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Problems of Ecology and Technogenic Impact on the Natural Environment of the Yamal-Nenets Oil and Gas Producing Region

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Abstract: Due to the discovery and development of oil and gas fields in the North of Western Siberia and in other regions of the Russian Federation, intensive construction and operation of infield facilities is underway in the Northern regions. Difficulties of economic development of these areas significantly increase the amount of capital investments in construction, so, an indispensable condition for the development of new territories is modern scientific and technical preparation, the most important element of which is hydrogeological, engineering-geocryological and ecological research. Of considerable importance in this is creation of a new scientific area-ecological geocryology which will study emerging problems.

Key words: Oil and gas producing region, technogenic impact, aquiferous complex, pollution, protection, wastewater, technogenic factors, ecological geocryology, natural technogenic systems

INTRODUCTION

On the territory of the Russian Federation as in many Foreign countries over the past decade a very complex ecological situation has formed and in some regions an ecologically critical one. There arose a new global international problem-protecting the environment of human life from the negative impact of technogenic processes. To solve this problem required fundamental as well as a number of new applied sciences, originated in the era of modern technogenesis (Beshentsev, 2008). The researchers conducted studies at oil, gas and fresh groundwater fields during which significant changes in the properties of the geological and often the environment as a whole including cryolithozones in the yamal-nenets oil and gas producing region, occur.

REVIEW OF THE EXISTING PROBLEM

The generalization and analysis of the large factual material collected on the basis of the results of many years of research enabled the researchers to make an attempt to develop the scientific and methodological foundations of ecological geocryology and to determine its structure and content. The first definition of ecological geocryology was given by the researchers in 2014 as a science on the environmental aspects of the formation and distribution of permafrost on the transformation of the cryolithozone as a component of the environment (lithosphere) under the influence of anthropogenic impact and natural and technical disasters (Beshentsev *et al.*, 2005). Ecological geocryology is in its content, applied science with a social focus and solves the problems of construction and operation of facilities under permafrost conditions.

The Yamal-Nenets autonomous Okrug has been one of the main oil and gas producing regions of the country, since, the second half of the last century. In the region, more than 70% of Russia and about 22% of the world's gas reserves are concentrated, 234 hydrocarbon deposits are discovered of which 72 are in commercial development and 19 are ready for operation. At present, exploration works are carried out at 146 deposits (Beshentsev, 2006).

In the mountainous part of the region (in the Polar Urals) the production of chromites is increasing, exploration of manganese, polymetallic deposits, gold and platinum, stones of semi-precious raw materials is conducted. Deposits of sand, crushed stone for piling roads and production of building materials are being developed everywhere. On the territory under consideration, modern cities and urban settlements have been built, Salekhard, Nadym, Novy Urengoy, Noyabrsk, Muravlenko, Gubkinsky, Tarko-Sale, Vyngapurovsky, Purpe, Yamburg and others. More than 1000 km of railroad, 4000 km of motor roads have been laid, thousands of kilometers of gas and oil pipelines, power lines have been built. The extraction and use of water resources are increasing. Under the influence of the above factors of technogenic impact, hydrogeological and engineering-geological conditions change, the composition and properties of groundwater and permafrost soils change, technogenic hydrogeological systems are formed.

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Natural waters of the region are most vulnerable in those areas where drilling, construction and operation of oil and gas wells are intensively carried out as well as where transportation and primary processing facilities for hydrocarbon raw materials are located. To date a large number of deep geological exploration wells have been drilled a significant number of which are located on the unallocated subsoil fund and drilled more than 40 years ago. All this represents a serious threat to the safety of industrial facilities and the ecology of the region.

One of the main factors is the violation of the natural temperature regime of permafrost rocks. When drilling wells through the permafrost zone, thawing and erosion of soils occur (especially, in the upper part of the section) with an intensive cavity formation which is the primary cause of almost all the complications during drilling of oil and gas wells associated with phase transitions in frozen rocks during the entire operation period.

The main sources of pollution of natural waters are drilling fluids and drilling muds, hydrocarbon leaks from pipelines, oil spills, associated mineralized reservoir and sewage waters, chemical reagents at oil production, preparation, dehydration and desalting facilities, oil and gas leakage in pipeline accidents. In the extraction of oil, more than 150 chemical products are used (Beshentsev, 2006; Beshentsev *et al*., 2005).

Of all the components of oil the most toxic ones for organisms and the environment are aromatic hydrocarbons, the bulk of which are homologues of benzene or naphthalene. Many components of oil, even at very low concentrations and doses have a toxic effect on living organisms. Basically, these are methane and aromatic hydrocarbons, especially, 3.4 benzapyrene, tungsten, nickel, aluminum, cobalt, uranium, hydrogen sulphide and mercaptans.

