Экономические науки
Econonic sciences

UDC 330.15 http://doi.org/10.21440/2307-2091-2024-1-137-146

Solving the waste problem from the perspective of conceptual provisions of the use of natural resources

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Abstract

Relevance. Mining in all cases is accompanied by the formation of waste – man-made mineral formations (MMFs) and their volume is greater, the faster the scale of mining production increases. Under these conditions, the importance of the problem of waste management and the need to establish trends in its development increase.
The purpose of the study is to assess the current state of affairs in the field of solid waste management and identify trends in the implementation of this activity.
Research methods are systematic approach, methods of analogies, comparisons, logical analysis.
Results. The increasing importance of MMFs, the mineral resources and environmental aspects of the latter has been confirmed. Changes in waste management are analyzed in relation to conceptual provisions regarding the use of natural resources. The analysis covers: the concept of rational and integrated use of natural resources, the concept of eco-development, waste-free production, sustainable development, the concept of clean production, and the circular economy. An increase in attention to the problem of waste has been revealed, which from objects accompanying mineral resources are gradually turning into objects of priority importance.
This trend is confirmed by changes in conceptual provisions that replace each other in the historical aspect, the role of technogenic deposits in expanding the mineral resource base, as well as the possibility of improving the environmental situation through the elimination of MMFs during their use.
Conclusion. The identified changes in the management of MMFs confirm the priority of this activity at the present stage and the increasing importance of processing solid waste in order to expand the mineral resource base and improve the quality of the environment.

***Keywords*:** concepts, time aspect, natural resources, man-made mineral formations, priorities.

Introduction

The development of the world economy is accompanied by a progressive increase in the use of mineral resources. Over the past 40 years, 80–85% of oil and gas from the total volume of their production in the entire history of human civilization has been used. For other types of mineral raw materials, the growth in use volumes increased by 3–5 times. In general, the volume of production and consumption of mineral raw materials increases annually and one cannot expect a change in this situation. Naturally, the extraction of minerals is accompanied by the excavation of waste rock to the surface, the mass of which depends on the method of extracting the mineral, the development system, etc. The volume of waste accumulation on the territory of the Russian Federation is about 100 billion tons, and their annual increase is no less than 5 billion tons. Under these conditions, the problem of using Man-made mineral formations (MMFs) becomes urgent.

The greatest interest from the point of view of expanding the mineral resource base is represented by MMFs containing useful components suitable for cost-effective extraction – technogenic deposits (TM), especially since the processing of MMFs provides the opportunity to eliminate sources of negative impact on the environment, improve the human environment, and preserve "health" of ecosystems. An example is single-industry towns with a mining profile, in which MMFs are located within the boundaries of urban areas and serves as a source of deterioration in the health of the population. The correlation between environmental pollution and the increase in diseases and mortality has been confirmed by numerous studies.

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Despite the importance of MMFs, the degree of attention to the waste problem does not remain constant: it is either updated or loses its urgency. One of the reasons for this attitude to the problem of waste management is changes in conceptual provisions regarding the use of natural resources in a temporary aspect.

Results

Changes in waste management activities required an analysis of the concepts that define the conditions for the use of natural resources, replacing each other in a temporal aspect. So, in the mid-60s of the XX century leading Soviet scientist D. L. Armand outlined in his book [1] a new approach to the use of natural resources, which he defined as "correct (rational) environmental management, defined as a careful attitude towards natural resources, presupposing their increased involvement in expanded economic use, accompanied by expanded reproduction, and protecting them from unreasonable, wasteful and predatory use.

Among the principles of rational exploitation and restoration of natural resources he included:

– involvement of natural resources in the national economy in different quantities and in different ways, depending on the natural and economic conditions of each area;

– the ability to foresee the consequences of each change made by man to one aspect of nature, to take into account its impact on all other aspects and sectors of the economy;

– expedient order of involvement of natural resources in the national economy;

– expanded reproduction of renewable resources;

– comprehensive and economical, i.e. without technically unjustified waste and loss of non-renewable resources;

– maintaining a qualitatively high level and rational redistribution in space and time of inexhaustible resources;

– creation of the best working conditions, recreation and health improvement for the population;

– transformation of nature, i.e. the creation of landscapes that are more productive and more appropriate to the needs of a socialist society than the original natural ones;

– preservation of scientific and aesthetic values created by nature and which are the pride of every people who loves their land;

– further decoration of the landscape and bringing it into a harmonious whole with architectural ensembles" [1].

