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On the issue of processing of accumulated solid waste of enterprises of the mining and metallurgical industry of Kazakhstan

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Abstract. Based on a detailed analysis of the current state of the accumulated solid waste of mining and metallurgical enterprises, new approaches to the classification of industrial waste are proposed. Outdated methods based on the industry principle do not allow to fully assess the danger of waste and effectively plan its disposal. The new solutions presented in the work for the creation of a technological and economic cadastre with the development of state standards for classified groups of waste will optimize the processes of their processing and disposal, ensure the environmental safety of production and environmental management. The introduction of the technological and economic cadastre of industrial waste involves the formation of a unified database containing information on the composition, properties, volumes of generation and possible methods of processing the accumulated solid waste. This will allow enterprises and processing organizations, as well as interested investors, to gain access to up-to-date information necessary to make informed decisions in the field of waste management. In addition, the developed inventory will become a key tool for monitoring and controlling the generation and movement of waste, which will increase the transparency and efficiency of the waste management system. In general, the introduction of a modern industrial waste classification system is a prerequisite for the transition to sustainable development and conservation of natural resources, including reducing the negative impact of waste on the environment, and creating new opportunities for economic growth.

Keywords: *waste, processing, classification, ecology, metal recovery, resource conservation, additional source of raw materials.*

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1. Introduction

Kazakhstan, with its large reserves of polymetallic ores, is a site for numerous processing enterprises specializing in lead and zinc. Although the key goal of beneficiation is to increase the concentration of valuable elements, this process is inevitably accompanied by the generation of a significant amount of waste. These wastes, however, retain residual concentrations of important metals, including non-ferrous metals and gold. Decades of active mining of precious metals have led to the accumulation of huge volumes of mining waste, forming dumps and tailings dumps. Man-made deposits have emerged, characterized by industrial reserves and a content of useful components comparable to low-grade ores, which are now actively involved in processing. Often, in mining waste, useful components, in particular, precious and non-ferrous metals, are presented mainly in a finely dispersed state and hard-to-extract forms [1-6]. Efficient recovery of hard-to-recover gold bound to sulphides, coated with films and finely interspersed in acid-soluble minerals is an important technological aspect that facilitates more complete metal recovery and waste recycling using modern methods.

In the current situation, the processing of man-made deposits, namely waste from processing plants, is a promising area that combines economic feasibility and environmental responsibility. Recycling not only recovers valuable metals, reducing dependence on primary mining, but also significantly reduces the amount of waste that has a negative impact on the environment.

The development of effective technologies for the extraction of valuable components from mining waste is an urgent scientific and technical task. Traditional ore processing methods are often inefficient enough to recover fine gold and other valuable metals from waste. In this regard, new methods such as bioleaching, sorption technologies, extraction and electrochemical methods are being actively researched and implemented.

An important aspect of waste recycling is an integrated approach that takes into account the mineralogical composition of waste, the content of valuable components and environmental limitations. The development of optimal technological schemes of processing requires detailed studies, including the analysis of the mineral composition, the determination of the optimal parameters of the leaching, ion exchange and extraction processes, as well as the assessment of the environmental safety of the technologies used.

Wastes from processing plants are characterized by a complex mineralogical composition, fine inclusions of valuable components and the presence of harmful impurities. This complicates the application of traditional metal recovery methods such as flotation and cyanidation. In modern conditions, the processing of minerals using traditional deep beneficiation technologies is becoming economically inexpedient, since their capabilities are limited and inefficient for ores with a submicrogranular structure, the mineral aggregates of which are difficult to selectively open into individual phases with a useful component [2, 3, 6, 7].

The reduction of reserves and the decrease in the quality of ores stimulates the use of more complex grinding and beneficiation schemes, equipment and reagents, which leads to an increase in the cost of processing, ahead of market prices for final products, a decrease in the competitiveness and investment attractiveness of the mineral resource complex of Kazakhstan. A radical solution to the problem is to change the ore processing scheme [8].

