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Assessment of impact of accumulated environmental damage to the quality of soil, surface and groundwater, agricultural products resulted from the mining enterprise

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Abstract. The study is devoted to the assessing the impact of environmental damage caused by mining enterprise to the quality of environment and agricultural products. It is shown that the waste storage of mining plant close to residential areas forms a complex of environmental and hygienic issues associated with pollution of air, surface and groundwater (including drinking water of private and public wells), soils with hazardous metals. The key problems include air pollution with suspended substances, lead, chrome and manganese – impurities typical for the mining plant wastes. Besides, increased level of some heavy metals in the water of city wells and the compounds in local food, a comprehensive combined effect of which might form a danger to public health, is also investigated. The current environmental situation requires the development of a set of environmental and ecological-hygienic measures aimed at improving of environmental quality and minimizing the negative impact environmental risk factors on people health.

1. Introduction

According to official statistical reports and State reports "On the state and protection of the environment of the Russian Federation" [1] the amount of waste generated in Russia over the past decade has increased by more than 40%.

In the Russian Federation the total amount of accumulated and measured production and consumption waste amounted to about 31.6 billion tons, including toxic – from 2 to 2.3 billion tons, at the end of 2017 [1]. The amount of used and neutralized production and consumption waste has almost doubled since 2006, but only 4% of wastes are recycled in country.

More than 90% of produced industrial wastes are wastes resulted from the extraction and processing of minerals. The waste generated when developing deposits and as a result of ore enrichment is placed in mine dumps and tailing dumps, which, as a rule, are abandoned, belong to bankrupt enterprises and are in state or municipal ownership [2-8]. The amount of accumulated material in them is estimated by astronomical figures, and the objects of accumulated environmental damage occupy large areas of land.

The composition of waste of mining and mine-mill industry includes metals of I-III hazard class: Pb, Cr, Ni, Cd, Mo, W, Be, Bi, As and others. Being in the lithosphere, hydrosphere and atmosphere, they penetrate the environmental objects, polluting the soil, atmospheric air (as a result of rotting and erosion processes), underground and surface water, agricultural products.

2. Problem statement and research methods

This study aims to assess the environmental objects in the zone of influence of waste of past economic activity of mining plant from ecological and hygienic point of view. In total, during the period of the plant's activity (60 years), 44.5 million tons of enrichment waste were created, which have been a source of pollution of the natural and man-made complex occupying area of more than 200 km^2 for many years and were stored close to residential area. The subject of the study were the parameters of metal distribution – components of waste of mining plant on the territory of its location and the levels of the formed exposure.

The plant and the settlement located nearby are in the mountain taiga region and the river valley (the river divides the city into 2 parts). The total area of the settlement is about 60 km^2 with a population (as of 01/01/2018) of about 11.2 thousand people. The residential area of the city in the east is in direct contact with the waste storage facilities of the mining and mine mill plant, which is the main sources of environmental pollution with metals. In the north, the observation area is the mouth of the river, where the delta sedimentation barrier is created, limiting the spread of pollution at large extent. Until the mid-1990s, there was a filtration of water from the sand massif and the suffusion of fine-grained deposits in its lower part. Now, we can see the carrying-out of loose sediments of the massif on the former hydraulic structures.

At the end of the last century, the mining and mine mill plant, being city-forming enterprise, was closed. This fact contributed to the increased attention to environmental and hygienic issues and led to out migration. In 2011-2013, about 10 million tons of sand (waste of plant) was delivered to another site, remote from residential area. Removal of sand was followed by intense dusting, which aggravated the situation. The technogenic sands of former bulk and alluvial tailing dumps were near the eastern outskirts of the city till 2013 and formed environmental problems, not to mention the fact that it had a negative impact on public health. Unfixed loose sand massifs with a complete absence of soil and vegetation layer were dispersed by exogenous destructive processes, active agents of which were wind, melt and rain waters, etc. Thus, man-made sands are concentrated now in organized tailing dumps and dispersed over the area of the settlement, as a result of exogenous factors, especially fluvial ones.

