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FORMATION OF A COMPLEX TAILINGS STORAGE FACILITY FOR ENRICHMENT WASTE SEPARATED BY QUALITY COMPOSITION

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Abstract. The article considers the current state of tailings ponds at mining and processing plants in the Kryvbas region, provides their parameters and prospects for the use of man-made formations in the form of enrichment waste stored in tailings ponds at mining enterprises. It was established that the formation of man-made deposits involves a process of localization of mineral components, and the localization of useful mineral components can be carried out with minimum energy and material costs.

In the work, the authors consider possible methods for the separation of minerals based on their specific properties, taking into account their further concentration in the process of forming man-made deposits during the operation of tailings ponds.

Based on the results of the analysis and patent search, the authors established the following main disadvantages of domestic and foreign methods for extracting valuable components from the enrichment waste hydro flow with formation of man-made deposits by means of local storage of mineral raw materials separated by their qualitative composition: most of the methods for extracting valuable components from enrichment waste are carried out without account ing the physical and mechanical properties of the particles; the extraction of valuable components from the turbulent flow of the pressure pipeline is carried out by a cylindrical fencing branch pipe, and the significant capital and energy costs are incurred. In addition, it was established that when forming enrichment waste storage facilities, it is necessary to take into account the factor of their possible further development.

It was determined that the most effective method for forming a man-made deposit at dumping enrichment waste by hydrotransportation is to divide it by density by natural gravitational forces for divided damping with preliminary separation of several (two or more) components from the hydro mixture according to the content of useful components, particle size, and density.

Based on the results of the research, the authors of the article propose a method for forming a complex storage facility for enrichment waste combined with a technology for increasing the height of its embankment dams, which ensures the formation of a man-made deposit from the productive part of the hydro mixture and the separate storage of the remaining enrichment waste with rock particles of different qualitative and quantitative composition.

Keywords: enrichment waste, complex tailings storage facilities, separate formation, man-made deposits.

1. Introduction

Ukraine ranks seventh in the world in terms of mineral reserves. The Kryvyi Rih iron ore basin is one of the largest in the world. Iron ore is mined both open-pit and underground by five mining and processing plants (MPPs): Northern, Southern, Central, Ingulets, and ArcelorMittal. During extraction, waste rock is formed, which is stored in waste rock dumps, and during the enrichment of mineral raw materials, enrichment waste is formed, which is stored in tailings ponds (parameters are given in Table 1), where man-made placers are formed during operation [1–4].

It is well known that improving the efficiency of mineral resource use largely depends on reducing raw material losses and waste. Achieving completely waste-free mining technology at this stage of technical development is associated with large capital expenditures and is therefore practically impossible in most cases. Therefore, this problem must be solved on the basis of a complex use of mineral raw materials. In this regard, a number of new tasks arise related to the storage and conservation of mining waste, the use of which is currently impractical for technical and economic reasons.

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Table 1 – Parameters of tailings storage facilities at Kryvbas Mining and Processing Plant

Name of tailings storage facility	Area, ha	Capacity, million m^3	Annual volume of enrichment waste supply, million m^3	Enrichment waste consumption, m^3/s
"United" PGZK and ArcelorMittal	350–550	320	6.5	0.21
Voikovoye	250	156.5	11.5	0.365
Tailings storage of InGZK	-	376	4.52	0.143
"Mirolyubivka" ArcelorMittal	324	107	10.6	0.336
Tailings storage of TsGZK	1706	290	7.0	0.222
Tailings storage of PivnGZK	1293	466	8.84	0.28

At the same time, it is necessary to take into account that the current storage of large-scale mining waste, and especially enrichment waste, must provide for its further processing in the future. Therefore, storage, and in essence, the formation of man-made deposits must be carried out in such a way that their development is justified in terms of technological and economic factors.

Thus, one of the most important issues in the formation of man-made deposits from enrichment waste is the process of localizing mineral components. The process of localizing useful mineral components is possible based on their individual properties and, naturally, must take into account the specifics of the formation of man-made deposits. In addition, the localization of useful mineral components must be carried out with minimal energy and material costs.

