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CLASSIFICATION OF METHODS FOR TREATING BENEFICIATION WASTE IN THE PROCESS OF FORMATION OF TAIL REPOSITORY

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Abstract. This article describes the classification of methods for treating beneficiation waste in the process of forming tailing dumps. The need for such classifications is caused by the fact that during the many decades of operation of the Kryvyi Rih Mining and processing plant (MPP) in the tailing dumps, which occupy an area of about 10,000 hectares, huge masses of beneficiation waste have accumulated, which can be considered man-made deposits. The development of industry and the need to support its raw material base, the increase in the productivity of mining enterprises cause an increase in the volume of waste output to dumps (tailing dumps). Such a provision leads to the emergence of numerous contradictions, the elimination of which requires the adoption of the necessary technological and ecological balanced solutions. In the article, the main principles of waste management are discussed. Literary sources and the current state of research aimed at increasing environmental safety during mineral extraction and recycling of minerals are analyzed, in particular, treatment of beneficiation waste of mineral raw materials. The classification of methods for treating mineral beneficiation waste in the process of implementing the principle of an ecologically oriented relationship to natural resources in the process of forming tailing dumps and sludge dumps formation is to divide many multi-parametric objects into a limited number of homogeneous classes or groups, identical in terms of technological, engineering-geological and other properties. The developed classification of methods for treating beneficiation waste is built taking into account the hierarchical importance of classification features. Time periods of application and intra-class compatibility of methods for treating beneficiation waste in the process of forming tailing dumps by classes A and B were established on the basis of a patent search, taking into account the time period from the invention to the introduction of the patents into production. The classification of methods for treating beneficiation mineral waste in the process of formation of tailing dumps is presented in the form of a table. The presence of a methodological and theoretical basis for determining the main parameters of technological solutions is also reflected. The development of a classification of methods for treating beneficiation waste in the process of formation of tailing dumps made it possible to identify the drawbacks in the methodological provision of their construction technology and to show the direction of further scientific research.

Keywords: waste management, man-made deposit, beneficiation waste, classification of waste management methods, mining industry, installation for selective extraction of the productive layer with a useful component.

1. Introduction

The problem of waste formation is typical for all countries of the world. Along with the growth of the economy, population and consumption, there is a rapid increase in both the volume and types of industrial waste.

The growing contradictions between human-made technologies and the natural environment are particularly evident in the operation of mining companies. Over many decades of operation of Kryvyi Rih MPPs, huge masses of beneficiation waste have accumulated in tailing dumps covering an area of about 10 thousand hectares, estimated at 5÷8 billion tons with a total iron content of 14–18% and can be considered technogenic deposits.

At the same time, the further development of the industry and the need to maintain its raw material base, as well as the growth of mining companies' productivity, entail an increase in the volume of waste going to dumps (tailing dumps). This situation has led to numerous contradictions: "dumps – rational land use"; "dumps – purity of the atmosphere"; "dumps – preservation of water resources"; "dumps – resource consumption and profitability of mining"; "dumps –

environmental situation in mining regions"; "dumps – imbalance of the global ecosphere". At the same time, dumps of waste from the technological processing of mineral raw materials should have a maximum capacity, meet the conditions of rational use of natural resources and environmentally oriented land use planning, and be located at a minimum distance from the place of waste from the technological processing of mineral raw materials. Obviously, to eliminate the contradictions that have arisen, it is necessary to make the necessary technological and environmental balanced decisions [1]. Such decisions should undoubtedly be based on the following basic principles of waste management:

1. Development and implementation of scientifically based standards of waste formation per unit of production (raw materials and energy) in accordance with advanced technological achievements.

2. Ensuring the development of the market for secondary material resources and their involvement in economic turnover as raw materials.

3. Preventing and minimizing waste generation.

4. Gathering, sorting and transportation of waste.

5. Waste storage and recycling.

6. Disposal of waste that is not subject to secondary resource use:

– removal;

– reciprocal neutralization;

– neutralization.

7. Control over the above operations.

8. Observation of waste disposal sites that have been utilized [2].

Therefore, fundamental and applied research on this issue is very relevant and will contribute to improving the socio-environmental aspects of the scientific and practical base of the mining industry.

