, if they are taken in combination, is greater than the sum of their individual importances. In other words, the quality of recognition could be improved by combining features Z and K;

• *independence:* the middle case when each feature contributes to the quality of recognition.

4. INTEGRAL ESTIMATION OF THE EFFICIENCY OF A FEATURE

Assume, the efficiency of feature Z should be estimated in three-dimensional space XYZ. Let there exist shadows S^A_{XZ} , S^B_{ZY} , S^B_{XZ}, S^A_{ZY} . Composition $XZ \circ ZY$ is formed:

(1) $S^A_{XZ} \circ S^B_{ZY}$ and

(2) $S^B_{XZ} \circ S^A_{ZY}$.

As a result, we come to two reduction factors: δ^A_{XZ}, δ^A_{ZY} in the first case and δ^B_{XZ}, δ^A_{ZY} in the second one. Quantity δ^A_{XZ} characterizes the reduction over axis Z with respect to class A for composition (1), whereas δ^B_{ZY} characterizes reduction over axis Z with respect to class B for composition (1). Quantity δ^B_{XZ} characterizes the reduction over axis Z with respect to class B for composition (2) but δ^A_{ZY} characterizes reduction over axis Z with respect to class A for composition (2). By taking a sum of those quantities over the classes $(\delta^A_{XZ} + \delta^A_{ZY}; \delta^B_{ZY} + \delta^B_{XZ})$ and taking then the difference of those sums, it is possible to obtain the importance of feature Z as well as to ascertain which class is represented by feature Z:

$(\delta^A_{XZ} + \delta^A_{ZY}) - (\delta^B_{ZY} + \delta^B_{XZ})$: if $(\delta^A_{XZ} + \delta^A_{ZY}) > (\delta^B_{ZY} + \delta^B_{XZ})$, feature Z is the feature of class A;

$(\delta^B_{ZY} + \delta^B_{XZ}) + (\delta^A_{XZ} + \delta^A_{ZY})$: if $(\delta^A_{XZ} + \delta^A_{ZY}) < (\delta^B_{ZY} + \delta^B_{XZ})$, feature Z is the feature of class B.

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ANALYSIS OF THE SIMULATED ANNEALING METHOD IN CLASSIC BOLTZMANN MACHINES

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ABSTRACT

The paper analyses a model of a neural net proposed by Hinton et al (1985). They have added noise to a Hopfield net and have called it *Boltzmann machine* (BM) drawing an analogy with the behaviour of physical systems with noises. The concept of *simulated annealing* is analysed. The experiment aimed at testing the state of thermal equilibrium for a Boltzmann net with three neurons, specified threshold values and weights at two different temperatures, T=1 and T=0,25, is described.

KEYWORDS

Recurrent networks, Boltzmann machine, simulated annealing, learning algorithm.

1. INTRODUCTION

A classic Boltzmann machine is treated as a neural net defined in (Ackley, Hinton and Sejnowski, 1985). The present paper illustrates concepts of *simulated annealing* and *thermal equilibrium* by an example

of the partial net. The technique of transition probabilities computation at different temperatures is described that makes use of Markov chains.

2. BOLTZMANN MACHINES AND HOPFIELD NETS

Two papers by Hopfield (1982, 1984) were of crucial importance in pointing out the connections between brain model and physical systems. Ackley, Hinton and Sejnowski (1985) proposed a neural model called *Boltzmann machine* that was a cross between a Hopfield network and the computation technique called *simulated annealing* which was described by Kirkpatrick, Gelatt and Vecchi (1983).

To understand Hinton's idea, one should imagine the interpretation of an energy landscape (see Fig.1). Each state of the system could be associated with a point in the energy landscape where there might exist points with either local minimum (E_1) and / or global minimum (E_2).

For the ball to be able to transit from state E_1 to state E_2, changes in the ball energy state are necessary. In the intuitive sense, this is an activation function or the concept of noise proposed by Hinton. The problem is how to find the global minimum of the function. Hopfield networks are efficient for finding local minimums, however, they do not find global ones.

