Ecological study of atmospheric air on the territory of the Trans-Baikal Territory "Charsky territorial mountain-metallurgical complex"

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Abstract. The article describes the impact on the atmospheric air, which are acute negative nature of mining enterprises and their infrastructure industries of the North of the Trans-Baikal Territory, which actualizes this problem in society. The object of the study is the territory of the advanced development of the Trans-Baikal region "Charsky territorial mountain-metallurgical complex". The subject of the study is the current ecological state of atmospheric air. The aim of the study is to analyse the negative impacts of mining production, as well as the accompanying infrastructural factors that have a complex impact on the ecology of the atmospheric air in the northern territory. The research tasks are reduced to the identification of sources and types of atmospheric air pollution during the quarrying of ore, its enrichment, and the impact of the supporting industries of mining industrial production. The methodological basis of the study is integrated, structural, factological principles and approaches. The article uses general methods of research (analysis, synthesis, generalization), as well as private-scientific-factor analysis, which means the methodology of complex and system study of interaction of factors on the size of the effective indicators and others. The factor analysis of published and stock materials on title issues allowed to perform a complex analysis of the influence of the main factors of quarry production on the air of the adjacent territory. Features of atmospheric air pollution during the quarrying of sites, ore enrichment and work of service industries have been identified. Identified toxic pollutants cause the occurrence and exacerbation of various human diseases. The urgency of solving the issue of dust suppression during the quarry development of the deposits of the Udokan hearth of mineral resources, as well as the issue of transferring quarry vehicles to the consumption of replenished fuel, i.e. electricity - replacing diesel dump trucks with dump trucks powered by a contact network (trolleybuses, diesel trolleybuses, trolleynoac-cumulative). The urgency of solving the issue of dust transfer at the quarrying development of deposits of the Udokanskiy hotbed of mineral resources was substantiated, as well as the development of the question of the transfer of career vehicles for the consumption of renewable fuels, t. e. Electric power - replacement of diesel pit dump trucks with dump trucks powered by a contact network (trolley vehicles, diesel-trolley-vehicles, troll-batteries).

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1 Introduction

Environmental problems in Russia are the object of close attention of the state and the scientific community. Their emergence is associated with the industrialization of most industries, the urbanization of territories, the intensification of the introduction into economic circulation of undeveloped spaces and human use of the planet's resources. A typical example is the intensive industrial development of the northern territories of Russia with the aim of involving natural resources in the economy, and in particular the Trans-Baikal mining region, in which two territorially isolated regions are distinguished - "South-East" and "North" (Chara mining region), where a number of large deposits of ferrous, non-ferrous, precious metals and coal. The Charsky mining region includes the Sredne-Vitimsky and Udokansky centers of mineral resources in the northeast of Russia.

Industrial development of new territories, especially at the initial stage, negatively affects not only the ecological state of nearby territories, but can affect the ecology of entire regions.

Ranking environmental problems according to the degree of relevance allows us to classify pollution of atmospheric air, soil, water of rivers, lakes and other natural bodies of water, which are negatively affected by industrial emissions and discharges, as among the most pressing. According to UNEP (United Nations Environment Program), air pollution is one of the most dangerous environmental threats [7].

Almost any industrial production can cause environmental damage, but the most problematic for the occurrence of negative consequences are the following industries: chemical, metallurgy, mining, transport. The situation is complicated by the fact that the industrial development of the involved northern natural resources cannot be carried out without the necessary infrastructure - developed transport support, which in the mining industry, together with diesel heavy-duty vehicles, is railway, as well as quarry equipment: various types of excavators, tractors , front-end loaders, bulldozers, motor graders, etc. The operation of transport and quarry equipment leads to inevitable pollution of ecosystems, causing significant damage to all its components.

The spatiotemporal combination of infrastructural industries serving production with a benefit-creating industry (mining) creates a generally unfavorable environmental situation for society. The production infrastructure of the region under consideration is associated with the development of heavy-duty road and rail transport in the BAM system.

Fundamental publications on geoecology include the works of B.I. Kochurov [13], G.N. Golubev [5]. Examples of the manifestation of modern scientific interest in environmental transport problems can be found in the works [12, 14, 20]. Scientific interest in environmental problems of mining production is realized in works [2; eleven; 1]. Features of ecology in beneficiation production are described in [3]. Despite the many works devoted to the impact of harmful emissions and discharges on the ecosystem of mining production and infrastructure systems, there are not enough examples of a comprehensive study of the problem.

2 Objects and methods of research

Block of main research tasks:

- Determine the sources and types of atmospheric air pollution during quarrying of deposits.
- Identify sources and types of atmospheric air pollution during ore enrichment.
- To establish the sources and types of air pollution in the infrastructure sectors of mining industrial production.

The methodological basis of the study is complex, structural, factual principles and approaches.