Together with oil, a huge amount of saline formation water is extracted to the surface which are separated during demulsification of oil and form the bulk of oil field waste water. According to statistics on average, 6 tons of associated reservoir waters, highly mineralized and environmentally hazardous are extracted in the world with 1 ton of extracted oil (Beshentsev, 2006; Beshentsev *et al*., 2005). Usually these waters are used to maintain reservoir pressure but in emergency situations they can penetrate into the geological environment which leads to soil salinization and contamination of fresh surface and ground water.

Due to defects in the development of production oil and gas wells, poor-quality conservation of prospecting and exploratory wells, flows of highly mineralized water, oil products and gas from deep horizons to the upper hydrogeological complex containing fresh groundwater are possible. Similar processes can occur during the construction of injection wells used for the disposal of industrial wastewater into the subsoil (Beshentsev *et al*., 2014). The breach of the annular space integrity in the production oil wells may appear to be a result of poor-quality cementing as well as destruction of the wells during the reverse freezing of permafrost.

The irreversible damage to the environment is caused by the annual burning of a huge amount of gas in flares. The volume of gross emissions of pollutants from gas combustion is about 827.779 thous.tons (Beshentsev, 2006; Sokolova, 2001; Beshentsev *et al*., 2014; Matusevich and Abdrashitova, 2013; Radchenko *et al*., 2009; Melnikov, 2009; Mimeev *et al*., 2016 and Beshentsev and Semenova, 2015).

Construction of engineering facilities on permafrost grounds is creating foci of concentrated technogenic impact on the natural environment and requires the observance of special technologies as well as detailed study of soils and monitoring of their condition during operation. Any violation of construction technology or the lack of conformity of the architectural plan to harsh climatic conditions can lead to deformation and subsidence of the engineering object. In addition, the situation is aggravated by the predicted global warming of the climate. On urbanized territories special natural-technogenic geocryological complexes are formed within which the dynamics of permafrost differs from natural conditions. The most unfavorable are technogenic wasteland-badlands (sludge and slag disposal areas, ash and tailing dumps and large sedimentation tanks of sewage treatment plants but even in the areas of tundra and forest-tundra that are in the zone of dispersion of pollutants and not so, affected by technogenesis there is a distinct increase in the depth of seasonal thawing, thermal conductivity of rocks connected with the fall of "Acid" rains and technogenic salinity of rocks which favors the thawing of soils in the summer.

The second most important source of technogenic impact on fresh groundwater is the Housing and Utility Complex (HUC). Waste water is the main source of pollution of natural waters in the region. According to the formation conditions they are divided into three categories, domestic, industrial and storm water. Annually in the Yamal-Nenets oil and gas producing region more than 40 million/m^3 of waste water are discharged into natural water bodies of which 3.7 million/m^3 in the sub surface horizons (Beshentsev *et al*., 2014; Matusevich and Abdrashitova, 2013; Radchenko *et al*., 2009; Melnikov, 2009; Mimeev *et al*., 2016 and Beshentsev and Semenova, 2015).

Pollution of groundwater is associated with the infiltration of contaminated runoffs from the river network, filtration fields, landfills with the drainage of sewage from engineering facilities. Emissions to the atmosphere from industrial enterprises, exhaust gases of transport play an important role in pollution. Of all contaminated wastewater, industry accounts for 50%, HUC-47% and others-3%.

Landfills of industrial and domestic waste are a serious threat to the pollution of natural waters. At present, 746 waste disposal facilities (38 landfills, 20 authorized and 27 unauthorized dumpsites, 651 other facilities including 632 slurry ponds) are located on the territory of the yamal-nenets oil and gas producing region (Beshentsev, 2006).

Due to their relative security, the presence of permafrost and sandy clayey sediments, located in the roof of aquifers, groundwater in contrast to surface water is polluted more slowly but the ongoing process of its pollution is irreversible.

The protection of groundwater from pollution is understood as a degree of closure of the aquifer by weakly permeable deposits preventing the penetration of pollutants from the surface of the earth into underground horizons (Beshentsev *et al*., 2005; Beshentsev, 2008; Goldberg and Gazda, 1984; Beshentsev, 2006 and Sokolova, 2001). The protection of groundwater depends on many factors which can be divided into three groups, natural, technogenic and physico-chemical.

