



Monitoring of the ecological security in the north-western region of the Republic of Sakha, Russian Federation

俄罗斯联邦萨哈共和国西北地区的生态安全监测

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Abstract – The paper is devoted to the environmental impact of industrial sector in Western Yakutia and the role of the Mirny Polytechnic Institute (branch) of the Ammosov North-Eastern Federal University in training specialists for oil and gas and diamond mining industries and the research carried out at the educational and scientific laboratory of complex analysis of anthropogenic disturbances of the Institute on compliance with the requirements.

Key words – environment, industry, oil and gas, diamond mining, ecological monitoring, East Siberia.

I. INTRODUCTION

The Mirny Polytechnic Institute (branch) of the Ammosov North-Eastern Federal University is located in the industrial centre of Western Yakutia, Mirny city, the heart of the diamond mining province of Russia and the centre of the oil and gas industry of the Republic.

Western Yakutia is adjacent to the Arctic territory with a harsh climate and permafrost, which complicates mining operations, and slows recovery of ecosystems, exacerbating the anthropogenic impact on the environment. The Arctic environment is known to be fragile, climate conditions are harsh and the operational season is short. Success in this remote area will depend on appropriate selection of existing technologies and development of novel, more efficient ones [1].

The core of Yakutian diamond, oil and gas complex is in its western part, as the majority of positive reserves of

diamonds and hydrocarbon crude are located in western and south-western parts of the republic. The largest diamond, oil and gas fields are situated in Western Yakutia.

II. INDUSTRIAL SECTORS OF THE REGION

The area of disturbed lands in Mirny district ranks second in the Republic after the Neryungrinsky district (about 9 thousand hectares).

The history of diamond mining in Yakutia dates back to 1954, when prospectors discovered the first diamond pipe, Zarnitsa ('Summer Lightning'). In 1957 the Soviet government established Yakutalmaz Group of enterprises, and diamond mining operations commenced. Two years later the USSR sold the first parcel of Yakutian diamonds on the world market. In 1963 the USSR entered into its first contracts with De Beers to sell its diamond production.

The history of ALROSA started in January 1957 as Yakutalmaz Group of enterprises. The Soviet diamond mining industry developed on the basis of the Mir open-pit mine and adjacent diamond placers. In those years its main open-pit mines, processing plants and related energy generating facilities were commissioned.

In February 1987 the USSR Ministry of Non-Ferrous Metals reorganized Yakutalmaz Group of production enterprises into Yakutalmaz Research and Production Association. The subsequent reorganization of Yakutalmaz and a number of state-owned enterprises into a single joint stock company called Almaz Rossii-Sakha (Diamonds of

Russia and Sakha) – ALROSA took place in 1992. ALROSA changed its legal entity form to public corporation.

Nowadays, ALROSA is the only diamond mining company which incorporates all the stages of diamond mining and beneficiation. In 2010 and 2011 it accounted for nearly one third of the global rough diamond production by volume, outperforming legendary De Beers. ALROSA is among the top ten of Russia's most efficient enterprises. The main operations of the company create 31,026 jobs [2].

Oil and gas extraction is a comparatively new industrial sector for Mirny district.

Russia possesses nearly a quarter of the world's proven natural gas reserves and produces around 18% of world output, second only to the US (BP, 2010 and IEA, 2012). Historically, the bulk of Russia's gas production came from the West Siberian area, which provided some 85% of the country's production in the 1990s and early 2000s. Today, the region's three major fields – Urengoykoe, Yamburgskoe and Medvezhje – are in steady decline [3]. Many analysts suggest that future of Russia's oil and gas sector will be connected with the Arctic region [4; 5; 6].

The Sakha Republic of the Russian Federation the vast territory of which is located in the Arctic and sub-Arctic regions possesses 34 deposits of natural gas (2716 billion cubic metres) and crude oil (546 billion tons). Inferred resources of the Republic are estimated at 12 trillion cubic metres of gas and 546 million tons of oil. At the moment, only 20% of the inferred resources of the Republic have been exploited [7].

Gas prospecting in Yakutia has reached 2.3 billion cubic metres, and oil development 300 billion tons. In the two neighbouring regions of the Republic – Lensk and Mirny – the largest oil, gas and condensate fields are located: Chayandinskoye, Talakanskoye, Srednebotuobinskoye and Taas-Yuriakhskoye. These fields are included in the federal oil and gas transportation project “Power of Siberia”.

