© VLADIMIR A. BESHENTSEV, ELENA I. PAVLOVA
lenka137772009@rambler.ru

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STATE OF THE ENVIRONMENT AS A RESULT OF TECHNOGENIC INFLUENCE CAUSED BY THE DEVELOPMENT AND OPERATION OF RUSSKOYE OIL AND GAS FIELD

SUMMARY. Modern development and operation of oil and gas fields has a huge man-made impact on the environment and creates a number of environmental issues that need to be urgently addressed. The main factor of the negative anthropogenic influence on the environment, including natural waters, is their chemical and physical contamination. Mitigation of such anthropogenic impacts occurring at all levels of industrial development is the most important environmental issue of our time.

KEY WORDS. Technological impact, natural water, concentration, soil, atmosphere.

Russkoye field is a heavy crude oil field located in the Tazovsky District, Yamalo-Nenets Autonomous Okrug, north of the Arctic Circle. The field was discovered in 1960, but for more than 35 years it was not developed. Its development was complicated by a number of factors: high oil viscosity, complex geological section, lack of infrastructure and severe conditions of the Arctic region. One peculiarity of Russkoye field is its extensive gas «cap» and water-bearing stratum. The field has 60 wells, of which 39 are exploration wells, 13 are prospecting wells, and 8 production wells. Judging by its geological reserves (1.5 billion tons) and recoverable reserves (410 million tons) the field is one of the largest in Russia. Carbon materials are located at a depth of 0.8-0.9 km. The initial production rate of the field was 9 tons of oil and 2 mln m^3 of gas per day [1].

Sources of anthropogenic impact

The main sources of pollution within the territory of Russkoye field are wells, wellhead equipment, industrial sites, vehicles and linear objects. Significant damage to the environment is caused by various chemical elements and compounds (V Ni Cr Zn Cu Hg Pb Cd As, petroleum hydrocarbons, etc.) found in the gas condensate and oil, mud, groundwater and reservoir water. All of these lead to contamination of the ground, surface and ground water and change of the landscape (vegetation degradation, activation of exogenous permafrost processes, etc.) [2].

Several oil components, even at very low concentrations and doses, have toxic effects on living organisms. They are mainly methane hydrocarbons, aromatic hydrocarbons, especially 3.4 benzapyrene, hydrogen sulfide, mercaptans, and the above mentioned chemicals.

Assessment of the condition of natural waters

The main sources of natural water pollution by oil and gas companies are drilling washings and cuttings accumulated in sludge pits at drilling. The volume of drilling wastes, including drilling fluids, in slurry ponds can reach 350-1500 m^3. Drilling fluids usually belong to toxicity class IV. Landfill cover does not prevent filtration of drilling fluids into the groundwater or their spread into the surface waters in case of destruction of the lining of mud tanks. It also does not protect them from contacting with the water and soil biota. Together with wastewater, oil products, mud and cement mortars with chemical agents and additives, washing liquids and saline formation waters enter the environment.

The hydrographic network of the studied area belongs to the basin of the river Taz. It is represented by the left-bank Taz tributaries of 1-4 order — the Pandymyyaha, Malaya Todydeottayaha, Pravaya Yangyaha, as well as many small unnamed rivers and streams. An important place in the hydrographic network is occupied by numerous small lakes. The investigated rivers are located in wetlands characterized by peat-bog soil types rich in iron, which gives the water a dark color. In chemical composition they are calcium bicarbonate waters of low and medium salinity, within a year the quantitative content and ratio of the major ions is not constant, which appears to be associated with nourishment of the rivers in different hydrological phases.

Due to the fact that the streams are located in the oil field, they experience significant human pressure. Anthropogenic impact assessment is carried out based on the analysis of the water quality.

The water quality is generally understood as the characteristics of its composition and properties that determine its suitability for specific uses (GOST 17.1.1.01-77); quality criteria are the signs by which quality is assessed. Rules of surface waters preservation, regulated by normative documents [3], establish water quality standards for water bodies and streams in terms of drinking, cultural and fishery uses. On this basis study of the quality of the Russkoye field natural water was held in comparison with the maximum allowable concentrations (MAC) of substances in the surface waters set by the normative documents.

The studies of the natural water of the surface flows in Russkoye field showed the following.

