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STATE-OF-ART REPORT ABOUT WATER TREATMENT AND ENVIRONMENTAL IMPACTS IN RUSSIAN MINING

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State-of-the-Art report about water treatment and environmental impacts in Russian Mining Industry

Abstract

Mining industry has a great impact on the environment including aquatic systems. Therefore, efficient water treatment is an important factor for sustainable development of every mining enterprise.

The study was done for the Finnish company Measurepolis Development Ltd. with the main aim to examine the current situation of water treatment and environmental impacts in Russian mining industry. The identification of the present needs and problems may help Measurepolis Development Ltd. to enter the Russian mining market with proper solutions and perspective technologies.

The Russian legislation controlling the environmental aspects of any activity is described. It includes the main procedure which must be conducted by every mining enterprise and a number of permits which must be obtained by every company whose activity might have a negative impact on the environment. Moreover, there is information about changes in the permit system and transition to the complex environmental permit.

The theoretical part contains the description of standard waste water treatment methods that are used in Russian mining such as mechanical, physicochemical and biological.

The research concerns five mining plants located in the South and Central parts of the Russian Federation. Description of water treatment facilities and methods which are used by these mining companies is provided. The assessments of water quality of the water bodies located close to the mining sites and that might be affected by waste water discharge or in any other ways were also performed.

As a result of this study, a negative impact of the mining plant on the environment is identified. The amount of contaminants in waters does not conform to the official requirements and exceeds the threshold limit values. Water treatment facilities and methods applied do not generally treat waters sufficiently because of their old conditions.

Subject headings, (keywords)

Mining, water treatment, Russian mining, environmental impact

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CONTENTS

1. INTRODUCTION

This chapter is intended to identify the background of the study, describe the methods and formulate the goals. The results of the work can be found in the chapters that follow, and they are based on the systematic study which involves the collection of state-of-art information, its analysis and comparison, making conclusions and possible proposals.

Concern for the environment and efforts of sustainable development of an enterprise has become one of the key questions for many industries. Since mining is a significantly polluting industry, it may have a great negative impact on the environment. Its activity destroys kilometers of land and discharges tonnes of contaminated water. Introduction of appropriate treatment facilities at a mining plant can minimize the adverse effect.

This report was written as a bachelor`s thesis of Environmental Engineering programme of Mikkeli University of Applied Sciences in Spring 2014. The study was conducted for a Finnish company within the frames of the internship during October - November 2014. *Measurepolis Development Ltd*. is a company which is owned by the City of Kajaani, and it operates internationally and employs ten technology and business experts in the cities of Kajaani (HQ), Kuopio, Oulu, Tampere and Espoo. *Measurepolis Development Ltd.* manages regional and national development programs in the area of measurement and information technology. The company produces technology, business development, information, marketing and communication services for its partners and customers. More information about the company can be found in Appendix 1. /1/.

The activity of *Measurepolis Development Ltd.* is divided into three directions: business development, development of technology and programs development. Moreover, it corresponds to different business areas such as forest industry, intellectual property rights and others. The new and perspective direction for the company business is mining and a new business area is Russian territory. Initially, *Measurapolis Development Ltd.* can provide new solutions for better control and decreasing of negative environmental impact for mining companies. Therefore, there arose a need to investigate the present Russian mining market in order to learn the problems to be solved and the needs to be fulfilled. The boundaries were identified and the key topic of research has become water treatment in the Russian mining industry and its impact on the environment.

The research of the Russian mining market was conducted. Approximately 200 companies that operate in this area were selected. They include mining plants, research institutes, geology companies etc. The task involved contacting by e-mail and telephone in order to offer cooperation with *Measurapolis Development Ltd*. However, only a limited number of responses were acquired. The monitoring of exhibitions, their participants, finding of new trends in mining water treatment and investigation of Russian research institutes was performed during the research process. The obtained information about the current situation in water treatment of Russian mining industry is represented in the following chapters.

2. WATER POLLUTION AND MINING INDUSTRY

Water is essential for life of every organism on the Earth. Therefore quality of our lives depends on the quantity and quality of water resources. Water pollution is contamination of different water bodies. Decrease in contamination of various water bodies is an important part of sustainable development. However, water quality is constantly deteriorating and reaches such levels of pollution, where the use of water for different purposes is very limited or water may be harmful to humans. This deterioration is due to the socio-economic development within the river basin. However, now even remote areas may be exposed with indirect contamination. /2/.

In most cases contamination of fresh water is invisible because pollutants are dissolved in water. But there are exceptions such as foaming detergents, floating on the surface of oil and raw sewage. However, there are several natural pollutants. The aluminum compounds which lie in the depths of the soil fall in freshwaters by chemical reactions. Floods wash out of the soil magnesium compounds that cause great damage to fish stocks. /3/. However, the amount of natural contaminants is negligible compared with human one. Annually thousands of chemicals with unpredictable effects fall in water basins, many of them are new chemical compounds. High concentrations of toxic heavy metals (such as cadmium, mercury, lead and chromium), pesticides, nitrates and phosphates, oil, surfactants, drugs and many others can be detected in the waters. One more reason of increased concentrations of heavy metals in water is acid rain. It is capable of dissolving minerals in the soil, which leads to increasing the heavy metal ions in the water content. The radioactive waste falls in water cycle from nuclear power plants. Discharge of untreated wastewater into water sources leads to microbiological contamination. According to the World Health Organization (WHO), /4/ 80% of diseases worldwide are caused by improper quality and unsanitary water. In rural areas, water quality problem is particularly acute - about 90% of the rural population in the world regularly use for drinking and bathing water which is contaminated. Pollutants are released into fresh water in various ways: as a result of accidents, deliberate discharges of waste, spills and leaks. /4/.

The main reason of water pollution is anthropogenic. The rush development of every industry has significant effect on water quality. Mining is one of the most polluting industries. Mining can have adverse effects on surface and ground waters by heavy use of water and contaminated discharge from this industry. In mining simultaneously with minerals extraction there is a huge water extraction which volume is several times greater than the volume of water consumption by this industry. Therefore to create undrained system at mines is not possible. However, part of water is reused. Water has to be gone through the proper treatment system in order to be discharged into water bodies without pollutants. /5/.Continuous transfer of mining operations to deeper levels leads to increasing the volume and contamination with different substances of simultaneously extracted water. Requirements to quality of water treatment when water is discharged to water bodies and when water is reused determine the wide usage of different water treatment methods and technologies. Apart from organic contamination and mechanical impurities, mine waters are characterized by high salinity that limits their use in complex industry without proper treatment as well as it is a real danger of contamination to surface and ground waters.

When coal or ore deposits are extracted there is a deformation of the layers that results into the land surface subside and water flood. /6/.

Mining impacts on water can be divided into following types:

- acid mine drainage (producing of sulfuric acid);
- heavy metal contamination and leaching;
- processing chemical pollution;
- erosion and sedimentation /6/.

The rate of water contamination in mining depends on the following factors:

- type of ore extracted;
- chemical used in mining extraction and mineral preparation;
- climate and seasons;
- life stage of mine (construction, open, closed);
- environmental management of enterprise etc /7/.

Waters which are contaminated with high concentration of different substances such as heavy metals, sulfates and salts, have negative effect on hydrosphere, aquatic ecosystem. It affects negatively on aquatic life. As example there might be change in species, problems with reproduction, increase of mortality. Human health problems can also occur if this water is used for supply or irrigation purposes. Therefore contamination of water results into necessity of additional water treatment. /7/.

3. ENVIRONMENTAL LEGISLATION IN RUSSIAN MINING

The system of Russian legislation is very strict and complicated. Before an economic or another activity starts it is necessary to get various types of permits and licenses. In mining industry this set of permissions includes a permit to use mining equipment, a license to operate the facilities that are highly explosive, a permission for the use of technical devices or equipment, a license for construction activity, a permit for geological mining prospects and land measuring, a license for explosive activity, a license for subsoil use and others.

The most important issues of environmental legislation are State Environmental Expert Review ("Ecological Expertise"), or SER, Environmental Impact Assessment, or EIA, and several permits. Two main Federal laws are the Federal Law No. 174-FZ, *On Environmental Expert Review* (“Environmental Expert Review Law”) /8/ and the Federal Law No. 7-FZ *On Environmental Protection (* “Environmental Protection Law”) /9/.

3.1. State Environmental Expert Review and Environmental Impact Assessment

Based on Environmental Expert Review Law /8/, Ecological Expertise is establishment of correspondence of the documents that justify economic or another activity with environmental protection requirements in order to prevent the negative impacts of such activities on the environment. In simple words, before starting any activity a company must prove that its activity doesn’t violate environmental protection requirements. There are two types of SER in the Russian Federation: State Environmental Expertise and Public Environmental Expertise. /8/. The first one is obligatory for objects of construction, re - construction, major repairs. It is organized and carried out by the Federal Executive Body in the field of environmental expertise and State Government Bodies of constituent entities of the Russian Federation. The construction and operation of various facilities are permitted only after getting a positive conclusion from the unified State Environmental Expert Review (SEER) with respect to the relevant project documentation and proposed activity. A positive SEER report is a necessary precondition for financing and implementing any project that might have an impact on the environment /8,10/. The consideration term of the State Ecological Expertise is:

- for simple objects - up to 30 days;
- for objects of medium complexity - up to 60 days;
- for complex objects - 120 days /8, 11/.

However, the term of the State Environmental Expert Review may be extended but cannot exceed six months for complex objects. Public Environmental Expertise is conducted very rarely in the Russian Federation /8,11/.

Russian environmental legislation also requires the performance of an Environmental Impact Assessment prior to the implementation of a project of any economic or other activities that may have an impact on natural resources. The EIA evaluates possible negative environmental impact and ecological consequences and develops measures for decreasing or preventing such adverse impacts. Environmental Impact Assessment results are documented in the materials prepared during this procedure. They are part of the documentation submitted to the State Environmental Expert Review. /12,13/.

3.2. Environmental permits

In the Russian Federation any economic or another activity that may have a negative impact on the environment is subject to issuance of a special permit. Mining industry is not an exception. Environmental permits allow an enterprise to conduct any activities that may have a negative impact on the environment. /12, 14/. They include:

- permits for general use of natural resources;
- permits for specific negative impact on the environment /12, 14/.

An environmental permit is not issued with respect to specially protected zones of high ecological importance. Any activity on such a territory is prohibited. /12, 14/.

3.2.1. Permits for general use of natural resources

Subsoil Use license is the main permit in the mining industry. However, Water Use Permit also plays an important role in this activity because a large amount of water used in a mining process is supplied from the nearest water body. According to the Russian Water Code, the right to use water bodies which are under federal or regional ownership can be granted either on the basis of a water use agreement or a decision of the relevant authority to grant water use rights. /12, 14/.

Subsoil usage is regulated by Federal Law No. 2395-1-FZ, *On Subsoil* /15/.The license for subsoil use is issued by the Federal Agency for Subsoil Use and attests the right of its holder to use subsoil on a certain territory, during a certain term and for certain purposes. This type of license is given for up to five years. The Federal Service for Supervision of Natural Resources Use conducts state control of subsoil management. Failure to comply with the terms of the subsoil license leads to charges, penalties, suspension or revocation of the subsoil license. /12, 15/.

3.2.2. Permits for specific negative impact on the environment

In order to have the right to emit hazardous substances into the atmosphere an enterprise is required to get the Air Pollution Permit. This permit is a positive conclusion on the project of the maximum permissible emission levels of the applicable hazardous substances. The air pollution permits are issued by the Federal Authority Rosprirodnadzor or by its regional branches. The official term of permit agreement by governmental authorities is five months. The Air Pollution Permit is issued for up to five years. /11, 12, 14/.

In order to collect, transport and/or dispose waste any company including mining enterprises is required to get the Waste Treatment Permit from Rosprirodnadzor that includes:

- a positive conclusion of SEER with respect to project documents for waste treatment facilities;
- established limits for the amounts of waste disposed;
- a waste management license or service contract with a company which has a waste management license;
- a passport of hazardous waste if applicable /11/.

The official term of agreement by governmental authorities is 30 days. The Waste Treatment Permit is issued for up to five years provided that the immutability of the production process and raw materials used is annually confirmed. /11,14/.

The right to discharge harmful substances into water bodies requires the Water Discharge Permit that sets out the maximum allowable concentration of the applicable harmful substances. The official term of agreement by governmental authorities is 30 days. The Water Discharge Permit is issued by Rosprirodnadzor for up to three years. /11,14/.

3.3. Complex Environmental Permit

According to the Federal Project No. 584587-5-FZ *On the alterations in the Federal Law On Environmental Protection and separate pieces of Russian legislation that concern the introduction of complex solutions and implementation of the Best Available Technologies (BAT)* /16/ and to the personal response №10-50/6006-05 from Mr. Inamov (Ministry of Natural Resources and Environment) /17/, nowadays it is decided to issue the Complex Environmental Permits with respect to a certain group of enterprises which are today the most polluting companies discharging and emitting not less than 50% of the total waste and emissions through the country (150-200 enterprises). In mining industry there are such enterprises as some mining plants owned by Severstal JSC., Gasprom JSC., Apatit Ltd., Lukoil Zapadnaya Sibir Ltd, Yujno-Uralskiy Nikelevskiy kombinat LTD, Visokogorskiy GOK Ltd and many others /18/. With respect to other enterprises it is offered to give complex permits on voluntary basis.