All in all, 21 license holders are operating in 60 license blocks on the territory of Yakutia. The most prominent of them are GAZPROM, ROSNEFT, SURGUTNEFTEGAZ, SAKHATRANSNEFTEGAZ, Yakut Fuel Energy Co., TAASYURIAKH NEFTEGAZODOBYCHA, IRELYAKHNEFT, GAZPROMNEFT ANGARA, IRKUTSK Oil Company, and others.

The crucial year in the development of the oil and gas industry was 2004, when one of the most prominent Russian oil and gas companies SURGUTNEFTEGAZ OJSC became a license holder in Yakutia. The entrance of this company resulted in the rapid growth of the oil and gas industry. The lion's share of this volume belongs to the Talakanskoye field. Severo-Talakanskoye, Vostochno-Alinskoye, Peleduyskoye and Yuzhno-Talakanskoye fields were discovered by SURGUTNEFTEGAZ OJSC in the Sakha Republic during the period of 2007-2011 [8]. Talakanskoye, Alinskoye, Severo-Talakanskoye and Vostochno-Alinskoye fields were

joined to the East Siberia – Pacific Ocean pipeline system and put into operation and maintenance. In Talakanskoye field, a pilot operation of a bitumen plant is being held at the moment.

Chayandinskoye oil and gas condensate field is located in the Lensk district of Sakha (Yakutia) Republic in the Far East region of Russia. The onshore field, also known as the Chayanda field, is being developed by GAZPROM. The onshore oil and gas field development forms a key part of the \$38bn project to build the Yakutia gas production centre along with the Yakutia-Khabarovsk-Vladivostok pipeline. The integrated project is expected to create 15,000 construction jobs. The first oil production from the Chayandinskoye field is expected in 2015 and gas production is expected to start in late-2018. The field development cost is estimated to be \$13.66bn. [9].

TAASYURIAKH plans to produce up to 1 million tonnes a year (20,000 barrels per day) from its East Siberian Srednebotuobinskoye field and aims to increase its output to 6.15 million tonnes (120,000 bpd) by 2016. The field with reserves of almost 1 billion barrels is connected to the East Siberia – Pacific Ocean by a 160 km pipeline [10].

The foundation of the Yakutian oil and gas production centre will increase local employment. Over 3,000 local petroleum engineers will be in demand to serve this sector [11].

The Mirny Polytechnic Institute (branch) of the Ammosov North-Eastern Federal University was founded in 1994 by the decision of Mikhail E. Nikolaev, the first President of the Sakha Republic who proclaimed this education policy to be the priority in the development of the Republic for the decades hence. It was intended to provide the ALROSA Company with needed specialists [12].

To meet the needs for specialists in oil and gas sector, the government of the Republic has opened the Petroleum Engineering Department in the Mirny Polytechnic Institute (branch) of Yakut State University (today's NEFU) in 2008.

At present the institute has prepared 2504 specialists, including 1438 mining engineers (976 of them employed by ALROSA) and 151 petroleum engineers. The majority are employed in ALROSA and leading oil and gas enterprises: GAZPROM, SURGUTNEFTEGAZ, LUKOIL, SAKHALINENERGY, SAKHATRANSNEFTEGAZ, LENSKGAZ, ALROSA GAS, IRELYAKHNEFT, BAKER HUGHES.

III. ECOLOGICAL PROBLEMS OF THE REGION

As investigators write, diamond mining development, accompanied by infrastructure and industrial development, caused significant negative environmental and social impacts in the diamond province, including:

- contamination of the river Vilyuy by dispersion of ground waters from kimberlite pipes and disposal of waste water from the processing operations;
- Twelve 'peaceful' underground nuclear explosions were carried out in Yakutia during 1967–1988; all but one were detonated on the territory of the present diamond province and one of them was directly linked to the diamond mining developments;
- creation of the Vilyuy hydroelectric power station and accompanying water reservoir contaminated the river with phenol and caused a reduction in the fish population in the river Vilyuy;
- deterioration of health amongst the population of the Vilyuy region linked to pollution of the river Vilyuy by heavy metals [13].

Here is the list of possible negative impacts on the environment of hydrocarbons extraction:

- deforestation on the sites for drilling wells, access roads and oil and gas pipelines;
- air pollution resulting from gas flaring and the operation of the equipment and transport;
- pollution of surface and ground water by discharge wastewater, technical liquids and petroleum products, and the depletion of water resources from excessive water consumption;
- pollution and destruction of soil and vegetation as a result of exposure equipment, and drilling waste disposal;
- the declines of wildlife populations because of disturbance of their habitats, migration routes and direct elimination;
- degradation of terrestrial ecosystems due to permafrost processes in open areas, and frequent fires caused by violation of fire safety rules;
- the degradation of terrestrial ecosystems due to changes in the hydrological regime and permafrost processes, and frequent fires caused by violation of fire safety rules.

