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ОЦЕНКА ЭКОЛОГИЧЕСКОГО СОСТОЯНИЯ ГОРОДА НОРИЛЬСКА

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Аннотация: Оценка современного экологического состояния проводится для территории городского округа Норильск Красноярского края Арктической зоны России. Особенностью территории является функционирование Норильского промышленного комплекса, что оказывает негативное воздействие на рассматриваемую территорию. Выявление очагов захламления наземных объектов в г. Норильске проведено на основе методики комплексной оценки состояния территории, где дислокация механического загрязнения выполнена по данным цифровой спутниковой съемки. В результате исследования авторы пришли к выводу, что общая площадь механических загрязнений составляет не менее 193,88 га. Уровень загрязнения компонентов окружающей среды можно охарактеризовать от «умеренного» до «очень высокого». Авторы подчеркивают необходимость устранения экологического вреда, накопленного в результате продолжительной и интенсивной деятельности.

Ключевые слова: накопленный вред окружающей среде, воздействие на окружающую среду, загрязнение природной среды, захламление, механическое загрязнение, экологическое опробование.

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Assessment environmental condition of the city of Norilsk

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Abstract: assessment of the current environmental conditions is conducted for the urban district of Norilsk, Krasnoyarsk Krai in the Arctic zone of Russia. The peculiarity of the territory is the operation of the Norilsk industrial complex, which has a negative impact on considered territory. Identification of foci of littering of surface objects in Norilsk was conducted based on the methodology of complex assessment of the condition of the territory, where the dislocation of mechanical pollution was completed according to digital satellite image data. As the result of the study, the authors concluded that the total area of mechanical pollution in the Norilsk is not less than 193.88 ha. The level of pollution of environmental components can be characterized from “moderate” to “very high”. The authors stressed the necessity to eliminate the environmental harm resulting from the long and intensive activities.

Key words: accumulated environmental damage, environmental impact, environmental pollution, littering, mechanical pollution, environmental sampling.

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1. Economic use of the territory

The unified municipal entity "Norilsk city" is represented by the cities of Greater Norilsk, as also includes group of settlements (Talnakh, Kaierkan, Oganeri, Snezhnogorsk). The total area of land-use within the jurisdiction of the administration is 4,500 km^2.

The Norilsk industrial complex (hereinafter referred to as the NIC) is on the area of about 2,600 км^2 in the south of the Taimyr Peninsula and represents a unified industrial mining and metallurgical complex. The development of the area has been carried out since 1935.

In the NIC, several key industries are present (Fig. 1) [1], the basis of which is the Transpolar branch of PAO Mining and Metallurgical Company Norilsk Nickel.

The largest enterprise is the Transpolar branch of PAO Mining and Metallurgical Company Norilsk Nickel. The main products of the enterprise are nickel,