As presented by D. L. Armand, rational environmental management presupposes, firstly, the complete use of non-renewable resources, excluding unreasonable losses and minimizing the generation of waste. Secondly, expanded reproduction of renewable resources; thirdly, taking into account possible consequences associated with changes in nature during subsoil development. Natural resources, according to D. L. Armand, should be involved not in economic use, but "in economic circulation, i. e. into a cycle of expenditure and renewal". The problem of waste does not remain unsolved. The systematic growth of industrial production actualizes the problem of supply of raw materials and disposal of waste, the amount of which is also growing. The concept of rational environmental management, which anticipated the concept of sustainable development, is also, like the latter, focused on balancing the interests of present and future generations in the use of natural resources, i. e. "the moral duty of each generation is to leave natural resources to the next in better condition and in greater quantities than it received from the previous one" [1].

In the development of the ideas underlying the concept of rational environmental management, in addition to D. L. Armanda took part: Yu. K. Efremov, Yu. N. Kurazhskovsky, N. F. Reimers, V. A. Anuchin et al. [2, 3]. The author [3] defines rational environmental management as "a system of activities designed to ensure the economical exploitation of resources and conditions and the most effective mode of their reproduction, taking into account the long-term interests of the economy and the preservation of human health". Rational use of natural resources presupposes the fullest possible extraction of all useful products from them, causing the least harm to economic sectors based on the same resource, and to the state of the natural environment necessary for human life.

In the definition of the authors [4] "rational use of mineral resources means the most complete and comprehensive extraction of minerals from the subsoil during mining (losses should not exceed economic limits), comprehensive extraction of mineral raw materials and fuel during their enrichment, processing and consumption, use of by-products and production waste, the most rational organization of transportation of raw materials at all stages of production, timely implementation of measures to restore the earth's surface, etc.". The ideas of rational environmental management quickly penetrated into the sphere of public administration and began to be used at the sectoral level (rational land use, rational water use, rational subsoil use, etc.) [5]. The economic branch of the concept is gradually gaining strength, in the development of which the following people took part: S. G. Strumilin, N. P. Fedorenko, P. G. Oldak et al.

Over time, the conditions for rational environmental management have undergone quite expected changes, but the idea of the concept – the preservation of natural capital – has remained unchanged [6].

In the new version of the conceptual provisions of rational environmental management, the social aspect plays a significant role, the need for payment for environmental management and the creation of protected areas for the purpose of direct protection of the most valuable of them are noted. As before, the problem of waste is considered only from the point of view of minimizing its volume in order to reduce the anthropogenic impact on the environment and represents one of the conditions for rational environmental management. The secondary importance of this problem is evidenced by the fact that among the priorities of Russia's national environmental policy (2009), the waste problem, as before, is not reflected [7].

The same period dates back to the addition of its concept of integrated use of raw materials and subsoil, aimed at the complete extraction of minerals from the subsoil and useful components from mineral raw materials [8–10], the basis of which is the multicomponent nature of most types of minerals, their uneven distribution in the earth bark and differences in quality. In each specific type, the target (main) component is in a genetic connection with a number of other components. Coal is accompanied by sulfur, methane and germanium, iron ores – vanadium, germanium, phosphorus, titanium, sulfur, etc. A great contribution to the development of ideas for the integrated use of mineral resources was made by N. V. Melnikov, A. V. Sidorenko, M. I. Agoshkov, N. A. Bykhover,

