Mine Tailings: Environmental Damage and Resource Potential

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Abstract. In this paper, the authors constructed a simulation model that allows economic assessment of environmental damage. Using the example of sulfide-bearing wastes from a mining and processing plant in the Kemerovo region, the total damage caused to water and land natural resources in 2018 was calculated. 659.7 million rubles. This damage amounted to 659.7 million rubles. The authors also made a forecast estimate, according to which the environmental damage in 2030 will amount to 950 million rubles. This forecast can be realized in case of failure to take any measures to eliminate or reduce the negative impact on the environment.

1. Introduction

The relevance of studies of sulfide waste in the processing of polymetallic ores is due to environmental risks associated with the formation of acid effluents that spread toxic elements tens of kilometers from storage facilities. This happens due to the leakage of highly mineralized pore solutions into the groundwater horizon, pollution of soils and atmospheric air by aeolian drift of finely ground ore material [1]. Interest in the topic of sulfide wastes is also associated with the prospects of extracting valuable components from them [2].

However, today the register of storages of non-existent mining enterprises that have completed their work with the collapse of the USSR has not yet been compiled. According to various data of such facilities in the territory of the Siberian Federal District alone, more than 100 with a total volume of over 1 billion tons. In total, about 16 billion tons of mining waste was accumulated in the territory of the Russian Federation (according to the State Statistics Committee, 2017). Assessing the current state and forecasting the development of the facility requires the following work: to assess the volume of tailings ponds, to outline the channels for filtering drainage solutions, the level of pollution of ground and surface waters (rivers, streams, reservoirs) in waste storage areas [3, 4]. At the final stage, economic calculations of environmental damage and the estimated cost of restoration measures [5-8] are carried out.

Today there are no methodological manuals for calculating environmental damage and predicting the potential hazard of waste, there is no regulation for the treatment of old storages that are not equipped with anti-filter screens. The purpose of the work is the creation of a methodology for calculating the environmental damage caused to water and land resources by sulfide-bearing mining waste.

According to the Federal State Statistics Service, in the budget of Russia in recent years less than 1% of the budget has been allocated for the environment. Since 2003, there has been a noticeable ten-
dency towards lower environmental protection costs. In 2018, costs amounted to only 0.7% of GDP. To stabilize the environmental situation in the country at the current level, it is required to carry out costs of at least 3% of GDP, to improve it - at least 4% of GDP, for a cardinal change - at least 5% of GDP.

Currently, experts in various fields of activity are involved in the economic assessment of environmental damage. Every year, new assessment methods are developed that allow the most complete way to take into account all aspects of the damage caused by the production activities of enterprises. Existing methods are diverse, each of which has its advantages and disadvantages.

In the domestic literature, five methods are considered for calculating the economic assessment of environmental damage: direct counting, damage assessment by a mono-pollutant, generalized indirect estimates, production function and enlarged.

The method based on a direct account (recipient approach) is to obtain a general estimate by summing up the assessments of environmental damage, expressed in cash, from the effect of the pollutant on specific recipients (population, housing and communal services, agricultural land, animals and plants, forest resources, elements of industry and transport, fish resources, recreational resources and others) [9]. Due to the high requirements for the volume and quality of information, the direct counting method rarely finds its implementation in practice. Simpler and often used method is the method of calculation according to a mono-pollutant [10]. The idea of the method of generalized indirect estimates is that the total damage assessment is made up of three components - estimates of pollution of the atmosphere, hydrosphere, and lithosphere [11]. The production function method is based on the fact that any production is the result of a combination of production factors (capital, natural resources, labor, etc.). The damage that is caused to production through a negative impact on each of the factors can be calculated as the sum of the negative effect, expressed in monetary terms [12]. Despite the fact that the calculation method seems simple, its practical application is also difficult.

Recently, the damage extended assessment method, which is an improved integration of some of the previously listed methods, has been widely used. Recently, the damage assessment method, which is an improved integration of some of the previously listed methods, has been widely used. The Ministry of Natural Resources and Ecology of Russia officially regulate the calculation formulas are specially developed by the departments of damage assessment. The whole set of foreign assessment methods is difficult to classify on any one basis. Therefore, in foreign literature it is often possible to meet the following classifications:

- classification depending on the number of stages of assessment [13-14]:

  Direct approach. In this case, an attempt is made to immediately assign a monetary value to the gain or loss in the quality of the environment. This approach combines the following assessment methods: the hedonistic method, the method of transport and travel expenses and the conditional assessment method;

  Indirect approach. He has the following idea: first of all, to determine the consequences of changes in the quality of the environment, and then to evaluate these effects in cash. This approach usually includes: a method of accounting for changes in the productivity of natural resources, a method of preventive costs, a method of recreated value, a method based on assessing changes in the quality of human capital.