After development of this mechanism, it is proposed to spread this test model through other working enterprises starting from 2021. Today the Ministry is specifying the criteria to define the program parameters of increasing the environmental efficiency for these enterprises while issuing them the environmental permits. /17/.

According to the new article 31.2 *Complex Permit on Negative Impact on the Environment* of the Environmental Expert Review Law /16/, the Complex Permit includes:

- established limits of permissible emissions of hazardous substances and discharged pollutants;
- temporarily allowed emissions and discharges of pollutants;
- allowable levels of physical impacts;
- limits for waste disposal of consumption;
- agreed program of Best Available Technologies implementation;
- agreed program of production environmental control;
- requirements for handling production and consumption waste;
- requirements for payment of charges for a negative impact on the environment;
- positive conclusion of SEER;
- term and conditions of the extension and revision of the Complex permit /16/.

The official term of agreement by governmental authorities is up to four months. The Complex Permit on Negative Impact on the Environment is issued for up to ten years. /16/.

Introduction of the Complex Permit is a key change in the range of legislative initiatives in the field of environmental protection and the most important in providing ecological safety of the country and technological modernization of Russian industries /17/.

3.4. Principle “pay to pollute”

Environmental legislation of the Russian Federation includes the principle “pay to pollute” that means in order to obtain permits companies have to pay respective fees for such permits for negative environmental impact caused by their activities:

- discharge of pollutants or any other substances into water bodies;
- emission of pollutants or any other substances into the air;
- disposal of waste;
- pollution of soil and subsoil;
- any other pollution with heat, noise, radiation etc /12/.

These principle “pay to pollute” payments are considered to be a financial tax, not a fine or sanction. In addition, the enterprise is obliged to recover any environmental damage which is caused by its activity. /12/.

4. ENVIRONMENTAL MONITORING IN RUSSIA

State environmental monitoring is conducted by the State Authority of Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet). The state environmental monitoring network solves the following problems:

- observing the level of the pollution of air, soil, water and sediments in rivers, lakes, reservoirs and seas by physical, chemical and hydrobiological indicators in order to examine the distribution of pollutants in time and space, assess and predict the environmental conditions, determine the efficiency of actions for its protection;
- provision of the government, business organizations and the population with systematic and emergency information about the changes in levels of pollution of air, soil, water bodies under the influence of economic activity and meteorological conditions;
- provision with the materials enabling to formulate the recommendations in the field of environmental protection and rational use of natural resources and economic development /19/.

Nowadays the State environmental monitoring network includes the following main types of observation of:

- air pollution in urban and industrial centers;
- pollution of soil with pesticides and heavy metals;
- pollution of surface waters and seas;
- transboundary transfer of air pollutants;
- environment pollution and vegetation status;
- chemical composition and acidity of precipitation and snow cover;
- background air pollution;

- radioactive contamination of the environment /19/.

The principles of the organization and carrying out regular observations are the following:

- complexity and systematic character of the observations;
- coordination of terms of the observations with typical hydrological situations and changes of weather conditions;
- definition of indicators by uniform procedures on the whole territory of the country /19/.

The environmental monitoring system is based on the network of monitoring observation points which are set in cities, on lakes and rivers in areas with high anthropogenic impact and in unpolluted areas /19/.
In the system of the Federal Agency of Water Resources state monitoring of water bodies is carried out with the following purposes:

- timely detection and prediction of negative processes which affect the water quality and the conditions of water bodies;
- development and implementation of measures to prevent the negative impact of these processes;
- assessment of the effectiveness of protection measures;
- information provision for proper management and control in the field of use and protection of water bodies /19/.

State monitoring of water bodies includes:

- regular monitoring of the condition of water bodies, quantitative and qualitative indicators of surface waters and groundwater;
- collecting, storage, updating and processing of observation data;
- creation and maintenance of data bases;
- assessment and prediction of changes in the conditions of water bodies, quantitative and qualitative indicators of surface water and groundwater /19/.

State monitoring of water bodies involves monitoring of surface water, groundwater bodies, hydroeconomic systems and structures.
The State Report about Environmental Situation in the Russian Federation is published every two or three years. Moreover, there are detailed reports in every region of Russia. They are in free access: paper versions are available in city libraries and electronic versions are published in the State Internet Portals.

In 2011 the first vice president of Russian Geographical Society Mr. Kasimov approved of the Project of Implementation of the Technological Platform "Environmental Technology Development" /20/. This project includes a paragraph devoted to technologies and systems of monitoring, assessment and prediction of environmental conditions, emergencies, negative impact on climate change, including innovative tools of pollution control. The main products of the Technological Platform are the following:

- technologies and systems of assessment of aquatic and terrestrial ecosystems, recovery of resource potential (soils, biological resources, water resources) in the areas with high anthropogenic influence;
- technologies of environmental monitoring and forecasting the state of the environment in large industrial cities and in specially protected natural areas;
- technology and environmental monitoring system (observation) of coastal zones, waters and ground waters;
- technology of instrumental control of emissions / discharges of pollutants in the atmosphere, water bodies and soil;
- technology of production, transmission and use of information about the state and change of the environment;
- technologies and systems for early detection and prediction of emergency situations;
- environmental risk management technology in offshore oil and gas fields in the waters;
- technologies and systems of preventing the cross-border negative impact on the environment;

- technologies and systems for monitoring of environmental impacts on the climate change /20/.

The existing system of State Environmental Monitoring requires modernization and development basing on modern technologies, primarily on the use of autonomous automated control systems. The usage of mechanisms of Best Available Technologies (BAT) indicators which are adopted in European Union requires from industries and control agencies using modern tools of instrumental control of waste discharge /20/. It is necessary to implement automatic wireless instrumental equipment and monitoring stations in environmental water monitoring. Different tools are used in this field such as a system warning about the increase in water level, a flood alarm system, a monitoring station floating in water, an ultrasonic inspection system of water consumption etc. The main demand in water monitoring includes technologies and tools which indicate quality and composition of water: level of surface and ground waters, integral indicators of quality and composition of water (pH, temperature, turbidity, suspended solids, RedOx-potential, oxygen demand, heavy metal or petroleum content etc.), meteorological indicators. /21/.

5. BASIC WATER TREATMENT METHODS IN RUSSIAN MINING

Because the volume of water in mining is very huge this aspect becomes very important. Waters are differed into several types:

- mining waters – waters come into contact with any mine workings;
- quarry waters – any surface or groundwater present at the mine site formed at open mine;
- processed or technological waters – used technological processes of mine plant;
- leachate waters – leaks through solid mine storage wastes and may contain dissolved minerals, process chemicals, metals and other contaminants.
- drainage waters – surface or ground waters which flow or have the potential to flow off the mine site;
- waste waters /5, 7/.

Waste water is known as water that becomes unsuitable for further use after single or repeated usage in industrial processes and has to be treated and discharged. However, all waters which are discharged into municipal treatment plants must meet certain requirements in order not to impair the operation of facilities and deteriorating operating conditions. These requirements are the same not depending on types of water /22/. The main ones are the following:

- water should not be aggressive to the materials of sewer networks, structures and equipment
- water should not contain impurities such size and specific weight, which could clog the sewer network or deposit on the bottom and on the walls of pipes;
- water should not contain as impurities combustibles (petrol, oils, esters etc) or dissolved gases which can form an explosive mixture in the pipes and sewer ducts in the receiving reservoir, pump stations and water treatment;
- temperature of water at the release site must not exceed 40 C /22/.

The conditions of discharge of mining waters into surface waters (rivers, lakes, reservoirs, sea) are regulated by the "Rules of the protection of surface waters against contamination caused by sewage" /22/. Although these rules allow some deterioration of water quality in water bodies after the discharging of waste water into them, it should not affect the life of the water bodies and on the possibility of their further use as a source of water for the needs of the population. According to these rules it is prohibited to discharge such waste waters as:

- containing stable compounds that are not subjected to biochemical, chemical and physical processes of self-purification, as well as radioactive substances;
- waters that might be used in use recycled water system in compliance with the technical and economic conditions;
- containing valuable waste that can be recycled/22/.

Concentration of most different organic and mineral substances, which are contained in the waste water discharged into water bodies, is standardized by governmental authority. In Russian mining industry Threshold Limit Value (TLV) for fishery water bodies is used for assessing polluted compounds in waste and other waters. They are the same for the whole territory of the Russian Federation. In Finland limit values are calculated for each case. The drinking water criteria are more appreciated in Finland. The comparison of water criteria for human consumption in Russia and Finland is shown in Appendix 2. Threshold Limit Values of the most popular substances in mining industry are shown in Table 1 /23/.

TABLE1. Threshold Limit Value for fishery water bodies./23/.

Name of pollutant	**Russian TLV,mg/l**
BOD	3
Petroleum products	0,05
Suspended solids	0,25
Dry matter	1000
Sulphates	100
Chlorides	350
Phosphorous	0,2
Total nitrogen	0,7
Ammonium nitrogen	0,5
Ammonium ion	0,5
Phenols	0,01
Nitrates	0,02
Surfactants	0б1
Iron	0,1
Copper	0,01
Zink	0,01
Nickel	0,01
Aluminium	0,01

Magnesium	40
Manganese	0,01
Methanol	0,1
Nitrite	0,08
Turpentine	0,2
Fluoride	1,5
Formaldehyde	0,01
Potassium	50
Calcium	180
Kraft lignin	2
Lignosulphate ammonium	1
Sodium	120
COD	15
Lead	0,06

Water treatment is water processing with the purpose of destroying or removing certain substances which are prohibited to be discharged into water bodies according to the Russian legislation or to be used in industrial water supply instead of fresh water. There are the following methods of waste water treatment:

- mechanical;
- physicochemical;
- biological /22/.

Mechanical treatment is used for removal of insoluble particulate matter which precipitates under the gravity force if its density is greater than water density and rises to surface if its density is smaller than water density. With the accumulation of precipitated or suspended contaminants they are removed.

Mechanical methods include separation of coarse dirt on lattices or sieves, sedimentation and filtration. *Filtration* in mining processing is a method of separation of two-phase slurry using a porous wall (filter) which holds the solid phase and transmit the liquid phase. This process is accompanied with formation of sludge cake in front of the filtering wall and filtrate behind it. These methods are used in the mining industry due to the fact that waters of mining enterprises are usually contaminated with products of disintegration ore and enclosing rock, and waters of oil producing companies are contaminated with oil products /22, 24, 25, 26/.

In clarification, waters which contain fine impurities are first aggregated with reagents: coagulants and flocculants. Whereas *clarification* is technological processing of slime waters of mining enterprises under gravity or centrifugal force, thickening of obtained slime sludge and separating it. Clarification is also called the process of separation of liquid and solid phases of the suspension (slurry). Depending on the technical requirements, water clarification is conducted to different degrees by sedimentation, filtration, centrifugation and flotation. Sedimentation and flotation are the most widely spread processes. /22, 24- 26/.

Sedimentation is a technological process division of coarse liquid system (e.g. slurry) into its component phases under the gravity. In the process of sedimentation, particles (droplets) of the dispersed phase drop out of liquid dispersed medium into the sediment or rise to the surface. Sedimentation as a technological method is used for treatment of waters from solid impurities. Efficiency of sedimentation rises with increasing of the difference in density of the separated phases and the particle size of the dispersed phase. In this process there should neither be any intensive mixing, strong convection currents nor any evidence of structure formation that prevents from sedimentation. /22, 24- 26/.

Flotation is a process of separating fine solid particles (mainly mineral) in an aqueous suspension (slurry) or in a solution, which is based on selective concentrations (adsorption) of particles at interfaces in accordance with their surface activity, or wettability. The hydrophobic (poorly water-wettable) particles are selectively fixed on the interface (usually of water and gas) and separated from the hydrophilic (water wettable fine) particles. Flotation is one of the main methods of mineral processing and is also used for water purification from organic substances (petroleum, oil), bacteria, fine precipitation of salts, etc. /22, 24- 26/.

Physicochemical methods are most commonly used ones. Selection of specific ways of water treatment depends on the composition of the dissolved substances and applied technology of mineral processing. In mining industry the reagent, sorption, electrochemical and other physicochemical methods of water treatment are used. *Reagent methods* include neutralization of acids and bases, transfer of ions into slightly soluble in state etc. *Sorption methods* consist of the separation of organic and inorganic contaminants on natural or synthetic sorbents and also the use of ion-selective materials. *Electrochemical methods* (electrodialysis, electrochemical oxidation and hydrolysis) are methods that are related to the exposure of electric current to the aqueous solution. Typically, electrochemical water treatment, as well as oxidation of the impurities (ozonation, chlorination), is related to destructive methods in which impurities are destroyed. *Destructive methods* are used in case of failure or economic unreasonableness of impurities extractions from the waste water. The use of other, so-called *regeneration*, water treatment methods allows not only neutralizing waste water but also deriving valuable impurities from these waters. Return of extracted impurities back to production reduces the loss of valuable mineral components, reagents and auxiliary materials and often makes the process of water treatment profitable. The prospect of a low-waste production on mining enterprises increases the importance of using regenerative methods of water purification. To these methods are included a number of physicochemical ones: extraction purification based on the extraction of pollutant with special solvent, distillation, rectification, adsorption on solid sorbents, froth flotation and others, all mechanical methods. *Rectification* is a physical process of separation of liquid mixtures onto almost pure components or fractions which differ with boiling points. *Adsorption* is taking up of individual components of the gas (steam) or liquid mixtures on the solid surface or liquid. /22, 24- 26/.