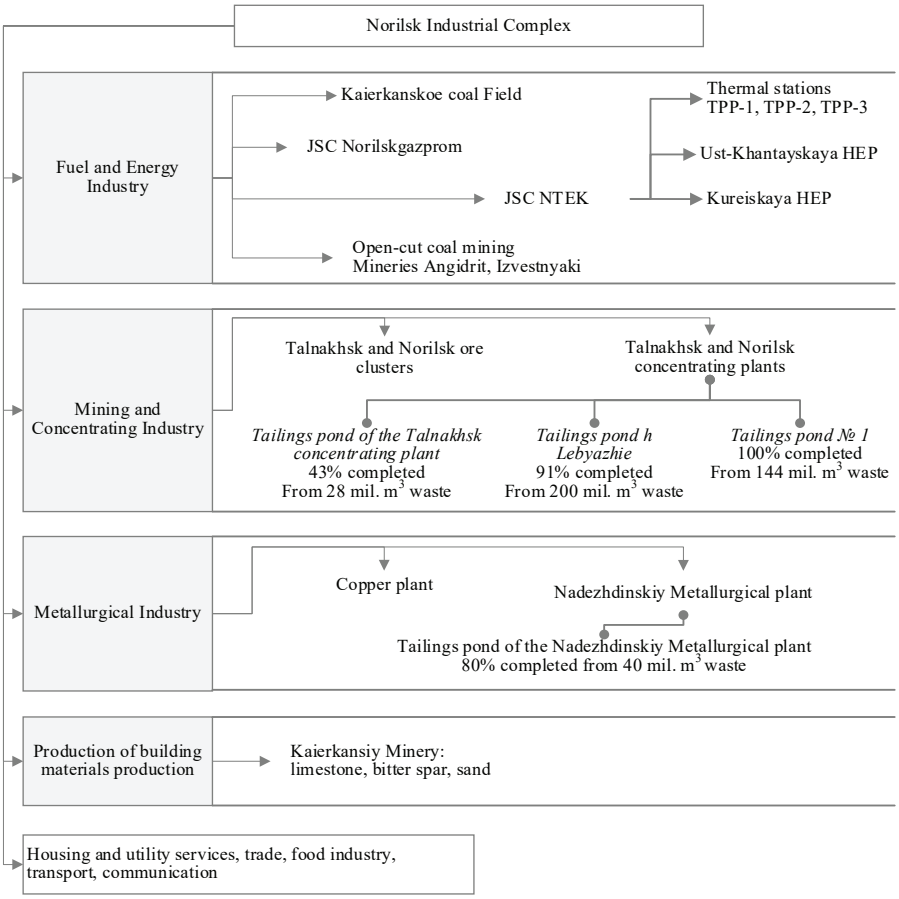

Fig. 1. Structure of NIC [4]

cobalt, copper, platinum metals, aurum, argentum. There are large deposits of sulphur, ruthenium and tellurium, iridium, aurum, and argentum in the subsoil that are also being successfully developed.

High economic and financial efficiency of MMC Norilsk Nickel provides for the development of mineral resource base of the Yenisey North, the introduction of metal products to the global market, and, thereby, the development of the economy of the territory, the region, and Russia as a whole [1—3].

While the NIC adds to the state treasury, but it also damages the environment and the health of the city's population through its negative impact on the state of the environment [5].

2. Assessment of the degree of littering

Identification of foci of littering of surface objects and working out the boundaries of areas with increased risk of NCDs was conducted using the methodology of comprehensive assessment of the state of the territory[6, 7].

Dislocation of mechanical pollution of the studied areas of the NIC was completed according to digital satellite image data, as well as photographic materials integrated into information-mapping systems Google Earth and Google Earth Pro. As an example, space images[1] and photographic materials assessing the present state level of Norilsk city are presented (Fig. 2).

Fig. 2a. Fugitive dumping of construction, utility, industrial-rubber and other waste (69°22'36.96 N, 88°10'34.69 E)

Fig. 2b. Bulk of rail delivery waste (69°19'24.28 N, 88° 3'44.86 E)

[1] According to Google Earth Pro ©Maxar Technologies, 2019.

Fig. 2c. Piling of industrial waste and metal (69°19'28.81 N, 88°11'24.19 E)

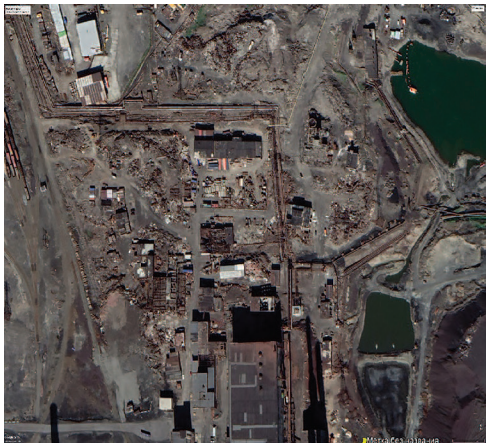

Fig. 2d. Piling of industrial waste and metal 69°19'7.54 N, 88°13'28.37 E

On this territory, there are areas of former economic use, which are pockets of littering and displacement of unaffected natural-anthropogenic complexes. There is also a significant amount of decommissioned or inactive coal-pits, mines, adits with surface facilities of industrial infrastructure, discharge lines, sections of narrow-gauge railroad, uninhabited settlements with ownerless buildings, as well as located within the boundaries of water conservation and water protection areas of water bodies.

The area of the territory subjected to man-made impact was calculated with scaling of space images in the contrast of the objects studied by decoding features using the built-in function of Google Earth Pro.

Therewith, the total area of mechanical pollution makes no less than 1 938 761 m^2 (193,88 ha) or 0,04% of the total area of Norilsk (4,5 thousands km^2 or 450900.85 ha).

The displacement is of the areas is characterized as "strong".

The above sections present the sources of negative environmental processes, insofar as they produce:

1) Mechanical impact due to excavation and construction operations during installation, reconstruction and dismantling of industrial facilities and littering of area with various wastes

2) Physical impact consists in compaction of soil surface by different types of covering and construction. At the same time, there is a noticeable compaction of soil change of its water, thermal, gas and biological regime

3) Chemical impact is manifested in direct and indirect pollution of the soil stratum with toxic components – spills and spillages of toxic materials and fields, erosion of pollutants on the surface and infiltration of grey water from the territories of industrial facilities. At the same time, f the danger of soil contamination increases for the northern regions, because in acidic, cold, hydromorphic and oligohumus conditions the degradation of organic substances is not any faster [8]. The level of chemical impact of the formed areas of littering needs additional elaboration in independent environmental sampling.