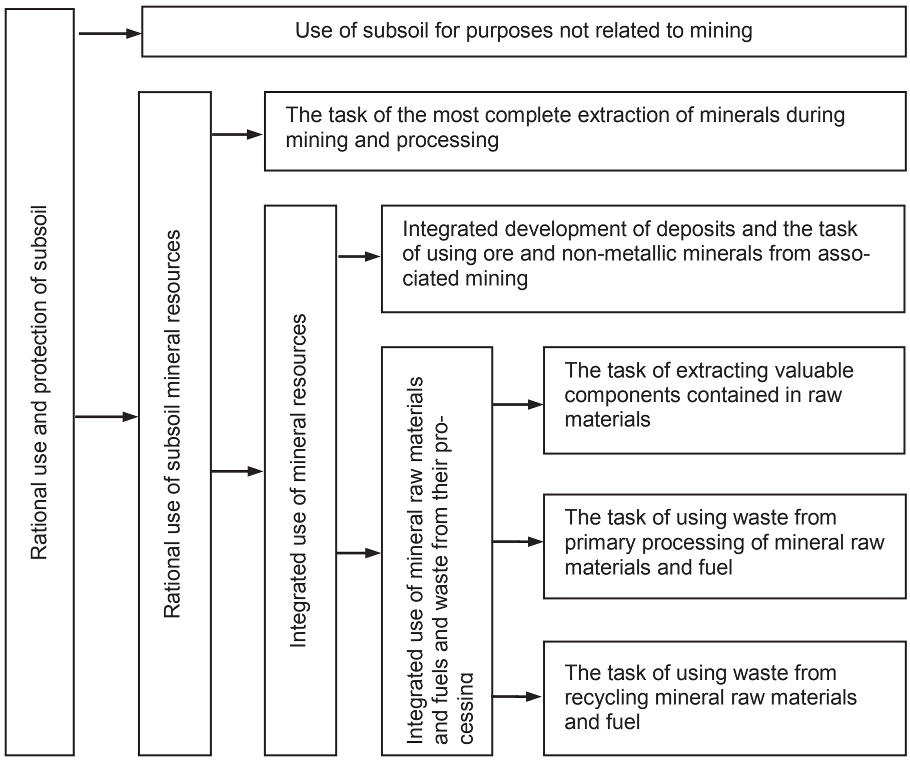

Figure 1. Scheme of subordination of the integrated and rational use of mineral resources [12]
Рисунок 1. Схема соподчиненности комплексного и рационального использования минеральных ресурсов [12]

N. G. Feitelman, Yu. V. Yakovets and others. Certain aspects of the problem are studied in the works of I. P. Zhavoronkova, V. N. Vinogradov, V. N. Leksin, M. A. Sergeev et al. The subordination of the problems of integrated use of mineral resources (IUMR) and rational use is reflected in fig. 1.

At the stage of the 80s, the content of IUMR expanded, the coverage of resource cycles of the use of mineral resources extended to all stages of their processing, as a result, the problems of recycling industrial waste were included in the general problems. However, this concept, like the concept of rational subsoil use, remains aimed primarily at natural mineral resources, since in the period 60–70, according to the authors [11], human activity in relation to the use of solid waste was just beginning.

The complexity of the use of raw materials is determined by technologies that ensure the profitability of obtaining products from raw materials, the quantity and quality of which corresponds to the maximum possible at the appropriate level of development of science and technology [13]. If the concept of rational subsoil use predetermines resource conservation by reducing the volume of mineral resources used, then the integrated use of raw materials and subsoil is focused on the complete extraction of minerals and useful components, which also helps to preserve non-renewable natural resources [4, 14]. Initially, rational, as well as integrated use of natural resources, including mineral resources, were considered as independent conceptual provisions; later, the requirement of complexity becomes one of the conditions for rational use [12].

The beginning of the 70s dates back to the emergence of the concept of eco-development, voiced at the First World Conference on Environment and Development in Stockholm in 1972. Eco-development as interpreted by researchers is "environmentally oriented socio-economic development, in which the growth of people's well-being is not accompanied by environmental deterioration habitat and degradation of natural systems". The development of the concept is a response to the deteriorating environmental situation, accompanied by an increase in morbidity and mortality of the population. The main idea of eco-development was to achieve environmental safety by taking into account the environmental factor in any decision-making. The fundamental principles of forming the concept of eco-development include the following:

– regional and local tasks of eco-development should be subordinated to global and national goals of preventing environmental disaster and optimizing the human environment (the principle of "thinking globally – acting locally");

– eco-development presupposes the need to prevent unfavorable environmental trends or provides a guarantee of their minimization (the principle "ignorance of the consequences does not relieve society from responsibility for the destruction of the natural environment");

– the goals of eco-development are primary in relation to the goals of economic development (the principle of the environmental imperative);

– the placement and development of material production in a certain territory must be carried out in accordance with its environmental technology intensity (the principle of environmental and economic balance);

– the environmental safety of a society is closely related to the level of culture, education and upbringing of people in this society.