2. Methods

The analysis of literature sources and the current state of research aimed at improving environmental safety in the processes of mining and recycling of minerals, in particular, management (storage) of mineral beneficiation wastes showed that they are characterized by the complexity and fragmentation of the study of this problem [3–6]. The main drawbacks of the existing aspects in the development of new technologies for treating mineral beneficiation waste are the methodological and methodical isolation of approaches to solving this multifactorial and complex problem.

The analysis of foreign experts' researches regarding treatment of beneficiation waste can be summarized as follows [7–10]:

1. Yassin Ait-Khoya, Mostafa Benzaazoua, Isabelle Demers examine the environmental desulphurization of mine waste through various mineral processing methods. The management of mine waste (e.g., waste rock and tailings) is becoming a growing global environmental issue for mining industries around the world. As environmental regulations become increasingly restrictive, there is a growing need to develop efficient and clean integrated methods for the sustainable management of

mine waste. Mine wastes often contain acid-forming minerals such as sulfides and sulfosols, which cause pollution. Environmental sulfur treatment using non-selective flotation has recently been introduced as an integrated approach to mine tailings management. In addition, physical separation techniques, which are commonly used in mineral processing and offer effective potential for the recovery of sulfur and valuable minerals, are rarely used for mine waste management. Sulphide and sulphosalt separation methods that are based on the physical properties of minerals can achieve the same performance as flotation. These physical properties are mainly related to: 1) the particle size distribution, 2) the difference in density between the target minerals (i.e. sulfides and sulfosols) and the rock minerals, 3) magnetic properties, 4) electrical characteristics and 5) response to specific probing.

Based on the differences between the properties of minerals, the authors of the paper propose various methods, including screening, hydrodynamic separation, gravity concentration, dense medium separation, magnetic and electrical separation, and sensor-based sorting. These methods can be considered more efficient, less expensive, and more environmentally friendly than flotation. This critical review aims to evaluate the suitability of these physical separation methods, in addition to the widely used flotation, for the desulphurization of mine waste.

2. In this paper, Xiang Li, Shuting Shen, Yue Xu, Ting Guo, Hongliang Dai, and Xiwu Lu review the beneficiation, extraction, and crystallization methods for phosphorus recovery from waste streams in wastewater treatment plants. They identify two interrelated problems: the non-renewability of phosphate rock as a resource and excess phosphate in the water system, leading to eutrophication. Removing and recovering phosphorus from waste streams at wastewater treatment plants is one of the most promising solutions. On this basis, they summarized and compared modern phosphorus recovery technologies. The choice of phosphorus recovery technology depends on the wastewater treatment and sludge treatment process. Most phosphorus recovery processes can meet financial needs following the recent sharp rise in phosphate rock prices. Safety requirements for phosphorus recovery products increase the cost of toxic removal, so it is necessary to control the discharge of toxic substances, such as heavy metals and persistent organic pollutants, from the source.

3. Efendiyeva Zarifa Jahangir Gizi is studying the possibilities for the integrated use of waste from the Dashkesan field. Based on her research, she made the following conclusions:

- blast furnace waste from the Dashkasan concentrator can be used as bulk aggregate (gravel) for construction and repair at road construction works.
- when concrete with a strength of 250-300 kg/cm^2 is removed from this waste, the resulting concrete is highly waterproof and frost-resistant. Due to these properties, this concrete can be used for the construction of hydraulic structures.

4. Khasanova A.V., Zhirgalova T.B., Osintsev K.V. propose a method for processing coal preparation waste with solid and volatile fuel inclusions. This method is used at coal preparation plants to process coal waste. This new method is implemented for the production of ash residue, which is used for the production of

silicate products and fuel gas in rotary kilns. The proposed method is related to the industrial processing of lignite beneficiation waste. The waste is obtained by flotation separation of rock particles up to 13 mm in size from coal. They contain both solid and volatile fuel inclusions (components). Due to their high humidity, high species content, and low calorific value, these wastes are not used in power boilers and are stored in storage facilities, polluting the environment.

None of the above works provides for the creation of a classification of methods of beneficiation waste management in the process of tailing dumps formation. Therefore, in this case, the most reasonable approach to solving of such a multifactorial problem as beneficiation waste management is to use the classification method to set priority tasks.

