Geoecological conditions of oil and gas fields of the unallocated subsoil fund of the southern industrial zone of the Yamal Peninsula

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Abstract. The paper presents the results of geoecological studies on the territory of the Rostovtsevsky and Nurminskoye deposits. It has been established that during the exploration work in the period from 1985 to 1995, the landscapes of the southern industrial zone of the Yamal Peninsula were subjected to significant anthropogenic impact. Subsequently, self-restoration of natural-territorial complexes in the area of drilling sites practically did not occur. There is a significant landscape-ecological difference from the background territories.

1 Introduction

The main direction of the development of the Arctic territories was the development of the mining industry [1-3]. Mining problems generally arise from detrimental environmental and social impacts and their cumulative impact on socio-ecological systems [4].

The Yamal Peninsula is one of the oil and gas bearing regions of Western Siberia. The landscape and ecological conditions of the peninsula are largely determined by the presence of permafrost and ongoing geocryological processes [5]. The landscapes of the peninsula are actively exposed to anthropogenic impact arising both in the process of geological exploration and development of deposits, and as a result of the implementation of traditional types of nature management by the indigenous peoples of the North, primarily reindeer breeding [6].

The development of hydrocarbon deposits in the south of the Yamal Peninsula occupies an important place in the plans for the development of the fuel and energy complex of the Yamalo-Nenets Autonomous District. The total annual gas production here can reach 30 billion cubic meters. m, and oil 7 million tons. There are 9 deposits in the southern industrial zone of the Yamal Peninsula, 5 of which (Nurminskoye, Rostovtsevskoye, Arkticheskoe, Sredneyamalskoye, Neytinskoye) belong to the unallocated subsoil fund. Currently, hydrocarbon production in this zone is carried out only at the Novoportovskoye field. Most of the plots are used primarily for reindeer herding. The special status of these territories is also determined by the fact that they belong to the South Yamal section of the Yamalsky State Nature Reserve.

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The search, exploration and development of deposits inevitably led to the formation of waste, and the lack of a systematic approach to their disposal and the low ability of northern ecosystems to self-cleanse resulted in accumulated environmental pollution [7, 8]. The forthcoming economic development of the southern industrial zone of the peninsula should be based on comprehensive landscape and environmental studies that allow collecting the most relevant information for developing measures to ensure the geoecological safety of the emerging natural and economic complex.

2 Materials and methods

The article presents the results of geoecological studies on the territory of the deposits of the unallocated subsoil fund of the Yamal Peninsula. The object of the study was the natural-territorial complexes of the Nurminsky and Rostovtsevsky deposits.

The deposits are located in the Yamal district of the Yamalo-Nenets Autonomous District of the Tyumen Region. Geographically, the deposits are located in the north of the West Siberian Lowland, in the southeastern part of the Yamal Peninsula. The Nurma field is located between the middle course of the Yuribey River and Lake Voyvareto. The Rostovtsevo field covers the interfluve of the Yuribey and Nurmayakha rivers (Figure 1).

Fig. 1. Map-scheme of the location of research objects.

The materials for writing the article were the results of the research work "Assessment of the current state of the environment at the Rostovtsevo hydrocarbon field of the Yamalo-Nenets Autonomous District" and "Comprehensive environmental monitoring of the territory of the original habitat of the indigenous small population of the Yamalo-Nenets Autonomous District" made at the Arctic Research Center of the Yamal-Nenets Autonomous District.