For the economy of Kazakhstan, the transition of the mining and metallurgical complex of the republic to a circular economy within the framework of the «zero waste» concept using resource-saving and energy-efficient technologies is of paramount importance [9]. The development and design of new technologies aimed at the integrated processing of multicomponent raw materials - accumulated waste from lead-zinc processing plants, seems to be very relevant.

The economic and environmental importance of involving tailings from processing plants will not only make it possible to obtain additional profits, but also significantly reduce the volume of stored waste, prevent pollution of soil and water resources, and, ultimately, improve the environmental situation in the regions where the enterprises are located.

In this regard, the development of innovative and environmentally friendly technologies for the extraction of valuable components from man-made deposits is a key factor for the sustainable development of the mining and metallurgical industry of Kazakhstan. Such technologies must ensure a high degree of metal recovery, minimize waste generation and resource consumption, and meet stringent environmental standards.

One of the promising areas is the use of bioleaching methods based on the use of microorganisms to dissolve sulfide minerals and release the valuable components contained in them [10]. Bioleaching offers a number of advantages, including low energy consumption, the ability to process low-grade ores and waste, and environmental friendliness. However, for the successful application of bioleaching, it is necessary to take into account the mineralogical composition of the waste, select the optimal strains of microorganisms and control the process parameters.

Another promising area is the application of methods for selective metal extraction using organic reagents, such as extractants and chelating agents. These methods allow to extract valuable components from solutions with high selectivity, minimizing loss and contamination. However, the selection of the optimal reagent and extraction conditions requires a thorough study of the chemical properties of metals and minerals, as well as laboratory and pilot tests.

This paper provides a substantiation of an integrated, innovative and environmentally friendly approach to the processing of waste from lead-zinc processing plants in Kazakhstan, aimed at increasing the efficiency of using the resource potential of man-made raw materials and reducing the environmental consequences.

The introduction of innovative technologies for processing waste from lead-zinc processing plants will allow Kazakhstan not only to strengthen its resource base and increase the competitiveness of the mining and metallurgical industry, but also to make a significant contribution to environmental protection and sustainable development of the regions. This requires active cooperation between scientific organizations, enterprises and government agencies, as well as attracting investment in the development and implementation of new technologies.

2. Analytical basis for assessing accumulated solid waste

Kazakhstan's geopolitical and economic interests in the long term will depend on the state of the country's mineral resource base. At the same time, taking into account the fact that primary sulphide ores are not unlimited, it has great interest to involve in the processing of accumulated solid intermediate products, sludges, slags and tailings of processing plants in order to comprehensively extract valuable metals from them.

According to of the Ministry of Industry and New Technologies of the Republic of Kazakhstan in dumps, tailings dumps and storage tanks of mining enterprises of Kazakhstan, about 34.2 *billion tonnes* man-made mineral formations (TMO): 72% are dump rocks, 20% are dump tailings of ore beneficiation, 8% are other TMOs. As of 2017, there are 775 objects of man-made mineral formations registered by the State Cadastre, of which 109 are free from subsoil use, 666 are located at operating enterprises and mines.

The annual growth in the volume of TMO accumulated due to the increase in mining and processing of minerals in Kazakhstan is 350-400 *million tonnes*. At the same time, the total annual level of TMO consumption is about 11% of the total output. In the developed industrial countries of the world, the level of industrial waste use reaches 70-80%.

Recently, the terms «technical mineral formations» or «technogenic raw materials» are increasingly found in various fields, including the mining and metallurgical industry and other sectors of the economy. It is important to emphasize the lack of a generally accepted and clear scientific definition for these categories. According to the study [11], «technogenic raw materials» are industrial wastes and dumps, which indicate the imperfection and low efficiency of the technologies, processes and equipment used.

The widespread use of this term, to a certain extent, hinders the disposal of waste from the mining and metallurgical complex, the integrated use of non-renewable natural mineral resources and the full involvement of secondary raw materials in the production cycle. Thus, the use of the concept of «technogenic raw materials» does not seem to be entirely justified.