2. Methods

An analysis of patent searches and a review of literature sources showed that currently, the problem of separation and subsequent localization of mineral raw materials according to the qualitative composition of enrichment contained in waste during their hydro-transportation to tailings ponds is only partially solved. The main disadvantages of domestic and foreign methods of extracting valuable components from the hydro flow of enrichment tailings, which should ensure the formation of man-made deposit by means of local storage, separated by the qualitative composition of mineral raw materials, are:

– most methods of extracting valuable components from enrichment waste are carried out without taking into account the physical and mechanical properties of particles, in which chaotic weighing occurs in the turbulent hydro flow of the main pipeline;

– the extraction of valuable components is carried out from the turbulent flow of the pressure pipeline using a cylindrical fencing branch pipe, which does not ensure the completeness and quality of these components extracting due to the gaps between the walls of the main pipeline and the fencing device, which leads to significant losses of mineral raw materials that are extracted;

– significant capital and energy costs associated with the purchase and operation of equipment that separates light (rock) particles from heavy (ore) particles in a gravitational field, followed by their separation into fractions under the action of laser radiation [5–13].

In this regard, it is necessary to develop an inexpensive and effective method for the selective separation of a productive layer with a valuable component from a wide range of enrichment waste class sizes, which can ensure the separation of ore and rock minerals in a gravitational field during the transformation of a turbulent flow of a hydro mixture into a temporarily stratified one, followed by separate storage of enrichment waste differentiated by quality composition.

3. Theoretical part

To implement the possibility of forming a complex tailings storage facility, a component of which is a man-made deposit, the IGTM of the NAS of Ukraine developed a classifier (Patent for a utility model No. 156577, Ukraine, IPC B038 9/06 "Method for selective separation of a productive layer with a useful component from transported enrichment waste," published on 10.07.2024, bulletin No. 29 [7]. The process of separating the turbulent flow of the hydro mixture of enrichment waste occurs as follows. First, the enrichment waste is transported through a main pipeline to a diffuser equipped with aerodynamic grilles. After passing through the grilles, the turbulent flow becomes stratified, forming stable layers of suspended particles separated by density and mass. Selective extraction of the valuable component from this flow occurs in the working chamber using a productive layer receiver. This receiver consists of two horizontal plates, the location of which corresponds to the upper and lower boundaries of the weighing of ore fraction particles of different sizes.

This placement of the productive layer receiver in the working chamber allows the flow of the enrichment waste slurry to be separated into three components: the productive part, the potentially productive part, and the unproductive part (barren rock). These separated flows are then fed through separate pipelines to the corresponding sections of the tailings storage facility. In the section where the productive part is delivered, a man-made deposit is formed, which is subsequently developed. After that, the vacated section is reused for the accumulation of productive enrichment waste.

In order to selectively separate the productive layer from the enrichment waste, a nomogram (Figure 1) was developed, which demonstrates how the physical and mechanical properties of rock particles and their granulometric composition in the waste affect the choice of parameters for separating the hydro-mixture flow. These parameters allow for the effective separation of the layer with the highest content of easy-to-enrich useful components, taking into account the distance traveled by particles of different fractions during damping.

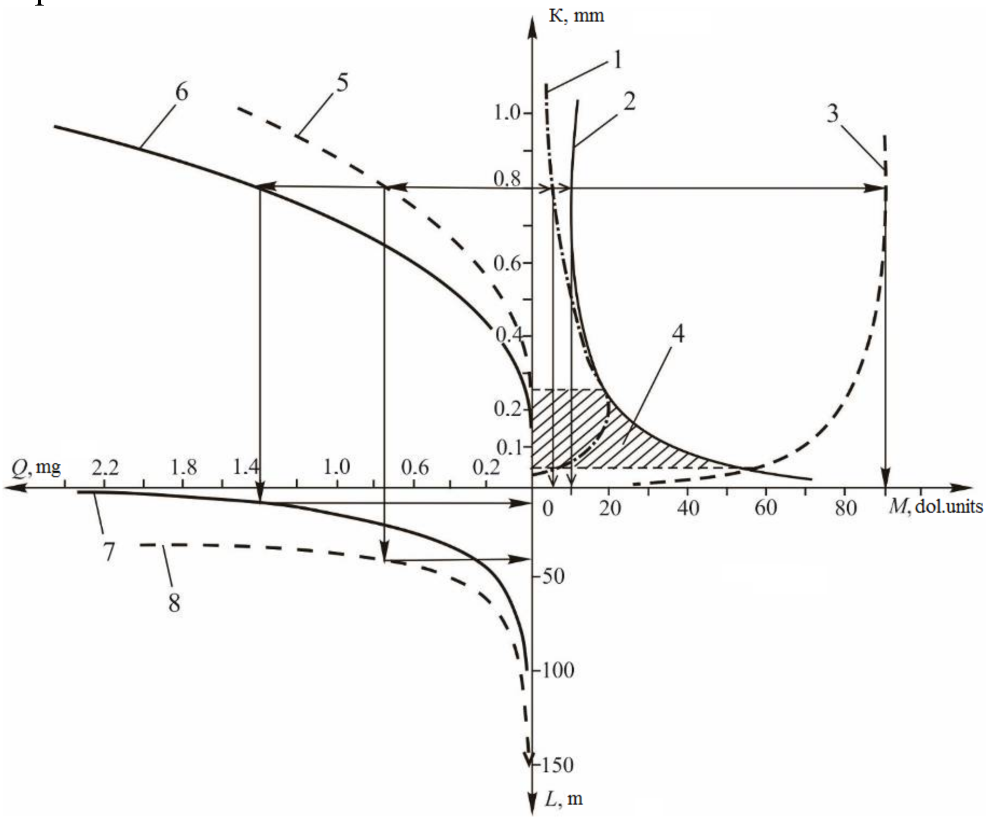
The first quadrant shows how the mass fractions are distributed by size class, total iron content, and the amount of barren rock. The points where graphs 1 and 2 intersect, as well as 2 and 3, indicate the most appropriate size classes for separating the hydro mixture flow and selectively extracting the valuable layer from the entire mass of enrichment waste.