Geobotanical descriptions of the territory were carried out on background and anthropogenic sites measuring 10m x 10m. The description of the soil was carried out in soil profiles according to generally accepted methods. Determination of soil types according to the 2004 classification. Soils were studied both in background areas and in abandoned drilling sites. The primary inventory of wildlife objects was carried out according to generally accepted methods; registration of species of terrestrial vertebrates - by the method of accounting for traces of their life on the routes (from the well to the place where the background soil was taken). Sampling of water and bottom sediments was carried out in accordance with the requirements of GOST R 59024-2020 "National Standard of the Russian Federation. Water. General requirements for sampling". Water samples were taken using a Niskin bathometer. Sampling of bottom sediments was carried out with a Petersen grab. Depth of water sampling 0-10 cm. Chemical analysis of soil samples included determination of pH of water extract, total nitrogen, NO^{-3}, PO_4, Cl^-, SO_2^{-4}, NH^{+4}, oil products, phenols, toxicity, surfactants, Ba, As , Cr VI, Hg, benzo(a)pyrene, bulk forms of Cu, Pb, Zn, Mn, Ni, Cd. Hydrochemical analysis of surface water samples was carried out for the content of: NH^{+4}, NO^{-3}, PO_4, Cl^-, SO_2^{-4}, surfactants, oil products, phenols, Pb, Zn, Mn, Cu, Ni, Cd, As, Cr VI, Hg , the level of acidity was determined. Analysis of samples of bottom sediments: pH of water extract, Cl^-, SO_2^{-4}, oil products, surfactants, As, Cr VI, Hg, bulk forms of Cu, Pb, Zn, Mn, Ni, Cd. The assessment of economic activity was carried out according to generally accepted economic-geographical and sociological methods.

3 Results

In the period from 1985 to 1995, exploration work was carried out at the studied fields, accompanied by the drilling of prospecting and exploration wells, which are currently either liquidated or are in a state of conservation. At the same time, despite the significant anthropogenic impact, work on the reclamation of disturbed areas was not carried out [5]. 25 wells were drilled at the Rostovtsevskoye field, and 20 wells at the Nurminsky field. Inspection of the wellheads showed that their condition does not meet environmental safety requirements. Surfaces around all wells are contaminated with scrap metal, cement, drilling mud.

At present, the territory under study is the most important artery of the traditional economy of the indigenous peoples of the North. Here are the paths of summer-autumn roaming of both reindeer herders of the Yarsalinskoye municipal enterprise (up to 15 thousand reindeer heads) and private reindeer herders (up to 1.7 thousand reindeer heads). In addition, both deposits are located within the Yamalsky State Nature Reserve.

The studied deposits are located in the zone of continuous occurrence of permafrost. The entire study area in geomorphological terms is an elevated dissected plain with linear-ridged relief forms. Permafrost landforms are widespread. The absolute relief marks in the studied part of the Yamal Peninsula vary from 0 m on the coast of the Gulf of Ob to 60 m on the watershed of the Nurmayakha and Yuribey rivers. The area is a gently sloping or flat-undulating tundra plain, reworked by denudation processes with numerous lakes and swamps. The relief is strongly dissected by valleys and ravines. The depths of cuts reach 20-25 m and more.

The deposits are confined to the third (IIIm, age Q2-3III) and fourth (IVm, age Q1III) marine terraces. Most of the surveyed area belongs to the upper part of the Neopleistocene of the third marine terrace, which is represented by the Ermakov horizon (m3III), formed by loams, sandy loams, and sands. The absolute marks of the surface here vary in the range of 35-50 meters above sea level. These are predominantly flat, unevenly drained surfaces with a spotty and small-hilly microrelief and represent a dwarf shrub-moss-lichen tundra.

The fourth marine terrace is represented by the Kazantsev horizon (m4III), composed mainly of sands, loams, sandy loams and, rarely, pebbles. The absolute marks of the surface here reach 56 meters above sea level. These are well-drained surfaces with patches-medallions and sandy swells, with open thin ground cover.

A significant part of the wells was drilled in the valleys of the Nurmayakha and Yuribey rivers composed of alluvial deposits (sands, loams, sandy loams), as well as in lake basins confined to them. The surface here is unevenly drained, grass-moss prevails, less often - hummocky shrub-moss bogs.

The hydrographic network is well developed and is represented by the non-navigable rivers Yuribei, Nurmayakha and their numerous tributaries. The area is replete with lakes. Small (up to 1 km across) shallow thermokarst lakes predominate. Large lakes are usually located in groups.