Biological methods are used for the treatment of municipal wastewater of enterprises and in some other cases. These methods are based on the ability of microorganisms to use during the life many organic and inorganic compounds and remove them from wastewater. In particular, the biological method is used for sewage treatment of flotation plants from flotation surfactants. During the biological purification the toxic substances are converted to harmless oxidation products: water, carbon dioxide, etc. As a rule, biological treatment is the final stage of wastewater treatment, there is range of other methods of water purification before biological one. Today biological methods are the most effective and technological. Aeration stations are related to these methods of water treatment. Stations of deep biological purification do not accumulate dirt; they clean water up to 99%. Biological treatment is a process of decomposition of organic pollutants by microorganisms. Bacteria use organic substance as nutrition. Substances, oxidized, break down into harmless inorganic compounds. /22, 24- 26/.

One or the other method of treatment of liquid mining waste can only be selected based on the study of its structure and properties, appropriateness of its regeneration or disposal and also after clarification of types and volume of water body, its economic importance and usage particularity to determine the possible discharge. /22, 24- 26/.

Set of engineering structures where the wastewater is treated from contaminants called water treatment facilities. Such facilities and water purification schemes are based on the volume and composition of treated water, requirements to completeness and economic considerations. /22/.

6. WATER TREATMENT AND ENVIRONMENTAL IMPACTS IN RUSSIAN MINING

In this chapter the contemporary situation of water treatment of Russian mining industry and environmental impacts of their activities is represented on examples of several mining enterprises (GOK - Mining and Processing Plants) which are located on the Russian Federation territory.

6.1. "Gorevsky GOK" JSC

Gorevsky GOK operates in the Krasnoyarsk region territory. The main activity is the creation of mining and metallurgical industries; and main production is mining and processing of lead-zinc ore of Gorevsky deposit. /27/.

GOK has the rights on practicing in Gorevsky deposit which is located on Motiginskiy District of Krasnoyarsk region (Figure 1) /28/.

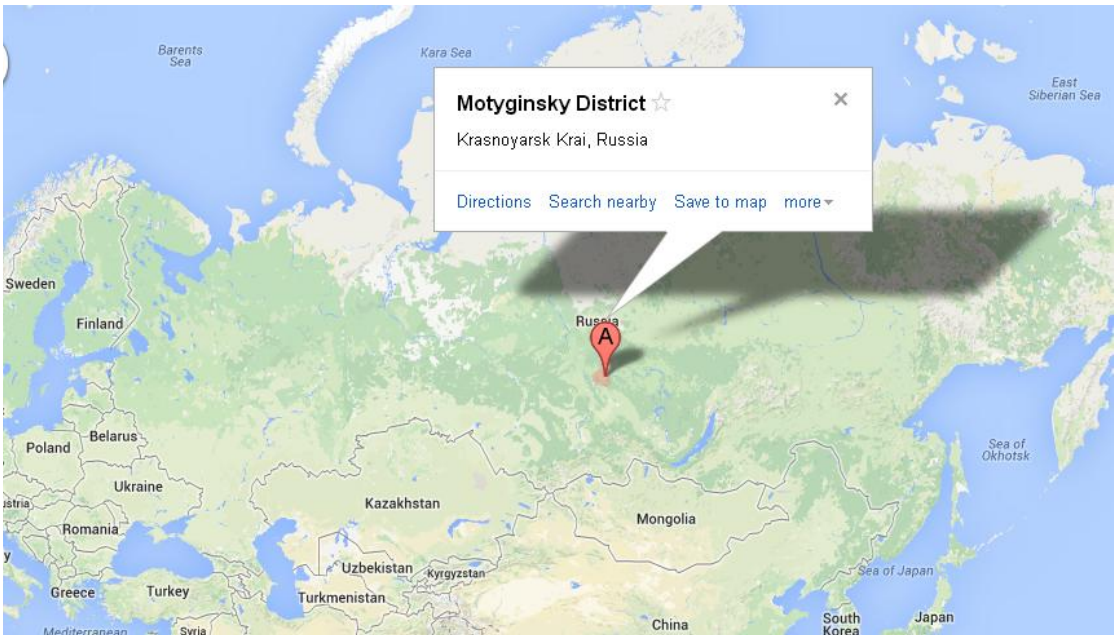

FIGURE1. Motiginskiy District of Krasnoyarsk region. /28/.

The company is among the five world leaders in the production of lead and zinc ores. The volume of production and processing of lead-zinc ore is 2.5 million tons per year with prospects of increasing to 4 million tons. Commodity output of enterprise is lead and zinc concentrates. Developed deposit is unique in ore reserves and ore quality. On 1^{st} January the deposit reserves are the following: 114.14 million tons of ore, 7.42 million tons of lead, zinc 1.83, 5879.3 tons of silver. The deposit is extracted in difficult mining conditions: part of the ore deposits is located under the bed of the Angara River; their extraction is protected by a waterproof dam. /27/

6.1.1. Water treatment of Gorevsky GOK

Functionality of the water treatment facility is to clean up the quarry waters of Gorevsky GOK with ensuring the quality of treated wastewater to the level of discharge requirements to fishery water bodies. The structure of the water treatment facilities includes the following objects:

- water treatment station/ plant;
- transformer substation;
- reservoirs of purified water;
- reservoirs of water after the filter;
- pumping stations № 1,2,3 /29/.

Scheme of quarry waters treatment includes two steps. Waters from mine are pumped to the treatment plant by the pumps of the industrial pump station. Treated waters are discharged by gravity into Angara River. Waste waters after filtration in filters of treatment plant are gone by gravity to the industrial pump station wherefrom they are moved by pumps to the tailings storage. /29/.

Reservoirs of treated water of 100 m^3 volume are designed for storage of fire water, supply of water for washing the filters and to adjust the discharge of treated water in a river. Reservoirs of water after the filter are designed for averaging the amounts of wash water for the uniform supply to pumping stations № 3. /29/.

Water is treated with mechanical method: sand filtration. There is a high-speed open two-layer filter in Gorevsky GOK water treatment facilities. Loading of two-layer filter (Figure 2) consists of crushed anthracite with thickness of 0.5 m with the grain size of 0.8-1.8 mm, located below a layer of quartz sand thickness 0, 7m with grains 0.5-1.25 mm. This filter also includes reagent treatment that allows minimizing the content of suspended solids to 1.5mg/l. /5/.

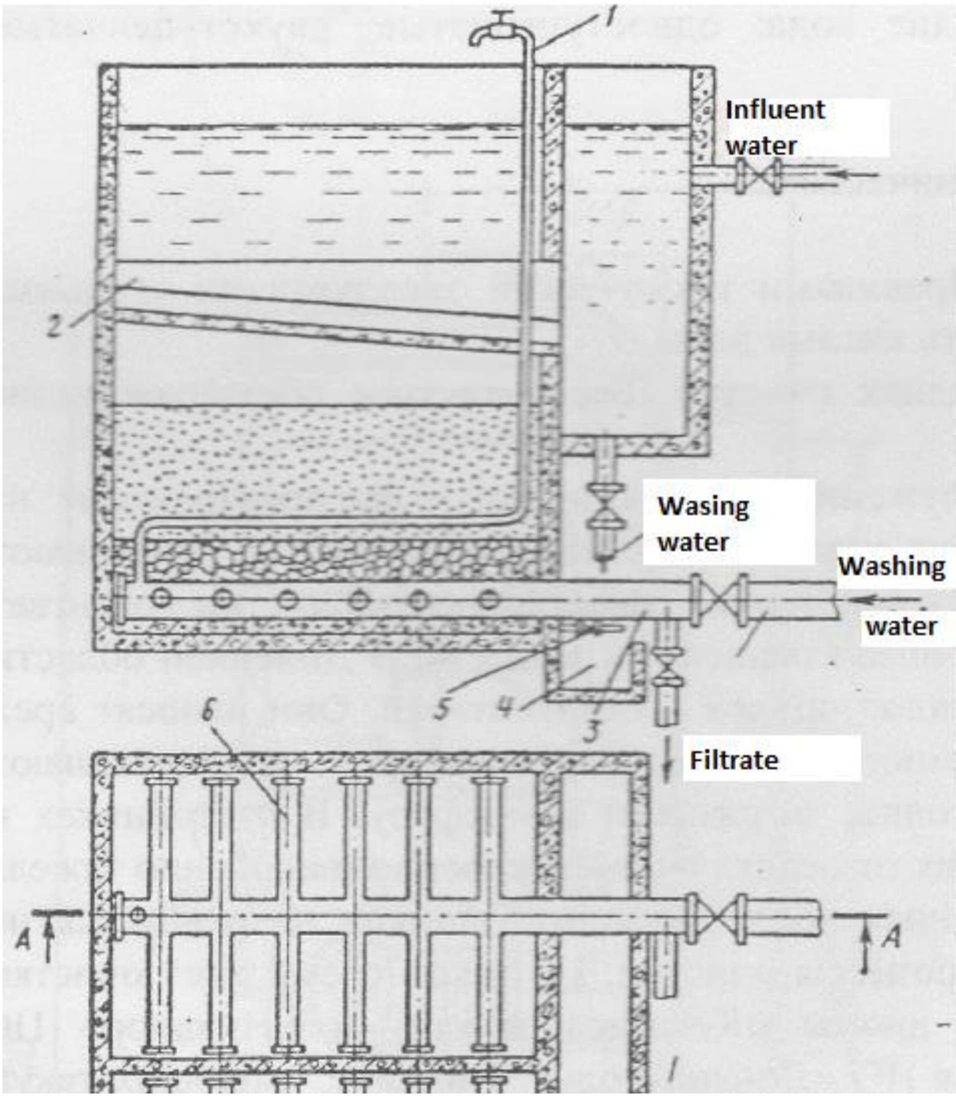

FIGURE 2. Scheme of high-speed open filter. 1 – vent pipe; 2 – combined trough; 3 – combined manifold of distribution system; 4 – tray for draining the washing water; 5 – tube for emptying the filter; 6 – branch of the distribution system. /5/.

The filters are periodically washed with filtered water which is supplied under the necessary pressure into the distribution system. It is better to use the air-water washing. Water treatment facilities are located on the territory of industrial site of Gorevsky GOK: on the left bank of the Angara River, 40 km from the mouth. /29/.

6.1.2.Environmental impact on water resources by Gorevsky GOK activity

According to the reports of Krasnoyarsk Regional Public Ecological Organization "Plotina" /30/ which made several studies on the ecological situation of Angara River, Gorevsky GOK activity has quite negative impact on water bodies in the nearest territories. The results of inspection in 2010 showed that waters in creek Kartichny which joins the Angara River and is the nearest water body to Gorevsky GOK are turbid and brownish. Bottom and coastal areas of creek are covered with sediments of unknown composition (30-50cm) having a viscous consistency. Color of sediments is grayish and it is looks like a cement. (Figures 3 and 4). /30/.

FIGURE 3. The difference between right area where mine is located and other territory. /30/.

FUGURE 4. Sediments in Kartichny creek. /30/.

In the study /30/, results of water samples in the creek Kartichny were the following:

- concentration of zinc is 0.12 mg / l (threshold limited value - 0.01 mg / l) and 12-fold TLV ;
- concentration of lead is 0.6 mg / l (threshold limited value - 0.006 mg / l) and 100-fold TLV;
- concentration of iron - 5.6.mg / l (threshold limited value - 0.1mg / l) and 56-fold TLV /30/.

Water of tributary Angara River (creek Kartichny) with lead concentration (100xTLV), iron (56xTLV), zinc (12xTLV) corresponds to the situation of ecological disaster /30/.

The water samples were also taken in Angara River new Gorevsky GOK location. There was also exceeding of threshold limited value: zinc concentration exceeded in 3.6 times, lead concentration – in 15 times, iron concentration - 23 times that also corresponds to ecological disaster zone. /30/.

In that year the compliance with the environmental requirements of Gorevsky GOK was also checked by governmental authority Rosprirodnadzor. As a result, the audit of Rosprirodnadzor found that the company in the process of its production activity discharged the quarry water into the Angara River. According to the protocols of laboratory studies (quantitative chemical analysis) the influence of discharged quarry waters on water quality in the Angara River was revealed. The Authority instituted administrative proceedings and imposed a fine with respect to legal entity “Gorevsky GOK” JSC. /30, 31/.

Unfortunately, the fine hasn’t had any influence on the actions of the enterprise and the situation hasn’t changed. During the summer 2013 Krasnoyarsk Regional Public Ecological Organization “Plotina” was monitoring the state of tributaries Angara River which were affected by mining activities. Rosprirodnadzor also conducted an examination of these water bodies. The results were a basis for filing a lawsuit in Krasnoyarsk Region court. /30/.

6.2.Sibay branch of “Uchalinsky GOK” JSC

Sibay branch of “Uchalinsky GOK” JSC (Sibay GOK) was formed in September 2004 by the use of the property complex of “Bashkir copper and sulfur plant” JSC. It is located in Sibay town in Republic of Bashkortostan (Figure 5). /28,32/.

