Eco-Geochemical Characteristics of Surface Waters in the Zone of Oil and Gas Deposits Development in the Western Yakutia

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Abstract. In Western Yakutia, the largest oil and gas fields are concentrated, on which several subsoil users currently work. Due to the intensive use of water by oil and gas companies for industrial purposes, the construction of transport infrastructure, a significant impact on the state of surface water is occur. An assessment of the ecgeochemical state of small rivers located on the territory of oil and gas industry impact in Mirny district was carried out. It is revealed that the construction of water intakes can lead to changes in the mineral composition of surface water. Road construction has a significant exposure on the ecological condition of rivers. The results indicated increased concentrations of heavy metals such as iron, zinc, copper, aluminium, manganese in the studied rivers.

1. Introduction

In Western Yakutia, the largest oil and gas fields are concentrated, including the Srednebotuobinskoye oil and gas condensate field (SBOGCF), which has been developed since 1984 [1]. At the same time, the volume of oil and gas production in its territory continues to increase. Due to intensive water use for industrial purposes, construction of transport infrastructure, oil and gas companies have a significant impact on the state of the rivers in the areas of their activity. Currently, local residents are extremely concerned about the state of the Ulahan-Botuobuya River, which is the main source of drinking water, a fishing place and a waterway for movement in the summer.

From 1976 to 1987, seven underground nuclear explosions (UNE) were carried out in the territory of the SBOGCF in order to develop the technology of industrial development of low-productive natural hydrocarbon deposits. There are numerous landscape changes in the form of polygonal soil subsidence caused by the melting of underground ice, areas of the dried dead forest with rapidly growing new forest vegetation, where radioactive spots of small size with high content of heavy metals and radionuclides in the soil and biota are found [2] [3].

Fluctuations in the geochemical characteristics of surface waters depend on the degree of contamination of drained landscapes, from where, after rain, pollutants can enter into natural watercourses in large quantities [4]. The degree of pollution of water bodies also depends on the water content and water exchange rate [5]. Small rivers are characterized by small streamflow, low water availability, low depth, which together determines the adverse conditions for self-purification. Therefore, small rivers experience the greatest anthropogenic load, affecting the formation of water quality of larger water bodies. Self-purification in the northern rivers occurs at a distance of 1500-
2000 km, whereas in the middle latitudes it occurs on a 200-300 km section, because at low temperatures the processes of oil evaporation from the water surface are weakened [4].

In addition to pollution rivers in the zone of subsoil users activity may experience a significant transformation of the hydrological regime as a result of changes in conditions of streamflow, withdrawal of water resources for water supply, destruction of vegetation in the water protection zone, etc. Reduced streamflows, contaminants from produced wastewater and fracking fluids, and elevated sediment inputs would alter ecosystem functions, such as whole-stream metabolism, decomposition of organic matter, and accrual of macroinvertebrate biomass over time [6]. A high degree of correlation between the frequency of gastrointestinal diseases and the content of nickel, copper, cobalt, cadmium, zinc in drinking water was established [7].

In connection with the rapid development of the oil and gas industry in the territory of Western Yakutia, it is necessary to develop scientifically grounded measures to prevent the deterioration of the quality of the waters of the rivers during the mining and geological exploration [8]. The aim of our work is to assess environmental and geochemical condition of the small rivers located on the territory of oil and gas industry impact in the Mirny district.

In June 2017, samples of water were taken in the area of a number of oil and gas companies activity in the Mirny district. Agreed with the companies representatives sampling points is shown in figure 1.