In 1992, the Government of Yakutia initiated a programme for rehabilitation of the river Vilyuy basin (covering Kobyai, Mirny, Nyurba, Suntar Verkhnevilyuysk and Vilyuysk districts) via establishing the 'Viluy' Fund [13]. Several important political and economic changes in Yakutia and Russia as a whole affected the further development of this environmental programme.

Now it is widely recognized that for the management of social and environmental issues to be truly effective, moves towards sustainable development should involve constructive input from each of the three main groups of participants – industry, government and civil society [14; 15].

The public ecological Committee 'Viluy' drew the attention of the Government of the Republic and Russia to the environmental problem in the Vilyuy region and

stimulated ALROSA to invest heavily in environmental protection measures.

To prevent or minimize disruptions to the areas where ALROSA operates the following principles aimed at reducing environmental risk are included:

- Compliance with national and international environmental legislation;
- Mitigation of negative impact on the environment by adopting management and technology solutions that take environmentally important aspects of the operations fully into account;
- Constant improvement of the environmental management system;
- Introduction of advanced technologies to achieve a higher level of environmental safety in all operating areas;
- Improved environmental awareness of the staff and their full involvement in efforts to reduce environmental risks;
- Providing open and accessible environmental performance information to the stakeholders [16].

ALROSA has now launched a new programme of environmental measures with activities mapped out from the present till 2018. They cover:

- Improvement of nature conservation management - including environmental auditing, environmental monitoring, the development and adoption of corporate standards of environmental management, and certification under ISO 14001:2004 and ISO 14001:2007 Environmental Management System';
- Scientific and technical support of environmental activities;
- Exploration, development and deployment of innovative technologies in waste management;
- Increased openness and promoting public awareness of environmental performance.

The Company's total environmental expenditure amounted to about RUB 5.96 billion in 2014 [16].

Over the last decade on the territory of the "diamond province", via the joint efforts of the Government of Republic, ALROSA, with the participation of the public, a lot of work aimed at reducing the negative impact of mining on the environment is being realized. As a result, the environmental situation has stabilized to a certain extent, the main problems and ways of their solution are identified.

Oil and gas extraction is a new industrial sector which also causes ecological problems to be considered and solved.

According to the Russian legislation companies should provide effective measures for the treatment and disposal of waste production and collection of oil (accompanying) gas and saline water at all stages of oil and gas production, reclamation of disturbed and contaminated land, reducing the negative impact on the environment and compensation for environmental damage caused during construction and

operation of these facilities [17]. Construction and exploitation of objects of oil and gas production, processing, transportation, storage and realization of oil, gas and products of their processing are allowed at presence of projects of restoration of contaminated land in areas of temporal and (or) permanent land use, a positive conclusion of state examination of project documentation [18].

The land code requires land owners and land users to implement the reclamation of disturbed lands, restoration of their fertility and other useful properties of land and timely involvement in the economic turnover; the removal, use and preservation of fertile soil layer in the work connected with the violation of land [19]. The choice of remediation techniques should correspond to the climatic conditions, agrochemical and agrophysical properties of rocks, sanitation, and plan for the future development of disturbed land in the area [20].

In conditions of the North reclamation of disturbed lands is problematic. The main problems in reclamation are cryogenic processes, extending the areas of the violations, the lack of fertile soil for earthing due to the small capacity of the humus horizon of soils, and the problem of finding seeds and plants for biological recultivation. Most of the applied methods of reclamation in Yakutia do not take into account the specifics of the Northern territories and prefer cheap and simple technologies for remediation of soil with low-environmental efficiency, developed for the southern regions of Russia. Industrial companies use only the technical stage, levelling of the site and applying some of the soil in reclamation of the disturbed lands. As a biological stage of reclamation sowing seeds of herbaceous plants or natural regeneration are applied. Naturally, the implementation of such reclamation activities may not radically improve the environmental situation. The landscape will keep almost forever technogenic character. As a result, significant changes in water and thermal regimes and topography can also cause the degradation of adjacent undisturbed landscapes.

The problem is that there is almost no system for monitoring the compliance of restoration works of the users with the obligations. At the moment, in fact, the only form of control over the observance of norms and rules in the field of environmental protection is the industrial ecological control (IEC). This means that the companies independently plan and produce environmental monitoring, record the information and report to state regulators.

We may name a number of objective reasons why IEC is still not an effective instrument of solving ecological problems.