During ore beneficiation, 75-85% of the base metals accounted for in the supplied ores are extracted into concentrates, the remaining part is stored in dumps. During metallurgical processing, the extraction of basic metals into rough products is 80-95%, the remaining part also goes to dumps. The ores of most non-ferrous metal deposits are complex. Their industrial value is determined by the presence of the content of the main components in them. In addition to the main components, ores contain precious metals (gold, silver, platinum).

The ores contain dispersed and rare metals (bismuth, selenium, tellurium, rhenium, cadmium, titanium, vanadium, etc.). The specificity and peculiarity of the beneficiation of such ores is characterized by the fact that the bulk of valuable metals is lost with dumps, substandard ores and tailings.

As the analysis shows, insufficient attention is paid to the problems of assessing the impact of industrial waste, including toxic, on human life arising from the disposal of industrial waste. At present, due to the lack of a proper system of accounting and control of industrial waste, specialized places for their storage and processing, it is not possible to determine the total volume of waste generation, both by type and by roll. The data available in official sources give a certain general picture of the current situation with industrial waste in the post-Soviet countries and reinforce the need to solve the problem of their disposal.

For example, in Russia, the volume of unprocessed and non-neutralized waste has increased by 16% over the past ten years. 4.5 billion tons of production and consumption waste are stored annually on the surface of the earth. The total amount of accumulated waste is 50 billion tons, and more than 250 thousand hectares of land are occupied for storage. In 2019 alone, about 130 million tons of toxic waste were generated at industrial enterprises, which is 9.2% more than in 2000. The main volume of toxic waste falls on ferrous and non-ferrous metallurgy enterprises.

According to the State Statistics Committee of Ukraine, during 2010, Ukrainian enterprises accumulated about 80 million tons of toxic waste against 77.6 million tons in the previous year. Moreover, of the total amount of accumulated waste, 48.8 million tons (62%) are placed in places of organized storage, of which 19% are in storage facilities that are operated in violation of environmental safety requirements, or do not meet current standards. At the same time, the country's industrial enterprises continue to send waste to landfills. As of January 1, 2004, 2745.1 million tons of toxic waste had accumulated in the storage facilities and on the territory of the country's enterprises. On average in the country *1 sq. km* at the beginning of 2004, 4.5 thousand tons of toxic industrial waste were stored in storage facilities and on the territory of enterprises.

Comparative data for Kazakhstan is not encouraging either. According to the official data of the Ministry of Industrial Development of the republic, to date, more than 20 billion tons of solid waste have already been accumulated, 75% of which falls on the share of mining enterprises, 20% on processing plants, and the remaining share on non-ferrous metallurgy enterprises.

For Kazakhstan, as well as for Russia and Ukraine, toxic waste, which is part of the structure of accumulated industrial waste, is particular concern in terms of the degree of impact on the environment and human life. On the territory of the republic, this category of waste is represented by a complex conglomerate of a mixture consisting of toxic, hazardous and mixed waste. The annual increase in their volumes, mainly stored in the open state, is the main reason for the observed serious violation of the ecological balance in the biosphere. As a result, the degree of impact of harmful substances on human life contained in toxic waste has significantly increased.

According to the Ministry of Emergency Situations, about 86 million tons of maintenance are generated annually in the republic, 63% of which falls on the share of non-ferrous metallurgy waste. The dynamics of the formation and use of toxic waste on our territory is shown in Figure 1.