**Figure 1.** The sampling points on SBOGCF: T1 - Ulakhan-Botuobuya river, 1 km from the village of Taas-Yuryakh; T2 - Taas-Yuryakh river, 500 m upstream from the road, 1 km from the Gazovikov village; T3 - Taas-Yuryakh river, 500 m downstream from the road, 1 km from the Gazovikov village; T4 - Taas-Yuryakh river, 500 m upstream from the road, 50 m from well No.8; T5 - Taas-Yuryakh river, 500 m downstream from the road, 50 m from well No.8; T6 - Taas-Yuryakh river, 500 m upstream from the road, 3 km from the checkpoint; T7 - Taas-Yuryakh river, 500 m downstream from the road, 3 km from the checkpoint; T8 - Telgespit river, 500 m upstream from the road; T9 - Telgespit river, 500 m downstream from the road; T10 - reservoir on the Telgespit river, above the water intake; T11 - reservoir on the Telgespit river, under the water intake.
The samples were studied in the accredited educational and scientific testing laboratory of technogenic environmental disturbances complex analysis of Polytechnic Institute (branch) of NEFU in Mirny. The content of suspended solids, mineral composition, petroleum products, heavy metals by capillary electrophoresis, fluorometry and atomic absorption spectrometry were determined.

2. Discussion

Srednebotuobinskoye oil and gas condensate field is located within the Lena-Vilyui plain of the Middle-Siberian plateau between the rivers Lena and Vilyui. In the area wetland landscapes of the middle taiga are developed. The main watercourses of SBOGCF are a right-hand tributary of the Vilyui Ulakan-Botuobuya river, and its right tributaries: the rivers Telgespit and Taas-Yuryakh. The river valleys are wide with gentle slopes and with extensive marshy floodplains, within which a network of small lakes is developed. The river network density is 0.3 km/km². All rivers of the region are characterized by extreme unevenness of flow by seasons. Shallow waters, until the complete cessation of runoff, especially in dry years, are replaced by powerful short-term floods. The rivers of the region are characterized by low water content - the rate of flow is less than 2 l/s/km².

The water regime of the area was studied only in relation to the main river – Ulakan-Botuobuya, where regular hydrometric observations have been carried out since 1964. The length of the river is 459 km, the catchment area is 17 500 km². The annual flow of the Ulakan-Botuobuya river is 120-130 million m³. In February-March runoff is usually absent due to freezing. In the middle reaches of the river Taas-Yuryakh village is located. For the villagers, the Ulakan-Botuobuya river is the only source of drinking water and household supplies. In the basin of Ulakan-Botuobuya oil and gas companies "ALROSA-GAZ", "Surgunneftegaz", "Taas-Yuryakh neftegasodobycha", "RNG", "Irkutsk oil company", "Gazprom Geologorazvedka", "Irelyakhneft" are working.

On the banks of the right tributary of the Ulakan-Botuobuya Telgespit river the wellheads of underground nuclear explosions "Neva-2", "Neva-3", "Neva-4" and "Oka» are located. The marshy Telgespit river flows mainly in the zone of activity of Taas-Yuryakh Neftegasodobycha. The riverbed is crossed by roads to wells and gas pipeline. The river feeds an artificial lake with a depth of 10 meters. About 700 cubic meters of water is supplied from it by pumps per day.

The river Taas-Yuryakh flows mainly from the South to the North-East and flows into the river Ulakan-Botuobuya at 219 km from the mouth. The river basin is mainly forested (about 95%), there are almost no marshes (less than 5%), lakes are also practically absent (less than 1%). The river bed is winding. The total length of the river Taas-Yuryakh is 58 km, the catchment area is 947 km². On the right bank there is a wellhead of the underground nuclear explosion "Sheksna". In the basin of the river ALROSA-Gas and RNG are developing oil and gas. The riverbed is repeatedly crossed by roads, in 2017, a water intake structure with a depth of 10 m and a volume of 500 thousand cubic meters was built by RNG.

The territory of Western Yakutia is characterized by magnesium-calcium sulphate waters. In the surface waters of the background areas of the SBOGCF region, the trace element content is very low, at the level of the lower detection limits, the water is pure, fresh, ultra-fresh [9].

In the water intake on the river Telgespit recorded the greatest mineralization with a predominance of calcium ions (23 mg / l) and sulfates (40-41 mg / l) (table 1). Earlier studies of surface water at SBSOKM revealed a higher content of sulphates in the middle reaches of the river Telgespit in comparison with other rivers [10], what the authors explained by the presence of hydrogen sulfide in marshy landscapes. Also, high levels of sodium, chlorine and sulfates are associated with the influence of the Cambrian aquifer complex [11]. However, it is known that the construction of roads and other engineering structures can also change the hydrochemical conditions in water bodies, which as a result increases the content of dissolved salts [12].
The rivers on the field are repeatedly crossed by roads laid to cluster sites. The results show a slight increase in the chloride content downstream of the bridges, and at two points there is an elevated suspended solids content downstream of the Taas-Yuryakh River.