Firstly, the large-scale transfer of monitoring data from local level to regional and national is missing. The main part of the observation results conducted at the local level, remains on the shelves of customers and are not added to regional or national data Bank for environmental monitoring, while the state network of observation is deficient from the

point of view of spatial coverage, number of points, controlled variables and control methods.

Secondly, industrial environmental control and monitoring at a considerable number of ecologically dangerous objects is not conducted or is limited to the minimum necessary scope of work, not related to the overall observing system.

Thirdly, the possibility IEC is limited by project budget, fixing the cost of the construction and operation of controlled objects.

This results in extreme distrust of the local population to reports of environmental authorities and nature users and thus to hardening of social tension. The main reason is inadequate awareness of the population about the state of the environment and insufficient objectivity and completeness of the results of industrial environmental control and monitoring.

The credentials of the controlling authorities of the Ministry of nature protection of the Republic do not apply to oil and gas companies because they relate to Federal facilities. There is also the problem of the complexity of monitoring because of location of oil and gas facilities in remote places in the forest. So the state control is conducted seldom. The state network of observation is deficient from the point of view of spatial coverage, number of points, controlled variables and control methods.

IV. ECOLOGICAL MONITORING SYSTEM IN MIRNY POLYTECHNIC INSTITUTE

At the moment, there are few investigations of the consequences of anthropogenic impacts on Northern ecosystems, there are no evidence-based recommendations for the development and restoration of lands in Yakutia.

On the basis of the educational and scientific laboratory of complex analysis of anthropogenic disturbances of our Institute the students under the supervision of the Candidate of science in Biology Elena V. Slepsova have organized an expedition and held an investigation of hard metals concentrations in the rivers adjacent to the oil and gas provinces. The samples of water, riverside soil and bottom silt were collected during August – September 2015 from the rivers Irelyakh, Chuonalyr, Ulakhan Botuobuya, Taas-Yuriakh and Ochuguy Botuobuya. Ulakhan Botuobuya and Taas-Yuriakh are located on the territory of Srednebotuobinskoye field next to Taas-Yuriakh settlement. For comparative analysis samples from the rivers Irelyakh, Chuonalyr and Ochuguy Botuobuya in the vicinity of Mirny town were taken. The analysis was carried out by means of the atomic absorption spectrometer ContrAA 700 according to the Measurement procedure-539-03 and Measurement procedure-80-2008.

Quantitative chemical analysis of heavy metals in the rivers in the area of Srednebotuobinskoe field showed the

exceedance of Iron, Aluminum and Cadmium, which applies to 2 hazard class.

The exceedance of maximum permissible concentration (MPC) [21] of Aluminium for drinking and household, cultural and social water consumption was registered in the Taas-Yuriakh (1,5 times) and the Irelyakh (2 times) rivers; of Iron – in the Taas-Yuriakh (1,3 times) and the Ochuguy Botuobuya (1,5 times) rivers; of Cadmium – in the Ulakhan Botuobuya river (2 times) (See Table 1).

TABLE 1, HEAVY METALS CONCENTRATIONS IN NATURAL WATER, µG/L

	Irelyakh	Chuonalyr	Ulakhan Botuobuya	Taas-Yuriakh	Ochuguy Botuobuya	MPC [21]
Manganese	33	51	6,4	31	5,4	100
Copper	<1	<1	<1	<1	18,8	1000
Cadmium	<0,1	<0,1	2,25	0,27	<0,1	1
Aluminium	412	104	75	293	47,1	200
Iron	182	122	75	390	451	300
Zinc	71	<1	<1	77	<1	1000
Cobalt	<1	<1	<1	<1	<1	100
Chrome	<1	<1	<1	<1	<1	50
Nickel	9	<1	<1	<1	<1	20
Lead	<1	<1	<1	<1	<1	10

The danger of the exceedance of MPC in riverside soil [22] lies in the fact that it is capable of interfering with the biochemical processes of living organisms. The exceedance of MPC of active forms of Copper is marked in the Irelyakh, Chuonalyr, Ulakhan Botuobuya and Taas-Yuriakh rivers; of Zinc in the Irelyakh and Chuonalyr rivers (from 13 to 52 mg/kg); of Chrome in the Chuonalyr river (from 2,4 to 7,8 mg/kg); of Nickel in the Irelyakh, Chuonalyr, Ulakhan Botuobuya and Taas-Yuriakh rivers (from 1,4 to 24 mg/kg) (See Table 2).