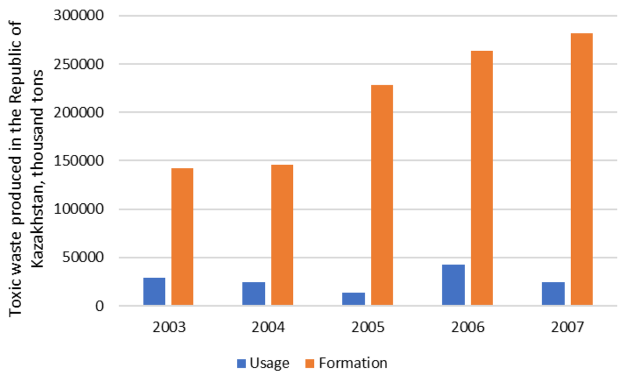


Figure1. Formation and use of toxic production waste in the period of 2003-2007

In most cases, technogenic raw wastes are located in places unsuitable for storage and are concentrated mainly in depressed regions of the republic. Thus, according to the state statistical reporting for 2007, as a result of the activities of industrial enterprises of the East Kazakhstan region (EKR), about 1401150 thousand tons of industrial waste were accumulated. The general structure of accumulated waste is presented in Figure 2.

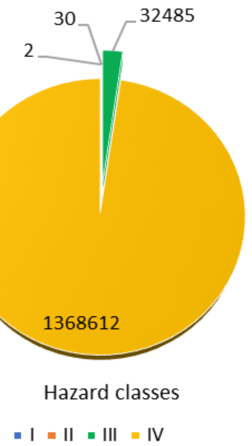


Figure 2. Structure of industrial waste accumulated in East Kazakhstan region (2007)

The situation in the region is aggravated by the fact that enterprises neutralize only an insignificant part of waste, and the main part of it, consisting of waste from the mining and processing complex and metallurgical production, is sent to places of organized storage.

The annual generation of waste from the mining and processing complex from overburden, tailings of processing plants belonging to hazard classes 3-4, with the widest range of ingredients, is about 20 *million tons.*

Metallurgical production waste is placed in dumps, waste heaps, sludge reservoirs and occupies an area of 436 hectares. Some of the dumps are stored in water protection zones. Such waste disposal leads to environmental pollution due to dust dispersion and erosion by rain and melt water, as well as pollutes surface and groundwater.

With the waste accumulated in the region, formed in the production chain "mining - processing - metallurgy", more than a third of the non-ferrous and precious metals mined with ores is lost, huge reserves of various construction raw materials are frozen. Through losses of metals are: lead – 33%, zinc – 28%, copper – 21%, gold – 41%, silver – 35%.

The total through losses, 15-20% of non-ferrous metals and 8-12% of precious metals are lost during mining, 43-48% and 74-75%, respectively, during metallurgy, 35-42% of non-ferrous metals and 14-17% of precious metals. The excess of losses of valuable components during beneficiation by 2-3 times compared to losses in mining and metallurgical processing led to the emergence of numerous technogenic deposits. According to the Territorial Department of Environmental Protection of East Kazakhstan region, it is currently not possible to accurately determine the volume of industrial wastes and, moreover, to manage them.

Waste management on a regional scale is carried out through the Ministry of Ecology and Natural Resources and their structural divisions, which limits the control, regulatory and management capabilities of local territorial departments. The Territorial Administrations are granted independence only in terms of issuing permits for the storage (burial) of waste.

From the above, it follows that if the issues of waste processing for enterprises are interest from a technological point of view, then in general, for the region, the solution of the issue is relevant, first of all, from the point of view of ensuring the environmental safety of the region.

The sustainability of the accumulated process, and the continuing growth in the volume of new waste received, significantly exacerbated the negative consequences, which began to seriously affect the life of people and the technological side. Thus, the comparative data given in Figure 3 show that the negative environmental consequences affecting human health in the republic are quite high.