In the microelement composition of the rivers, elements unusual for surface water, such as lead, chromium, nickel, cobalt were found (table 2). According to the data obtained by Argunova et al. (2012), in the areas of peaceful underground nuclear explosions on the territory of SBOGCF, trace elements Co, Ni, Ti, V, Cr, La, Y, Be enter surface watercourses and reservoirs. In comparison with the data of 2012, the content of zinc in the waters of the rivers rose significantly - 5 times in the river Ulahan-Botuobuya, up to 25 times in the middle course of Telgespit and up to 35 times in the river Taas-Yuryakh.

Almost everywhere there is pollution with heavy metals: copper - 1,5-4,9 MPC, zinc - 1,01-5,01 MPC, iron - 3,6-9,3 MPC, aluminum - 5,7-12,8, manganese - 2,2-20 MPC. In most rivers of southern and Western Yakutia, there is an increased content of copper, manganese, zinc, aluminum and iron [13] [14] [15] [16] [17]. The high content of iron and aluminum is observed in the swampy waters of the tundra and North taiga zones, characterized by high color and acidity [18]. Yannikov and Dagaeva (2018) suppose that the excess of MPC content of manganese, copper and aluminum within the Mirninsky kimberlite field have a natural origin associated primarily with the lithological and petrographic composition of sedimentary cover rocks [19].

However, it is known that heavy metals deposited on road surfaces and transferred to roadside environments by rainfall and snowmelt runoff can have serious impacts on receiving ecosystems [20]. Thus, according to our results, there is a clear dependence of the zinc content on the presence of roads: a significant increase in the zinc content in the water is observed downstream from the bridges at Taas-Yuryakh and Telgespit rivers (table 2). It can be stated with sufficient confidence that the increased content of zinc in northern rivers has anthropogenic origin. Further research is needed to determine the exact causes of high concentrations of zinc and other metals.

### Table 1. Component composition of surface waters on the territory of SBOGCF (mg/dm³).

| Sampling point number | suspended solids | oil product | Cl⁻ | SO₄²⁻ | NO₃⁻ | F⁻ | K⁺ | Na⁺ | Mg²⁺ | Ba²⁺ | Ca²⁺ |
|-----------------------|------------------|-------------|-----|--------|-------|----|----|-----|------|------|------|
| T1                    | 6.4              | 0.012       | 1.13| 10.7   | 0.28  | <0.10| 0.52| 1.37| 4.99 | <0.1 | 19.9 |
| T2                    | 0.6              | 0.014       | 0.7 | 6.96   | 0.22  | <0.10| <0.5| 1.88| 2.77 | <0.1 | 11.6 |
| T3                    | 1.57             | 0.019       | 4.99| 8.01   | 0.84  | <0.10| <0.5| 1.85| 2.76 | <0.1 | 11.7 |
| T4                    | 6.4              | 0.022       | 0.88| 7.05   | 0.21  | <0.10| <0.5| 1.97| 2.83 | <0.1 | 12.3 |
| T5                    | 15               | 0.022       | 0.96| 7.28   | 0.20  | <0.10| <0.5| 1.74| 2.81 | <0.1 | 11.8 |
| T6                    | 15.1             | 0.030       | 0.90| 9.84   | 0.32  | 0.12 | 0.51| 3.16| 3.75 | <0.1 | 13.5 |
| T7                    | 5.0              | 0.062       | 1.41| 3.37   | 0.34  | 0.14 | 0.57| 3.67| 5.82 | 0.15 | 18.4 |
| T8                    | 7.69             | 0.021       | 1.65| 14.8   | 0.89  | <0.10| <0.5| 3.54| 2.45 | 0.12 | 11.4 |
| T9                    | 1.92             | 0.021       | 1.72| 14.7   | 0.30  | <0.10| <0.5| 2.32| 2.56 | 0.11 | 11.6 |
| T10                   | 2.75             | 0.021       | 7.09| 41.8   | 0.27  | <0.10| 0.53| 3.00| 4.78 | 0.42 | 23   |
| T11                   | 1.0              | 0.020       | 6.92| 40.5   | <0.20 | <0.10| 0.51| 5.09| 4.44 | 0.44 | 23.6 |

| maximum permissible concentration (MPC) | 0.05 | 300 | 100 | 40 | 0.05 | 50 | 120 | 40 | 0.74 | 180 |