4 Discussion

The results of the study show that typical and shrub tundra prevail on the territory of the Rostovtsevskoye field. Complex bogs are widespread, incl. valley complexes and multi-lake areas. The floristic complex is represented by 217 species of vascular plants belonging to 109 genera and 43 families. Typical tundra along the relief elevations represent a variety of communities with wild rosemary, lingonberry, shiksha, blueberry, along the slopes - willow and dwarf dwarf tundra in combination with sedge-cotton grass meadows and low-lying swamps along hollows and depressions, in places with tall bushes in the valley areas. Spaces with a developed lichen cover along the convex parts of the watersheds form forb-grass groups. Shrub tundras are represented by dominant species of willows and dwarf birches, berry shrubs are common - lingonberries, blueberries, rosemary is also found. Sedges and cotton grass grow in waterlogged areas, and grasses and herbs grow in drained areas. The moss cover is well developed.

Vegetation cover of the studied virgin territory is not continuous; patches of oppressed vegetation, dead (dry) phytomass and freshly growing areas, as well as arctic fox burrows and deer paths are often found in the background areas. This area is traditionally used by the local population in the process of life, bushes are cut down for firewood, berries and mushrooms are collected, deer chopping routes pass here, so the herbage is disturbed in places. Particularly large violations are typical in the vicinity of the surveyed wells, where landfills and rusty metal structures are common [9].

Plant communities of anthropogenic objects are represented by synanthropic associations, including ruderal associations, where restorative successions are at different stages. Areas with suppressed vegetation (sometimes completely absent), as a rule, are associated with such anthropogenic manifestations as placers of cement, rubble, and rusty scrap metal. At the same time, it was in these areas that the Red Book species were found - polar eremogone (Eremogone polaris (Schischk.) Ikonn.) and Asian forget-me-not (Myosotis asiatica (Vestergr.), included in the Red Book of the YNAO. Along the route from well No. 81 to the reservoir, open swimsuit (Trollius apertus Perf.ex Igosch.), also included in the Red Data Book of YaNAO In this case, the anthropogenic factor is an unconditional favorable environmental criterion for the growth of rare cenophobic plants that can exist only in areas with local disturbances of the background vegetation cover.

Basically, the soil cover of the Rostovtsevo deposit is represented by gleyzems, cryozems, peat-gleyzems. This is due to the increased hydromorphism of landscapes and the predominance of relatively leveled landforms. With sufficient dissection of the relief, cryozems are formed on drained slopes and adjoining uplands. Stratozems appear in valleys and hollows. Peat soils and peaty gleyzems occur in vast river valleys and depressions [10].

At the Rostovtsevo deposit, traces of the vital activity of domestic reindeer, white hare (Lepus timidus) and rodents (Rodentia) are quite common. The end products of the metabolism of other species (arctic fox, geese) are to a lesser extent.

The vegetation of the Nurma deposit is generally typical for the subzone of shrub tundra, but the features of the relief, soils and frozen soils determine some peculiarity of the vegetation cover - large areas here are occupied by slope surfaces of various steepness, overgrown with shrubs and shrub-moss-lichen vegetation. A combination of diverse tundra communities is formed on the slopes, common to which is the presence of synusias of shrubs - dwarf birch, willows, from 50 cm to 2 m high, and forbs.

Plant communities in the described background areas can be conditionally divided into phytocenoses with a predominance of shrubs or with a predominance of mosses. Dominated (9 plots out of 20) were both pure dwarf dwarf-willow communities and the same, but with the participation of other species: dwarf dwarf-sedge-moss community with willows, dwarf-green moss community with wild rosemary, dwarf dwarf shrub-moss, in some places sedge-moss with the participation of cloudberries, dwarf birch-willow-moss with the participation of sedges, dwarf birch-green moss with the participation of sedges. There were sedge-dwarf birch communities. In 5 plots willow-sedge communities prevailed with variations: sedge-willow, willow-sedge-moss, sedge-willow with horsetail. Four communities with a predominance of mosses were identified: shrub sedge-green moss community;