According to the natural qualities the studied streams are slightly acidic to neutral (pH ranges from 4.34 to 6.7), according to hardness they are very soft (hardness value ranges from less than 0.1 mol/dm^3 to 0.2 mol/dm^3), their oxidizability varies from low to high.

The natural waters are characterized by the presence in their composition of such pollutants, which are indicators of anthropogenic impact, as (mg/l): suspended solids — 8-40,8, iron — 0,26-1,3, copper — 0,23-9,8; nickel — 0,01-6,672, zinc — 0,010-18,898; lead — up to 5.945, cadmium — 0,010-0,408, mercury — 0,050-0,140, phenols — 0,001-0,0015, oil products — 0,033-0,06 mg/l. The maximum level of oil content, 3.94 times more than MAC, is marked in an unnamed lake, located 1 km from the eastern boundary of the Linac. (ЛУ?)

The studies have shown that the waters of Russkoye field are already contaminated. Concentration of pollutants that are indicators of anthropogenic impact exceeds MAC by several times (Fig. 1).

In general, the ecological state of the natural waters can be regarded as satisfactory. Their industrial pollution within the test field is characterized by local distribution (in some tested parts) and mosaic pattern.

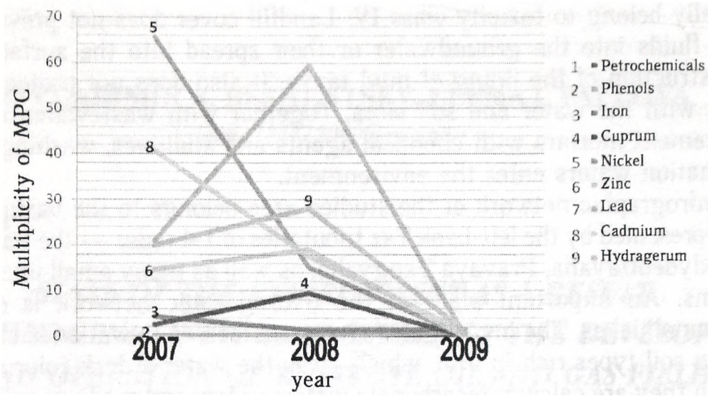

Fig. 1. MAC multiplication over time

Assessment of the soil condition

Impact of the activities that cause pollution of soil provides a more complete picture of the extent and degree of contamination in the survey area as well as significantly narrows and specifies the number of indicators.

In the absence of MAC for a pollutant (oil products), the MAC growth multiplication factor is equal to background multiplication.

The basics of the theory and practice of hygienic standardization of harmful substances in the soil is as follows [4]:

1. Not any introduction of exogenous chemicals in the soil should be considered as dangerous to human health and the environment.

2. Safe delivery of chemicals in the soil is determined by unacceptable excess of adaptation capabilities of the most sensitive population groups or threshold of the ecological (self-cleaning) ability of the soil.

3. Setting of the standards is based on the data obtained in the extreme climatic and soil conditions (maximum migration of the substance into the environments contacting with the soil) with account of the influence on the processes of self-purification and microbiocenosis.

4. Hygienic standards are established taking into account the limiting hazard indicator: sanitary, migratory water, air (transition from soil into water or air), organoleptic, phytoaccumulative (transfer and accumulation in plants) and toxicological.

5. Given the extreme variability of the climatic conditions of soil formation, the experimental basis for the MAC can be considered as a reference value to be used for risk assessment of soil contamination in the specific soil and climatic conditions.

Selection criteria for environmental soil assessment are determined by its specific location, genesis, buffer, and diversity of its use.

The degree of soil contamination is characterized by five levels [4]: 1 — acceptable, 2 — low, 3 — medium, 4 — high, and 5 — very high (Table 1).

Types of soil of the studied field contain the following contaminating components: oil products ranging from 5 mg/kg to 58 mg/kg (average 14.42 mg/kg); iron ranging from 500 to 4925 mg/kg, with an average of 2333 mg/kg; lead ranging from 10, 25 mg/kg (1.7 MAC) to 34 mg/kg (5.6 MAC) (average 13.4 mg/kg); copper reaches 8.75 mg/kg, which is equivalent to 4 6 MAC; zinc ranging from

6.3 mg/kg (0.27 MAC) to 27.38 mg/kg, which exceeds MAC (23 mg/kg) by 1.19 times; nickel ranging from 10 to 10.9 mg/kg; cadmium ranging from 0.15 mg/kg to 0.33 mg/kg; phenols ranging from 0.25 to 1.5 mg/kg; mercury ranging from 0.025 to 0.05 mg/kg.