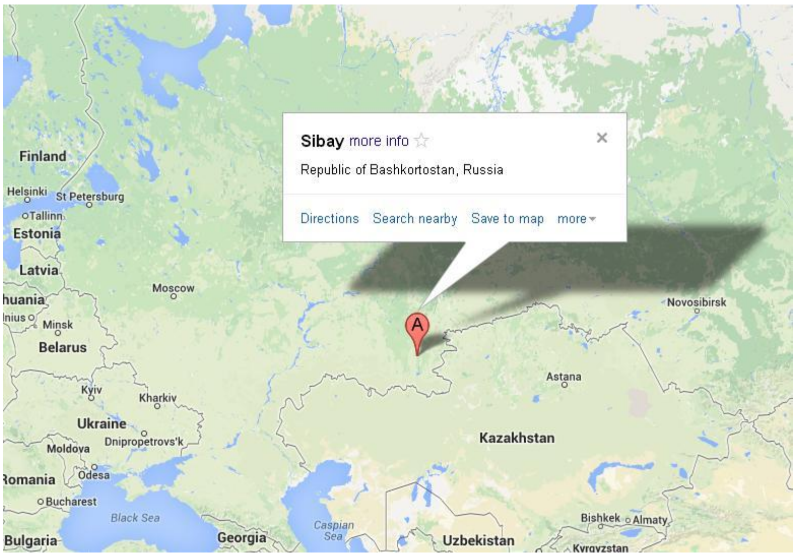

FIGURE 5. Sibay town in Republic of Bashkortostan. /28/.

Sibay GOK has all the infrastructure of mining and processing production. It includes underground mine, concentration plant, lime-pit and supporting manufactures: railway and energy workshops, central laboratory, service of information technology and communications, inspection service. /32/.
Main products of Sibay GOK are copper concentrate, zinc concentrate, crushed limestone and lime /32/.

6.2.1. Water treatment of Sibay branch of Uchalinsky GOK

During the decades the treatment of waste water had been done by mechanical method in precipitation tanks: particulate matter deposited on the bottom of the tank, and the liquid discharged into natural water bodies. However, this method had not sufficiently cleaned water from heavy metals: only 50 % of total emissions were removed. /33, 34/.

In 2012 a new treatment station of neutralization of quarry and waste waters was implemented basing on enterprise chief executives` decision to achieve production without negative impact on the environment. In order to build a new system of water treatment facilities the company spent more than 200 million Rubles which is approximately 10 million Euros. According to the project, the capacity of new facilities is to treat up to 400 cubic meters of water per hour. In fact, about 360 m^3 of quarry water is treated every hour. Containing heavy metals water comes from a depth of 700 meters. At the outlet of treatment plants the concentration of harmful substances in the water close to the maximum allowable. It applies the physicochemical wastewater treatment process using the so-called lime milk and flocculant, mechanical dewatering of sludge in a filter press and disinfection of a special facility. /33, 34/.

In order to implement this method quarry waters are neutralized with 5% lime milk to pH 9,4-9,5, then anionic flocculant in the concentration of 5-8 mg / l and pyrite tailings from mining production in a concentration of 2.5 10 g / l are added. The resulting blend is mixed and settled. After sedimentation, the water is separated into two streams. One stream is sent to the advanced treatment before being discharged into water bodies. Another stream is directed to irrigation of dump of open-cast mine for partial neutralization quarry waters forming a recirculation flow. The rate of recycling of water used for irrigation dumps is 20-30%. The method provides a reduction in consumption of lime milk and reducing the number of formed sediments. The Figure 6 /35/ shows a scheme of waste quarry waters treatment with water recycling for irrigation damps. /35/

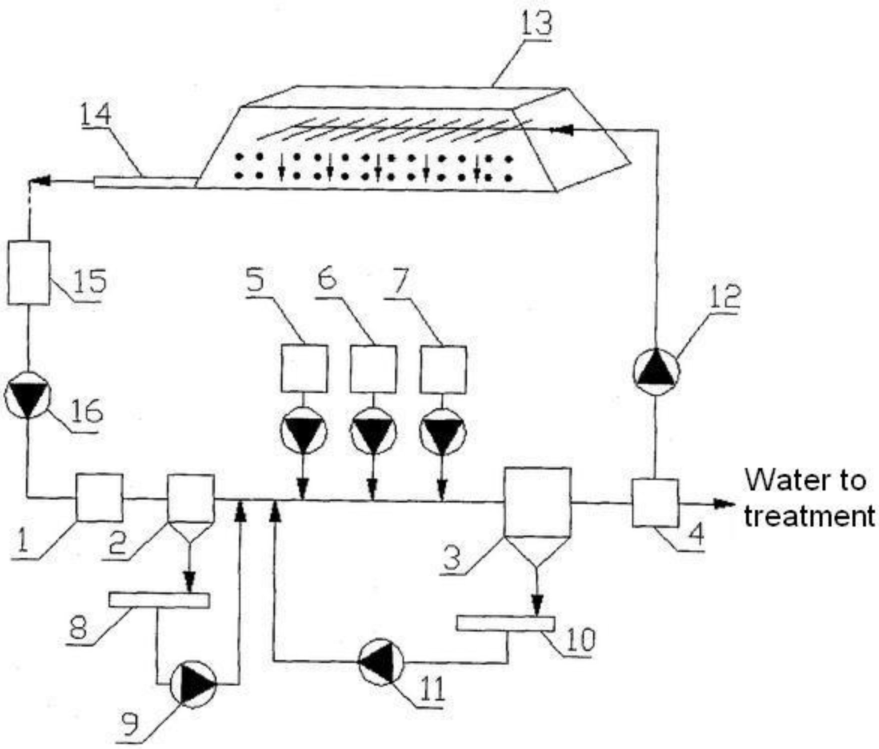

FIGURE 6. A diagram of waste quarry waters treatment with water recycling for irrigation damps. /35/.

A scheme contains grate (1) to remove the debris, sand trap (2) to extract sand gravel fractions, settler with flocculation chamber (3) and reservoir with treated water (4). Water treatment plants are equipped with reagent facility (5) with metering pump for lime milk, reagent facility (6) with metering pump for flocculant, reagent facility (7) with metering pump for pyrite tailings. Sand fractions from sand trap (2) are removed to sand platform (8) equipped with drainage water removal system with pump (9). Sediments are removed from settler to slurry platforms (10) for dehydration equipped with drainage water removal system with pump (11). Neutralized water is moved with pump (12) from reservoir with treated water (4) to irrigation of dump of open-cast mine (13). Quarry waters are moved with tray (14) to the storage tank (15), from where are moved with pump (16) to water treatment facilities. /35/.

The process of neutralization of acidic quarry wastewater is implemented as follows. Quarry waters with pH 3,0-3,2 with help of tray (14) go by gravity to the storage tank (15), from where are moved with pump (16) to grate (1) to remove large debris and sand trap (2) to remove sand gravel fractions. Neutralization of quarry waters is done by 5% lime milk which is moved to the tube with reagent facilities (5). Flocculant and pyrite tailings are moved with reagent facilities (6, 7) into the same tube. In the flocculation chamber (3) there is a formation of metal hydroxides which become insoluble and form flakes of coagulant in an alkaline environment. Organic molecules of flocculant amalgamate flakes of coagulant, on which surface there is sorption of colloidal particles of gypsum. Pyrite tailings play role of adulterant that accelerates the deposition of suspended solids. Sediments are periodically removed from settler (3) to slurry platforms (10) for dehydration and disposal. Water which is treated in settler (3) is moved to the treated water reservoir (4). This water is alkaline (pH 9,4-9,5), contains sulphates and heavy metals in concentrations exceeding TLV for discharge into water bodies, so it requires additional treatment. At reservoir exhaust, the water is separated into two streams. One stream is sent to the advanced treatment before being discharged into water bodies. Another stream is directed to irrigation of dump of open-cast mine (13) with help of pump (12) (recirculation flow). This measure was motivated by the fact that from long-term monitoring of quarry water it was found that with decreasing pH of quarry water the concentration of sulphates and heavy metals increases, so irrigation of dump by quarry waters with alkaline reaction should lead to partial neutralization of quarry waters and reduce their pollution. It results to increasing of the amount of quarry water that requires increasing the capacity of water treatment plant. However, on the other hand, decreasing in the concentration of pollutants in quarry waters requires less consumption of lime milk, and amount of sediment is decreased and, consequently, cost of its disposal is reduced. /35/.

The rate of water cleaning is 97- 99 % of heavy metals and 80-95 % of suspended solids. Water treatment facilities of Sibay GOK reduce the concentration of harmful substances in the water in 100 times as a whole. Treated water is discharged into the Karagaily River. Copper ore tailings and liquid phase of slurry are stored in tailings storage of Sibay GOK. This artificial lake was built in two years and it was introduced into technological process in 2013. Construction has the following parameters: area is 600,000 m^2, volume is 4 million m^3 and depth is 5.8 m. According to Sibay GOK management chiefs, this tailing storage will be enough for five year usage. Tailings storage bed has special membrane material which eliminates any contact of liquid with the ground. /33, 34/.

6.2.2. Environmental impact on water resources by Sibay branch of Uchalinsky GOK activity

Treated waters of Sibay branch of Uchalinsky GOK are discharged into the Karagaily River. Mouth of the river is 27 km on the right bank of the river Hudolaz. The river is 28 km. It belongs to the drainage basin of the Ural River. /36/.

According to the State Report of Bashkortostan Republic 2010 /37/ and Smirnova`s researches in 2009 /38/ , anthropogenic sources of pollution of the small rivers in the Bashartastan Republic are waste water from mining, food, energy industries, agriculture etc. One of the main examples is the Karagaily River which suffers from quarry waters of Sibay mine and waste waters from Sibay concentration plant. The samples were taken from different points which are shown on Figure 7 /38/.

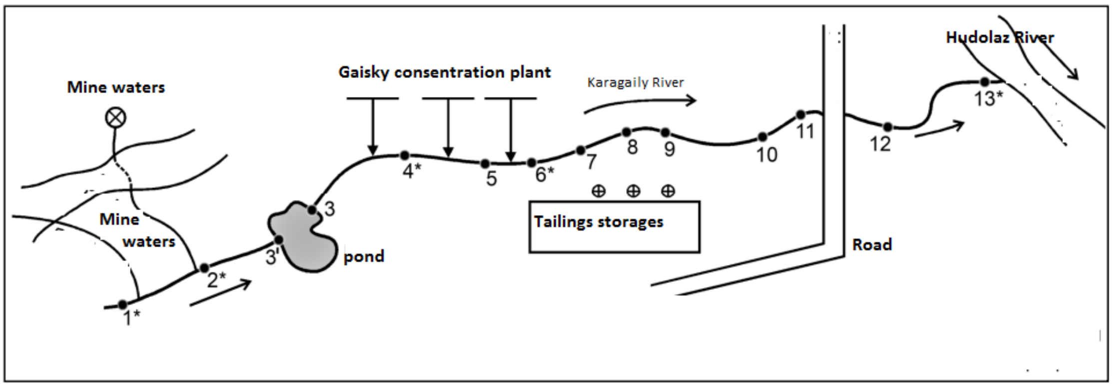

FIGURE 7. Places of water samples of the Karaigaly River. /38/.

Assessment of water quality and sediment of the Karagaily River was conducted by comparing obtained results with the TLV. Table 2 /38/ provides the information about the main hydrochemical indicators of water quality and the content of heavy metals, sulphates and sulphides.

TABLE 2. Results of water samples of the Karagaily River in 2009. /38/.

Indicators	Contaminating substunces, mg/l								TLV for fish.body, mg/l
	т.1	т.2	т.3`	т.3	т.6	т.9	т.11	т.13	
pH,	7,7	4,3	6,4	6,2	6,5	6,9	7,0	6,8	6,5-8,5
COD	11	15	14	13	35,5	15,1	16,2	16,3	---
Dissolved O2	7,0	6,8	6,5	6,5	6,7	2,8	<0,1	1,9	not less than 4
Mineralization	285	2720	2810	3062	1945	1668	1859	1959	1000
Chloride	6,7	73,4	81	84	163	125	133	133	300
Nitrate	<1,0	9	11,6	8,2	44	39	38,5	34,6	40
Nitrite	<0,02	0,17	0,14	0,10	<0,02	0,02	0,03	0,03	0,08
Phosphate	0,20	0,62	0,16	0,95	0,89	0,98	1,28	0,44	0,2 (onP)
Sulphides	<0,005	<0,005	<0,005	<0,005	<0,005	0,008	0,100	0,270	0,005
Sulfates	60	1600	1704	1589	905	996	989	1044	100
Copper	0,001	1,3	0,98	1,8	0,030	0,77	0,019	0,001	0,001
Zink	0,10	19,4	11,2	20	12,4	11,1	6,5	2,70	0,01
Manganese	0,03	4,2	5,2	4,3	2,4	2,6	1,3	1,3	0,01
Cadmium	<0,005	0,047	0,053	0,056	0,026	0,020	0,025	0,009	0,005
Total Iron	0,62	12,0	0,24	0,17	0,62	0,80	1,0	1,51	0,1

As it is seen from Table 2: results of water samples of the Karagaily river according to Smirnova`s researches in 2009 /38/, water quality of the Karagaily River worsens when mine waters are discharged. Content of heavy metals and sulfates increased in the water. High concentrations of these components are kept on all the sites studied channel and exceed TLV in many times. Discharge into small rivers, waters enriched with heavy metals and sulphates that create high toxicity of the river water, a high level of water pollution with these ingredients results in a concentration of heavy metals and sulfur compounds in the sediments. Water quality in different points of the Karagaily and Hudolaz Rivers is assessed as from moderately contaminated to very contaminated which indicates insufficient of treatment by mechanical method which was used in Sibay GOK. /38/.