Although the studied area of the Nurminskoye deposit is quite extensive, unlike the Rostovtsevskoye deposit, the species diversity of its synanthropic (weedy) flora is much poorer: there were no Red Data Book and endemic species along the research route, but some areas of anthropogenic emissions were completely captured by monodominant synanthropic species - for example, chamomile Hooker (Mathricaria hookeri (Sch. Bip.) Hutch.) actively develops polluted anthropogenically transformed areas unsuitable for most other synanthropic species. The projective cover of Tilesius sagebrush (Artemisia tilesii Ledeb.) in some areas reached 85%, and the height exceeded 1 m. dense well-formed clumps, displacing native species.

Peat-gleyzems and peat soils predominate in the soil cover of the Nurminskoye deposit: oxidized-gley peat-gleyzem on permafrost loams, peat-gleyzem on permafrost loams, humus-peaty peat-gleyzem on permafrost loams, oligotrophic peaty euclay loamy soils on permafrost naya on permafrost loams. Cryozems are widespread: coarsely numused oxidized gley cryozem on stratified loams, gleyic podzolized cryozem on permafrost. There is a redoxymorphic gley coarsely humus cryoturbated soil [10].

The fauna of the Nurminskoye deposit is relatively poor: end products of the metabolism of rodents, hares were found, representatives of the partridge family were noted, as well as traces, paths and excrement of domestic reindeer.

Water samples taken from reservoirs located in the area of wells of both fields correspond to the level of fresh (judging by the concentration of sulfates and chlorides) natural surface waters with neutral pH values and, in general, with a favorable oxygen regime. Excess MPC levels for surfactants were not recorded. Quite often, the maximum permissible content of oil products is exceeded in the samples (Figure 2). It should be noted that in a number of points the excesses are duplicated in both water and solid samples, that is, these are places where the flow of oil products occurs constantly, being reburied in the sorbed form in bottom sediments. These objects require special attention in terms of reclamation.

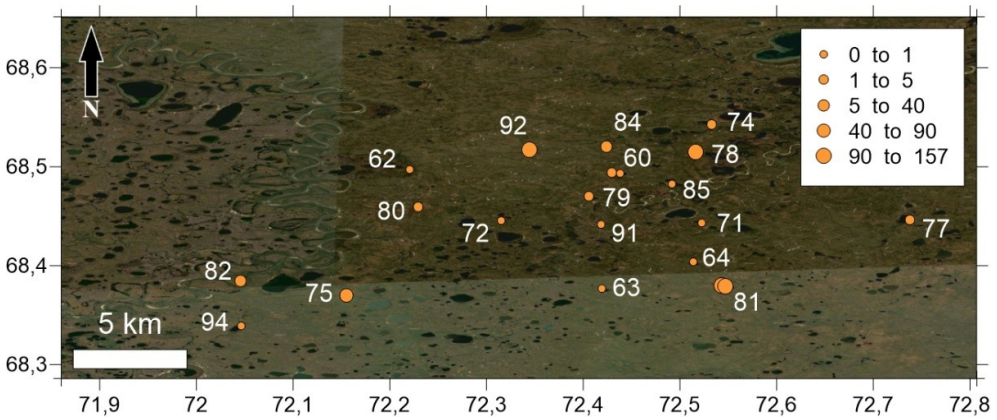

Fig. 2. Geochemical anomalies in water samples for oil products, the frequency of exceeding the maximum permissible concentrations (numbers on the map indicate the numbers of wells).

In almost all reservoirs, an excess of the maximum permissible concentration of manganese was found, but these values fall within the range of river waters and are a feature of this region. The assessment of the ecological state of water bodies demonstrates that most of the objects belong to clean and conditionally clean waters of the 1st class. However, nine reservoirs belong to the 2nd and 3rd water quality classes (conditionally polluted and polluted samples).