This allows determining the granulometric composition of fractions containing easy-to-enrich iron with a sufficient degree of ore mineral liberation.

The second quadrant shows graphs demonstrating the change in particle weight depending on their size class and density: for barren rock particles – 5 ($\rho = 2.65$ t/m^3), and for particles containing a useful component – 6 ($\rho = 5$ t/m^3).

The third quadrant shows graphs illustrating the change in the distance traveled by particles with useful components and barren rocks depending on their weight at different hydro mixture flow rates $Q_p = 0.1$ m^3/s.

An enrichment waste storage facility is an engineering structure with a complex internal structure characterized by heterogeneity caused by both design features and technological processes.



1 – graph showing the distribution of the mass fraction of fractions by size class; 2 – graph showing the distribution of the mass fraction of total iron by size class; 3 – graph showing the distribution of the mass fraction of barren rocks by size class; 4 – optimal area for selective extraction of the productive layer; 5 – graph of the change in the weight of barren rock particles (ρ=2.65 t/m^3) by size class; 6 – graph of the change in the weight of particles with a useful component (ρ=5 t/m^3) depending on their size class; 7, 8 – graphs of the change in the travel distance of particles containing a useful component and barren rocks along the alluvium beach (mixture flow rate Q_p=0.1 m^3/s) respectively

Figure 1 – Relationship between the granulometric and qualitative composition of enrichment waste and the parameters of the productive layer and the travel distance of particles of different size classes along the alluvium beach

When creating tailings storage facilities, the possibility of their further development should be taken into account, as the rocks contained in these wastes may find application in various sectors of the economy in the future. This may include re-enrichment of waste with a high content of useful components, as well as the use of large and medium fractions of barren rocks for the production of building materials, etc. Therefore, storage facilities should be designed with maximum efficiency of their further use in mind.

Simultaneous separation of the enrichment waste hydro flow by a classifier into three components with different granulometric and qualitative characteristics (Table 2), as well as the optimal placement of this classifier on the main pipeline, which ensures the delivery of each of the layers of the separated hydro mixture to the corresponding sections of the complex tailings storage facility, determines the expedient configuration of the latter in terms of layout (Figure 2).

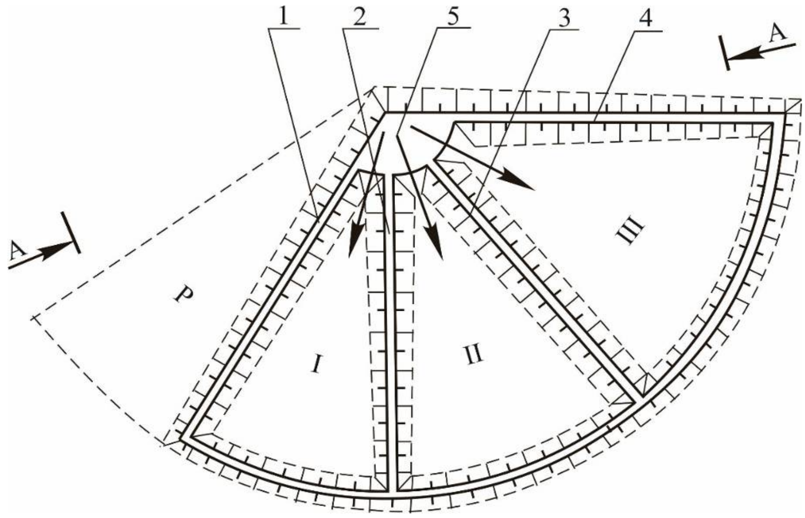
Table 2 – Particle size distribution of the separated flow of the hydro mixture from the enrichment waste of the Central Gold and Silver Plant