All the principles under consideration are aimed at the integration of economy and nature, the creation of balanced ecological and economic systems, and the comparison of technogenic load with the environmental technological intensity of the territory. The thesis that existed at that time about the advisability of economic growth without any restrictions was criticized. The existence of strict environmental restrictions (limits) to economic development has been strongly argued [15].

The idea of balance was continued in the works of V. G. Ignatov, A. V. Kokin, L. A. Baturin, V. G. Ignatov, A. V. Kokin, P. G. Oldak [16], N. P. Golubetskaya [17] and others, including in relation to environmental management. For the first time, the requirement to establish environmental restrictions during economic development and strict control over their compliance was justified. Subsequently, the requirement for balance, as well as the complexity of the use of raw materials and subsoil, was included among the fundamental principles of rational subsoil use. There is no waste as a direct object of regulation in the concept of ecodevelopment. Indirectly related to them is only the requirement to comply with environmental restrictions (not exceeding the assimilation capacity of the territory where the waste is disposed).

In the first half of the 80s, the concept of waste-free production became widespread, which, in relation to subsoil use, assumed the full use of mineral raw materials, including waste, as subsoil resources. The basis of waste-free production is the use of waste-free technology, which is defined by the author [18] as "the principle of functioning of the national economy, region, industry, production, in which all components of raw materials and energy are rationally used in the cycle primary raw materials of production–consumption–secondary raw materials and the ecological balance is not disturbed". Low-waste technology occupies an intermediate stage in creating waste-free production.

In accordance with the Declaration on Low-Waste and Zero-Waste Technologies and Waste Management adopted by the ECE Environment (Geneva, 1979), zero-waste technology is defined as "the practical application of knowledge, methods and means in order to provide, within the framework of human needs, the most rational use of natural resources and energy and protect the environment" [19]. In a number of Western European countries, instead of low- and waste-free technology, the term "clean" or "cleaner technology" is used, which is essentially the same thing. "Clean technology, in their definition, is a method of producing products using the most rational use of raw materials and energy, which allows simultaneously reducing the volume of pollutants released into the environment and the amount of waste generated during the production and operation of the manufactured product" [11]. The concept of waste-free production continues to consider primary mineral resources as the main object of regulation. With regard to solid waste, the task is to reduce their formation "at the end of the pipe". Waste recycling, according to the authors [11], "is a separate process closely related to waste-free production." At the same time, when defining a waste-free technology, the authors of [11] believe that it should comprehensively process raw materials and dispose of the bulk of the waste within economically feasible limits.

The next stage in the development of mining waste management activities dates back to the early 90s and the emergence of the concept of sustainable development, the adherence of which, along with other countries, was recognized by Russia [20]. The concept of sustainable development defines a new stage in economic development, a transition to economic development that is safe for the environment. Sustainable development is a model of socio-economic development in which the vital needs of the present generation of people are met without future generations being deprived of this opportunity due to depletion of natural resources and environmental degradation [21]. The key issue in implementing the concept is the balance of the ecological, economic and social subsystems [22–24], which primarily involves balancing economic development with the requirement to preserve the "health of ecosystems", which is reflected in the conceptual provisions regarding the use of natural resources (Table 1).

The criteria under consideration allow us to conclude that for the first time, mining waste is considered as an independent object of regulation along with primary mineral resources. The formed requirements in relation to waste relate to minimizing its formation, maximizing its use and preventing environmental limits from being exceeded, which can lead to a deterioration in the environmental situation of the territory. The requirement to reduce the mass of waste is aimed at reducing the negative impact of the latter on the environment, i. e. the mineral and raw materials aspect of waste remains not particularly in demand.