According to long-term studies, the major factors of risk typical for liquid and solid wastes of the mining plant are the following metals: tungsten, molybdenum, lead, chrome, cadmium, nickel, copper, manganese, zinc, etc.

This study included 2 stages:

- spatial reference of waste storage places of mining plant, points of monitoring of atmospheric air, drinking water, soil cover, and food quality;
- comprehensive ecological and hygienic assessment of environmental quality parameters.

Locations of tailing dumps, sampling points of soil, air, food, drinking water were mapped to the electronic map of the territory.

Ecological and hygienic assessment of the quality of environmental objects and factors (atmospheric air, drinking water, soil, food) was carried out according to the data of full-scale studies of Federal State-Funded Healthcare Institution "Centre of Hygiene and Epidemiology ..." of the subject of the Russian Federation, which includes the study area, Federal State Budgetary Scientific Institution "Federal Scientific Center for Medical and Preventive Health Risk Management Technologies", Federal Publicly Funded Institution of Science "Institute of Physical Materials Science of the Siberian Branch of the Russian Academy of Sciences" for 2009-2016.

In total, during the study period, 1020 atmospheric air samples were taken to analyze the content of 26 chemical impurities, including 12 metals (lead, cadmium, copper, nickel, manganese, chrome, magnesium, aluminum, titanium, vanadium, iron, cobalt) at various points of the residential area, as close as possible to and as far away as possible from the places of waste storage. The sampling program covered all seasons of the year, taking into account all meteorological conditions, including adverse ones, and involves the determination of one-time and average daily concentrations of impurities in the atmosphere.

To assess the quality of drinking water according to sanitary and chemical indicators, 654 water samples were taken from centralized and non-centralized water supply systems at 16 points in the city. When sampling, it was taken into account that about 90% of the city population is provided with water from a centralized drinking water supply system. The source is groundwater raised from a depth of 49-72 m using artesian wells. The rest population of Zakamensk (about 10%) uses water from public and private wells. In all drinking water samples, the content of 13 following metals was determined: iron, manganese, magnesium, cadmium, copper, lead, zinc, beryllium, molybdenum, chrome, mercury, arsenic, nickel.

The soil for chemical and analytical research was taken in 86 points of the city, located in kindergartens, playgrounds, private gardens and vegetable gardens. In total, 762 soil samples were taken and the concentrations of 8 following metals were determined: mercury, zinc, lead, cadmium, copper, nickel, manganese, chrome.

The content of 9 chemical impurities – heavy metals was estimated in agricultural products, namely fruits and vegetables (cabbage, potatoes, beets, carrots) and meat and dairy products produced in private farms and country-horticultural cooperatives of the study area: lead, arsenic, cadmium, mercury, nickel, chrome, zinc, copper and manganese (total 273 samples).

The content of heavy metals in habitat objects was determined using atomic absorption spectrometry and inductively coupled plasma-mass spectrometry method ICP-MS approved in the prescribed manner and included in the register of measurement methods of the Russian Federation. The results were processed using mathematical statistics methods (Statistica 9.0).

3. Main results of environmental hygienic assessment

The environmental and hygienic assessment of the atmospheric air quality in the investigated area for 2009–2016 showed that there were no violations of hygienic standards for most hazardous and extremely hazardous chemicals - waste components of the past economic activity of the mining plant. Cadmium, chrome, vanadium, copper, nickel, manganese, aluminum, cobalt, magnesium, and titanium concentrations were at levels below MAC. In 5% of the samples, the limit-exceeding daily average concentrations of lead compounds were recorded (up to 2 MPC s.s. - up to 0.0006 mg / m^3) and in 2.5% of samples - iron compounds (up to 1.1 MPC s.s. - up to 0.008 mg / m^3). The amount of particulate matters exceeded the established hygienic standards in 22.5% of samples, reaching in some cases 2.3 MPC s.s. (1.15 mg / m^3) and 1.9 MPC s.s. (0.29 mg / m^3).