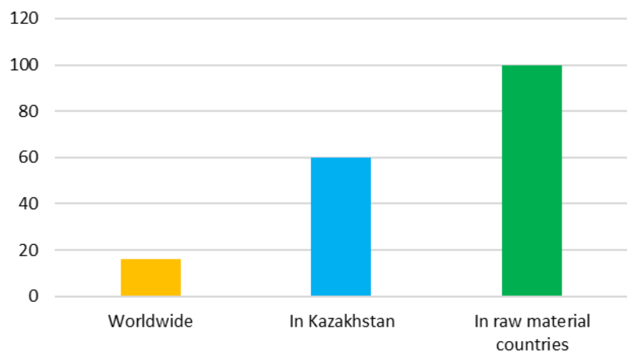
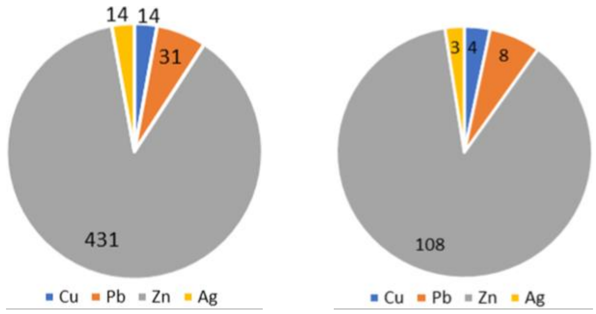


Figure 3. Solid waste yields, t/person per year

The negative consequences of accumulated industrial waste are associated with the fact that more than a third of non-ferrous, rare, rare-earth, strategic and precious metals mined with ores are lost with waste. The content of valuable components in waste often exceeds their content in developed deposits. If we take into account that the problem of increasing the use of production waste lies not only in its negative impact on the environment, but also in its potential value as a possible secondary raw material resource, then it is quite possible to assert that they are used as a strategic raw material for additional extraction of a complex of valuable metals. The data given in Figure 4 confirm the opinion expressed.

As the analysis shows, the main reason for the negative impact on the environment, and human life, consists not so much in the growth of production, as in the absence of integrated processing of minerals, as well as the disposal of large volumes of accumulated and current waste on the territories of enterprises.



(a) (b)

Figure 4. Volumes of non-ferrous metals accumulated in solid waste in Kazakhstan (million tons): (a) mineral processing; (b) metallurgy

Existing methods of processing industrial substandard waste, «tied» to the main technological schemes, have already become difficult and ineffective. The complexity of the use of raw materials has decreased, there has been a decline in the end-to-end extraction of even base metals. In addition, the disruption of horizontal ties between enterprises, associated primarily with changes in forms of ownership, led to a significant accumulation of solid waste and tailings directly on the territories of mining and metallurgy industries, causing significant damage to the environment and human life. This picture is especially characteristic of those regions where lead enterprises are located.

The organization of solid waste processing would make it possible to additionally extract not only base metals, but also valuable associated metals, the cost of which is commensurate, and sometimes even exceeds the cost of the main products of the enterprise. After the extraction of valuable metals, the demetallized silicate part can be used for the production of building materials. In favor of solid waste processing, we can also cite the absence of special costs for extraction and transportation, which make up the largest part in the cost structure.

As a result of the lack of effective technologies for processing solid tailings and waste, there is an incomplete, not comprehensive development of the mineral resources of the republic, technologically returned valuable components - rare and trace metals - are irretrievably lost. To solve the problems of environmental protection and the use of natural resources, the Government of the Republic invests considerable amounts of financial resources every year. Moreover, as the dynamics of investments shown in Figure 5 shows, their volumes increase every year.

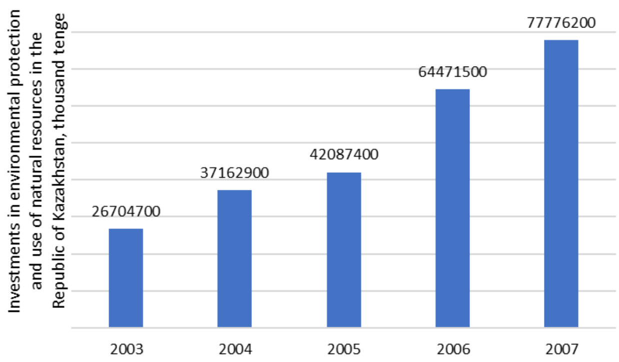


Figure 5. Growth of investments aimed at environmental protection and use of natural resources of the Republic of Kazakhstan