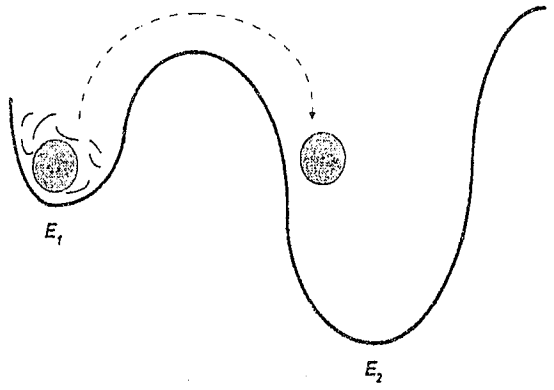


Fig.1. A noisy ball finds the lowest hill.

In real world physical systems, with energy landscape there is associated the concept of temperature. In 19th century, Austrian physicist Ludvig Boltzmann showed that the energy of gas molecules depends on

the temperature. If a system is able to easily transit from one state to another, the most probable configuration of its being in any state could be computed as follows:

$$\frac{P_{E1}}{P_{E2}} = e^{-(E1-E2)/T} \tag{1}$$

Hinton therefore used the name of Boltzmann to convey the idea that the energy of the state of a neural net could be changed depending on the temperature. At t=0 the net behaves similarly as the Hopfield model. Hinton has proposed a network operation mode that could find the global minimum, which is called *simulated annealing*, that is the gradual decrease of the temperature in the network.

3. THE ARCHITECTURE OF BM

In what follows, we will use denotations and a net with three nodes (see Fig. 2). (Alexander and Morton, 1991):

For the above net, the following holds:

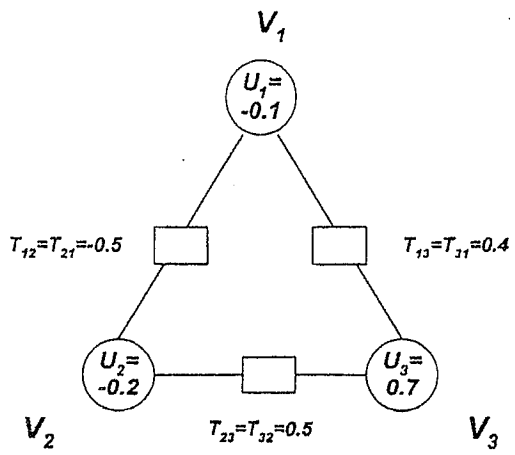


Fig.2. The net nodes.

$V_i=1$, if $\sum_{i\neq j} T_{ij}V_j > U_i$ and

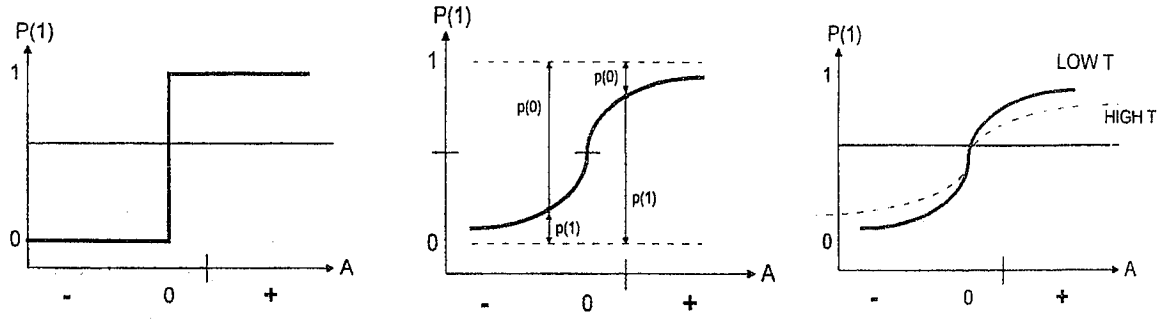
$V_i=0$, if $\sum_{i\neq j} T_{ij}V_j < U_i$ (2)

where V_i stands for the firing state of the neuron ($V_i=0$ when not firing and $V_i=1$ when firing); U_i is the threshold of the neuron and

$$\sum_{i\neq j} T_{ij}V_j - U \tag{3}$$

is the activation of the neuron, T_{ij} being the weight liking neuron i to neuron j.