- classification depending on the degree of objectivity of the assessment [15]:

  Methods of identified preferences. The group of these methods proceeds from the fact that individuals by their behavior reveal how they react to changes in environmental quality. The methods of subjective assessment include the widely used in world practice methods of preventive and transportation costs, the hedonic method, methods of alternative and recreated value, as well as the method of accounting for changes in the productivity of natural resources;

  Methods of declared preferences. Here, unlike the previous method, consumer behavior is not monitored. Researchers directly ask consumers how much they need sustainability in carefully structured surveys. The group of these methods includes: the method of conditional assessment and experimental selection.
Thus, the main objective of the study is an economic assessment of the impact of waste from mining and industrial activities on the environment. The novelty of the study lies in the systematization of Russian and foreign methodological approaches to the economic assessment of environmental damage and in the calculation of accumulated environmental damage by the example of sulfide-bearing wastes from a mining and processing plant in the Kemerovo region. The authors made recommendations for reducing and eliminating environmental damage caused by the studied object.

2. Data
In this work, the waste of the mining and processing plant of the Kemerovo region was selected as the object of study. The main chemical characteristics of soils and water bodies within the territory of the enterprise were obtained by employees of the Institute of Petroleum Geology and Geophysics SB RAS. The source of economic indicators is the Federal State Statistics Service (gks.ru).

3. Methods
According to the methodology of the integrated damage assessment, the economic assessment of environmental damage is the sum of the damage assessments caused by each of the components of the biosphere, multiplied by correction factors that take into account the reliability of the enlarged method. The calculation of environmental damage from water pollution was applied in stages, according to the following methodology.

Assessment of environmental damage from pollution of the water sector (Y_w) was determined by the formula:

\[
Y_w = \gamma_w \cdot \sigma_w \cdot M_w, \tag{1}
\]

Where
- \(\gamma_w\) – the indicator of the specific damage (price of pollution) to water resources caused by a unit (conventional ton) of the reduced mass of pollutants at the end of the reporting period for a water body in the considered region, rub. / conv. ton;
- \(\sigma_w\) – coefficient of environmental significance for water bodies in the basins of major rivers;
- \(M_w\) – reduced mass of pollutants entering the water resource during the reporting period of time, conv. tons.

The reduced mass \(M_w\) is calculated as the sum of the products of the mass of discharged pollutant \(i\) (\(m_i\)) and the relative hazard index of the \(i\)th substance (\(A_i\)):

\[
M_w = \sum_{i=0}^{N} A_i \cdot m_i, \tag{2}
\]

\(N\) – total amount of pollutants.

The relative hazard indicator of the \(i\)th substance \(A_i\) is determined on the basis of the maximum permissible concentration (MPC) of the chemical substance in the water of water bodies of drinking, cultural and domestic water use:

\[
A_i = \frac{1}{P_{MPC_i}}. \tag{3}
\]

The mass of the polluting substance \(m_i\) in water resources was determined based on the average concentration of the substance in water (grams per cubic meter) and the assessment of the volume of polluted water resources.

When assessing the environmental damage from pollution of land resources and soils, the following parameters were taken into account: the area of the territory contaminated with the \(i\)th substance, the degree of pollution with the \(i\)th substance, the depth of pollution, the coefficient of environmental significance of the region’s land resources, the standard of land value in the region. Environmental damage from land pollution (Y_z) was calculated by the formula:

\[
Y_z = H \cdot k_3 \cdot \sum_{i=1}^{N} S_i \cdot k_{3i} \cdot k_{ri}, \tag{4}
\]

\(H\) – the cost of settlement land in the region (rubles per square meter);
\(S_i\) – area contaminated with \(i\)th substance (square meter);
\(k_{3i}\) – coefficient characterizing the degree of pollution with the \(i\)th substance;
\(k_{ri}\) – coefficient characterizing the depth of contamination with the \(i\)th substance;
\( k_\text{э} \) – coefficient of ecological significance of land resources in the region; 
N – amount of pollutants.