The work uses general research methods (analysis, synthesis, generalization) and specific scientific ones (factor analysis, which identifies factors that have a complex effect on the resultant parameter).

3 Results and Discussion

Geographically, the study is confined to the northern part of the Trans-Baikal Territory. Administratively, the territory belongs to the Kalarsky district of the Trans-Baikal Territory, equal to the regions of the Far North. In the north of the region there is a section of the Baikal-Amur Mainline, in 1975 the construction of the Tynda-Chara line was completed, at the end of 2005 the Chara-China branch with a length of 64 km was laid for the development of the Chineyskoye field.

The Baikal-Amur Mainline was designed and built to involve the natural resources of the northern and eastern regions of the country, 700...1000 km away from the Trans-Siberian Mainline, into the state economy. Its length is 4324 km. The BAM is a supporting element of the infrastructure of an economically poorly developed and sparsely populated corridor 400 km wide, stretching in the latitudinal direction from the city of Ust-Kut in Eastern Siberia to the village Vanino on the Pacific coast.

Currently, the highway is going through difficult times, but remains practically the only transport artery that ensures the involvement of the natural resources of its northeastern part in the Russian economy. In the Trans-Baikal Territory, these include the Udokan source of mineral resources [23].

The Udokan focus is based on the Udokan copper ore deposit, which ranks third in the world in terms of explored reserves, amounting to 1.3 billion tons, the world's largest deposit of vanadium-containing titanomagnetite ores, located south of the Bamovskaya station New Chara. From this station, the development project provides for the construction of non-public railway tracks, i.e., intended only for production services of the Udokan mining and metallurgical plant [9].

It is also planned to build a category IV access road from the Novaya Chara station to the site of the Udokan mining and metallurgical plant.

The Udokan source of mineral resources also includes the Katuginskoye deposit of complex rare metal ores (tantalum, niobium, chromium, zirconium, thorium) with reserves of more than 700 million tons, the value of which can be considered unique. Its insignificant distance from the station China (25 km) and the Udokan deposit (50 km) create favorable preconditions for the creation of powerful steelmaking production. The nearby Apsatskoye deposit of high-quality hard coal with reserves of over 2 billion tons also contributes to this.

The object of study is the priority development area (TAD) “Chara territorial mining and metallurgical complex” located in the Kalarsky district of the Trans-Baikal Territory and belongs to the Udokan source of mineral resources in the north-eastern part of Russia. The project is being implemented within the framework of the priority development territory “Transbaikalia” [15].

The study area is a high-mountain area, which is part of the Stanovoy Highlands. The Chara Basin is located between two ridges: from the north Kodar with pointed peaks and canyon-like slopes, from the south Udokan - with flat dome-shaped peaks.

The climate of the region is sharply continental with insufficient precipitation and large daily and annual amplitudes of air temperature fluctuations (in some areas the annual amplitude is 94 ^{o}C or more). The climate of the study area can be described as ultracontinental.

3.1 Ecology of mining

The Katuginskoye, Chineyskoye and Udokanskoye deposits are being developed (planned for development) by open pit mining [4, 10].

From the perspective of environmental impact, any operating quarry is a mining enterprise that has a negative impact on the environment. All processes, from construction, laying energy and transport routes to its industrial operation, negatively affect the main components of the human environment: atmospheric air, surface and groundwater. Damage is also caused to the soil layer, forest parks, and habitats of animals and birds.

The main production processes of open-pit mining include dumping of overburden. Large masses of overburden are placed in specially prepared landfills. Atmospheric precipitation, filtering through the body of the dump, is saturated with the components present in the dumps. In groundwater in contact with rocks, the content of heavy metal ions lead, zinc, and various salts increases, which leads to increased acidity. Geological processes such as landslides, gullies, sloughs, and waterlogging can also be a consequence of open-pit mining.

The main technological processes in quarrying also include blasting. Explosive energy is used to destroy rocks as the most effective method. Mass explosion technology is used - the process of simultaneous or sequential (with a certain time interval) explosion of a large number of BB charges in rocks (the total mass of charges reaches 1000 tons, the volume of broken rock is 1 million m^3, the volume of dust and gas cloud is 15...20 million m^3). A directed explosion is used to move overburden rock in a given direction.

When ore is broken by exploding explosive charges, a large amount of toxic substances is released into the atmosphere. A significant amount of toxic gases is recorded in the explosion products of industrial explosives - mainly toxic CO, NO and NO_2. With incomplete combustion of explosives, they contain 50...60% carbon dioxide, 20...25% carbon monoxide and 15...20% nitrogen oxide. Carbon monoxide penetrates deep into the fractured rock mass to a depth of 700 mm and is retained for 15 days with a carbon monoxide concentration of up to 0.5%.