The level of chemical impact of the identified littering sites requires additional clarification in the process of

independent environmental testing, with the involvement of "Arctic personnel" [9]

3. Impact of NIC production on the environment

3.1. Atmospheric air pollutions

An assessment of the condition of atmospheric air in the NIC area and surroundings, based on the analysis of materials from the Government report [10], showed an insufficient number of observations to obtain an objective assessment of the quality of atmospheric air. According to information from the FSBI Central Siberian Territorial Administration for Hydrometeorological and Environmental Monitoring (TAHEM), it is not possible to provide data on background concentrations of pollutants in the atmospheric air of Norilsk due to a number of reasons: — Monitoring of the condition of atmospheric air in Norilsk has been carried out using a mobile environmental laboratory only since 2014.

– Data on the condition of atmospheric air in 2014 and 2015 are not available, as observations during this period were carried out in test mode.

– Observations in 2016 and 2017 were carried out under a reduced program.

– Since 2018, atmospheric air monitoring has been conducted under an incomplete observation program.

During atmospheric air monitoring for 2016—2019, there is a violation of the homogeneity of data series, the annual volume of data of discrete observation sample from a number of single concentrations is less than 800 [11].

In general, in the atmosphere of the city, there are registered exceedances of MPC average daily and the highest single MPC for the main substances — suspended solids, SO_2, NO_2, NO, H_2S [10].

The main sources of atmospheric air pollution are industrial sources of emissions of pollutants into the atmosphere, coal mines, tailings of industrial enterprises [12], as well as motor transport. The Nadezhdinsky Metallurgical Plant accounted for most of the emissions.

The distribution of emissions in the city of Norilsk looks like most of them fall on the facilities of the Polar branch of PAO MMC Norilsk Nickel (more than 1500 thousand tons). Emissions of JSC NTEK (more than 10 thousand tons) and JSC Norilskgazprom (more than 4 thousand tons) pollute the atmospheric air to a much lesser extent [10].

An indirect indicator of atmospheric air quality is the snow cover. It is a good sorbent and accumulates pollutants contained in the dust and gas emissions of industrial enterprises and the automobile exhaust gases [13, 14].

Information about the properties of the snow cover in Norilsk and its surroundings is limited due to small number of studies. As a result of anthropogenic load, the physical and chemical properties of the Norilsk snow cover have changed: alkalinity has increased, the mineralization of melted snow water has increased compared by 10.4—13.6 times compared to the background, and the ionic composition has changed. City snow water is characterized by sulfate type mineralization, while the background territory is characterized by sulfate-nitrate composition of melt water. The priority pollutants for the solid snow fraction of the city are Cu, Co, Fe, Mn, Ni, Cr, Sr, Ba, Ti, W, Cd, Zn. They come with emissions of enterprises.

3.2. Pollution of vegetative ground cover

Norilsk is located in areas of continuous permafrost. This is due to low moisture evaporation and the development of gley formation processes. The soil cover of Norilsk is highly heterogeneous and consists of tundra clay soils, swamp and alluvial soils. Soil-forming rocks are

moraines and heavy loams of marine origin, less often — light and medium loams [15, 16]. The main types of soils are located in the area of strong thermal pollution (metallurgical plant, heating networks), which has a warming effect on the permafrost for many years, and as a result, on its spatial variability and degradation. In the process of production activity of the industrial complex in the territories adjacent to the city of Norilsk, a man-made landscape is formed with technogenic-transformed soils formed as a result of backfilling, deformation, deposition and mixing of man-made substrates, soils and underlying rocks [17]. Anthropogenic impact on soils and vegetation cover is caused by atmospheric transport of gas and dust emissions from industrial plants and through sludge reservoirs.

Anthropogenic emissions of sulfur dioxide and sulfuric acid to the soil cover of the NIC lead to acidification of soil and accumulation of high concentrations of sulf salts of not only of alkali and alkaline earth elements, but also heavy metals and their high mobility in soils. In the upper horizons of contaminated soilsgross content of Cu is higher than Co and Ni, in contrast to the background soils, this is due to a large intake of Cu in the enterprise emissions. Penetration of heavy in the soil profile spreads to an average depth of 25 cm [16].

It is also noted [18] that the proportion of heavy metals soluble in water, specifically sorbed (flexible) compounds associated with organic matter and with amorphous Fe and Mn compounds increases in contaminated soils. The seasonal development of gleying processes increases the mobility of Fe, Mn and associated Cu, Ni and Co compounds, which increases the likelihood of their migration into water bodies.