Table 1

Indicators of the level of soil chemical pollution

Element, compound	Content (mg/kg) corresponding to level of pollution				
	1 level acceptable	2 level low	3 level medium	4 level high	5 level very high
1	2	3	4	5	6
Inorganic compounds					
Lead	**<MAC**	MAC — 125	125-250	250-600	>600
Zinc	**<MAC**	MAC — 500	500-1500	1500-3000	>3000
Copper	**<MAC**	MAC — 200	200-300	300-500	>500
Nickel	**<MAC**	MAC — 150	150-300	300-500	>500
Organic compounds					
Phenols	**<MAC**	-	1-5	5-10	>10
Oil and oil products	<MAC	from 1000 to 2000	from 2000 to 3000	from 3000 to 5000	>5000

Note: Components highlighted in bold show that they belong to the first acceptable level of pollution.

Assessing the current state of the field soils, it can be concluded that this component of the environment due to climate conditions and low self-purification capacity is highly susceptible to human impacts which can manifest themselves as pollution and disturbance in the soil profiles. The current situation on the territory of Russkoye oil and gas field shows that the level of contaminants is slightly higher than MAC and is equal to the first Level of Contamination (Table 1).

Assessment of the air quality

Outdoor air pollution is the introduction into the atmosphere of harmful (polluting) substances in concentrations exceeding the state standards of hygiene and environmental air quality ("On Air Protection" № 96-FZ).

Assessment of the air condition is given on the basis of the analysis of the samples taken by the authors in Russkoye oil field and their comparison with the existing standards (Table 2).

Table 2

MAC for substances in the atmosphere

No.	Component	MAC in air in residential areas, mg/m^3	Hazard class
1	Hydrocarbons (gasoline)	5	4
2	Nitrogen dioxide	0.085	2
3	Sulfur dioxide	0.5	3
4	Soot	0.15	3
5	Carbon oxide	5	4

In the course of the research we identified a complex air pollution index (CAPI), which is calculated by the following formula [5]:

$$CAPI = \sum\left(\frac{M_i}{MAC_i}\right)^{a_i},$$

where Mi — weight (ton/year) of substance "i" in the emission;
MACi — average daily MAC of substance "i";
ai — dimensionless coefficient which lets compare the degree of harmfulness of substance "i" with harmfulness of sulfur dioxide gas.

If CAPI is less than 2.5, the atmosphere is considered clean; if CAPI ranges from 2.5 to 7.5, the atmosphere is slightly polluted; if CAPI ranges from 7.5 to 12.5, the atmosphere is polluted; if CAPI ranges from 12, 5 to 22.5, the atmosphere is heavily polluted; if CAPI ranges from 22.5 to 52.5, the atmosphere is highly polluted; and if CAPI is above 52.5, the atmosphere is extremely polluted [6].

Soil CAPI was calculated on the basis of seven elements: hydrocarbons, nitrogen oxide, nitrogen dioxide, sulfur dioxide, soot, carbon monoxide, and suspended solids. These calculations, made in different years, showed the following:

— In 2007, CAPI was 2.014, the atmosphere is clean;
— In 2008, CAPI was 2.438, the atmosphere is clean;
— In 2009, CAPI was 2.672, the atmosphere is slightly polluted;
— In 2010, CAPI was 1.334, the atmosphere is clean.

The following is a description of some of the elements that affect the air quality.

The air contains the following pollutants (mg/m3): carbons ranging from 1.9 to 3.43, nitrogen oxide ranging from 0.02 to 0.0395, nitrogen dioxide ranging from 0.02 to 0.028, sulfur dioxide ranging from 0.011 to 0.032, soot ranging from 0.025 to 0.041, carbon monoxide ranging from 1.87 to 3.87, and suspended solids ranging from 0.26 to 0.36.

The air in the studied field is classified as «clean». No excess of MAC was registered. However, there is a tendency towards the increase of pollutants in the course of time. This is, apparently, due to the fact that all the technological processes in the field are potentially negative for the atmosphere.

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