The rivers on the field are repeatedly crossed by roads laid to cluster sites. The results show a slight increase in the chloride content downstream of the bridges, and at two points there is an elevated suspended solids content downstream of the Taas-Yuryakh River.
3. Conclusion

In recent years the oil and gas industry has been actively developing in the territory of South-West and Western Yakutia. Accordingly, the anthropogenic load on the environment, including surface water, is significantly increased. An increasing network of linear objects (roads, oil and gas pipelines) and constructed water intake facilities affect the hydrological regime, change the geochemical composition of rivers.

The most adequate predictive estimates of the oil-producing complex impact on the environment can be obtained only on the basis of spatial and temporal models of natural objects restructuring. The problem of studying the transformation of ecosystems under the influence of oil and gas companies lies in the inaccessibility of the location of their facilities, the restriction of movement through the territory of licensed areas and the possibility of selecting sampling points only in agreement with subsoil users. It is necessary to develop a legal mechanism that allows to conduct comprehensive research in territories developed by several oil and gas companies without hindrance.

4. References

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Table 2. The content of heavy metals in surface waters on the territory of SBOGCF (µg/dm³).

| Sampling point number | Pb  | Cd  | Cr  | Mo  | Cu  | Ni  | Co  | Zn  | Fe  | Al  | Mn  |
|-----------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| T1                    | 1.8 | <0.01 | 1.0 | 0.22 | 2.8 | 5.3 | 0.28 | 10.1 | 582 | 288 | 48  |
| T2                    | 0.57 | <0.01 | 0.7 | 0.12 | 2.2 | 1.9 | <0.2 | 4.6  | 695 | 359 | 22  |
| T3                    | <0.2 | <0.01 | 0.36 | <0.1 | 2.0 | 1.9 | 0.6  | 8.0  | 482 | 319 | 22  |
| T4                    | 0.58 | <0.01 | 0.6 | <0.1 | 4.2 | 2.0 | 0.27 | 6.4  | 630 | 512 | 23  |
| T5                    | 2.1  | <0.01 | 1.0 | <0.1 | 4.9 | 2.0 | 0.34 | 19.0 | 701 | 513 | 22  |
| T6                    | <0.2 | <0.01 | 0.6 | <0.1 | 1.6 | 1.9 | <0.2 | 5.6  | 360 | 421 | 31  |
| T7                    | 0.73 | <0.01 | 0.3 | <0.1 | 1.5 | 2.0 | <0.2 | 35.0 | 792 | 470 | 200 |
| T8                    | 4.1  | <0.01 | 0.63 | <0.1 | 2.6 | 3.7 | 0.48 | <1   | 932 | 394 | 178 |
| T9                    | 3.4  | <0.01 | 0.8 | <0.1 | 2.1 | 3.5 | 0.73 | 19.0 | 927 | 365 | 220 |
| T10                   | <0.2 | <0.01 | 0.7 | <0.1 | 1.4 | 2.6 | 0.73 | 31.0 | 475 | 229 | 192 |
| T11                   | 2.9  | <0.01 | 0.36 | <0.1 | 2.7 | 2.1 | 0.64 | 51.0 | 597 | 300 | 191 |

Maximum permissible concentration (MPC)

| Pb | Cd | Cr | Mo | Cu | Ni | Co | Zn | Fe | Al | Mn |
|----|----|----|----|----|----|----|----|----|----|----|
| 6  | 5  | 70 | 1  | 1  | 10 | 10 | 0.01 | 100 | 40 | 10 |
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