NATURAL FACTORS INCLUDE

The presence of weakly permeable rocks in the study, the depth of occurrence of groundwater, the capacity of the aeration zone, the thickness and filtration properties of the overlaying rocks, the ratio of the groundwater levels of various horizons and the interrelationship of groundwater and surface water. In addition to the above factors in the permafrost zone where the yamal-nenets oil and gas producing region is located, the frozen or thawed state of the rocks plays an important role. Based on this, the determination of the degree of groundwater protection in the region is carried out taking into account permafrost conditions (Matusevich and Abdrashitova, 2013).

Technogenic factors on the territory of the region under consideration have been poorly studied. They include conditions for the presence of pollutants on the surface of the earth (storage of wastes in storage tanks, slurry storage, discharge of sewage into surface sources and filtration fields, etc.) conditions and nature of the penetration of pollutants into underground horizons (Sokolova, 2001). Physico-chemical factors in the yamal-nenets oil and gas producing region have not been studied and require additional studies these factors include specific properties of pollutants their migration capacity, sorption, chemical resistance, interaction of pollutants with rocks and groundwater.

When assessing the protection of groundwater, qualitative and quantitative indicators are considered. The former are based on natural factors and are estimated by the sum of scores, the latter on technogenic and physico-chemical factors on the basis of determining the time for which pollutants filtered from the surface of the earth reach the groundwater level. Quantitative evaluation is usually performed with detailed studies on local sites (Beshentsev, 2008; Goldberg and Gazda, 1984).

The main indicators in assessing the natural protection of groundwater in the region under consideration in the permafrost development zone are the structure and thickness of the permafrost which serves as a cryogenic aquiclude. Studies conducted by the researchers in the Yamal-Nenets oil and gas producing region showed that areas with protected aquifers and complexes include areas of water-bearing cryogenic-talik complexes of the quaternary and eocene-quaternary age (Beshentsev, 2006; Beshentsev *et al*., 2005; Beshentsev, 2008; Goldberg and Gazda, 1984; Beshentsev, 2006 and Sokolova, 2001). This area is characterized by a powerful aeration zone (more than 8-10 m) and the presence of clay and loamy layers (more than 3 m) in its composition in the hydrodynamic sense it is non-pressure and sub-pressure waters. The overlaying stratum is represented mainly by sands with interbeds of clays and silts, the total thickness of which sometimes reaches 20 m. However, the existing irregularity of low permeability deposits over the area leads to a certain deterioration in the conditions for the protection of groundwaters. The tight hydraulic connection of surface sub-pressure water also reduces the degree of protection of the latter in areas outside the permafrost distribution contours. Territories with unprotected aquifer complexes are delineated along the Ob, Nadym, Pur and Taz rivers and their large tributaries. It is a water-bearing talik Quaternary complex which includes water-bearing deposits of the floodplain and the first above-floodplain terraces. In the hydrodynamic, sense they are non-pressure water with a small power of the aeration zone (usually >1 m).

Based on the analysis of hydrogeological study, the researchers conducted area studies to assess the qualitative characteristics of groundwater protection against pollution. The studies showed that group 3 (with groundwater reliably protected against pollution) includes water intakes and groundwater deposits exploiting the water-bearing complex represented by pressure water and covered with permafrost rocks of different lithologic composition.

Group 2 (with conditionally protected groundwater) and group 1 (groundwater unprotected against pollution) includes infiltration water intakes and groundwater

Table 1: Groundwater deposits with approved reserves

Deposit	Approved operating reserves (Thous.m^3/day)	Start of operation	Estimated operation period	Groundwater extraction (Thous.m^3/day)	Protection group
Nadymskiy	21.4	1977	25	24.7	3
Kharpskiy	11.0	No information	25	5.3	1, 3
Pangodinskiy	174.0	1972	25	8.31	2
Nydinskiy	12.0	1978	25	2.98	2
Shchuchinskiy	29.0	Not in operation	25	-	3
Novourengoyskiy	100.8	1980	25	46.0	2
Tarkosalinskiy	54.0	1990	25	4.4	2
Krasnoselkupskiy	10.5	1987	25	1.58	2
Noyabrskiy	90.0	1981	25	35.38	2
Muravlenkovskiy	60.0	1986	25	14.45	2
Vyngapurovskiy	20.0	1987	25	2.1	2
Urengoyskiy	13.2	Not in operation	25	-	2
Tabyahinskiy	4.5	1985	25	0.78	2
Salekhardskiy	20.0	Not in operation	25		3
Evoyakhinskiy	82.1	Not in operation	25	-	2
Tarasovskiy	60.0	Not in operation	25	-	1
Long-Yuganskiy	2.4	1973	25	1.07	2
Pidejyakhinskiy	15.0	Not in operation	25	-	1
Farafontievskiy	28.6	Not in operation	25	-	1
Yagelny	14.0	1983	25	0.91	2
Vyrchinskiy	9.0	Not in operation	25	-	2
Karantiyny	12.6	Not in operation	25	-	2
Khalzutayakhinskiy	15.0	Not in operation	25	-	1
Kholmogorskiy	10.8	Not in operation	25	-	2