However, in spite of the cardinal measures taken, in almost all regions of the republic there is an inappropriate, and most importantly, irrational use of the allocated financial investments. An increase in the efficiency of the use of allocated funds can be achieved and, in the case, where and when the indicated problem has a fundamental justification for its solution, taking into account the specifics of the object under study and the region as a whole. In some cases, the absence of such approaches cannot provide a concrete solution to the problem on the part of responsible executors in full. For example, in the Register of Environmental Problems of the Republic of Kazakhstan, in the column «problem» (in relation to the East Kazakhstan region), it is indicated: *the presence of ownerless waste from the mining industry*. Further, in the column «Ways to solve the problem», the general solution is indicated - *the disposal of ownerless waste from the mining industry.* The following column deserves special attention – «Measures taken», which states literally the following: *«The issues of reclamation of dumps and tailings of the mining industry are not being resolved due to lack of financial resources. At existing enterprises, the issues of neutralization and reclamation of dumps are not included in investment obligations»*. There are many such examples in the Register. We think that there is no need to comment here.

In our opinion, a significant obstacle to the effective disposal or treatment of solid waste is the use of outdated approaches to assessing its quality. Methods, regulations, standards and technical conditions developed back in the Soviet period do not correspond to modern realities.

It is important to note that many existing standards, specifications, certificates and passports created for certain types of industrial products and waste are currently either not applied or have lost their relevance. For example, all technical specifications regulating substandard industrial products (such as lead-copper mattes) and oxide-sulfide melts of lead production are no longer in force, although the volume of accumulated waste reaches tens of thousands of tons.

The lack of up-to-date regulations governing the handling of these products makes it difficult to process them rationally. These wastes continue to be disposed of in open areas, occupying significant areas. The presence in them, along with base metals, of a high content of toxic impurities, increases their negative impact on the ecological situation, environmental protection and public health. Similar examples can be found in various regions of the country.

The negative consequences of waste become especially serious when it contains toxic substances, which, as previously demonstrated, is relevant for accumulated waste in the East Kazakhstan region.

3. Results and discussion

3.1. Classification of accumulated industrial waste

Good classification of solid waste is essential for effective waste management, including planning for recycling and the necessary investments. An analysis of scientific publications shows that existing approaches to the classification of industrial waste are often based on their origin by industry.

Production waste is the remains of raw materials, materials and semi-finished products that have lost their original properties in the production process. However, the re-involvement of this waste in recycling can give it new, valuable properties. It is necessary to study, analyze and classify them, preparing them for processing in order to extract useful components, and send the remaining slag materials to the construction industry. Despite the existing classification based on industries, each industry has its own system, which makes comprehensive waste management difficult. New approaches to classification are needed, taking into account common characteristics, which will make it possible to group industrial waste into separate categories.

Optimization of environmental safety of production in non-ferrous metallurgy is achievable with an integrated approach to each object under study - semi-product, industrial waste or slag. Separate processing of industrial products and waste from processing plants and metallurgical enterprises will have a positive effect on the environment. The involvement of secondary raw materials from dumps will clean the territories of enterprises, prevent pollution of water basins and reduce dust emissions into the atmosphere.

First stage research should include the implementation of measures to Classification of each type of industrial waste, with the establishment of their quantitative and qualitative completeness, with further identification of various wastes according to common features and grouping into common groups of interest for the extraction of a particular valuable component from them. This is the basic and necessary condition. It should be noted that in this case the concepts of «inventory» and «classification» should not be identified.

As the analysis [12, 13] shows, the old classifications of wastes by industry and morphological composition that have been developed and are still in force can no longer be a criterion for judging their hazard and choosing a method of disposal. This is due to the fact that each type of waste generated contains a set of chemicals characterized by their different toxicity, which can have a different polluting effect on the soil, groundwater, water of open water bodies and cause a negative impact on human health along ecological chains.

The implementation of the first stage of work will allow to most accurately determine the hazard class of a particular waste, and optimize the choice of the method of disposal, neutralization and disposal of waste. Identification of waste by properties and its classification will create an opportunity for further development of a state standard for each specific group of waste.