Unfortunately, there are no official evidences from 2012 year about water quality of these rivers which can truly testify that the change of water treatment facilities in Sibay GOK made water better. However, according the interview of Gulnara

Nugmanova, head of the territorial department of the Ministry of Ecology and Environmental Sciences of the Republic of Bashkortostan, the environmental conditions had greatly improved during one year. Concentration of heavy metals significantly decreased and fish appeared in the rivers. Results of samples have shown the effectiveness of the station. Mine waters were treated by 98 percent, which is fully fulfilled the environmental requirements in TLV. /34/.

6.3.“Urupsky GOK” JSC

Urupsky GOK was founded in December 1997. Now it is a part of Ural Mining and Metallurgical Company (UMMC) which is the second largest copper producer in Russia. Enterprise is located in Mednogorsky Township, Karachaevo-Cherkesskaya Republic (Figure 8). /28,39/.

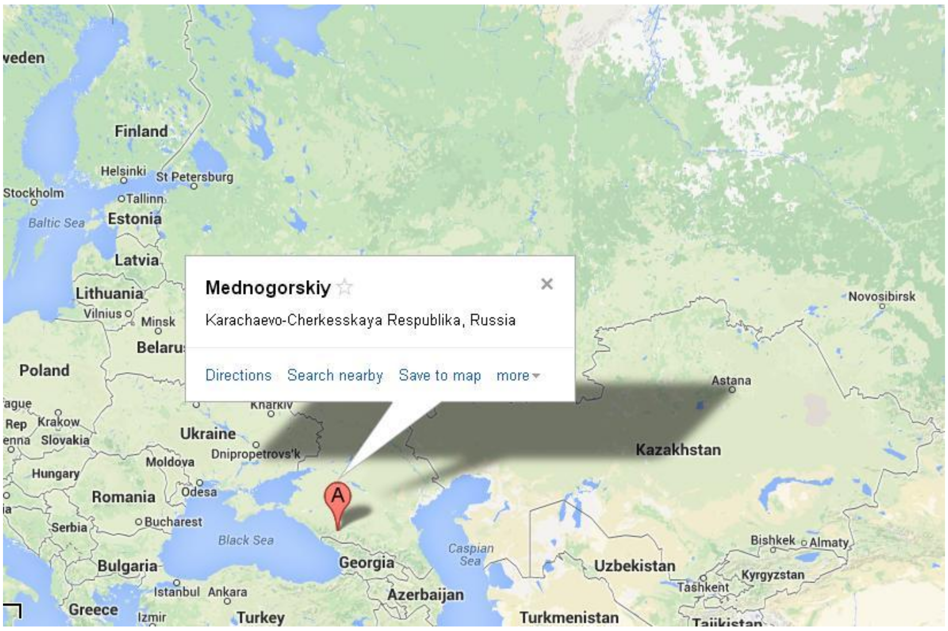

FIGURE 8. Mednogorsky Township, Karachaevo-Cherkesskaya Republic. /28/.

The company was built for mining and concentration of copper-pyrite ore. Today the main product of Urupsky is copper concentrate from which, in addition to copper, silver and gold are extracted. This copper concentrate also contains zinc. A Structure of Urupsky GOK includes underground mine, concentration plant, repair shops, energy supply facilities, and warehousing facilities with a railroad. /39/.

6.3.1.Water treatment of Urupsky GOK

Local water treatment facilities for mine waste water of Urupsky GOK of copper-zinc ores were built and put into operation in 1971.The reagent treatment method using lime milk to neutralize waters and alumina as a coagulant had been used. The results of chemical analysis of treated wastewater showed that the concentration of copper and zinc ions exceeded the Threshold Limit Value which is allowed discharging to fishery water bodies. The precipitate which was formed in the amount of 260 m^3/day during treatment process was difficult to be dehydrated, did not recycle, and was exported to tailings storages by special vehicles. /40/.

The high cost of delivery of reagents in the upper of Urup River, additional pollution of mine waste waters by ions of calcium, aluminum, and sulfate, increased requirements for the quality of treatment and discharge waters into the river which has fishery and agricultural value required to find and implement new technologies excluding the these disadvantages. /40/.

In order to solve these problems the North Caucasus branch of the State institutions of the Ministry of Natural Resources of Pyatigorsk City did a project work on water treatment technology development. The result was the introduction of the integrated galvanochemical technology of deep treatment mine waters from ions of heavy metals in Urupsky GOK. This technology was patented (patent № 2318737). Integrated galvanochemical technology treats waste water from different pollutants:

- heavy ions and non-ferrous metals;
- simple and complex cyanides;
- various organic compounds, including amino acids, proteins, carbohydrates, sugars;
- organic and inorganic colorants;
- hydrocarbons, including mineral or organic fat, surfactant;
- liquid radioactive waste;
- mineral and organic fine suspended solids, etc /41/.

About 40% of sulfates and 95% of phosphates, partially nitrates and calcium ions are extracting from waste water into sediments and salinity is decreased by this technology. As a final step of waste water treatment the technologies of sorption, ion exchange or reverse osmosis are used. Chemical reagents are not used and there is no gassing of harmful substances. Process of this type of treatment is easy automated and managed. A main device for control of treatment process is pH-meter which indicators are analyzed in order to estimate the level of residual contamination and active reaction of treated water returned into production or discharged into water bodies. /41/.

The main and first step of this technology is galvanochemichal method. This method is based on sorption and ion exchange capacity of the oxide slurry which is formed in a rotating horizontal machine – galvanocoagulator (Figures 9 -12 /41,42/.) by galvanochemical dilution of anode load when waste waters go through this load. The metalworking waste such as metal scrap, cuttings, fillings can be used as anode load. The intensification of processes of dilution of metals and formation of slurry is reached by adding cathode material: coal casting coke.

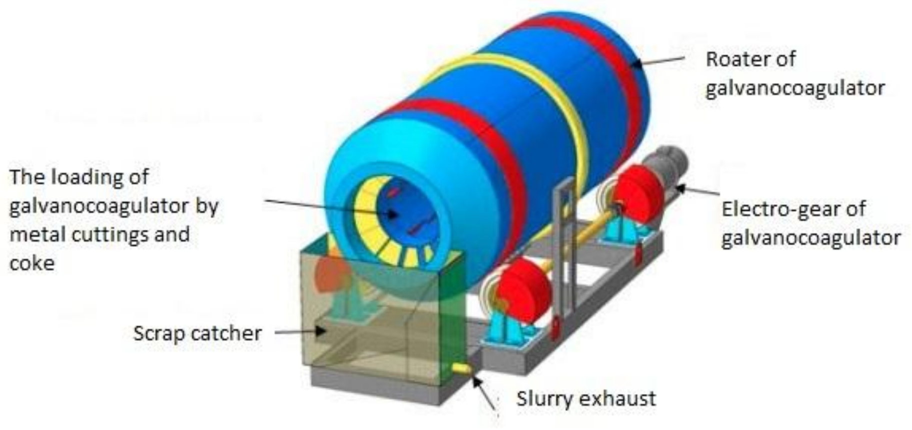

FIGURE 9. Scheme of Galvanocoagulator. /41/.

FIGURE 10. Galvanocoagulator of Urupsky GOK in fitting process. /42/.

FIGURE 11. The internal cavity of Galvanocoagulator of Urupsky GOK. /42/.

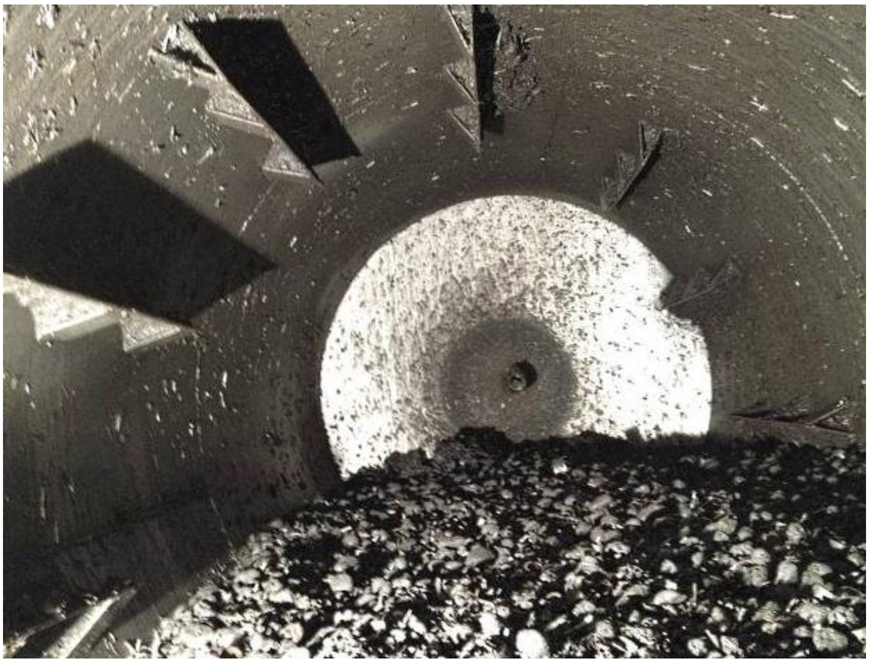

FIGURE 12. Inside view of galvanocoagulator with Iron and coke load. /42/.

Iron and coke in the treated solution are polarized with different periodic potentials: standard potential (E^0_n) of Iron is -0.44 and coke is +0.36 that constitutes a mass of galvanic pair. When galvanocoagulator is rotating and galvanic pairs is alternately contacting Iron is intensively dissolved and ions Fe^{2+} and Fe^{3+} are formed in a volume of treated solution. The result of the intermediate chemical reactions in galvanocoagulator is a formation of sorption and ion exchange slurry in a form of ferromagnetic iron oxides type g-FeOOH with the structure of the mineral lepidocrocite and magnetite with formula $FeO \cdot Fe_2O_3$. /41/.

Cations of heavy and non-ferrous metals, which pollute wastewater, actively introduce into the crystal lattice of magnetite with formation of ferrites of these metals. Reactions describing the occurrence of magnetite in slurry in galvanocoagulator and formation of ferrites of nonferrous and heavy metals can be expressed by the following formulas (Figure 13). /41/.

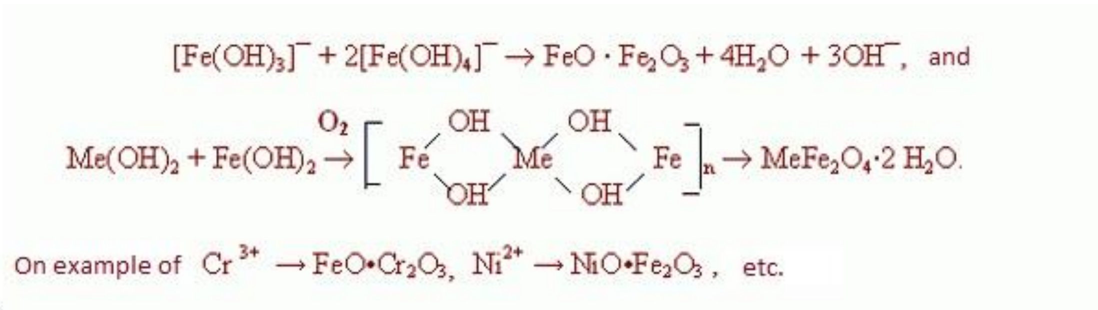

FIGURE 13. Formulas of occurrence of magnetite and formation of ferrites. /41/.

Sediment which mainly consists of ferrites of heavy metals has a crystalline insoluble form, so it quickly precipitates and is easily dehydrated /41/.

This integrated galvanochemical technology of deep water treatment has the following operations:

- separation of waste water into acid waters with ions of ferrous and heavy metals, including hexavalent chromium and pH <4 and the alkaline waste water with pH> 10;

- storage of washing waste waters;
- treatment of acid waste waters from ions of heavy metals and organic substances by galvanocoagulation method (1st step of treatment technology);
- after treatment of acid waters from galvanocoagulator and treatment of alkaline waters by ferritization method with slight alkalizing of slurry in galvanokoagulator to pH = 9.0 and saturation of slurry with atmospheric (2nd step of treatment technology);
- sedimentation of slurry after fertilization in high-speed storages and mechanical filtration of clarified phase of solution after storages;
- deep treatment of wastewater from residual contamination by sorption and ion-exchange materials with the return of up to 70% of treated water into production (3d step of treatment technology);
- if it is necessary the final treatment by reverse osmosis method /41/.

The scheme of the whole process of deep treatment technology which is used in Urupsky GOK is shown on Figure 14 /41/.