Classification is a systematic distribution of subjects, phenomena, processes by kind, class, type, or any significant features for the convenience of their study; grouping of initial concepts and their arrangement in a certain order reflecting the degree of similarity.

The classification analysis usually involves two main tasks: building classes and separating objects by classification criteria. The meaning of classification of methods of mineral beneficiation waste management in the process of implementing the principle of environmentally oriented attitude to natural resources in the process of tailing and sludge dumps formation is to divide a set of multi-parameter objects into a limited number of homogeneous classes or groups identical in terms of technological, engineering, geological and other properties. The classification should provide a list of features, characteristics and their values that affect the efficiency of beneficiation waste management and the choice of a rational method of formation of tailing dumps.

At the same time, it should be noted that the main purpose of classification is not only to separate a set of objects by their similarities and differences, but also to establish both the direction of further research and ways to solve emerging problems.

The analysis of classifications of existing and designed tailing dumps [11] showed that when constructing classes and separating objects by classification criteria, the «regular» form of their formation dominates in the plan, as a rule, these are squares and rectangles. However, the correct plan view can be of any type, and in accordance with the terrain, it ensures that the required condition – the maximum internal volume for waste storage with a minimum area of land allocation – is met. In addition, it should be taken into account that the angle of inclination of the tailing dump base relative to the horizon is practically leveled after one or two increases in the height of the dumps, i.e. they practically become horizontal, which significantly limits the scope of their application.

3. Results and discussion

The developed classification of methods for treating beneficiation mineral waste is based on the hierarchical significance of the classification features. The methods for treating beneficiation wastes generated in the process of processing the extracted minerals are accepted as the features of the upper hierarchy (classes): formation of accumulating benefication warehouses (class A), formation of tailing dumps with

partial separation of beneficiation waste by fractions (class B), formation of technogenic deposits from beneficiation waste and separate storage of waste rock (class C), compatibility of storage processes and involvement of beneficiation waste in secondary processing (class D). The subclasses include methods of forming the internal structure of tailing dumps.

The following hierarchical features are groups and subgroups – methods of filling the tailing capacity and methods of separation of beneficiation waste by composition.

The final features of this hierarchical classification are species and subspecies: methods of increasing the height of the embankment dumps and methods of lighting with recycling water extraction.

The time periods of application and intra-class correspondence between the methods of beneficiation waste management in the process of tailing dumps formation in classes A and B were established on the basis of the patent search, taking into account the time period from the invention to the introduction of patents into production. The classification of methods of beneficiation waste management in the process of tailing dumps formation is presented in the form of Table 1, which, in addition to the listed classified features, includes a column reflecting the availability of a methodological and theoretical basis for determining the main parameters of technological solutions. To establish the direction of further research, the methods of beneficiation waste management (classes A÷D) are classified in chronological order:

– class A of beneficiation waste management methods used until 1950-1970 of the last century are characterized by the formation of accumulation warehouses with single or multi-sectional structure of the internal space with their gross filling with turbulent flow of hydraulic mixture with natural separation of mineral particles along the facets of the warehouse and their deposition in accordance with the transformation of natural forces acting in the hydraulic flow in the process of its movement along the washing dusting surface: A-I-1-a – from the lower tailings dump to its top; A-I-2-a – from the top of the tailings dump to the lower dump; A-I-3-a – from the center of the dusting surface alluvium to the peripheral tailing dumps. The buildup of the embankment dumps was carried out by hydraulic dredging or by gradually increasing their width and height. The recycling water was taken from the clarifier pond after the fine particles were settled. The methodological basis for calculating the main parameters of this method of beneficiation waste management is available.

It should be noted that the development of such storage facilities for re-beneficiation of stored waste is unattractive due to the almost uniform distribution of the remaining useful components over the storage area;

– currently, class B of tailing dumps (1970-2023) are characterized by a multi-sectional structure of the internal space, divided by drainage or overflow dumps into separate sections to implement their cascade filling with a turbulent flow of hydraulic mixture, which provides partial fractional separation of beneficiation waste.