Studies [19] have shown that Norilsk city plants accumulate toxic substances that affect the growth and development of higher plants.

The accident that occurred in 2020 at the TPP-3 of AO NTEK with discharge of diesel fuel into the environment resulted in soil contamination of the floodplain territory, while the territory of the industrial zone of AO NTEK, where liquidation works were carried out including excavation and removal of soil from the territory to storage facilities, being affected to a greater extent. Maximum concentrations of petroleum products were recorded in the soils of the land plot adjacent to the industrial zone of AO NTEK, along the artificial watercourse — 30 g/kg of soil. Soils adjacent to the coastal zone, falling within the water protection zones along the Bezymyannaya and Daldykan rivers, were polluted sporadically due to the features of these water bodies (steep shores and their high graveliness); the level of soil pollution did not exceed 2—3 g/kg. The soils of the floodplain of the Anbarnaya River, which has a gentle stream, are polluted, the maximum concentrations of petroleum products were detected in the peat horizons with maximum sorption capacity. The level of impregnation with petroleum products was 15—20 cm, in some cases up to 30 cm, but further their migration was prevented by a geochemical barrier in the form of permafrost. Thus, the level of soil pollution as a result of the accidental spill is characterized as “low””». The area of contamination was about 50 ha.

3.3. Pollution of surface waters

Despite the available information [20, 21] on the characteristic of water bodies in the area of Norilsk, the long-term dynamics of the rivers of the north of the Krasnoyarsk Krai belonging to the Pyasina River basin, where the NIC is located, remains poorly studied [22]. There are no permanent water observation stations

here. So, it was only in the summer of 2020 that state monitoring was resumed on the Barna River after the accident that occurred as a result of an accidental release of diesel fuel from the tank of TPP-3 if AO NTEK.

Consistently high concentrations (compared to MPC) of copper and nickel compounds are associated with both natural and anthropogenic factors of water formation. The Norilo-Pyasinsky water system catchment area is characterized by distribution of sulfide copper-nickel ores. Therefore, concentrations of copper and nickel compounds in water bodies are associated with a special geochemical background [21].

The mining and smelting plant discharges into the surrounding water bodies untreated or insufficiently treated wastewater in the amount of about 700 thousand m^3/year [20], containing suspended substances, sulfates of chlorides, oil products. About 3 thousand hectares are occupied by rock dumps [22]. Engineering of the dumps does not prevent heavy metals and other substances from entering streams and water bodies (Fig. 3).

About 3 thousand ha are occupied by rock dumps [23]. Engineering of the dumps does not prevent heavy metals and other substances from entering streams and water bodies (Fig. 3).

3.4. Pollution of bottom sediments

According to research data, in the Norilsk Region there is enrichment of bottom sediments of water bodies with Sg, Ni, V and C, coming from enterprise effluents, as well as from surface water runoff. At the same time, the content of such elements as Rb and Ag is significantly lower [23, 24]. A particular environmental danger to the Pyasino ecosystem pose Hg and As, exceeding the values determined in bottom sediment samples from background areas [25, 26].

4. Conclusion and consequences

In the context of the studies performed it has been established that on the territory of Norilsk there are areas of the current and past economic use, which are centers of flooding of natural-anthropogenic complexes. The total area of mechanical pollution is not less than 193.88 ha. Displacement of territories on these areas is characterized as “strong”. The level of chemical impact of of the formed areas

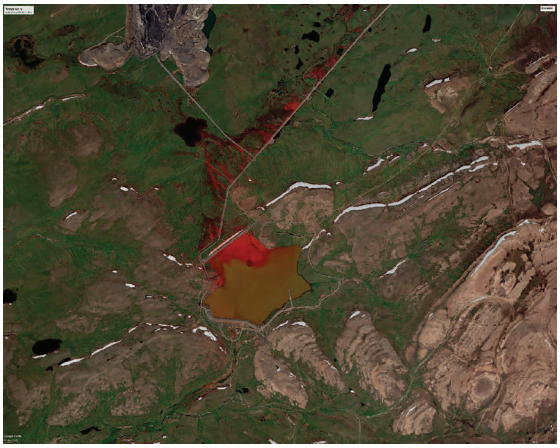

Fig. 3. Tailings pond of the Nadezhdinskiy Metallurgical Plant[1]

[1] According to Google Earth Pro ©Maxar Technologies, 2020.

of littering needs further elaboration in independent environmental sampling.

The level of pollution of environmental components can be characterized from "moderate" to "very high". Consequently, the need to eliminate environmental damage resulting from long-term and intensive operation of the NIC is more relevant than ever.

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