In the second half of the 90s, the problem of waste turned out to be directly related to the concept of environmentally friendly production [25, 26], which is considered as the completion of the process of transformation in the system of environmental protection measures. EFP covers all aspects of production (Fig. 2).

It assumes:

– reduction at source and reuse of waste on site (in the same technological process or another, but within the enterprise);

– production of environmentally friendly products, which, whenever possible, are made from renewable raw materials and secondary materials.

The basic principles of EFP include:

– locality – the manifestation and negative impact of pollutants is limited only by the place of their formation;

– preventiveness – the formation of pollutants or their negative impact is prevented at stages preceding their possible appearance, including the receipt of raw materials or semi-finished products;

– the beginning and end of the pipe – the entire technological process is presented conditionally in the form of a "pipe" and the analysis of the formation of pollutants is carried out starting from the end of the pipe and moving towards its beginning while simultaneously identifying and separating the places where certain contaminants appear;

– waste flow – a set of liquid, solid and aerosol substances generated during technological processes and transported through various highways to general treatment facilities or outside the production area;

– the end of the waste transport line – the final part of the waste transport line at the enterprise, after which the mixed waste is not separated or processed, but only sent to natural objects or general treatment facilities;

– systematicity – a clean production scheme that takes into account the entire production process from raw materials

Table 1. Criteria for sustainable development
Таблица 1. Критерии устойчивого развития

Authors	Criterion 1	Criterion 2	Criterion 3	Criterion 4
1. S. N. Bobylev	The amount of renewable natural resources or the ability to produce biomass should at least not decrease over time, i.e. provide simple reproduction mode	The maximum possibility of slowing down the rate of depletion of reserves, with the prospect of replacing them in the future with other unlimited resources	Possibility of minimizing the amount of waste based on low-waste resource-saving technologies	Environmental pollution in the future should not exceed its current level; it should be possible to minimize pollution to a socially and economically acceptable level
2. E. V. Girusov	The amount of renewable natural resources or their ability to produce biomass should at least not decrease over time, i.e. at least a simple reproduction regime must be ensured	Slowing down the rate of depletion of non-renewable natural resources with their possible replacement in the future with unlimited types of resources	Minimizing waste generation based on the introduction of low-waste resource-saving technologies	Environmental pollution in the future should not exceed its current level. Possibility of minimizing pollution to socially and economically acceptable levels
3. I. I. Drogomiretsky, E. L. Kantor, L. A. Chikatueva [27]	Preservation of the amount of renewable natural resources, their ability to produce biomass (at least simple reproduction) must be ensured)	Slowing down the rate of depletion of non-renewable natural resources as much as possible	Possibility of waste minimization based on the introduction of low-waste, resource-saving technologies	Environmental pollution (total and by type) should not exceed its current level
4. A. P. Moskalenko [et al.]	Ensuring at least a regime of simple reproduction of renewable natural resources, their quantity or the ability to produce biomass should not decrease over time	Maximizing the slowdown in the rate of depletion of non-renewable natural resources with the prospect of their replacement with alternative or other unlimited resources in the future	Minimization of waste from production activities based on the implementation of low-waste, energy- and resource-saving technologies, technological chains of complex and (or) deep processing of raw materials, integrated use of energy, recycling of consumer waste	Minimize pollution to socially and economically acceptable levels. In the future, at a minimum, total and structural pollution should not exceed current levels
5. N. N. Yashalova, D. A. Ruban [28]	The amount of renewable natural resources and their ability to produce biomass should not decrease over time, i. e. simple reproduction regime must be ensured	The maximum possible slowdown in the rate of depletion of non-renewable natural resources with the prospect of their replacement with other unlimited types of resources	Possibility of waste minimization based on the use of low-waste and resource-saving technologies	Environmental pollution in the future should not exceed its current level