In this case, before each subsequent overflow dump, the largest particles of the remaining fractions are naturally deposited after the hydraulic mixture flow is transferred through the previous dump (separation of mineral particles by their size

Table 1 – Classification of methods of beneficiation waste management in the process of tailing dumps formation

Classes	Subclasses	Groups	Subgroups	Types	Subtypes	Notes
Methods for treating beneficiation waste (Stages of application)	Methods of forming the internal structure of tailing dumps	Methods of filling the tailing dumps capacity	Methods of separation of beneficiation waste by grade	Methods of increasing the height of dumps	Methods of clarification and extraction of recycled water	Availability of a methodological framework for determining the main parameters
1	2	3	4	5	6	7
A. Formation of accumulation warehouses from beneficiation waste (The stage of application has passed, by 1950)	A-I. Single-section forming of embankment dumps	A- I - 1. Gross filling with a turbulent flow of the hydraulic mixture from the lower dump to the top.	A- I- 1a. Natural deposition of particles and their concentration in the area of the lower dump under the influence of natural forces acting on mineral particles in the flow of the hydraulic mixture.	A- I- 1-a-n. Increasing the width and height of the lower embankment dump in stages.	A-I-1-a-n-o. Drainage of water through the lower embankment dump into the clarification pond. Clarification of water and its withdrawal from the clarification pond.	The methodological basis for calculating the main parameters is available.
		A- I - 2. Gross filling with turbulent flow of the hydraulic mixture from the top to the lower dump.	A- I- 2-a. Natural deposition of particles and their distribution over the dusting surface alluvium under the influence of natural forces acting on mineral particles in the flow of the hydraulic mixture.	A- I- 2-a-n. Increasing the height of the embankment dump by hydraulic slurry.	A- I- 2-a-n-o. Gravitational deposition of particles on the dusting surface alluvium. Fencing of water from the clarification pond.	The methodological basis for calculating the main parameters is available.
		A- I - 3. Circular gross filling with a turbulent flow of hydraulic mixture.	A- I- 3a. Natural deposition of particles and their distribution from the centre of the dusting surface alluvium under the influence of natural forces acting on the particles in the hydraulic mixture flow.	A- I- 3-a-n. Increasing the height of the embankment dam after increasing the width of the primary embankment dump.	A- I- 3-a-n-o. Recycling water extraction from the clarification pond by means of an enclosing collector with holes located along its length and height.	The methodological basis for calculating the main parameters is available.
		A- I - 4. Combined gross filling with a turbulent flow of hydraulic mixture.	A- I- 4-a . Natural deposition of particles and their distribution on the dusting surface alluvium depending on the combination of methods of filling the capacity.	A- I- 4-n. Combination of the above methods of increasing the height of the embankment dump.	A-I-4-a-n-o. The method of water clarification and withdrawal depending on the combination of methods of filling the tailing dump capacity.	The methodological basis for calculating the main parameters is available.

Continued from Table 1

1	2	3	4	5	6	7
	A-II. Multi-sectional formation of the internal structure by longitudinal and transverse dividing dumps.	A-II-1. Gross sectional layer-by-layer filling with a turbulent flow of hydraulic mixture from the embankment dumps of each section.	A- II-1-a. Natural deposition of particles and their distribution on the dusting surface alluvium under the influence of natural forces acting on mineral particles in the flow of the hydraulic mixture.	A-II-1-a-n (1). Sectional bulldozing to increase the height of the embankment dumps by filling them with dried beneficiation waste.	A- II- 1-a-n (1)-o. Drainage through dividing dumps with a centralized catchment ditch.	The methodological basis for calculating the main parameters is available.
				A-II-1-a-n (2). Increasing the height of the embankment dumps with partial placement of the base of the new dump on the roof below.	A- II- 1-a-n (2)-o. Drainage through dividing dumps with a centralized catchment ditch.	The methodological basis for calculating the main parameters is available.
				A-II-1-a-n (3). Increasing the height of the tailings pond with the location of the base of the new dump on the dried surface of the beneficiation waste.	A- II- 1-a-n (3)-o. Drainage through dividing dumps with a centralized catchment ditch.	The methodological basis for calculating the main parameters is available.
		A-II - 2. Gross sectional filling with a turbulent flow of hydraulic mixture from the dividing dam.	A- II- 2-a. Natural sedimentation of particles and their concentration in the area of the dump of the upper section and along the dusting surface alluvium of the lower section	A- II- 2-a-n. Increasing the height of embankment dumps made of bulk soils with the arrangement of protective screens on the inside and at the base of the increased dumps.	A- II- 2-a-n-o. Gravitational deposition of particles along the dusting surface alluvium, fencing of water from the clarification pond with a fencing collector with holes located along its height.	The methodological basis for calculating the main parameters is available.