The effect of temperature might be shown as alternation of probabilities (see Fig.3):



(a) threshold function (b) BFPF (c) BFPF

Fig.3. The effect of temperature on firing probability.

Hinton has shown that Boltzmann function correctly characterizes this effect:

$$p(1) = \frac{1}{1 + e^{\frac{-A}{T}}}$$

We shall refer to this as the Boltzmann firing probability function (BFPF). This function has been plotted in Fig.4 for temperatures of 0,5 and 0,25 (in arbitrary units):

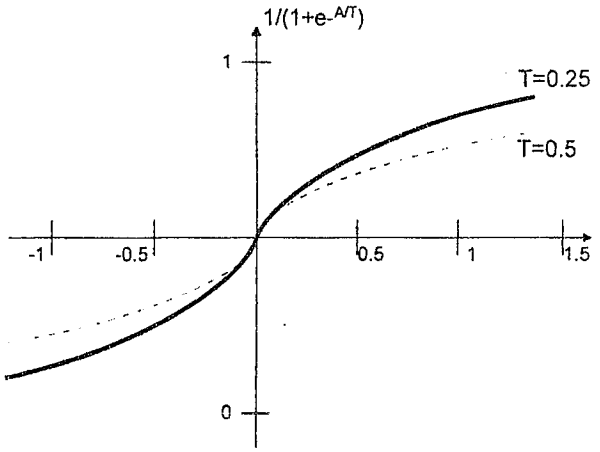


Fig.4. The S-shaped BFPF.

To characterize a BM, the following is required:

(1) Compute activation function by formula (3) for each state $V_1V_2V_3$:

For example: $V_1V_2V_3 = 0\ 1\ 0$.

$A_1 = T_{12}V_2 + T_{13}V_3 - U_1 = -0,5 + 0,1 = -0,4$

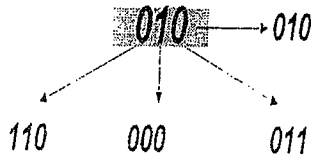
$A_2 = T_{12}V_1 + T_{23}V_3 - U_2 = 0 + 0 + 0,2 = 0,2$

$A_3 = T_{13}V_1 + T_{23}V_2 - U_3 = 0,5 - 0,7 = -0,2.$

(2) Compute probability for each neuron by formula (4) at various temperatures [p (0) = 1- p (1)].

Neuron	T=0.25		T=1.0	
number	p(1)	p(0)	p(1)	p(0)
1.	0.17	0.83	0.4	0.6
2.	0.69	0.31	0.55	0.45
3.	0.3	0.7	0.45	0.55

(3) By using values from point (2), transition probabilities should be computed. In general case, if a network consists of N elements, a neuron might remain in the same state or to transit to N other states.
From state 010 the following transitions could be obtained:



Transition probabilities are computed as follows:

$$\left[V_j(p(1)_j + (1 - V_j)p(0)_j\right] / 3 \qquad (5)$$

Determine probabilities for T=1:

$010 \rightarrow 110 - p(1)_1 = 0,13$

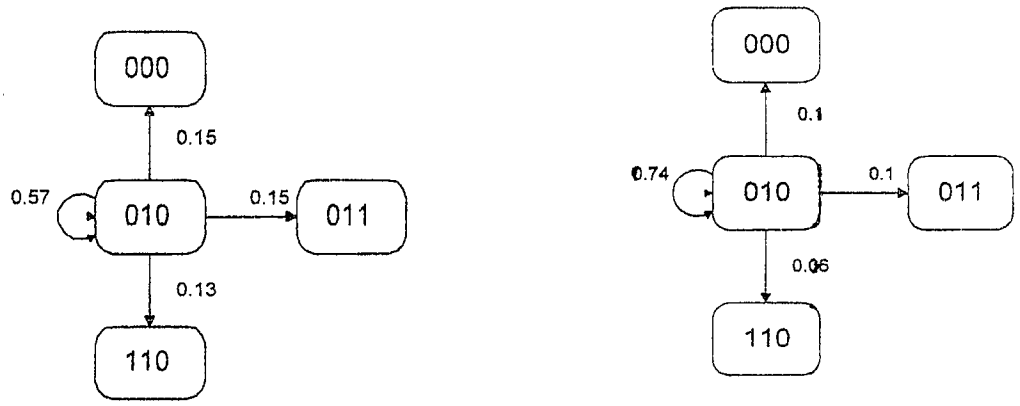
$010 \rightarrow 000 - p(0)_2 = 0,15$

$010 \rightarrow 011 - p(1)_3 = 0,15$

$010 \rightarrow 010 - p = 0,57.$

Application of this formula for state 010 for each neuron at different temperatures is illustrated in Fig. 5.

(4) On obtaining thus transition diagrams for all the states, one could then draw the BM state diagram for each temperature. In practice, however, this is a labour-intensive process, that is why another technique is used. A chain of events S_0, S_1, S_2,..., S_{m-1} is given and a system is known for which the events follow each other with known probabilities p(i, j). The system might be represented as a matrix m×m. This techique is referred to as Markov chain. It enables one to determine the probability of system's being in any state and at any time. The results are given in Table 1 where the number of state is set by a binary number, e.g. S2=010. The shaded column shows the state used for illustration.



(a) Boltzmann behaviour (T=1.0) (b) T=0.25

Fig.5. Transition probabilities at different temperatures.

Table 1

Next State	CURRENT STATE							
	S_0	S_1	S_2	S_3	S_4	S_5	S_6	S_7
S_0	0.55	0.31	[illegible]	0	0.13	0	0	0
S_1	0.02	0.08	[illegible]	0.02	0	0.04	0	0
S_2	0.23	0	[illegible]	0.23	0	0	0.27	0
S_3	0	0.31	[illegible]	0.58	0	0	0	0.17
S_4	0.2	0	[illegible]	0	0.71	0.26	0.26	0
S_5	0	0.3	[illegible]	0	0.08	0.47	0	0.1
S_6	0	0	[illegible]	0	0.08	0	0.24	0.1
S_7	0	0	[illegible]	0.17	0	0.23	0.23	0.63

Markov chain for T=0,25

Next State	CURRENT STATE							
	S_0	S_1	S_2	S_3	S_4	S_5	S_6	S_7
S_0	0.53	0.22	0.15	0	0.16	0	0	0
S_1	0.11	0.35	0	0.11	0	0.13	0	0
S_2	0.18	0	0.57	0.18	0	0	0.2	0
S_3	0	0.22	0.15	0.54	0	0	0	0.17
S_4	0.18	0	0	0	0.56	0.19	0.2	0
S_5	0	0.21	0	0	0.14	0.5	0	0.15
S_6	0	0	0.13	0	0.14	0	0.42	0.15
S_7	0	0	0	0.17	0	0.18	0.18	0.53

Markov chain for T=1,0

It is known that the probability of being in state S_i at time t is $P_i(t)$, so as the probability of being in some state j at time t+1, $P_j(t+1)$ may be worked out by adding up all the probabilities of entering that state, taking into account the probability of being in the previous state:

$$P_j(t+1)=\Sigma P_i(t)\, p(i, j) \qquad (6)$$

For example, say the probability of being in any state at t=0 is 0,125 (that is 1/8). The probability of the system being in state S_3 will be as follows:

$P_3(1) = P_0(0)p(0,3)+P_1(0)p(1,3)+P_2(0)p(2,3)+P_3(0)p(3,3)+P_4(0)p(4,3)+$
$+P_5(0)p(5,3)+P_6(0)p(6,3)+P_7(0)p(7,3) =$
$= 0,125*0+0,125*0,22+0,125*0,15+0,125*0,54+0,125*0+0,125*0+$
$+0,125*0+0,125*0,17 = 0,125(0,22+0,15+0,54+0,17) = 0,135.$

4. STIMULATED ANNEALING

By using the possibility to compute network nodes in any state and at any time, one could observe what happens if the temperature of the network is changed. Let us turn to formula (6) and compute probabilities of being in any network state at time t using a Markov chain for T=1 and T=0,25. The results are given in Table 2.