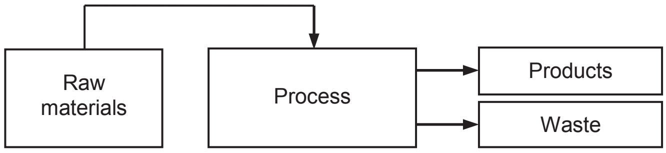

Figure 2. Objects affected by EFP
Рисунок 2. Объекты воздействия ЭЧП

to finished products (energy, services) and includes measures at all stages of this process to develop economically feasible ways to prevent, neutralize or recycle pollutants with an assessment of the resulting environmental and economic effects. An ideal clean production scheme has no treatment facilities or waste storage areas;

– the "3P" principle – preventing environmental pollution is more profitable than paying penalties for this pollution. The abbreviation "3P" is a combination of the words "prevention, pollution and payment", which means "preventing pollution is beneficial" [25].

The EFP strategy considers waste as raw materials and auxiliary materials that are lost during the production process. Therefore, the goal is to find opportunities to use them if the possibility of prevention turned out to be impossible. Although, according to the UN Environment Program, up to 70% of all waste can be prevented. The list of ways aimed at minimizing waste is shown in Fig. 3.

Achieving EFP goals, in particular, becomes possible with the use of appropriate technologies, i. e. the EFP concept corresponds to the strategy of "best existing technologies" or "best available technologies" (BAT) [29, 30]. The goal of introducing BAT is an integrated approach to the problem of pollution, when all components of the natural environment (air, water and soil) are considered together, in contrast to the traditional approach, which involves considering one of the components of the natural environment [30]. An important novelty is the abandonment of the current system of standardization of impacts on individual components of the environment, established individually for specific natural resource users, and the transition to technological standardization.

Technologies classified as BAT must ensure protection of the environment as a whole, and not its individual components. Nature users have the right to choose any of the technologies, provided that its impact on the environment does not exceed the technological standards determined for this BAT process [29]. In the EFP concept, the problem of waste plays one of the leading roles in creating environmentally friendly subsoil use. A positive aspect of the EFP concept is the requirement to reduce waste "at the beginning of the pipe", i. e. at the beginning of the production process, which eliminates the growing volumes of environmental costs associated with the elimination or reduction of waste "at the end of the pipe". The EFP concept is considered as a development of the concept of waste-free production, in which the problem of waste is actualized. Russia has signed the International Declaration of Cleaner Production, proposed by UNEP in 2001 as the main document defining the role of this concept in ensuring sustainable development of society. A number of notions of the concept have determined the main directions of economic development and environmental protection in Russia [31, 32], however, these provisions still remain declarations that are not provided with regulatory, organizational and financial support from the state and extremely limited from business [33].

Period 2010–2015 is characterized by the spread of the idea of the concept of a circular economy (CE) (closed-cycle economy), the subject of which in subsoil use is waste [34–37]. Waste management is becoming one of the priority areas of the circular economy, because its main principle is to ensure maximum efficiency from each process in the life cycle of a product or service. This type of economy is characterized by the "3Rs" – Reduce, Reuse and Recycle: optimization of the production process, reuse or sharing of the product, waste recycling [38, 39]. It should be noted that the idea of closed cycles is not new; the tasks of a gradual universal transition to closed technological cycles were considered at all-Union meetings on the problems of waste-free production at the Noginsk Scientific Center of the USSR Academy of Sciences and in Voroshilovgrad back in 1977–1978. Under the circular economy, the authors [34] understand "an economy that uses resources as efficiently as possible and uses closed loops as often as possible". The most cited definition given by the E. MacArthur Foundation is an economy that is restorative and circular in nature, involving the creation of a continuous development cycle that reduces natural capital and increases its value, increasing the return on resources by optimizing their use [40]. The field of mining is considered by domestic and foreign researchers as potentially suitable for the implementation of CE, but is far from a priority [38].

For subsoil use conditions, the most acceptable CE business models are:

– circular value chains;

– a model in which limited resources are replaced with completely renewable ones;

– recovery and recycling – models that provide for the recovery and reuse of resources on the basis of technological innovations (closed waste recycling cycle).

Business models for introducing waste recycling technologies and using secondary resources can be effective, and the organization of business models should be interconnected with the use of BAT. In fact, CE promotes the transition to BAT.