3.2. Development of a technological and economic cadastre

The purpose of the research should be to create a technological and economic cadastre of solid waste from mining and metallurgical enterprises. This will make it possible to streamline the received and accumulated materials and waste, determine their hazard class and impact on the environment, assess the economic feasibility of recycling and develop effective technologies.

Outdated methods based on the industry principle do not allow to fully assess the danger of waste and effectively plan its disposal. The proposed integrated approach, including the creation of a technological and economic cadastre and the development of state standards for classified groups of waste, will not only optimize the processes of processing and disposal, but also ensure the environmental safety of production and environmental management.

The introduction of a technological and economic cadastre of industrial waste involves the creation of a single database containing information on the composition, properties, volumes of generation and possible methods of processing each type of waste. This will allow enterprises and processing organizations to gain access to up-to-date information necessary to make informed decisions in the field of waste management. In addition, the cadastre will become a tool for monitoring and controlling the generation and movement of waste, which will increase the transparency and efficiency of the waste management system as a whole.

3.3. Standardization of waste groups and processing priorities

Second stage – development of state standards for newly classified wastes in a single group. Such a solution will make it possible to carry out certification, certification of waste and products of its processing, as well as to provide information about waste as hazardous substances or secondary material resources. At the same time, it will be possible to perform any actions related to the storage, placement, processing and transportation of waste, including marketing, storage, disposal, burial or destruction.

The implementation of the complex of these works should be carried out under the strict control of state bodies of republican, regional and local significance with the involvement of a wide range of scientific specialists in a particular field. These works should be aimed at solving key areas, such as:

– classification of accumulated and current waste in the territory of the republic with the identification of the volumes of valuable components contained in them;

– substantiation and development of proposals for additional production of metals from classified waste by replacing primary sources of raw materials;

– providing up-to-date complete information on waste for potential investors wishing to purchase a particular group of waste or take part in their processing;

– preparation and adoption of competent decisions by experts authorized by local authorities when considering issues of storage, transportation, processing or disposal of waste;

– selection of the most effective technologies for the processing of specific metal-containing waste.

The development of national standards for classified waste groups is an important step to ensure the uniformity and comparability of waste data, as well as to establish requirements for their treatment and disposal. Standards must take into account both environmental and economic aspects, as well as comply with international norms and requirements. This will create clear rules of the game for all participants in the waste management market and stimulate the introduction of the best available technologies.

4. Conclusions

The analysis highlights the need to move to new approaches to the classification of industrial waste. The need for a transition to new approaches to the classification of industrial wastes is shown.

The implementation of the proposed measures will require the active participation of government agencies, scientific organizations and the business community. State bodies should ensure the development and implementation of a regulatory framework, as well as monitor compliance with requirements in the field of waste management. Scientific organizations should conduct research on the development of new technologies for waste processing and disposal, as well as participate in the development of standards and inventories. The business community should invest in the creation of infrastructure for waste processing and disposal, as well as introduce modern technologies at their enterprises.

In general, the introduction of a modern industrial waste classification system is a prerequisite for the transition to sustainable development and conservation of natural resources. This will not only reduce the negative impact on the environment, but also create new opportunities for economic growth and development.

Author contributions

Conceptualization: ND, YZ; Data curation: ND, YZ; Formal analysis: AA, ND, VK; Funding acquisition: AA; Investigation: ND, YB; Methodology: ND, VK; Project administration: YZ, YB; Resources: AA, VK; Software: AA, VK; Supervision: ND, AA; Validation: YZ, VK; Visualization: AA, YZ; Writing – original draft: AA, ND; Writing – review & editing: ND, VK. All authors have read and agreed to the published version of the manuscript.

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Conflicts of interests

The authors declare no conflict of interest.