Layers separation flow hydro mixture	Classes of size, mm	Mass fraction of fractions, %	Mass fraction of particles containing total iron, %	Mass fraction of particles containing magnetic iron, %	Mass fraction of barren rocks, %
Potentially productive	+1.00	2.9	11.1	1.7	88.9
	-1.00 +0.63	7.1	12.1	2.9	87.9
	-0.63 +0.45	11.1	12.7	3.0	87.3
	-0.45 +0.25	19.8	16.7	3.8	37.5
Productive	-0.25 +0.16	22.1	27.9	10.1	94.5
	-0.16 +0.07	12.5	38.3	16.3	84.1
	-0.07 +0.05	2.15	71.6	25.1	28.4
	-0.05	9.83	100	39.9	0.0
Non-productive	-0.06 +0.05	2.95	0.00	0.00	100.0
	-0.05	9.56	0.00	0.00	100.0

The sections of the complex tailings storage facility are filled with separate streams of hydro mixture simultaneously. The parameters of the tailings storage facility itself and each of its sections are determined separately for each mining and processing plant, taking into account the volumes of enrichment waste generated, their granulometric composition, and costs.

According to the practice of operating existing tailings storage facilities, their capacity can be increased quite effectively using a proven method of building up embankments on dewatered and already settled tailings [13].

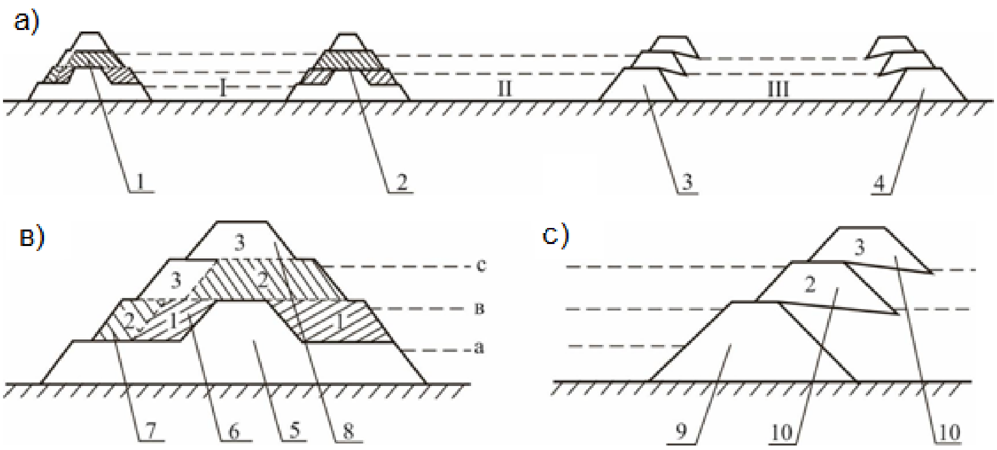
Similarly, it is permissible to build up the primary embankments of a complex waste storage facility to increase the volume of each section. However, from a design point of view, the primary embankments and the embankments used for build them up (secondary) have differences. The design features of these embankments are shown in Figure 3.



I, II, III – sections for storing productive, potentially productive, and barren rock flows, respectively; P – reserve section; 1, 2, 3, 4 – tailings pond section embankments; 5 – location of the hydro mixer flow distributor

Figure 2 – Complex tailings storage facility for storing separate flows of hydro mixture divided into sections

Section along A-A



a – cross-section of the complex tailings storage facility along A-A; b – cross-section of the embankment dams of sections I (dams 1 and 2); c – cross-section of the embankment dams of sections II and III (dams 3 and 4); 5 – primary embankment dam of sections I and II; 6 – stage I of the primary embankment dam of sections I and II; 7 – stage II of the primary embankment dam of sections I and II; 8 – stage III of the primary embankment dam of sections I and II; 9 – primary embankment of sections II and III; 10 – secondary embankments of sections II and III (second and third stages of increasing the height of the primary embankment)

Figure 3 – Design features of primary and secondary embankments

4. Results and discussion

Since the third section of the complex enrichment waste storage facility is filled exclusively with fine-grained particles of barren rock, the construction of primary and secondary embankment dams is carried out in accordance with established technologies. Their parameters, materials, and construction sequence are determined in accordance with applicable building codes governing the design, construction, reconstruction, conservation, and reclamation of tailings ponds and slurry storage facilities [11] (Figure 3, a, b). At the same time, for section I, where it is planned to place the productive part of enrichment waste with a high content of useful components, such a method of constructing and building up dams is unacceptable. This is due to the fact that valuable mineral resources are "buried" in the side areas, which makes their further development impossible without prior dismantling of secondary dams.