4. Result and discussion
Wastes from the mining and processing of polymetallic (barite-lead-zinc) ores, the production of concentrates, the extraction of precious metal sands from gold-bearing and gold-quartz deposits, the mining of precious metals, the extraction of sulfuric pyrites and the storage of copper in natural storages (as it happened at the dawn of development USSR mining industry in the 30s), and not on specially equipped sites, negatively affects the state of the local ecosystem [16-17].

In this article, the authors evaluated the environmental damage from pollution of water resources, which include a hydraulic dump, drainage, and a well. Authors also evaluated the annual environmental damage from surface and underground runoff of polluted waters into the river.

The initial data were information on the concentration of various heavy metals in water bodies that are exposed to an anthropogenic research object. Based on the data on the rate of discharge of substances from the pipe (900 cubic meters per hour), the mass of pollutant emissions by the source per year \( (m_i) \) was calculated.

Based on the hygienic standards of GN 2.1.5.1315-03 «Maximum permissible concentration (MPC) of chemical substances in the water of water bodies of drinking and cultural and domestic water use», the relative hazard indicators \( A_i \) of substances were determined and the reduced mass \( M \). The quantitative value of specific damage \( U_\text{уд}^\text{вод} \) to the water resources of the Kemerovo region related to the Ob river basin, the Irtysh tributary, was determined on the basis of the value of this indicator in the Methodology for Determining Prevented Ecological Damage, approved by the Chairman of the State Committee of the Russian Federation for Environmental Protection Danilov-Danilian V. I. on November 30, 1999. In 1999, according to regulatory documents, specific damage was estimated at 10 616.5 rubles per conventional tons.

To assess the unit of damage for 2018, the method of bringing to the modern value is used. So, taking into account the dynamics of inflation for the period 1999-2018, the specific damage to water resources amounted to \( U_\text{уд}^\text{вод} = 114 162.8 \) rubles per conventional tons. In calculating the economic damage, the value of the coefficient of environmental significance for water bodies of the Kemerovo region at the level of \( G = 1.16 \) was applied.

The results of calculations of the assessment of environmental damage from pollution of water resources, including hydraulic dump, drainage, a well and a river, showed environmental damage in the amount of 626,581,874.9 rubles.

When assessing the environmental damage from pollution of land resources, the following parameters were taken into account: the area of the territory contaminated with the \( i \)-th substance, the degree of pollution with the \( i \)-th substance, the depth of pollution, the ecological significance coefficient of the land resources of the region, the standard value of land in the region. The initial data were the concentration of heavy metals at different depths of the soil at a distance of 750 meters from the plant.

The value of the land plot was determined in accordance with the Decree of the Administration of the Kemerovo Region «On the approval of the average levels of the cadastral value of land on the lands of settlements of the Kemerovo region in municipal districts (urban districts)» taking into account inflation indicators. So, the cost of land is 1092.9 rubles per square meter [18]. The area contaminated by the plant is 1,767,146 square meters. The level of pollution with the \( i \)-th substance was determined based on the degree of excess of the concentration of the \( i \)-th substance in the soil over the MPC level. Later, for each substance, the pollution coefficient was determined.

The pollution depth is characterized by a level of more than 150 cm, which corresponds to a coefficient of pollution depth \( k_{ri} = 2 \). The value of the coefficient of environmental significance in the region is accepted \( k_\text{э} = 1.2 \).

The results of calculations of the assessment of environmental damage from land pollution showed that the area around the stored waste caused environmental damage in the amount of 33,080,973.12 rubles. The total environmental damage assessment in 2019 amounted to 659,662,848.01 rubles.
Further, the authors calculated the predicted values of environmental damage for the period 2019-2030 with no measures taken to eliminate pollution. Thus, in 2030, the environmental damage caused by the stored sulfide-bearing waste to the environment, if no measures are taken to eliminate or reduce the negative impact (such as the liquidation of a solid waste landfill, a deep landfill in the bowels of industrial wastewater and an unorganized landfill for industrial waste, the disposal of a sludge collector and the subsequent provision of environmental rehabilitation of territories), regardless of the scenario, will amount to almost 950 million rubles.

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