Soil samples taken from territories subjected to technogenic impact several decades ago contain a number of consequences of this impact, which is reflected when they are compared with the composition of the corresponding soil samples selected as a background. Based on the data obtained, it can be noted that the soils are contaminated with oil products, sulfates, barium, zinc and phenols (Figure 3). But at the same time, numerous excesses of MPC were established only for zinc and arsenic, and for both elements, high concentrations were also noted in background samples, which can be considered a feature of the region.

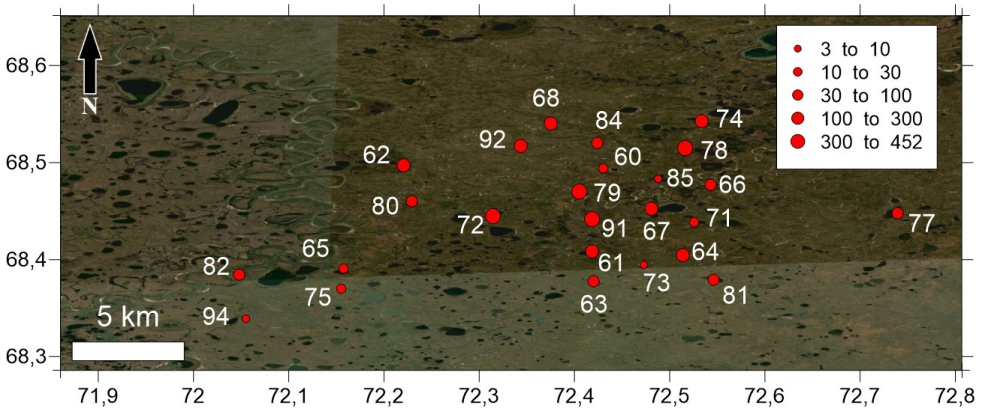

Fig. 3. Distribution of the relative content of oil products in the upper (5-10 cm) soil horizon. Symbols: The numbers indicate the numbers of wells.

The concentrations of heavy metals (cadmium, manganese, copper, nickel, mercury, chromium) in all studied samples are below the MPC (or APC). For cadmium and mercury, the contents in the anthropogenically modified and in the background territories practically do not differ. But nevertheless, the highest mercury content refers to anthropogenically modified samples. For the remaining elements, there are significant excesses of

concentrations from the zone subjected to technogenic impact over the background, which indicates their technogenic source.

It has been established that the copper content in anthropogenically modified soils exceeds the corresponding value (according to the soil horizon and sampling area) in background samples in 21 (out of 25) cases from 1.2 to 16.8 times in the upper horizon (5-10 cm), and in 21 (out of 25) from 1.7 to 12 times - in the lower (10-20 cm) (table 125). This indicates that the increased content of copper is caused by technogenic impact.

The high contents of barium, together with the elevated contents of sulfates already considered, confirm the hypothesis about the contamination of anthropogenically modified soils with barium sulfate. This is also confirmed by the coincidence of the distribution of the relative excess of the content of barium in the upper and lower soil horizons and the corresponding distribution of sulfate ions.

5 Conclusion

In the southern industrial zone of the Yamal Peninsula, a natural and economic system with difficult landscape and ecological conditions has been formed. In the coming decades, it is expected to intensify the industrial development of deposits of the unallocated subsoil fund. In addition, the traditional economic activity of the indigenous population - reindeer herding - will continue. The implementation of economic activity in such conditions requires an objective environmental justification for the implementation of large projects of economic activity, the use of approaches to ensure the stability of the environmental situation that meet the current landscape and environmental conditions.

The surveyed areas require work to be carried out to clean them from waste and pollutants, to restore and rehabilitate the disturbed components of the environment. It is necessary to carry out work to bring the wellheads into a state that meets the requirements of environmental safety. When carrying out work, it should be taken into account that the territory has a special nature protection status, the presence of Red Data Book species of vegetation here.

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