After massive explosions, the dust and gas cloud reaches a height of up to 300 m in 1 minute or less, and a volume of 20 million m^3 or more. In this case, the cloud itself can spread over a distance of more than 20 km from the quarry, especially in the dominant direction of the “wind rose”. The total dust emission from the quarry can be 5...16 tons per day. The area of dusty surfaces increases with the depth of the quarry, since the length of roads, one of the infrastructural sources of dust and gas emissions, increases significantly.

An example of the negative influence of the prevailing wind direction is the territory of the Chineyskoye titanomagnetite ore deposit. Climatic (sharply continental climate, low temperature) and landscape (mountainous terrain) conditions of the territory create unfavorable conditions for the dispersion of dust and gas pollution in the atmospheric air. In table 1 shows data substantiating this thesis.

Table 1. Climatic indicators of the territory of the Chineyskoye field.

Average annual air temperature, °C		**Average wind speed, m/s**	**Prevailing average annual wind direction**
max	min	5.0	Northeast
+16.0	-35.3		

A comparison of the prevailing average annual wind direction in the territory of the Chineyskoye deposit with the location of deposits in the Udokan source of mineral resources shows that most of them are located in the zone of influence of dust and gas pollution.

3.2 Ecology of ore dressing

The ore mined in the Udokan quarries undergoes a technological process to separate pure copper from the natural rock. The enrichment process is preceded by preparatory operations (crushing, screening and classification) associated with abundant dust emission. After several stages of ore preparation, small fractions of the rock (up to 170 microns) enter flotation machines, where two components are formed: useful (a concentrate containing the maximum possible amount of copper and tailings, containing mainly waste rock minerals.

Of each ton of mineral ores mined, only about 2% is converted into useful products, the rest is waste, concentrated in dumps, tailings dumps, and other places for storing and storing rock mass and products, and representing fine-grained material with a certain amount of chemical reagents used.

Enrichment waste is a source of pollution of the atmosphere, groundwater, and soil in the area where it is located. The dry surface of tailings is a source of intense dust emission and environmental pollution with toxic elements. The negative impact of tailings dumps on the environment is associated with changes in the topography of the adjacent territory, changes in the temperature regime of permafrost soils, and disruption of runoff parameters and the chemical composition of surface and groundwater.

As already noted, enrichment is accompanied by abundant dust emission with typical ingredients released during fuel combustion in roasting departments and concentrate drying plants. These are nitrogen oxides, carbon monoxide, sulfur dioxide, ash, benzo(a)pyrene (first hazard class). To this should be added special polluting chemical compounds that accompany flotation processes - coagulants (unpurified aluminum sulfate, as well as ferrous sulfate $FeSO_4•H_2O$, ferric chloride $FeCl_3$) and flocculants (starch, dextrin, ethers, celluloses).

A promising area of ore beneficiation is geotechnology (heap leaching) - an industrial mining process used to extract precious metals, copper, uranium and other compounds from ore using a series of chemical reactions that absorb certain minerals and form concentrated productive solutions. Then the primary components are isolated from them. The described technology creates significant environmental risks caused by the use of aqueous solutions of mineral (sulfuric, nitric, hydrochloric) and organic acids (for example, acetic), soda, ammonium salts, etc. Potentially negative consequences of heap leaching can also occur if the waterproofing base of the ore stack is defective, leaks in the system for collecting productive solutions.

Geotechnology has undergone experimental testing on the ores of the Udokan and Katugin deposits. The pilot plant is located in close proximity to the Udokan deposit, 7 km from the village and Novaya Chara station of the Baikal-Amur Mainline in the Kalarsky district of the Trans-Baikal Territory.

For the processing of Udokan copper ores, it is also planned to use our own patented flotation-hydrometallurgical technological scheme.

Ecology of infrastructure sectors of mining industrial production. The most important infrastructure sectors of mining production are railway transport and heavy-duty road transport. Based on the principle of environmental impact on atmospheric air, quarry equipment is also classified as transport vehicles: various types of excavators, tractors, front loaders, bulldozers, motor graders, fuel tankers, etc. The engines of quarry equipment are mostly represented by diesel units.

One of the main polluting factors inherent in motor vehicles is exhaust gases from internal combustion engines. They are a determining factor in the condition of the air basin of the quarry and the surrounding area.

Automotive quarry transport is represented by heavy-duty dump trucks, equipped mainly with diesel engines with a capacity of 200...3550 horsepower, and to a lesser extent

- carburetor engines, which during operation emit a complex mixture of gases, vapors and solid particles into the atmosphere (Table 1).

The most dangerous gases are carbon and nitrogen oxides, nitrogen dioxide and sulfur dioxide. Thus, when operating at maximum power, the BelAZ 75215 diesel mining dump truck (load capacity 180 tons) emits into the atmosphere every hour in the form of aerosol gases: 1.961 kg of CO; 8.605 kg NOx; 0.804 kg CH; 0.225 kg C [8]. A dump truck can pollute about 4 million m^3 of air per shift to the maximum permissible level.