Table 2: Groundwater intakes with unapproved reserves

Water intake	Start of operation	Groundwater extraction (Thous.m^3/day)	Protection group
Krasnoselkupskiy	1981	1.65	2
Tolkinskiy	1985	0.886	1
Yuzhno-Russkiy	1995	3.6	2
Nydinskiy	1995	0.96	2
Pangodinskiy-1	1976	0.41	2
Pangodinskiy-2	1983	0.447	2
Pravohettinskiy	1983	1.197	2
Priozerny	1993	0.946	2
Staronadymskiy	1986	0.5	2
Yagelny	1996	0.936	2
Salekhardskiy	1984	4.8	3
Vostochno-Urengoyskiy	1997	1.8	2
Vyngapurovskiy	1977	0.452	2
Gubkinskiy	1998	12.546	2
Zapadno-Tarkosalinskiy-1	1994	0.665	2
Zapadno-Tarkosalinskiy-2	1995	0.442	1
Krayniy	1998	1.768	1
Korotchayevskiy	1984	2.761	1
Muravlenkovskiy-1	1994	2.702	2
Muravlenkovskiy-2	1986	0.533	2
Novourengoyskiy-1	N/A	0.432	2
Novourengoyskiy-2	1997	1.8	1
Noyabrskiy-1	1989	2.608	2
Noyabrskiy-2	1978	0.454	2
Purovskiy	1983	0.394	2
Purpeyskiy	1985	0.504	2
Samburgskiy	N/A	1.085	2
Startovy	1991	0.535	1
Sutorminskiy	1998	1.76	2
Yagenetskiy	1979	0.425	2

deposits that have a direct link to surface waters. When assigning deposits and water intakes to the appropriate group, the lithologic composition and the remoteness of the water intake from the river drain were taken into account. Data on the degree of protection of groundwater are given in Table 1 and 2.

As can be seen from Table 1 and 2, the majority of water intakes in the underground region under consideration belong to groups 1 and 2 with conditionally protected and unprotected groundwater against pollution therefore, the engineering development of the cryolithic zone of the Yamal-Nenets oil and gas producing region should be carried out taking into account new technologies, risks and engineering solutions aimed at preventing negative technogenic impacts.

Further development of ideas about the protection of groundwater of the region is seen in the use of data on the so-called Dynamically Strained Zones of the lithosphere (DSZ) (Matusevich and Abdrashitova, 2013). DSZ is the active boundary of a block reflecting an element of disjunctive tectonics on the day surface denoted by a lineament. A comprehensive analysis of geophysical, geological, hydrogeological data and lineament analysis allows us to distinguish DSZ in the rock stratum. In some cases, DSZ can be active channels of vertical filtration (of both natural and technogenic solutions). In other cases, DSZ serve as hydrodynamic screens, changing the structure of the filtration space and the direction of groundwater flows. Consideration of DSZ in the Yamal-Nenets autonomous Okrug in connection with the presence of a high technogenic load and an extremely "Sensitive" geological environment is especially, important (Radchenko *et al*., 2009; Melnikov, 2009; Mimeev *et al*., 2016).

The term natural technogenic systems was formulated in the second half of the 70 s of the last century by Russian scientists L.I. Mukhin, O.N. Tolstikhin and A.P. Kamyshev as a set of states of interaction between the components of the natural environment and engineering structures under conditions of their dynamic equilibrium at various stages of their functioning from design to reconstruction. Natural technogenic systems have their own internal structure, allowing us to explore its functional components in accordance with both their natural cause-effect relationships in development and with the requirements of national and international regulatory documents that regulate the norms of their socio-ecological safety of functioning.

CONCLUSION

As stated earlier, the creation and operation of any engineering structure is accompanied by the emergence and deepening of direct and reverse links which on the one hand, lead to a change in the qualitative composition of the habitat and on the other hand to a decrease in the potential for natural self-healing of natural complexes. Therefore, the main task at present is to optimize this impact in order to minimize the reverse reaction of the natural environment. That is why, the solution of environmental problems and the creation of a new scientific direction of ecological geocryology is now a priority.

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