Suspended matters and lead compounds can be considered as potentially the most dangerous aerogenic factors for the population associated with the waste storage from the mining plant near the residential area. The latter is connected with the fact that the average lead content in man-made sand and the products of their dispersion is from 0.12% to 0.21%. Lead content at levels up to 1600 mg / kg, which is more than 50 times the maximum permissible concentration of lead for soils, was recorded at individual points of tailing dumps.

The results of the environmental and hygienic assessment enable to qualify the air pollution level in the investigated area as “increased”, requiring strengthening of laboratory and instrumental monitoring of the atmospheric air quality, as well as the development of measures to reduce its pollution.

Assessment of the drinking water quality according to sanitary and chemical indicators showed that the water of the centralized water supply system meets the regulatory requirements for all parameters with the exception of iron compounds (up to 3.4 MAC - up to 1.03 mg / dm^3). In samples taken from public and private wells, iron is present in concentrations up to 21 MAC (up to 6.3 mg / dm^3), lead - in concentrations up to 4 MAC (up to 0.04 mg / dm^3, 8.3% non-standard samples). In addition, nontypical nickel levels were found in the wells' water (up to 1.1 MAC - up to 0.022 mg / dm^3, 22.2% of nontypical samples). Cadmium concentrations were noted at the boundary of 1 MAC (0.001 mg / dm^3). High levels of toxic metals in the water of private and public wells due to the weak protection of the aquifer (depth of 2-3 meters) from the penetration of water-soluble forms of ore caused elements, which main supplier is adit and quarry water [9].

Ecological and hygienic assessment of the soils quality in the investigated area showed that the analyzed substances did not comply with the hygienic standards for the period under study for content in soil of lead (43.2% of samples), zinc (45.9% of samples), copper (37.0% of samples), nickel (35.7% of samples) and manganese (9.5% of samples). The soils are intensively polluted: the maximum MAC was exceeded in 85 times (514 mg / kg) for lead, in 56 times (170 mg / kg) for copper, in 32 times (736 mg / kg) for zinc, in 8 times (32 mg / kg) for nickel, in 1.3 times (126 mg / kg) for manganese. The rest of the studied metals were recorded in "significant" concentrations without exceeding the hygienic standards.

All metals found in the soils of the investigated area are part of the waste of the past economic activity of the mining plant, which are dispersed by exogenous destructive processes, such as wind blow, water erosion, rain-wash, etc. Open soil areas are secondary air pollution sources, what requires soil cover by vegetation, solid materials (asphalt, tiles).

The safety assessment of agricultural (fruit and vegetable, dairy, meat) products produced in personal subsidiary farms did not reveal any hygienic standards excess for the studied chemical indicators. Maximum concentrations were recorded in carrots and potatoes for cadmium and copper at the level of 1 MAC (0.03 mg / kg and 5 mg / kg, respectively).

4. Conclusion

The environmental and hygienic assessment of the quality of environmental objects and factors in the investigated area, where waste from the past economic activity of the mining plant has been stored for a long time, showed the presence of a whole complex of environmental and hygienic problems associated with pollution of atmospheric air, surface and groundwater (including drinking water of private and public wells), residential soils with metals of I-III hazard classes.

The main problems include air pollution with suspended matters, lead, chromium and manganese - impurities typical for mining plant waste, a high content of a heavy metals number in the water of wells in the city and the presence of these compounds in food of local origin, which comprehensive combined effects may pose a risk to public health.

To improve the ecological situation in the territory, it is necessary to finish completely the remediation of the disposal sites of the mining plant; to provide shelter for dusting surfaces of the soil in the city through the creation of grassy lawns, laying tile or asphalt; to exclude private and public wells from the drinking water supply of the population and expand the centralized water supply system to the entire residential area; to organize systematic quality control of habitat objects (air, soil, surface and groundwater, agricultural products); to develop measures for negative impact minimization of external environmental factors on the population health till the standard quality of environment objects achieves.

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