Gasoline engines cause similar environmental damage: when burning 1 ton of gasoline, 180...300 kg of carbon monoxide, 20...40 kg of hydrocarbons, 25...45 kg of nitrogen oxides are formed [8].

The movement of vehicles, as well as the operation of excavators, bulldozers, motor graders, and front-end loaders during loading and unloading operations is accompanied by the release of large amounts of dust, which spreads over tens of kilometers, polluting not only the atmospheric air, but almost all other components of the human environment. The effect of dust on the human body results in a wide range of diseases.

Table 2. Approximate composition of exhaust gases of carburetor and diesel engines.

Component	Carburetor engines	Diesel engines
Nitrogen, vol. %	74–77	76–78
Oxygen, vol. %	0.3–8.0	2–18
Water vapor, vol. %	3.0–5.5	0.5–4.0
Carbon dioxide, vol. %	5.0–12.0	1.0–10.0
Carbon monoxide, vol. %	0.5–12.0	0.01–0.5
Nitrogen oxides, vol. %	0.0–0.8	0.0002–0.5
Non-carcinogenic hydrocarbons, vol. %	0.2–3.0	0.009–0.5
Aldehydes, vol. %	0.0–0.2	0.001–0.009
Soot, g/m^3	0.0–0.4	0.01–1.1
Benz(a)pyrene, $\mu g/m^3$	To 10–20	To 10

Quarry vehicles, which transport up to 80% of the rock mass, in addition to the disadvantages associated with negative environmental impacts, also have operational ones: relatively low energy efficiency, complex maintenance, significant operating costs, etc.

A significant role in open-pit mining is played by railway quarry transport, which operates in a closed cycle: loading of the train (about 30% of the cycle time), unloading (25%) and movements with cargo and empty (45%).

It is generally accepted that in terms of negative impact on the environment, railway transport is much more efficient than others (70 times automobile, 600 times aviation), however, with its intensive use in limited areas of mining regions, this advantage is practically not realized.

The main source of air pollution is the exhaust gases of diesel locomotives (Table 2).

The workshops supporting quarry railway transport include locomotive and carriage depots, boiler houses operating on solid fuel, gas or fuel oil. When burning coal, oxides of sulfur, carbon, nitrogen, fly ash, soot are released into the atmosphere; when burning fuel oil, sulfur oxides, nitrogen dioxide, and solid products of incomplete combustion of vanadium are released.

The scope of the study did not include consideration of energy sources of air pollution - electromagnetic and ionizing radiation, noise, vibration, ultrasound, etc.

4 Conclusion

Atmospheric air is the main and most important vital element of the space surrounding a person. With every breath, atmospheric pollutants present in the air penetrate into the body. In mining, the most dangerous are small (up to 0.0025 mm) solid particles of dust and soot - the most characteristic components of the open-pit mine space. In combination with other toxic pollutants (carbon oxide and dioxide, nitrogen oxides, etc.), they provoke exacerbations of diseases of the cardiovascular, reproductive and nervous systems, increasing the risk of diabetes, cancer, and lung diseases. The data obtained corresponds with the five main pollutants identified by WHO experts: carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, and dispersed particles.

The study, based on factual and statistical information, identified the features of air pollution during quarrying, ore beneficiation and the work of production facilities serving them.

The most important factor that has a negative environmental impact is dust formation during mass explosions - the volume of the dust and gas cloud, containing mainly toxic CO, NO and NO_2, can reach 15...20 million m^3. Using the example of the Chineyskoye deposit of titanomagnetite ores, it is shown that the climatic (sharply continental climate, low temperature regime) and landscape (mountainous terrain) conditions of the territory create unfavorable conditions for the dispersion of dust and gas pollution in the atmospheric air. A comparison of the prevailing average annual wind direction in the territory of the Chineyskoye deposit with the location of deposits in the Udokan source of mineral resources shows that most of them are located in the zone of influence of dust and gas pollution.

Infrastructure support for quarry production (heavy dump trucks, excavators, bulldozers, motor graders, front loaders), operating mainly on diesel power, also causes irreparable damage to the atmospheric air.

These two factors justify the study of the issue of transferring quarry vehicles to the consumption of renewable fuels, i.e. electricity - replacing diesel quarry dump trucks with dump trucks powered by an overhead contact network (trolley trucks, diesel trolley trucks, trolley-battery ones).

The practical homogeneity of the chemical composition of harmful emissions in the processes of quarrying, ore beneficiation and the functioning of infrastructure support for mining industries makes it possible to develop preventive measures that help minimize the negative consequences of the impact of quarry mining on the mine atmospheric space.

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