Continued from Table 1

1	2	3	4	5	6	7
B. Formation of tailing dumps with partial separation of beneficiation waste by fractions (Stage of application - current, 1950-2023)	B-I. Two-section formation of the internal structure with one overflow dump.	Single-cascade filling of sections : B- I- 1. Gross filling of the upper section with a turbulent flow of hydraulic mixture from the embankment dump.	B- I-1-a. Natural deposition of particles of large fractions in front of the overflow dump of the upper section and distribution of the remaining fraction particles on the dusting surface alluvium of the lower section.	B- I- 1-a-n. Filling of new dumps along the perimeter with partial location of their base on the dried surface of the beneficiation waste.	Recycled water is not collected from the upper section of the tailing dump.	The methodological basis for calculating the main parameters is available.
		B- I- 2. Dispersed filling of the lower section with a stratified flow of hydraulic mixture through the overflow dump.	B- I- 2-a. Natural sedimentation of coarse fraction particles in front of the overflow dump of the upper section and distribution of the remaining fraction particles on the dusting surface alluvium of the lower section.	B- I- 2-a-n. Increasing the height of the embankment dumps of the lower section after filling the persistent prism from the outside.	B- I- 2-a-n-o. Forced deposition of fine particles on the lower dusting surface alluvium by floating booms.	The methodology for determining the parameters of the technological process of forced deposition of fine particles is not sufficiently developed.
	B-II. Multi-sectional formation of the internal structure by several overflow dumps.	*Multistage filling of sections :* B-II-1. Gross filling of the upper section with a turbulent flow of hydraulic mixture from the embankment dumps.	B-II-1-a. Natural deposition of coarse particles in front of each overflow dump and distribution of fine particles on the dusting surface alluvium.	B-II-1-a-n. Increasing the height of the embankment dumps with partial placement of the base of the new dump on the roof below.	No recycling water is taken from the upper section of the tailing dumps.	The methodological basis for calculating the main parameters is available.
		B-II-2. Scattered cascade filling of lower sections by stratified flow of hydraulic mixture through overflow dumps.	B- II-2-a. Natural sedimentation and accumulation of particles of appropriate fractions before each overflow dump.	B- II-2-a-n. Increasing the height of the embankment dumps by constructing further build-up dump tiers on the dusting surface alluvium	B- II- 2-a-n-o. Forced deposition of fine particles on dusting surface alluvium with the help of surfactants.	The issues of forced precipitation of fine particles are not sufficiently developed.

Continued from Table 1

1	2	3	4	5	6	7
C. Formation of technogenic deposits from beneficiation waste and separate storage of waste rock within the tailing dump (Stage of application - future, after 2023)	C-I. Multi-sector management of tailing dump with a single-sector formation of a technogenic deposit and several sectors for storage of waste rocks with different quality composition.	C- I-1. Selective filling of different tailing pond sectors with separated stratified streams of hydraulic mixture : 1) a productive flow of a technogenic deposit; 2) potentially productive flow of a separate section; 3) a separate sector with a flow of hydraulic mixture with waste rock.	C- I-1-a. Forced selective separation of mineral particles by the qualitative and fractional composition of beneficiation waste by mechanical means.	C- I-1-a-n (1). Sector of filling with productive flow («man-made deposit») - gradual increase in the width of the dumps and their height.	Methods of recycling water clarification and extraction have not been developed yet.	No methodological basis for calculating the main parameters is available.
				C- I-1-a-n (2). The waste rock filling sector is an increase in the height of the embankment dumps by constructing further tiers on the dusting surface alluvium.	Methods of recycling water clarification and extraction have not been developed yet.	No methodological basis for calculating the main parameters is available.
	B-II. Two-section formation of the technogenic deposit sector by a dividing dump (for its alternate development).	B-II-1. Alternate filling and development of sections of the technogenic deposit sector with a stratified productive flow of hydraulic mixture.	B- II-1-a. Selective extraction of mineral particles with a mineral (productive flow) from a stratified hydraulic mixture flow.	B-II-1-a-n. Without increasing the height of the dumps, the dumping of an technogenic deposit is done by alternate filling and mining of sections.	Methods of recycling water clarification and extraction have not been developed yet.	No methodological basis for calculating the main parameters is available.
D. Combining the processes of storage and recycling of beneficiation waste with elements of their pre-benefication (Application stage - future)	I. Multi-sectional cascade formation of the internal structure of tailing dumps by overflow dumps.	G- I - 1. Selective filling of different sectors of the tailing dump with stratified flows of hydraulic mixture.	G- I- 1a. Natural and forced separation of beneficiation waste by chemical and mechanical methods.	G- I- 1-a-n. No increase in the height of the dumps and overfilling of the sectors of technogenic deposits is carried out (alternate mining of sections and sectors of the tailing dump), and with waste rock - a layer-by-layer increase in the height of the embankment dumps.	Methods of recycling water clarification and extraction have not been developed yet.	No methodological basis for calculating the main parameters is available.