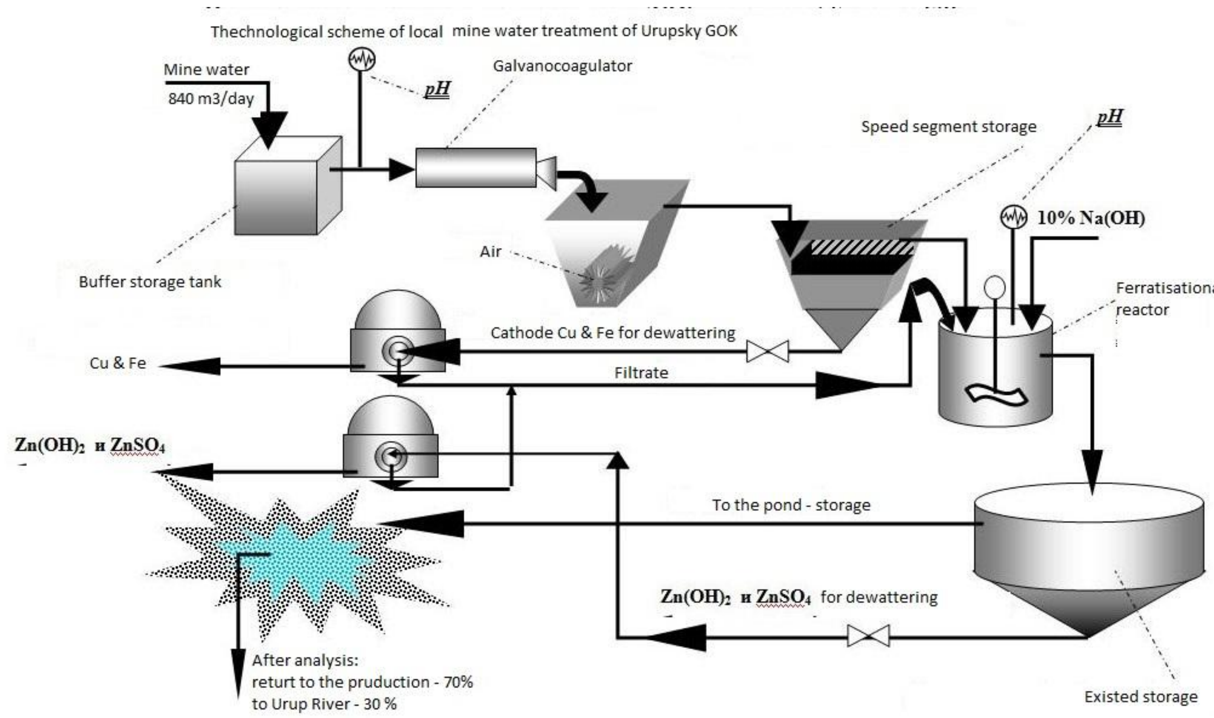

FIGURE 14. Technological scheme of local mine water treatment of Urupsky GOK. /41/.

The average results of mine water treatment in Urupsky GOK by Integrated deep treatment technology are shown in Table 3. The capacity is 25 m^3 per hour.

TABLE 3. The average results of mine water treatment in Urupsky GOK by Integrated deep treatment technology. /41/.

Treatment process	Name and concentration of polutants, mg/l			
	pH	Cu2+	Zn2+	Fe2+
Input data	2,5	420	298	82
After galvanocoagulation	5,6	42,5	49,72	122
After ferritization	8,6	3,2	12,6	0,8
After sedimentation and filtration	8,5	0,1	0,6	0,5
Treatment degree, %		99,98	99,8	99,39

The results of implementation of this treatment technology were fully fulfilled. Treatment of mine water from the copper ions was almost 100%, from the zinc ion was 99.5%, from the iron ions was 99.2% and from the sulfate ions was more than 38%. pH of treated wastewater increased from 2.0 - 2.3 to 6.5 by electrochemical processes in galvanocoagulator and ferritization that allowed refusing the use of reagents which polluted wastewater with calcium and aluminum salts. /42/.

6.3.2. Environmental impact on water resources by Urupsky GOK activity

The renovation of water treatment was done in 2001. According to the Federal State Authority of Kubansky Centre of water body monitoring /43/, discharged waste waters of mine of Urupskiy GOK contain large amounts of sulfate - up to 2199mg / l (22 times more than TLV), calcium - up to 1029 mg / l (5.72 times more than TLV), chlorides – up to 276 mg / l (0, 9 times more than TLV), magnesium - to 62 mg / l (1.6 times more than TLV), so they are strongly mineralized waters (dry residue is 4599.5 mg / l). It is noted the presence of zinc ions wastewater - to 0,635 mg / l (63 times more than TLV). Discharge of such quality water has a negative impact on the water body – the Urup River. /43/.
According to the State water monitoring in 2004 the main polluted substances of the Kuban River, which the Urup River goes to, are the following:

- containing copper - 0.4 - 7 times more than TLV;

- volatile phenols - 0.4 - 2 times more than TLV;
- organic matter (BOD5) - up to 0.32 - 2.0 times more than TLV;
- total iron - up to 0.6 - 2.6 times more than TLV;
- petroleum products - up to 0.7 - 4 times more than TLV /43/.

According to the State Report about environmental situation in Karachaevo-Cherkeskaya Republic /44/, in 2011 year high anthropogenic impact on surface water bodies exist in the mining area Urupsky GOK. The Urup River is polluted by direct runoff of mining operations and by additional transfer of pollutants from the catchment areas. In the process of geo ecological mapping work dangerous areas on the degree of contamination of the river sediments were identified. Degree of pollution is dangerous because pollutants are heavy metals. Pollution intensity explains the influx of pollutants of surface waters, which are the main source of groundwater recharge. /44/.

According to the State Report of water supply and sewerage in Karachay-Cherkessia Republic 2011 /45/, the reconstruction cleaning system of mine water treatment facilities of Urupskiy GOK was done. However, other sewage treatment plants in this Urupskiy area do not work effectively. Wastewaters from Pregradnaya treatment plant are discharged into the Urup River without adequate cleaning and disinfection. Volume of wastewater is 1384 thousand m3 /year. Pregradnaya sewage treatment plant was put into operation in 1969. Since the time its overhaul has not conducted. Two levels settlers, sand trap, aeration tanks and filters of sewage treatment plants are in poor technical condition. So the contamination of water body is caused not only by mining enterprise. /45/.

6.4.“Gaisky GOK” JSC

Gaisky GOK is the largest mining enterprise in Ural region. Gaisky GOK is located in Gay City of Orenburg Region (Figure 15) /28/. The Ural River flows 18 km new Gaisky deposits. Iriklinskoe storage reservoir is near 26 km to Gaisky GOK. /46/.

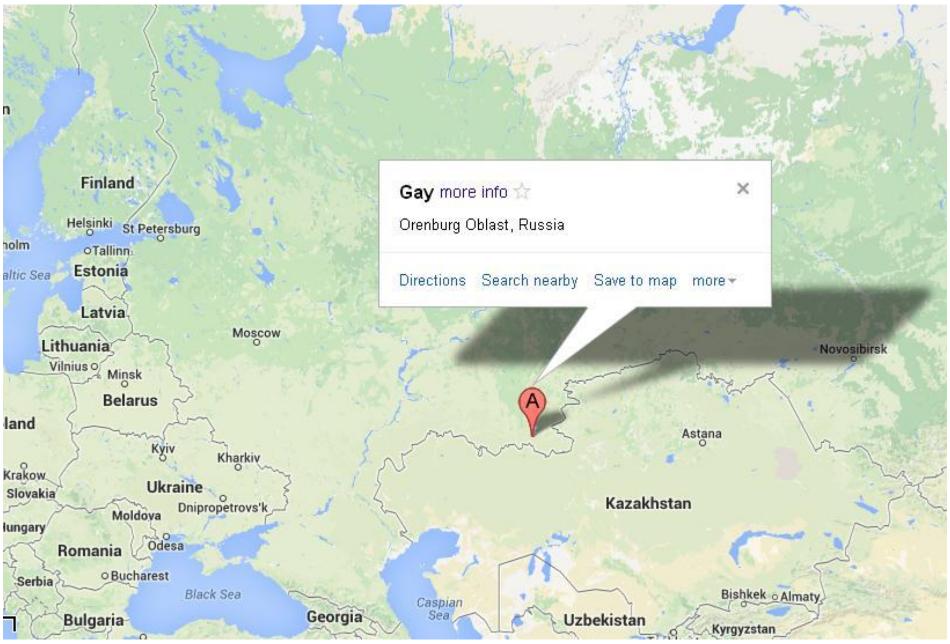

FIGURE 15. Gay City of Orenburg Region. /28/.

The enterprise was founded in May 1959. It becomes a part of Ural Mining and Metallurgical Company in 1999 and now it is the main raw material base of UMMC holding. The main production of Gaisky GOK includes the following units:

- underground mine;
- open pit mine;
- concentration plant;
- shaft constriction department /46,47/.

The main products are copper concentrate, zinc concentrate, pyrites, copper, zinc. Gaisky GOK with 7000 persons of work staff provides up to 60% of Gay City budget. /46,47/.

6.4.1. Water treatment of Gaisky GOK

Process of mining, quarrying waste waters in Gaisky GOK is conducted from 2000 year by using the module of electro flotation treatment and additional treatment by reverse osmosis. Water treatment facilities (Figure 16) /48/ were constructed by

Interregional eco technology engineering company MIEK Ltd. which is located in Novosibirsk city. The capacity of this water treatment is 120 m^3/hour. /48/.

FIGURE1 6. Water treatment facilities of Gaisky GOK. /48/.

Module of electro flotation treatment which is shown in the Figure 17 /48/ is machinery of continuous action for nonchemical (without reagents) treatment of industrial waste waters from suspended solids, metals, oil, surfactants and other contaminants. /48/.

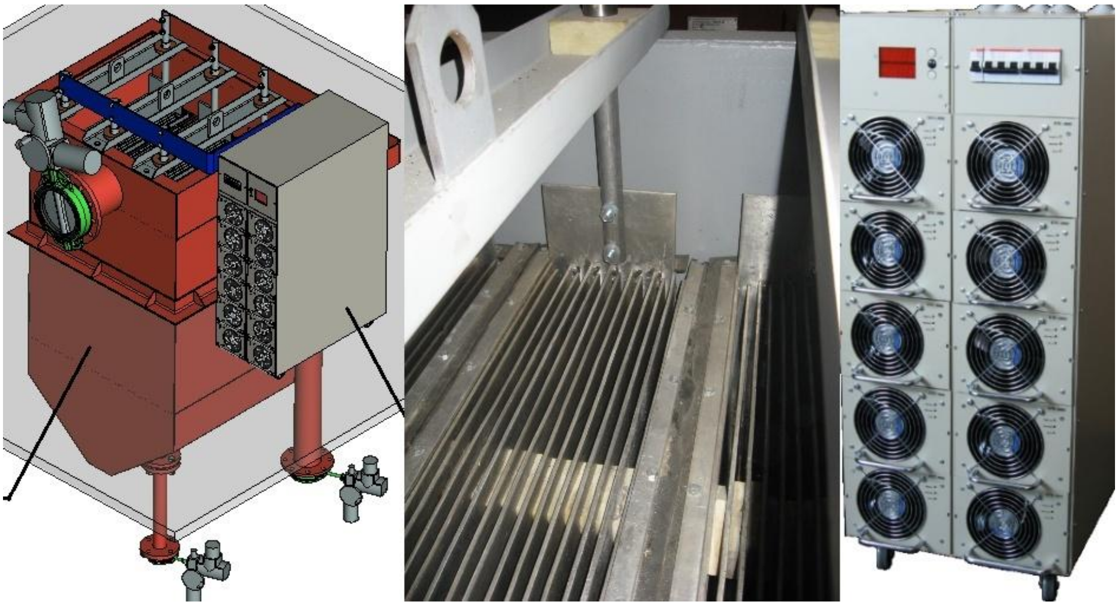

FIGURE 17. Module of electro flotation. /48/.

The principle of operation is based on the processes of electrochemical dissolution of the anode, coagulation, electrolysis and flotation effect – allocation electrolytic microbubble gases. The main parts of module are an electrical flotocoagulator with soluble electrodes, a cupboard for control of foam collecting device and a current source. The body of electrical flotocoagulator is made of carbon steel with polymer coating. The main advantages of the module are the following:

- ability to use module for treatment of acid waters ($pH<5$) without preliminary neutralization of them;
- high capacity;
- compactness;
- treatment degree is up to 90% and treatment degree from heavy metal is 99%. /48/.

Reverse osmosis unit which is shown in the Figure 18 /45/ is designed for deep treatment and desalination industrial wastewater pretreated from suspended solids, oil, iron and manganese. The principle of operation is based on passing the treated water under pressure through the semipermeable membrane, retarding the dissolved molecules and ions. /48/.

FIGURE 18. Reverse osmosis unit of Gaisky GOK. /48/.

The results of mine water treatment in Gaisky GOK by using the module of electro flotation treatment and additional treatment by reverse osmosis according to the interregional engineering eco-technological company /48/ are shown in Table 4.

TABLE 4. The results of mine water treatment in Gaisky GOK according to the interregional engineering eco-technological company /48/.

	Input Water	**Treated water**	**TLV for fishery bodies**
pH	4,2	7,2	6,5-8,5
Sediment, mg/l	6098	82	1000
Hardness, mg-Eq/l	23	1	7
Chlorides, mg/l	355	32	300
Sulfates, mg/l	3570	20	100
Iron, mg/l	78,4	0,06	0,1
Copper, mg/l	63,6	<0,002	0,001

Zink, mg/l	1,5	0,004	0,01
Manganese, mg/l	9	<0,05	0,01

As it can be seen the results of water treatment are fulfilled the official requirements for fishery water bodies.

