EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology 2022, 23(3), 7–14
https://doi.org/10.12912/27197050/147142
ISSN 2719–7050, License CC-BY 4.0

Received: 2022.02.02
Accepted: 2022.03.15
Published: 2022.04.01

Disposal of Mining Waste and its Impact on the Environment

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ABSTRACT

The activities of mining enterprises are inextricably linked with the formation of a large amount of industrial waste, which harms the environment. Another important factor in emergency pollution is the deterioration of communications and equipment obsolescence, which in some mining enterprises reaches 70%. The problem of waste management and management, despite a large number of scientific works and developments in this area, in the conditions of modern Russia is extremely relevant and requires the latest research from an economic point of view on waste, minimizing its impact on the environment, and safely storing it in specially equipped storage facilities to attract it as secondary raw materials. One of the biggest problems associated with mining waste is a significant burden on emergencies as a result of irrational and unorganized management of some of the waste. Most of this waste is generated in the processes of ore extraction and processing. In economic terms, waste is considered to be unused residues of raw materials, semi-finished products, heat carriers, and other types of unused material resources that appeared in the production process, lost their consumer properties, and, accordingly, cannot be used for their intended purpose.

Keywords: waste, soils, heavy metals, environment

INTRODUCTION

On average, about 5% of the total amount of raw materials produced materializes as a final product (Bavec, 2016). The remaining 95% enter water bodies and settle to the bottom, dissipating over large areas polluting the atmosphere or concentrating on the soil cover.

From an economic point of view, the integrated use of mineral raw materials is extremely effective, first of all, the secondary extraction of valuable components from production waste significantly reduces the cost of production and partially solves the problem of limited raw material base (Gosar, 2015). Thanks to an integrated approach to the management and use of mineral raw materials, it is possible to significantly increase the volume of production at lower capital costs. Now the issue of integrated use and management of mining waste, which includes overburden, rock dumps, enrichment tailings, slags, slags, etc., has become acute (Covelli, 2017).

Among the total amount of waste accumulated in Russia, about 28 billion rubles. tons of mining and processing waste, more than 3 billion tons. tons of metallurgical slags. Every year, the industry generates more than 1.6 billion industrial waste tons, as well as about 2 million tons. tons of total discharges and emissions. Among industrial waste, the largest share of 84% is waste from the processing and extraction of mineral raw materials, 7% is metallurgical slags (Gosar, 2016). Waste from mining enterprises can be divided into three groups: overburdened rocks, waste-containing rocks, and waste from the ore processing process (Gribust, 2019).

The first group is nonmetallic waste related to rocks of sedimentary origin and formed as a result of overburden operations, they are stored in dumps. The second group of waste consists of rocks formed as a result of the heterogeneity of ore bodies. Mining enterprises operating in Russia annually produce more than 60 million tons of coal along the way. m3 of rocks, most of which are recyclable for the production of crushed stone. The third group is an ore-processing waste. at the processing plant, concentrate and processing waste are obtained during the ore processing process, waste usually accounts for 45% of the total volume of ore that is processed.

Waste accumulated and concentrated in settling tanks, reservoirs, and storage tanks are dangerous, since the waste in them undergoes complex physical and chemical changes in contact with the atmosphere, seeping into the lithosphere and hydrosphere. As a result, a large number of compounds are formed and released, including dangerous and toxic ones, which are moved by the environment and directly affect the quality of all environmental components. In the advanced economies of the world, great attention is paid to the issue of efficient management and use of mining waste, due to which their level of utilization is 65–80% (Ivanisova, 2019).

MINING WASTE DISPOSAL METHODS

Research, experience, and production tests of some industrial facilities demonstrate the possibility of mining and processing waste being used as raw materials for the production of building bricks, ceramics, aggregates for concrete, crushed stone, and other materials that are in demand in construction.

It is advisable to develop and use an integrated approach to significantly reduce the amount of waste produced by mining enterprises and partially solve the problem of accumulated waste. It should also be taken into account that waste is dangerous for the environment and can be used as a substitute for Natural Mineral Resources after processing. The composition of accumulated waste includes both mineral components that can be used in the construction industry, and metals, in some cases Ferrous, Non-Ferrous, rare earth, and even sometimes precious. The cost of recycling and extracting materials in this way after the payback period expires will be lower than extracting the same materials from limited reserves of natural raw materials.