and weight fractions under the influence of natural forces acting in the hydraulic mixture flow).

Multi-sectional formation of the internal space of tailing dumps with cascade filling of their sections ensures the percentage of raw minerals before each overflow dump, which will further increase the profitability of the development of tailing dump with a higher concentration of the useful component.

Recycling water can be clarified either naturally or by forced action. Forced sedimentation of the smallest fraction of particles can be carried out by using surfactants (SAS).

In most cases, the height of the embankment dumps is increased by filling in new dumps with their base partially located on the roof of the lower dump and the dewatered mass of beneficiation waste from the filled section of the existing tailing dump.

It should be noted that additional research is required to determine parameters of tailing dump where chemicals (surfactants, etc.) are used for clarifying recycling water.

To form an technogenic deposit from beneficiation waste and separate storage of waste rock within the tailings pond (class B), a multi-sector tailing dump arrangement is envisaged. Such formation of the internal structure of the tailing dump ensures selective filling of its sectors with stratified streams of hydraulic mixture with different qualitative composition of mineral raw materials.

In order to realize the possibility of forming technogenic deposits from beneficiation wastes with a high percentage of minerals, the M.S. Poliakov Institute of Geotechnical Mechanics of the National Academy of Scienses of Ukraine developed an installation for selective extraction of a productive layer with a useful component from the wastes transported through the pipeline. This installation provides transformation of the turbulent flow of the hydraulic mixture into a stratified flow with different weighing limits of particles of different density and further separation of the flow into three components:

1) nonproductive top layer consisting of particles of "barren" rocks of fine fractions;

2) productive middle layer, consisting of rock particles, contains the maximum amount of useful component;

3) potentially productive layer consisting of low-ore and hard-to-clean rock particles of medium and course fractions.

Separated by their quality composition, the flows of the hydraulic mixture from the beneficiation waste are stored in different sectors of the tailing dump. In addition, the technogenic deposit sector can be divided into two sections by a dump to ensure their alternate development.

For class B, a combined method of increasing the height of the dumps is used: the height of the dumps in the sector of the technogenic deposit is increased by gradually increasing their width and height, and in the sectors with «barren» rocks – by constructing further tiers on the dusting surface alluvium.

It should be noted that no methods of recycling water clarification and extraction have been developed for waste management methods for beneficiation waste of class B, and there is no methodological basis for calculating the main parameters of tailing ponds.

The most promising method of beneficiation waste management (class D) is the one, which involves a combination of storage and involvement of man-made deposit areas in secondary processing with an increase in the concentration of useful components. To ensure the process of pre-beneficiation of the "lost" useful component within the man-made deposit, it is necessary to form a multi-section cascade pattern of the internal structure of tailing dumps with overflow dumps.

In this case, the sections of the technogenic deposit sector are filled with a productive layer with a higher percentage of the useful component and the sections of the tailing dump with "barren" rocks selectively removed from the general flow of the hydraulic mixture by a stratified flow of beneficiation waste. In the process of filling the sections of different sectors, the mineral particles are naturally separated by fractional composition.

Within the man-made deposit, in front of each overflow dump, particles of different fractions with useful components are deposited and concentrated in accordance with their physical and mechanical properties and changes in the natural forces acting in the stratified flow that overcomes the overflow dumps and moves along the dusting surface alluvium of the respective sectors.