6.4.2. Environmental impact on water resources by Gaisky GOK activity

According to the official site of “Gaisky GOK” JSC /46/, there was a number of large environmental events which allowed to minimize the negative impact of contaminated mine water discharged into the nearest rivers and ponds. In 1997, the construction of two storages - ponds to collect acidic mine water of quarries № 1 and № 2 with each volume of 0.5 million m3 was completed. It led to stop the discharge of water into the Kalpachka and the Urals Rivers. The specialists of Gaisky GOK are constantly monitoring the groundwater level, their chemical composition in accordance with the "Program of establishment and introduction of monitoring ground and surface waters at Gaisky copper-pyrite deposits" which is approved by the Committee for Natural Resources of the Orenburg region. In 1999 - 2000 years of acidic quarry water from ponds number № 1 and № 2 were involved in the recycling of water. The volume of clarified water discharge into open waters was reduced on 500 thousand m^3 per year. Today the volume of recycled and reused water is 92-95% . The introduction of new water treatment technology allowed to minimize discharge of waste waters and finally to the Suhaya Guberlya and the Ural Rivers. /46/.

According to Artamonova /49/, analysis of concentration of heavy metals in into water of the Yalangas creek (Figure 19) /49/ shows standard hydrological regime for small rivers and creeks with minimum concentration in spring period (March-April) and less shown minimum in summer period (July-August). Winter maximums are noticed in the changing of heavy metals concentration. However, besides common dynamic there are high peaks of concentration of separate contaminants. For example, the concentration of Copper in July and December 2001 and May 2002 in waters of Yalangas creek. /49/.

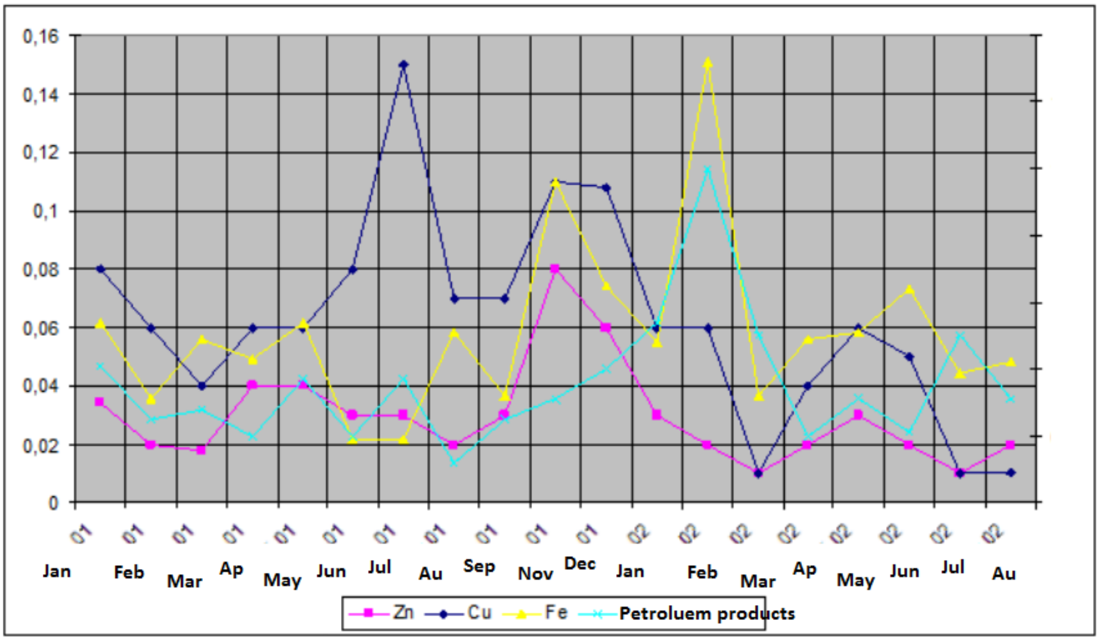

FIGURE 19. Dynamics of heavy metals [mg/l] in waters of Yalangas creek in 2001 and 2002. /49/.

According to Kaliev /50/, the analysis of the chemical composition of the waste and natural waters near Gaisky GOK (Table 5) shows that the concentrations of the defined substances are below threshold limited values for the water used for domestic purposes and irrigation. /50/.

TABLE 5. The chemical composition of the waste and natural waters adjacent to the Gaisky GOK territory. /50/.

(mg/l)

Place of taken water sample	pH	Copper	Zinc	Iron	Calcium	Magnesium	Hardness	Cobalt	Chlorides	Sulfates	Dry residue	Xanthate	Petroleum products	Suspended solids
Suhaya Guberlya River above the confluence Tashkut River	6,9	0,0093	0,06	0,37	166	55,2	12,9	0	402,71	167,89	1474	0	0	31
Yalangas Creek above the discharge	7,75	0	0,01	0,063	352	112,8	27	0	100,68	1096,2	2544	-	0,25	24
Month average: discharge from clarification pond of concentrating plant	7,76	0,044	0,054	0,7	607	25,8	32,5	0,00042	220,233	2100,03	4350,5	0,0025	0,188	31,95
Yalangas Creek bolow the discharge	7,4	0,0046	0,06	0,16	520	110,4	35,2	0	281,90	1911,0	3678	0	0,25	32,5
Tashkut River	7,45	0	0,03	0,37	514	49,2	29,8	0	674,54	1608,14	4104	0	0	55,5
Suhaya Guberlya below the confluence Tashkut River	7,75	0,023	0,043	0,63	332	72	22,6	0	251,70	1022,17	2264	0	0	67
Maximum allowable concentrations	5,5 7,5	2	20	20	500	300	21,3	4	350	400	2500	-	100	3000

Content of elements in the public water sources is located below the contamination source is significantly higher than at points located on top of the river. The increase in the concentration of copper, zinc, iron, calcium, magnesium and sulfate has to be noticed. Finally, the mineralization of Yalangas creek and Suhaya Guberlya River became more in almost 2 times. /50, 51/.

6.5. “Mikhailovsky GOK” JSC

Mikhailovsky GOK is the second largest complex of extraction and concentration of iron ore in Russia. It was found in 1957. Plant is located in Zheleznogorsk City of Kursk Region (Figure 20). /28,52/.

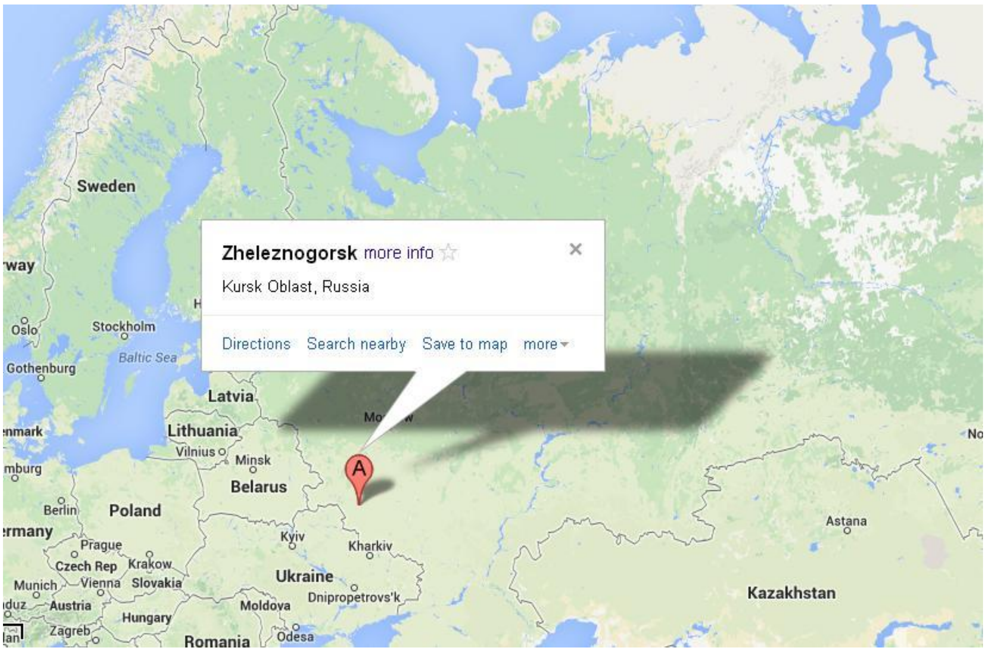

FIGURE 20. Zheleznogorsk City of Kursk Region. /28/.

Technological process of Mikhailovsky GOK includes the following basic steps:

- mining operations;
- production of sintered ore and ore blast;
- concentrate production;
- production of pellets.

Volume production of Mikhailovsky GOK is 18% of iron ore concentrate and sinter ore of Russian total production. It has the largest explored and estimated reserves of ore in Russia. /52/.

6.5.1. Water treatment of Mikhailovsky GOK

One of the most important directions of Mikhailovsky GOK activity is protection of environment by implementation in production process new scientific achievements and best technologies. Environmental protection work is accompanied in respect with annually issued enterprise order "On environmental protection". Organization of production ecological control, implementation of new technologies and protective projects are under responsible of the environmental protection department. Control of discharges and emissions of harmless substances into the environment is realized by sanitary and technical laboratory which has state accreditation. /53/.

Usage of surface water bodies is accomplished basing on license for water usage. Mikhailovsky GOK has ten systems of recycling of industrial waters. Domestic waste waters from plant objects are gone to local station of water treatment by biological method and to city water treatment station. Waste quarry waters before to be discharged are treated by mechanical method. The reconstruction of tailings storage is continued. /53/.

6.5.2. Environmental impact on water resources by Mikhailovsky GOK activity

According to the State Report about ecological situation and environmental protection in Kursk Region /54/, the main anthropogenic load falls on the Seim River with its tributaries Tuskar and Svapa where the largest industrial enterprises such as Mikhailovsky GOK are located. In 2011 water quality near Mikhailovsky GOK has improved in comparison with 2010. It becomes to belong to slightly contaminated water class. Waters in the Svapa River near Mikhailovsky reservoir shown exceeding TLV of total iron (2 times TVL), organic matter BOD_5 (1,5 times TVL), ammonium nitrogen (1,2 times TVL) The average concentrations of other substances didn't exceed TLV in 2011. Oxygen regime in the reservoir is satisfactory during whole year. Concentrated wastewater discharges into the reservoir on the Svapa River are absent. /54/.

7. RESULTS AND CONCLUSIONS

The water treatment of five mining plants and their environmental impacts on nearest water bodies was studied in this project based on data from plants, water treatment companies, previously published reports and the Russian environmental authorities. Their locations on the Russian Federation territory can be found on the Figure 21. /28/.

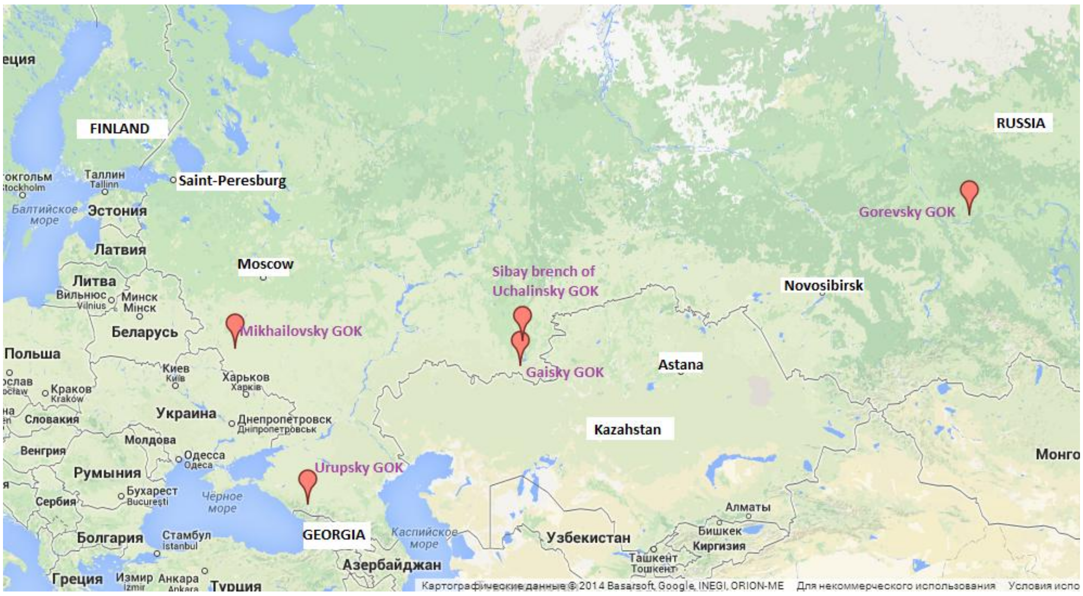

FIGURE 21. Location of mining plants on the Russian Federation territory. /28/.

Mining industry plants are located in different parts of Russia and an interesting territory from Finnish point of view is the one which is near to Finland. However, because of the absence of available information and unwillingness of Russian companies in this area to share the information, the mining plants which are studied in this state-of-art report are located in the South and Central parts of the Russian Federation. Different water treatment methods are implemented at the following five mining plants:

- Gorevsky GOK which mechanical method – filtration – applied is located in Central part of Russia;

- Sibay brench of Urupsky GOK with physicochemical method with neutralization by lime milk is located in South part of Russia closed to Kazahstan boarder;
- Urupsky GOK with integrated galvanochemichal technology is located closed to Georgia boarder;
- Gaisky GOK where module of electro flotation treatment is applied is located in the same area with Sibay brench of Urupsky GOK closed to Kazahstan;
- Michailovsky GOK where mechanical method is used is located in South West of Russia closed to Ukraine and Belorussia.