Despite the availability of technologies for processing most of the waste, the amount of waste placed in dumps and tailings dumps is growing every year. Current trends in waste generation in the economic development of metallurgical and Mining Enterprises cause further deterioration of the already difficult environmental situation in the areas where they are located, so this problem requires further consideration and research in the field of minimizing their negative impact on the environment by introducing a circular economy (Ke, 2016).

The analysis of modern sources of information makes it possible to conclude that the unsatisfactory environmental situation is caused by the consequences of the production activities of mining enterprises in Russia and is caused by a complex of reasons (Khuzhakhmetova, 2019):
- imperfection of existing legislation in the field of waste management;
- lack of a functioning economic mechanism for regulating relations between waste producers and potential consumers of by-products;
- the inability to regulate the mechanism of the careful attitude of entrepreneurs to the environment through market relations;
- lack of a systematic approach on the part of management structures in solving the problem of waste.

Most limestone mining and processing enterprises do not use a significant part of the raw materials after processing, such waste requires significant storage costs. Limestone mining waste is usually a mixture of crushed 0–15 mm limestone with sand and clay material. Undesirable for metallurgy and the construction industry are clay impurities in limestones, the reasons for their presence are inefficient technology for processing raw materials; lack of information about the latest technologies and equipment for processing limestone. A circular cycle for the mining industry is developed and proposed (Kotnik, 2015), in the essence of which the secondary use of limestone mining waste is planned to clean emissions of harmful gases formed during quarry blasting operations, as well as to treat wastewater from mining enterprises.

The issues of wastewater treatment of mining enterprises in the conditions of Modern Russia are among the most important and require the latest research to minimize the impact of such waters on the environment. The waters of mining and processing plants contain pollutants that need to be cleaned before being discharged into water bodies, and the captured substances, if possible, can be recycled and reused. The most common pollutants of such waters are chlorine and sulfuric acid compounds, soluble salts, mainly heavy metal sulfates: zinc, iron, copper, manganese, and nickel. Such waters cannot be used for industrial purposes without preliminary treatment and neutralization, and the captured and deposited pollutants from industrial effluents are further suitable for use in construction, industrial and other purposes.

Currently, most industrial enterprises in their technological processes produce a large amount of toxic wastewater containing heavy metal ions, such effluents are dangerous sources of environmental pollution. Most heavy metal ions belong to hazard class I-II, they differ in carcinogenic, mutagenic properties and have a cumulative effect (Kruzhilin, 2019). For heavy metals, there are no reliable self-cleaning mechanisms. Heavy metals are only redistributed from one natural source to another, interacting with various living organisms and leaving visible undesirable consequences of this interaction everywhere.

The toxicity of metal is related to its effect on the metabolism of living organisms and human health. The general toxic effect of heavy metals on humans and animals leads to changes in the systems of hematopoiesis, internal secretion, malignant neoplasms, and disorders of the hereditary apparatus occur. The simultaneous presence of two or more heavy metals in water usually causes an increase in the toxic effects of such water on the biota, including humans, with the simultaneous presence of copper and zinc compounds in the water, there is an increase in the level of toxicity by five times. In water and soil systems that are deficient in dissolved oxygen, the toxic effect of heavy metals on microorganisms increases sharply (Liu, 2017).

Protection of the water basin from industrial wastewater contamination is possible if reversible water supply cycles are introduced. However, the organization of recycled water supply using wastewater at the enterprise is possible only if they are deeply cleaned of wastewater. The use of untreated water containing heavy metal ions for production purposes will necessarily lead to the following problems: corrosion, reducing the service life of equipment, increasing operating costs for maintenance and repair of technological equipment (Pavlowsky, 2017).

With inefficient methods of wastewater treatment containing heavy metals, they end up in natural reservoirs. As a result of such seepage, many problems arise the loss of the natural ability of reservoirs to self-clean, disruption of the functioning of activated sludge at urban wastewater treatment plants, and in general, the level of load on emergencies increases.