Thus, areas with an even higher percentage of the useful component are formed within the technogenic deposit, and light fractions with "barren" rocks are transferred to the lower section of this sector, where recycling water is clarified by using chemical reagents or mechanical devices.

Fractional separation of «barren» rocks in other sectors of the tailing dump will ensure their further integrated use as mineral raw materials.

Increasing the height of the embankment dump within the technogenic deposit is not carried out, since it is planned to develop its sections alternately, and increasing the height of the embankment dam of the sectors with «barren» rocks can be carried out by any method, the effectiveness of which is determined in each case.

It should be noted that no methods for recycling water clarification and extraction have been developed for treating beneficiation waste of class G, and there is no methodological basis for calculating the main parameters of the tailing dump, within which the man-made deposit is separately located, as well as sectors and sections filled with potentially productive mineral raw materials and «barren» rocks.

4. Conclusions

The development of a classification of methods of beneficiation waste management in the process of forming tailing dumps allowed us to identify the drawbacks in the methodological support of their construction technology and show the direction of further research.

In addition, the analysis of the results of the studies performed to establish the feasibility of selective formation of technogenic deposits using the developed method showed that their further development is very attractive, since:

1) there is no need for additional alienation of land for mining allotment for access to mineral resources;

2) the percentage of useful components in such deposits is comparable to natural ones, and sometimes even higher;

3) during the development of these deposits, there are no such processes of open pit mining as preparation of rock mass for excavation and dumping;

4) there is no need to crush the mineral before beneficiation;

5) it is possible and feasible to develop technogenic deposits by hydraulic means;

6) it is possible to use hydraulic transport to deliver the rock mass to the processing plant;

7) it is possible and feasible to reuse the tailing dump space to form a new technogenic deposit.

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КЛАСИФІКАЦІЯ СПОСОБІВ ПОВОДЖЕННЯ З ВІДХОДАМИ ЗБАГАЧЕННЯ В ПРОЦЕСІ ФОРМУВАННЯ ХВОСТОСХОВИЩ

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Анотація. В даній статті описана розроблена авторами класифікація способів поводження з відходами збагачення в процесі формування хвостосховищ. Необхідність в розробці такої класифікації викликана тим, що за багато десятиліть роботи Криворізьких ГЗК у хвостосховищах, які займають площу близько 10 тис. га, скупчилися величезні маси відходів збагачення, які можуть вважатися техногенними родовищами. Розвиток промисловості та необхідність підтримки її сировинної бази, зростання продуктивності гірничодобувних підприємств спричиняють за собою нарощування об'ємів виходу відходів у відвали (хвостосховища). Таке положення призводить до виникнення численних протиріч, для усунення яких вимагаються ухвалення необхідних технолого-екологічних збалансованих рішень. В статі розглянуті основні принципи поводження з відходами. Класифікації способів поводження з відходами збагачення корисних копалини в процесі реалізації принципу еколого-орієнтованого відношення до природних ресурсів в процесі формування хвосто- і шламосховищ полягає в тому, щоб безліч багатопараметричних об'єктів розділити на обмежене число однорідних класів або груп, ідентичних за технологічними, інженерно-геологічними і іншими властивостям. Розроблена класифікація способів поводження з відходами збагачення корисних копалин побудована з урахуванням ієрархічної значущості класифікаційних ознак. Часові періоди застосування і внутрішньокласова відповідність між собою способів поводження з відходами збагачення в процесі формування хвостосховищ в класах А і Б було встановлено на основі проведеного патентного пошуку з урахуванням часового періоду від винаходу до впровадження патентів у виробництво. Класифікація способів поводження з відходами збагачення в процесі формування хвостосховищ представлена у вигляді таблиці. Розробка класифікації способів поводження з відходами збагачення в процесі формування хвостосховищ дозволила виявити ті недоліки в методичному забезпеченні технології їхнього будівництва і визначити напрям подальших наукових досліджень.

Ключові слова: поводження з відходами, техногенне родовище, відходи збагачення, класифікація способів поводження з відходами, гірничодобувна промисловість, установка селективного відбору продуктивного шару з корисним компонентом.