Starting with equal probabilities (i.e. 1/8), the system then reaches t=7 at the temperature equal to 1. By testing experimentally the next steps, one can conclude that the probabilities are not actually changed at this temperature. According to Hinton, this effect is called *thermal equilibrium*. The probabilities will start changing when the temperature is changed. From Table 2 it is seen that the temperature is decreased

up to 0,25. Thermal equilibrium is reached again at t=15. If we transit to T=0 at this point then a final state of the network could be obtained:

T.	Time	P(0)	P(1)	P(2)	P(3)	P(4)	P(5)	P(6)	P(7)
0	28	0	0	0,494	0	0,313	0	0	0,193

The network is in three states what gives the local minimum of the system. At the end of the annealing process the system is seen to finish in the stable states of the net with a probability related to their energy. If the initial conditions of point (2) are satisfied, then it can easily be seen that state S_2 with the least energy, 0,1 , has the highest final probability, 0,494, state S_4 with the energy 0,1 at the beginning has the final probability 0,313 and, at last, state S_7 has the lowest final probability. For all the other states, the final probabilities are equal to zero.

The aim of Boltzmann approximation was to prove that the final probabilities in partial state greatly depend on the energy of the state.

Table 2

T.	Time	P(0)	P(1)	P(2)	P(3)	P(4)	P(5)	P(6)	P(7)
1.00	1	0.13250	0.08750	0.14125	0.13500	0.14125	0.12500	0.10500	0.13250
1.00	2	0.13326	0.07630	0.14966	0.13586	0.14770	0.12052	0.10211	0.13457
1.00	3	0.13350	0.07198	0.15417	0.13548	0.15002	0.11715	0.10321	0.13450
1.00	4	0.13372	0.07001	0.15694	0.13498	0.15094	0.11487	0.10457	0.13398
1.00	5	0.13396	0.06899	0.15873	0.13461	0.15133	0.11336	0.10555	0.13345
1.00	6	0.13420	0.06843	0.15993	0.13436	0.15151	0.11238	0.10617	0.13302
1.00	7	0.13441	0.06810	0.16074	0.13421	0.15159	0.11172	0.10655	0.13268
0.25	8	0.13054	0.01528	0.20866	0.13741	0.19140	0.09850	0.06050	0.15671
0.25	9	0.12228	0.01052	0.23237	0.13194	0.20334	0.08186	0.05802	0.15866
0.25	10	0.12019	0.00920	0.24609	0.13000	0.20520	0.07376	0.06000	0.15456
0.25	11	0.12024	0.00869	0.25585	0.12913	0.20451	0.06930	0.06104	0.15024
0.25	12	0.12100	0.00845	0.26317	0.12872	0.20314	0.06656	0.06138	0.14658
0.25	13	0.12189	0.00833	0.26875	0.12851	0.20169	0.06473	0.06143	0.14366
0.25	14	0.12272	0.00826	0.27306	0.12842	0.20038	0.06342	0.06137	0.14137
0.25	15	0.12341	0.00822	0.27639	0.12838	0.19926	0.06246	0.06128	0.13959

5. CONCLUSIONS

All the examples used above to analyse the simulated annealig methog might be implemented with the help of either programming language. The computing technique for transition probabilities and thermal equilibrium is necessary for further application in Boltzmann machine learning (Ackley, Hinton and Sejnowsky, 1985; Alexander and Morton, 1991; Kappen, 1995).

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