Field development has a different impact on the hydrological conditions of the adjacent territories. This largely depends on the location of mineral deposits. Climate, terrain, the presence of reservoirs and watercourses nearby, the composition and structure of overburden, the depth of the productive reservoir, the tectonic structure of the area – all these factors determine what exactly will be the impact on hydrological conditions. Water content is determined during the operation of deposits with the help of artificial factors,

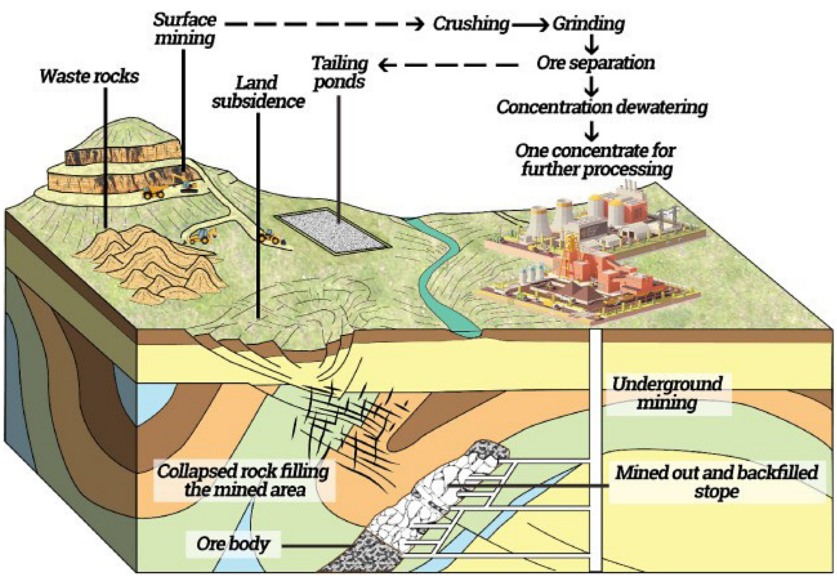

Figure 1. Diverse wastes generated during ore extraction and processing

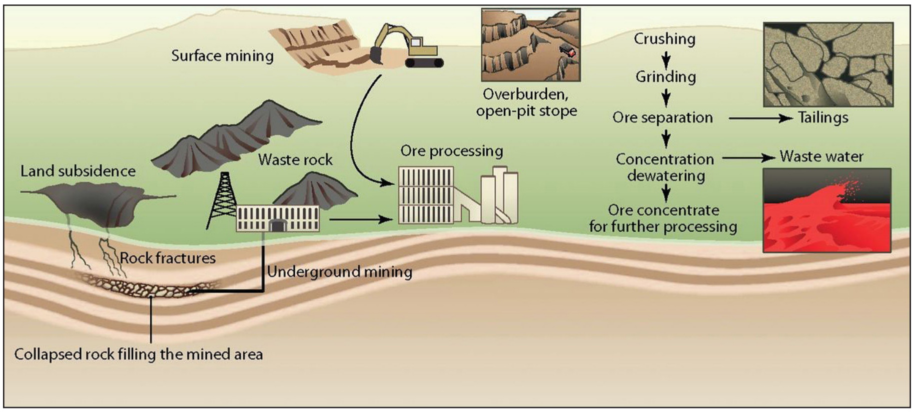

Figure 2. Process of reusing mining waste

which are determined by the method of opening and the field development system. This is due to the redistribution of hydrodynamic and hydrostatic pressure, drainage of water, increased water supply to mine workings from open watercourses and reservoirs, filtration, and infiltration of precipitation, which is caused by surface deformation during field development.

The surrounding areas are affected by hydrological and engineering-geological phenomena that occur during the development of deposits. As a result of such phenomena, the feeding conditions and movement of underground water change, which contributes to the formation of depression craters and the cutting of all aquifers, and a decrease in the water level in Wells.

Mining and processing enterprises use water in large quantities for domestic, technological, and technical needs, in particular, for dust drying, for use in the technological processes of processing plants, processing plants, during the use of Hydro-mechanized development, for use by the population (Schrope, 2013).

During the construction and operation of quarries, significant complications may occur due to the presence of surface and underground water, in particular:

- terrain deformations;
- deformations of mine workings;
- complications during blasting operations;
- reduced productivity of process equipment;
- complications during drilling operations.

Therefore, the drainage of deposits is one of the priorities and main features of mining production. Drainage in mining is a set of technical measures that significantly reduce the flooding of mineral deposits and the regime of water inflow into mine workings during the construction of mining enterprises and the operation of deposits with complicated hydrogeological conditions. Therefore, mining operations are usually accompanied by artificial water reduction, but when pumping or wastewater is discharged, this leads to contamination of water bodies with salts, heavy metals, and petroleum products.