TABLE 2, ACTIVE FORMS OF HEAVY METALS CONCENTRATIONS IN RIVERSIDE SOIL, MG/KG

	Irelyakh	Chuonalyr	Ulakhan Botuobuya	Taas-Yuriakh	Ochuguy Botuobuya	MPC [22]
Manganese	236	533	185	212	125	140
Copper	29,9	36,9	5,4	4,45	1,34	3
Zinc	52	32	15	17	13	23
Cobalt	4,1	2,8	3,8	2,6	1,5	5
Chrome	5,2	7,8	4,7	5,8	2,4	6
Nickel	24	23	9,2	5,8	1,4	4
Lead	8,1	1,3	0,97	1,3	0,71	32

The pollution of river water, riverside soil may lead to the contamination of bottom silt which may cause secondary contamination of water. The analysis of heavy metals concentrations in bottom silt displays the exceedance of MPC [22] of Manganese in the Chuonalyr and Ochuguy Botuobuya rivers. The exceedance of Copper is registered in all the rivers; of Zinc in Irelyakh and Chuonalyr; of Chrome in Irelyakh; of Nickel in Irelyakh, Chuonalyr and Ulakhan Botuobuya (See Table 3).

TABLE 3, ACTIVE FORMS OF HEAVY METALS CONCENTRATIONS IN BOTTOM SILT, MG/KG

	Irelyakh	Chuonalyr	Ulakhan Botuobuya	Taas-Yuriakh	Ochuguy Botuobuya	MPC [22]
Manganese	132	263	129	72	153	140
Copper	28,5	19,9	4,25	41,34	33,8	3
Zinc	53	34	9,1	18	12	23
Cobalt	3,1	4,3	3,1	1,6	1,2	5
Chrome	7,8	3,6	4,2	2,8	1,7	6
Nickel	40	8,7	7,7	2,5	0,41	4
Lead	8,4	0,55	0,8	0,1	0,33	32

The data show that the rivers, riverside soil and bottom silt in the oil and gas province are contaminated by heavy metals.

For the purpose of optimization of water pollution control we suggest the foundation of ecological observation station and regular monitoring.

We are planning further comprehensive studies with the aim of obtaining a coherent picture of the impact of oil and gas complex on environment on the territory of Western Yakutia. Effective assessment of the ecological state of Northern ecosystems is needed to predict and analyze the impact of developing industries of mining in Western Yakutia. The research results will allow to develop recommendations for the most appropriate and cost-effective ways of mining and remediation techniques in permafrost condition.

The Institute’s educational and scientific laboratory of complex analysis of anthropogenic disturbances pursues the following goals:

- creation of conditions for environmental monitoring in Western Yakutia;
- investigations by specialists of MPTI in the field of ecology involving students in research activities;
- improvement of environmental education of MPTI students.

In December 2015 the laboratory was included in the register of accredited organizations, which allows controlling the objects in conformity with the necessary

requirements and ensures the accuracy of the results. In future we plan to expand the scope of accreditation.

V. CONCLUSION

The institute has close ties with industrial enterprises operating in Mirny district: ALROSA, GAZPROM, ROSNEFT, SURGUTNEFTEGAZ, TAASYURIAKH NEFTEGAZODOBYCHA, IRELYAKHNEFT and others.

Organization of public ecological monitoring system in the West of Yakutia with the involvement of research and material resources of the Mirny Polytechnic Institute (branch) of Ammosov North-Eastern Federal University will give an objective integrated assessment of the impact of the oil and gas industry on the environment on the territory of Western Yakutia, which should encourage subsoil users to apply more effective measures to reduce the impact on the natural environment and increasing payments for environmental damage.

Since 2012 the institute takes part in public hearings of industrial enterprises where companies present the feasibility study of their mining projects in which they are expected to follow environmental and rehabilitation codes. One of the latest public hearings took place on March 25, 2016 in the centre of Evenkiysky National district – Olenyok, where the ALROSA Company presented the project of launching mining operations in Verkhnemunskoye deposit of the region. The meeting was attended by the local population and authorities, the representatives of the Ministry of Ecology and other public officials. The hearings resulted in signing an agreement on mining operations by ALROSA.

In April 2016 all these companies reported their activities during 2015 in Mirny administration in the presence of the indigenous population inhabiting the district.

May 24, 2016 the public hearings devoted to the ecological issues took place at the site of the TAASYURIAKH NEFTEGAZODOBYCHA with the participation of the members of the Government of the Sakha republic, administration of Mirny district and local population.

As the result of the debates during these meetings the companies were demanded to meet the requirements of the people in order to establish adequate communication between industry, local authorities and local population.

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