Data availability statement

The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

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Қазақстанның тау-кен металлургия кешені кәсіпорындарының қатты жинақталған қалдықтарын қайта өңдеу мәселесіне

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Аңдатпа. Тау-кен-металлургия кешені кәсіпорындарының жинақталған қатты қалдықтарының ағымдағы жай-күйін егжей-тегжейлі талдау негізінде өнеркәсіптік қалдықтарды жіктеуде жаңа тәсілдер ұсынылды. Салалық принципке негізделген ескірген әдістер қалдықтардың қауіптілігін толық бағалауға және оларды жоюды тиімді жоспарлауға мүмкіндік бермейді. Қалдықтардың жіктелген топтары үшін мемлекеттік стандарттарды әзірлей отырып, технологиялық-экономикалық кадастр құру жөніндегі жұмыста келтірілген жаңа шешімдер оларды қайта өңдеу және кәдеге жарату процестерін оңтайландыруға мүмкіндік береді, өндіріс пен табиғат пайдаланудың экологиялық қауіпсіздігін қамтамасыз етеді. Өнеркәсіптік қалдықтардың технологиялық-экономикалық кадастрын енгізу жинақталған қатты қалдықтардың құрамы, қасиеттері, түзілу көлемі және оларды қайта өңдеудің ықтимал тәсілдері туралы ақпаратты қамтитын бірыңғай деректер базасын қалыптастыруды көздейді. Бұл кәсіпорындар мен қайта өңдеу ұйымдарына, сондай-ақ мүдделі инвесторларға қалдықтарды басқару және басқару саласында негізделген шешімдер қабылдау үшін қажетті өзекті ақпаратқа қол жеткізуге мүмкіндік береді. Сонымен қатар, әзірленген кадастр қалдықтардың пайда болуы мен қозғалысын бақылау және бақылаудың негізгі құралы болады, бұл қалдықтарды басқару жүйесінің ашықтығы мен тиімділігін арттырады. Тұтастай алғанда, өнеркәсіптік қалдықтарды жіктеудің заманауи жүйесін енгізу қалдықтардың қоршаған ортаға теріс әсерін азайтуды және экономикалық өсу үшін жаңа мүмкіндіктер жасауды қоса алғанда, табиғи ресурстарды орнықты дамытуға және сақтауға көшу үшін қажетті шарт болып табылады.

Негізгі сөздер: *қалдықтар, қайта өңдеу, жіктеу, экология, металдарды алу, ресурстарды үнемдеу, қосымша шикізат көзі.*

К вопросу переработки твердых накопленных отходов предприятий горно-металлургического комплекса Казахстана

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Аннотация. На основании детального анализа текущего состояния накопленных твердых отходов предприятий горно-металлургического комплекса предложены новые подходы в классификации промышленных отходов. Устаревшие методы, основанные на отраслевом принципе, не позволяют в полной мере оценить опасность отходов и эффективно планировать их утилизацию. Приведенные в работе новые решения по созданию технолого-экономического кадастра с разработкой государственных стандартов для классифицированных групп отходов позволит оптимизировать процессы их переработки и утилизации, обеспечит экологическую безопасность производства и природопользования. Внедрение технолого-экономического кадастра промышленных отходов предполагает формирование единой базы данных, содержащей информацию о составе, свойствах, объемах образования и возможных способах переработки накопленных твердых отходов. Это позволит предприятиям и перерабатывающим организациям, а также заинтересованным инвесторам получить доступ к актуальной информации, необходимой для принятия обоснованных решений в области обращения и управления с отходами. Кроме того, разработанный кадастр станет ключевым инструментом для мониторинга и контроля за образованием и движением отходов, что повысит прозрачность и эффективность системы управления отходами. В целом, внедрение современной системы классификации промышленных отходов является необходимым условием для перехода к устойчивому развитию и сохранению природных ресурсов, включая снижение негативного воздействия отходов на окружающую среду, и создания новых возможностей для экономического роста.

Ключевые слова: *отходы, переработка, классификация, экология, извлечение металлов, ресурсосбережение, дополнительный источник сырья.*