Mining enterprises are characterized by a significant predominance of the volume of wastewater over the volume of water used to support technological processes. Drainage water flowing from the surface of dumps cannot be used in the mining cycle without appropriate preparation and treatment, in the absence of treatment facilities, surface water is polluted by low-quality wastewater: suspended particles, fuel, and lubricants, clay particles, water with elevated temperature, rock mineral dust.

The technology of production activity of mining and processing enterprises is associated with the formation of a huge amount of industrial waste. Most of them are waste generated in the processes of ore extraction and processing. Huge volumes of waste generation and accumulation cause aggravation of economic, environmental, and social problems and require immediate measures to solve them (Semenyutina, 2019). To significantly reduce the number of mining enterprises' production waste, it is necessary to use an integrated approach to solving this issue. It should also be taken into account that such wastes can be used as a substitute for natural resources and at the same time they are dangerous to the environment.

Mining enterprises currently do not have production waste from an economic point of view, it is not reflected in the financial statements and does not affect the indicators of economic activity. Thus, a vicious circle has been formed at mining enterprises: industrial waste is not recorded because it is not economically profitable, and it is not profitable because it is not recorded. The development and implementation of an effective management system for industrial waste management operations should provide for the availability of an information base based on environmentally oriented data accounting.

For effective management of industrial waste, it is necessary to study the economic essence of mining production waste, taking into account industry characteristics and determining the characteristics by which such waste will be classified as accounting objects. With the introduction of the term "production waste" into production practice as an economic group, it will have an impact on the construction of a special information base, and its creation based on environmentally oriented accounting data, to effectively manage the industrial waste of the mining and Industrial Complex.

Regulatory documents had a significant contribution to solving the issue of determining the economic essence of industrial waste from mining production. The issues of organizing accounting for mining and industrial waste and operations with them are poorly understood and extremely relevant for all mining enterprises in Russia.

The reference literature provides a general definition of the term "waste". Water-unsuitable for the production of certain products types of raw materials, its unused residues or substances that arise during technological processes (solid, liquid, and gaseous) and energy that is not subject to recycling in the production under consideration; waste from one product can serve as raw materials for another (Taha, 2017). Mining waste is the unused product of extraction and processing of mineral raw materials, which can be isolated from the rock mass in the complex processes of development of mineral deposits, their processing, chemical, and metallurgical processing.

From an economic point of view, the term waste refers to unused raw materials, materials, semi-finished products, heat carriers, and other material resources that have arisen in the technological processes of production and have lost partially or completely their original consumer properties, and therefore their use is accompanied by increased costs, including a decrease in the amount of output or are not used at all in production for their intended purpose. The cost of such waste is deducted from the total cost of raw materials and supplies.

In the mining industry, the term "waste" can be considered conditional at a certain stage of product development. The key reason for the formation of most waste is now considered to be the imperfection of existing technological schemes for working with material resources. Therefore, it is fair to assume that such waste is the result of one of the unfinished production processes, that is, it is a semi-finished product. Along with scientific and technological progress, the amount of resources that are now called "waste" is decreasing, as technologies appear and develop, the main raw material for their implementation is previously generated and accumulated industrial waste. In this case, raw materials are secondary material resources.

The issue of developing and implementing such a method of industrial wastewater treatment