In order to gradually distribute capital expenditures for the construction of embankment dams for the first and second sections of the complex enrichment waste storage facility (items 1 and 2 in Figure 3), it is planned to first construct the primary dams, which will subsequently be increased as the corresponding sections are filled (Figure 3, b).

The parameters of the primary dams and the specifics of their further build-up are determined individually in each case based on the applicable regulatory documents [1]. At the same time, it should be noted that the height of the primary embankment dams for each section varies in the area from the point of installation of the hydro mixture distributor to the stop dam. This variability is determined depending on the slope of the earth's surface, the characteristics of the alluvium beach of enrichment waste of various granulometric composition, as well as the physical and mechanical properties of the rock particles that make up the hydro mixture. The process of forming embankment dams for positions 1 and 2 – the first section (Figure 2 (a)) is implemented as follows. The initial dam 5 (Figure 3) structurally provides for two horizontal terraces for laying overburden rocks for its further build-up. After filling the first section with the productive part of the enrichment waste to level (a), the overburden rocks of the first stage are laid on the horizontal terraces of the dams (positions 1 and 2 in Figure 3 (b)). When level (c) is reached, the height of the dams is increased by placing the overburden of the second stage. When the filling level reaches mark (d), it becomes necessary to place the overburden of the third stage.

5. Conclusion

Based on the results of the studies, it was determined that the proposed approach to creating a complex storage facility for enrichment waste, combined with the technology of increasing the height of embankment dams, makes it possible to form a man-made deposit from the productive fraction of the hydro mixture (Section I) and to store other enrichment waste containing rock particles of various compositions and qualities separately (Sections II and III).

Conflict of interest

Authors state no conflict of interest.

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ФОРМУВАННЯ КОМПЛЕКСНОГО ХВОСТОСХОВИЩА ДЛЯ СКЛАДУВАННЯ РОЗДІЛЕНИХ ЗА ЯКІСНИМ СКЛАДОМ ВІДХОДІВ ЗБАГАЧЕННЯ

Медведєва О., Якубенко Л., Демченко О., Молдабаєв С.

Анотація. В статті розглянуто сучасний стан хвостосховищ гірничо-збагачувальних комбінатів Кривбасу, наведено їх параметри та перспективи залучення техногенних утворень на гірничих підприємствах у вигляді відходів збагачення, які складовані у хвостосховищах. Встановлено, що під час формування техногенних родовищ є процес локалізації мінеральних компонентів, а також локалізація корисного мінерального компонента здійснюється за мінімум енергетичних і матеріальних витрат.

В роботі авторами розглянуті можливі варіанти поділу мінералів, які ґрунтуються на специфічних властивостях з урахуванням їх подальшої концентрації в процесі формування техногенних родовищ в процесі їх експлуатації хвостосховищ.

За результатами виконаного аналізу та патентного пошуку авторами встановлено, що основними недоліками вітчизняних і зарубіжних способів вилучення цінних компонентів з гідропотоку відходів збагачення, які повинні забезпечити формування техногенних масивів за допомогою локального складування, розділеного за якісним складом мінеральної сировини є те, що більша частина способів відбору цінних компонентів з відходів збагачення здійснюється без урахування фізико-механічних властивостей часток, відбір цінного компонента з турбулентного потоку напірного трубопроводу здійснюється огорожним циліндричним патрубком та значні капітальні і енергетичні витрати. Крім того встановлено, що під час формування сховищ відходів збагачення необхідно врахувати фактор можливої їх подальшої розробки, тому що гірські породи, що входять до складу цих відходів.

Визначено, що найбільш ефективним для формування техногенного родовища при складуванні відходів збагачення гідротранспортом є спосіб їхнього поділу за густиною, що ґрунтується на застосуванні природних сил гравітації. Тобто під час роздільного намиву з попереднім поділом гідросуміші на кілька (дві та більше) складових частин із різним вмістом корисного компонента, крупністю та густиною.

За результатами проведених досліджень авторами статті запропоновано спосіб формування комплексного сховища відходів збагачення спільно з технологією збільшення висоти дамб його обвалування забезпечує формування техногенного родовища з продуктивної частини гідросуміші та роздільного складування решти відходів збагачення з частками гірських порід різного якісного та кількісного складу.

Ключові слова: відходи збагачення, комплексні хвостосховища, роздільне формування, техногенні родовища.