7.1.Summary

The most deplorable situation concerns ***Gorevsky GOK.*** They use out-of-date primitive mechanical method – sand filtration – for treating the waste mine waters. Filtration is usually used as one of the steps of water treatment to remove dirtiness: wire, rags, pieces of wood, coal, as well as sand, earth, scale, particulate organic matter, oils and petroleum products, etc. When reagent water treatment with coagulants and flocculants is applied due to the enlargement of suspended particles and other changes, the allocation of particulate matter in filtering improves. So it is possible to remove suspended solids from waste waters, however, application of this method is not enough to remove heavy metal and treat water well.

Situation with quality of the nearest water bodies is quite catastrophic. In 2010 water of tributary Angara River (creek Kartichny) contains lead concentration (100 times more than TLV), iron (56 times more than TLV), zinc (12 times more than TLV), water of Angara River itself contains zinc concentration exceeded in 3.6 times, lead concentration – in 15 times, iron concentration - 23 times that corresponds to ecological disaster zone. /30/.

The reason of such situation is obviously contaminated waters which are discharged without proper treatment by Gorevsky GOK. The final examination of water bodies in 2013 was a basis for filing a lawsuit in Krasnoyarsk Region court. Previous fines had no force on Gorevsky GOK to improve their treatment facilities. /31/.

Water of ***Sibay branch of Uchalinsky GOK*** was treated by mechanical method in precipitation tank. Concentration of such contaminants as copper, zinc, sulfates, manganese and sulphides in nearest water bodies exceeded the threshold limited values. Water is classified as contaminated. Therefore the management chiefs of Sibay GOK decided in 2012 to implement new water treatment facilities with applies the physicochemical process using the so-called lime milk and flocculant, mechanical dewatering of sludge in a filter press and disinfection of a special facilities.

According to the head of the territorial department of the Ministry of Ecology and Environmental Sciences of the Republic of Bashkortostan /33/, this new treatment helps to treat waters by 98 percent that had fully fulfilled the environmental requirements. Unfortunately, the State report about the ecological situation in the Russian Federation and its regions is issued one time per two years and there is no official evidence to prove this information. Theoretically this method can provide enough treatment and if maintenance is done properly the water quality should be satisfactory. Capital repair and change of treatment facilities at mining enterprise is a positive evidence of improving the sustainable development and attention to the environment in the mining industry.

In 2001 the new integrated galvanochemical technology was introduced in ***Urupsky GOK***. According to the company which is a developer of this technology, the results of implementation of this treatment technology were fully fulfilled. Reduction of zinc ion from waste water was 99.5%, from the iron ions was 99.2% and from the sulfate ions was more than 38%. The data about environmental situation at 2001-2002 years is not available. There is the information at 2004 and 2011 showing not satisfactory results: waters of the nearest water bodies contained the contaminated substances such as sulfate, copper, magnesium, iron and others which exceeded the threshold limited values. /36/.

In State Report /34/ it is said that the renovation of waste water treatment facilities of Urupsky GOK was done. However, other sewage treatment plants in this Urupskiy area don’t work effectively. Therefore the contamination of these water bodies might be caused by discharge from other sources. The unproper maintenance of treatment facilities of Urupsky GOK might also cause unsatisfactory work of them that may lead to improper water treatment and discharge of contaminated water.

Treatment of mining waste waters in ***Gaisky GOK*** is conducted by using the module of electro flotation treatment and additional treatment by reverse osmosis. According to the company which implements this technology, the water quality of water treated by this treatment technology are fully fulfilled according to the official requirements. The official web-site of mining plant says that they strive to minimize negative impact on the environment: decrease the volume of discharged waters and increase volume of recycled water. /46/.

Data about the environmental situation in the nearest water bodies is different. The concentrations of the defined substances of the waste and natural waters near Gaisky GOK are below threshold limited values for the water used for domestic purposes and irrigation. However, the concentrations of elements in the water sources located below the contamination source are higher than at points located on top of the river. The increase in the concentration of copper, zinc, iron, calcium, magnesium and sulfate has to be noticed. Anyway, this increase in the concentration is not dramatic. Water belongs to the second class which is slightly contaminated. /51/.

The last mining plant is **Mikhailovsky GOK.** The data which is available about it is quite contradictory. On the one hand, the administrations of mining says that Mikhailovsky GOK has priority to sustainable development and production ecological control, implementation of new technologies and protective projects on environmental protection are accompanied by this enterprise. On the other hand, they used as waste quarry water treatment a mechanical method which is not enough to treat water properly. /54/.

Environmental situation in the nearest water bodies is not satisfactory. In 2011 water quality near Mikhailovsky GOK has improved in comparison with 2010. It becomes to belong to slightly contaminated water class. Only the concentrations of total iron, organic matter, ammonium nitrogen exceed TLV in 1,2-2 times. The average concentrations of other substances do not exceed TLV. Anyway there is not enough available information to make a conclusion how Mikhailovsky GOK improved the quality of water. /55/.

7.2.Conclusions

As it can be seen, there is no one perfect situation at any mining plant. The nearest to GOKs water bodies are all contaminated with different rates. Danger of this contamination by mining plants is about the content of heavy metals which are harmful for aquatic system and consequently for people. Therefore, the situation requires improving.

Some mining enterprises are still using primitive water treatment, i.e. mechanical methods, which are not sufficient to treat waters to the level of official requirements. Two situations exist. Gorevsky GOK is not concerned about the water quality at all. The concentration of the contaminants increases the limits in dozens of times. The ecology near the plant is in a catastrophic state. During the last five years not a single attempt to improve the situations was performed. Fines had not become a reason for this. It represents one type of non-eco-friendly behavior when the only aim of business activity is making financial profit in short-term perspectives.
Mining industry is usually very profitable. The system of fines is not an effective method to force the company not to damage the environment because these fines are not high enough. The raise of fine cost in a huge number of times and implementation of criminal liability might have an effect on improving the situation with ecological responsibility.

Other enterprises such as Mikhailovsky GOK seem open to sustainable development. They made several steps for environmental protection work. In the case that there is a reasonable, financially beneficial project of changing the water treatment facilities they may join it. However, any heavy implementation which especially demands large costs may be attractive for Russian chief managers if this implementation becomes beneficial in the future.

Some mining enterprises such as Sibay, Urupskiy and Gaiskiy GOKs have replaced their old water treatment facilities to new effective ones. However, the environmental situation near these plants is not good either. Consequently, there is a need in monitoring of water quality to understand the reasons for exceeding the contaminant limits. The proper maintenance of treatment facilities must always be carried out because the deterioration of equipment may worsen the quality of their work. The permanent control of water treatment process and water content at mine exhaust should be an essential part of water treatment management.

One of the main problems in the development of environmental sustainability in Russian mining industry is the fact that the enterprises are closed for any interference. They do not share the information about their internal activities and processes including water treatment. The information represented in this study was mainly obtained from a project and technological companies which implemented these water treatment methods. Establishment of open and productive communication with mining industries is a long and hard process which should be with perspectives and benefits. However, it is happening step by step. Two days ago I had a call from the coal mining enterprise “Sahalin Ugol”. Today they have no water treatment equipment but they are planning the Development Project which will include both production increase and environmental protection.

A few companies cooperate with the environment protection agencies and institution, implements new technologies, control their emissions. However, they are still not ready to have transparent activity for public.

Nowadays, the question of environmental protection stays on a new governmental level of importance. There are new programs of implementation of Best Available Technologies and other environment orientated technologies. The right ecological direction for industries is set, now a proper implementation should be performed.

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APPENDICES

APPENDIX 1 (1)

MEASUREPOLIS DEVELOPMENT LTD AND FIELDS OF ITS BUSONESS

Measurepolis Development Ltd is a technology and business development company specializing in measurement and information technology that aims to create profitable business for its partners. The company’s main customers are process industry firms and research institutes operating in the field of measurement and information systems.

The company, owned by the City of Kajaani, operates internationally and employs ten technology and business experts in the cities of Kajaani (HQ), Kuopio, Oulu, Tampere and Espoo.

Measurepolis Development Ltd manages regional and national development programmes in the area of measurement and information technology. The company produces technology, business development, information, marketing and communication services for its partners and customers. /1/.

Description of organization, its business and services

The activity of company is divided into three directions: business development, development of technology and programs development.

In business area Measurepolis Development Ltd fulfils its owner's objective of developing measurement and information systems entrepreneurship in Kajaani by promoting Kajaani as a location for businesses. It implements cooperation with UPM to develop Renforsin Ranta into a business park for measurement and information systems. Measurepolis Development Ltd continually interacts with measurement technology research institutes and charts any research-driven measurement technology ideas, inventions or innovations. Company evaluates the technical and commercial opportunities provided by the inventions by determining, for instance, the technological competitiveness and risks of the inventions, patent status, market needs

APPENDIX 1 (2)

and competition status. It also finds a suitable way to commercialize innovation and seeks out the appropriate financing instruments and implementation partners. Company continually interacts with measurement technology enterprises and identifies their cooperation and development needs and opportunities.

In development of technology Measurepolis Development Ltd creates, designs and kick-starts measurement and information systems technology development projects that are based on the needs of its cooperation partners. Company formulates project plans, finds the best experts to implement the projects, finds the required cooperation enterprises and negotiates with private and public funding sources as required.
As references the following ones can be shown:

- Online measurement development project for the mining industry;
- Renewable chemical forest industry technology program for UPM, Metso and the University of Oulu;
- Technology program for measurement in mechanical wood processing.

In third area Measurepolis Development Ltd, with its cooperation partners, manages and implements wide-ranging programs that develop measurement technology and information systems. Development projects in these programs are designed so that the enterprises we cooperate with benefit from the knowhow and technology created. Measurepolis Development Ltd is an active member of several national networks. The Measurement, Monitoring and Environmental Assessment (MMEA) - program will create new tools, standards and methods for environmental measurement, monitoring and decision support for mining industry. The program promotes new applications and services based on environmental data to improve the energy, quality and material efficiency of infrastructures and industrial processes. /1/.

APPENDIX 1 (3)

Contact information

Measurepolis Development Ltd is located in Kajaani city in Finland. Its post address is Kehräämöntie 7, Technology park P.O. BOX 103, 87400 Kajaani FINLAND, fax is +3588 6149 205, website is http://www.measurepolis.fi/.

The company employs ten technology and business experts in several cities. The contact of the main one is written below:

- CEO *Jussi Mäkinen* (gsm +358400 995 466; jussi.makinen@measurepolis.fi);
- VP, Business Development *Outi Laatikainen* (gsm +358447101662, outi.laatikainen@measurepolis.fi);
- Communication & Marketing Manager *Marko Lipponen* (gsm +358447100 102, marko.lipponen@measurepolis.fi);
- Technology Expert *Merja Rautiainen* (gsm +38408333783, merja.rautiainen@measurepolis.fi);
- Technology Expert *Petri Österberg* (gsm +358447500779, petri.osterberg@measurepolis.fi);
- Technology Expert *Antti Juva* (gsm +358505111716, antti.juva@measurepolis.fi).

They all are great specialists in the area of their interests. /1/.

APPENDIX 2

DRINKING WATER CRITERIA IN FINLAND AND RUSSIA

TABLE 6. Drinking water criteria in Finland and Russia /56,57/.

Chemical standards (maximum possible concentrations)	**Finland Amount of chemical, mg/l**	**Russia, Amount of chemical, mg/l**
1. Acrylamid	0,0001	0,01
2. Aluminum	0,2	0,5
3. Ammonium (NH4)	0,5	0,5
4. Ammonium (NH4 - N)	0,4	-
5. Antimony	0,005	0,05
6. Arsenic	0,01	0,05
7. Barium	-	0,1
8. Benzene	0,001	0,01
9. Bentso(a)pyrene	0,00001	0,005
10. Beryllium	-	0,002
11. Boron	1,0	0,5
12. Bromate	0,01	-
13. Cadmium	0,005	0,001
14. Chlorophenols, total	0,1	0,25
15. Chromium	0,05	0,05
16. Chromium (residual free)	-	0,05
17. Chromium (residual binding)	-	1,2
18. Copper	2,0	1,0
19. Cyanide	0,05	0,035
20. 1,2-dichloroethane	0,003	0,2
21. Epichlorohydrin	0,0001	0,01

22. Fluoride	1,5	1,5
23. Formaldehyde	-	0,05
24. Iron	0,2	0,3
25. lead	0,01	0,03
26. Marganese	0,05	0,1
27. Mercury	0,001	0,0005
28. Molybdenum	-	0,25
29. Nickel	0,002	0,1
30. Nitrate	50	45
31. Nitrate nitrogen	11,0	-
32. Nitrite	0,5	3
33. Nitrite nitrogen	0,15	0,1
34. Ozone, residual	-	0,3
35. Pesticides	0,0001	0,002
36. Pesticides, total	0,0005	0,002
37. Polyacrylamide	-	2
38. Polyphosphate	-	3,5
39. Polycyclic aromatic hydrocarbons	0,0001	0,015
40. Selen	0,01	0,01
41. Silicic acid, activated	-	10
42. Strontium	-	7,0
43. Sulphate	250	500
44. Sodium	200	200
45. Tetrachloroethene and Trichloroethene, sum	0,01	0,05
46. Trihalomethanes, total	0,1	0,2

47. Vinyl chloride	0,0005	0,05
48. Zinc	-	5