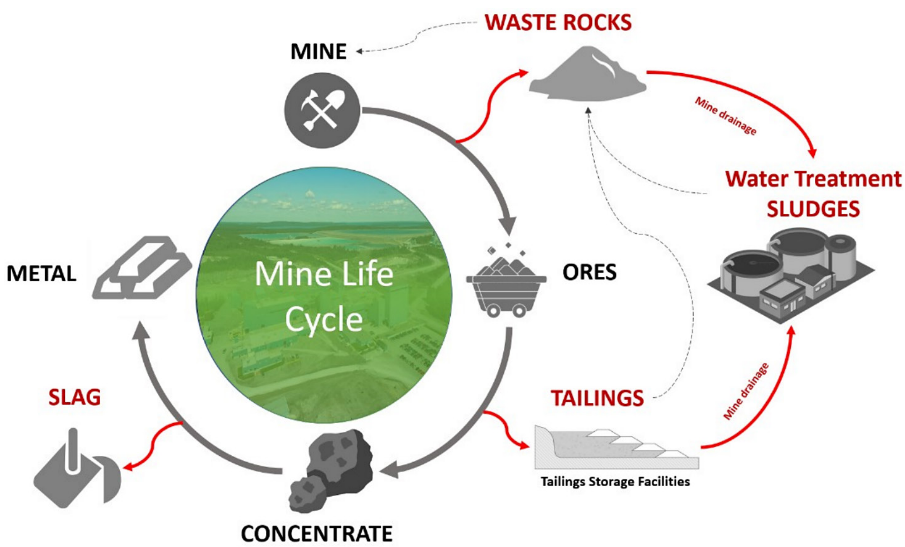

Figure 3. Mine life cycle

from heavy metal ions and other SPs with their subsequent disposal, which would be effective both from an environmental and economic point of view, is very relevant. It can be solved by using various chemical methods, in particular: the process of precipitation, extraction, distillation, and Ion Exchange. The methods currently used for industrial purposes are determined by the dispersion, composition of impurities, and volumes of wastewater. Based on the number of pollutants available and their composition, it becomes necessary to combine cleaning methods to increase their efficiency. Such methods are divided into chemical, physicochemical, mechanical, biological, and thermal.

Chemical methods of industrial wastewater treatment are based on chemical reactions that result in the formation of new substances that can be removed by any available methods. A special feature of these methods of industrial wastewater treatment is the high consumption of reagents and the bulkiness of equipment. In addition, there is the problem of storing and reusing sediments formed during chemical reactions.

Among chemical methods, ozonation and chlorination of industrial waters are the most important. These methods are used for post-treatment of wastewater and neutralization of organic and inorganic SPS. Reagent methods are based on the processes of reagent deposition of heavy metal ions in the form of slightly soluble compounds and their subsequent extraction from wastewater by settling and filtration. Heavy metal ion deposition processes are carried out by the introduction of alkalis, sulfides, and carbonates. Treatment of industrial wastewater with alkaline reagents is currently the cheapest and most traditional method of extracting heavy metals in Russia (Tereshkin, 2019).

Electrochemistry methods are also used for wastewater treatment, in particular: electroflotation, electrodialysis, and electrocoagulation. These methods make it possible to continuously and periodically carry out the process of industrial wastewater treatment using partially or fully automated technological schemes to obtain substances from wastewater suitable for reuse in industrial cycles of enterprises. Physico-chemical methods are used to purify water from colloidal, fine, and dissolved substances. These include the following purification methods: distillation, rectification, flotation, coagulation, adsorption, flocculation, extraction, and reverse osmosis. To remove metals from wastewater, ion-exchange treatment is used, which allows both effective purifications of contaminated water from toxic substances and to capture some chemical compounds that can then be reused in industry. The ion exchange method is based on cations and anions extracted from industrial effluents using sorption processes.

Mechanical methods include settling, straining, filtering, and lightening. These methods are used to purify industrial water from coarse particles of 5–10 microns in size. Settling tanks, hydro cyclones, grilles, and filters are used for this purpose. With the help of biological treatment methods, both industrial and municipal wastewater can be treated using a variety of microorganisms. However, the mechanisms of the influence of heavy metals on the biochemical treatment of wastewater are still insufficiently studied. According to the theory that explains the inhibitory effect of metals on microorganisms, heavy metal cations react with the active components of cells, including respiratory enzymes, thus forming stable complex compounds. The rate at which such complex compounds are formed depends on three independent parameters: the concentration of suspended solids in the silt mixture, the concentration of metal ions, and the amount of biomass.

A high level of adsorption capacity of activated sludge biomass, along with the selectivity of the components that are sorbed, is used for industrial wastewater treatment. The extraction of metals dissolved in water using this method depends on the shape of the metal in the water. For example, in ionic form, copper is more effectively sorbed by activated sludge than copper in combination with cyanide. During treatment with activated sludge, heavy metal ions are removed from the solution due to adsorption by the cell polymer and bacterial cell walls, or due to accumulation in the cytoplasm of cells. Before discharging the waters of mining enterprises into reservoirs, they must be cleaned and, if possible, the captured substances processed into secondary raw materials, since they carry various kinds of pollutants.

The most common pollutants in these waters are sulfuric acid and chlorine compounds. The former often accompanies soluble salts, usually heavy metal sulfates such as copper, manganese, iron, nickel, and zinc. Such waters cannot be used for industrial purposes without preliminary purification and neutralization. The most affordable object of such treatment is field waters, from which it is possible to obtain additional substances that can be reused in the industrial cycle. At the same time, only industrial wastewater that significantly exceeds the maximum permissible concentration of pollutants is subject to complex types of treatment. For the treatment of field waters, in most cases, it is enough to keep them in settling tanks, where colloidal components and mechanical impurities are deposited, and Ion-soluble substances that are the most dangerous for the environment merge with clarified waters. Alkaline waters are usually acidified, while acidic waters are neutralized. Field waters are most often used to replenish recycled water supply systems of mining enterprises (Valentine, 2013).

As coagulants for water purification of the mining industry, it is recommended to use: soda, lime, iron sulfate, aluminum sulfate. Thanks to them, it is possible to achieve the efficiency of industrial wastewater treatment from most impurities by 90–99%. Large-scale treatment and chemical treatment of acidic and metal-containing Waters is used in the treatment of Canadian deposits. Some enterprises operate according to schemes that do not use drains. Thus, some Xstrata factories have created a recycled water supply system for nickel deposits. To reuse the treated water, a system for storing tailings in the bays of Lake Mus and neutralizing wastewater using lime was developed.

In the UK, in coal mines, iron–containing mine water is usually treated with magnesium or calcium carbonate, less often with lime. Alkaline or neutral waters containing iron are aerated before being discharged for deposition in special reservoirs. For the treatment and settling of such waters, the mines in Derbyshire use the Cascade aeration method, water from suspended particles is usually cleaned using mechanical methods. Japan has patented its method of field water purification from sulfate ions and heavy metal ions. During the application of this method, the field waters are treated with barium sulfide in a special mixer. Barium binds to the sulfate ion, and ions of other metals are deposited as sulfides (White, 2012). The remaining barium ions are removed by foam flotation with fatty acid in the presence of a foaming agent. Purified water at the outlet is 90% of the initial amount of the solution. In the United States, for example, acidic industrial effluents are mostly treated with limestone, caustic soda, quicklime, and slaked lime. Neutralization of acidic water using limestone is 2.6 times cheaper than treatment of such water with quicklime and 3.8 times cheaper than neutralization with slaked lime. Sometimes desalination plants are built for wastewater treatment, the economic profitability of which is due to the use of purified water by thermal power plants.

Biological and chemical methods are also used in some enterprises to purify wastewater from hydrogen sulfide, along with aeration. Such mineralized water is purified using reverse osmosis, usually combining this method with neutralization, in which case the purification efficiency reaches 99 %. Also in the United States, freezing and electrolysis methods are used to desalinate mining wastewater.

Currently, the method of wastewater treatment with a “live” filter, using plants that can absorb inorganic compounds and toxic compounds, for example, phenol, is relevant. However, this method is not universal and is not capable of solving the problem of industrial wastewater, since its use requires large territories. When exposed to toxicants, plants die, and in northern and temperate latitudes, these plants can function for a relatively short period. It is advisable to use these cleaning plants to extract minimal residues of pollutants, at the final stages of water purification of mining enterprises, immediately before their discharge into reservoirs. For industrial wastewater treatment processes, which include a large number of different heavy metals, the most appropriate and effective method is to use the reagent method. This method includes redox reactions, neutralization, precipitation, and drying processes of the resulting sediment, and allows you to effectively neutralize acids from wastewater and remove heavy metal ions.

CONCLUSIONS

Management of mining waste requires first of all the implementation of the main regulatory areas of activity in this area, in particular: a properly organized accounting system for the formation, collection, processing, disposal, and disposal of waste; the introduction of a system for controlling the material balance of mining production to stimulate the introduction of low-waste and waste-free technologies in production; the introduction of special monitoring control of waste generation and use at all production stages. Mining waste usually refers to non-toxic waste, most of it occurs in production cycles, which are waste from mineral extraction, processing, and agglomeration production. To separate mining waste into returnable and irreversible, it is necessary to monitor their relationship with the possibility of further use as raw materials for the main product, other use, or storage.

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