According to [37], there are three components of this economy: complete circulation of materials; extending the cycle of resource use; efficient use of renewable energy.

Waste recycling, as follows from the concept of CE, prevents waste disposal and reduces the extraction of primary natural resources. The transformation of waste into a secondary resource is stimulated and the process of technological renewal is accelerated.

Conclusion

As follows from the analysis, firstly, the development of activities for the management of solid waste is interconnected

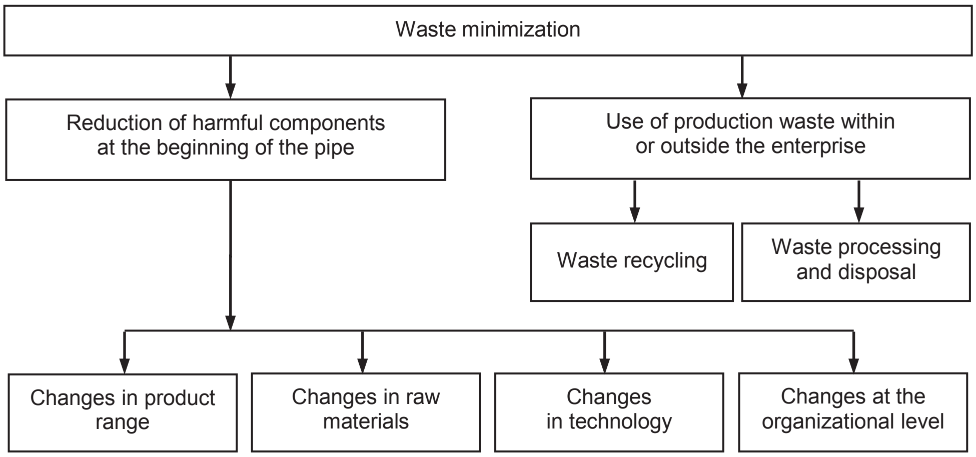

Figure 3. Main ways to minimize waste
Рисунок 3. Основные пути минимизации отходов

with changes in conceptual provisions of the use of natural resources. Secondly, MMFs from among the secondary objects of regulation have over time become the main ones, and the problem of solid waste management is becoming a priority. Thirdly, in the analyzed concepts until the early 90s, solid waste was considered primarily from the perspective of environmental pollutants, and measures to reduce the negative impact on the environment were linked to the "end of the pipe". Active actions regarding MMFs are carried out only from the moment of their formation, i. e. when they leave the production sphere in the form of waste. In general, this activity does not give the desired results, because impact requirements are constantly becoming more stringent and the costs of achieving them are rising. Fourthly, in the concept of sustainable development, among the requirements for the use of natural resources, solid waste is for the first time considered as independent objects on a par with natural mineral resources, and the requirements for their minimization are linked to the "beginning of the pipe". Fifthly, over time, the mineral resource aspect of MMFs becomes increasingly important.

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The article was received on January 10, 2024

УДК 330.15 http://doi.org/10.21440/2307-2091-2024-1-137-146

Решение проблемы отходов с позиции концептуальных положений по использованию природных ресурсов

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Аннотация

Актуальность. Добыча полезных ископаемых во всех случаях сопровождается образованием отходов – техногенных минеральных образований (ТМО), и их объем тем больше, чем более высокими темпами увеличиваются масштабы горнодобывающего производства. В этих условиях возрастает значимость проблемы обращения с отходами, необходимость установления тенденций в ее развитии.

Цель исследования – оценка современного состояния в области обращения с ТМО и выявление тенденций в осуществлении этой деятельности.

Методы исследования – системный подход, методы аналогий, сравнения, логический анализ.

Результаты. Подтверждены возрастающая значимость ТМО, минерально-сырьевой и экологический аспект последних. Проанализированы изменения в обращении с отходами во взаимосвязи с концептуальными положениями, касающимися использования природных ресурсов. Анализом охвачены: концепция рационального и комплексного использования природных ресурсов, концепции экоразвития, безотходного производства, устойчивого развития, концепция чистого производства, циркулярной экономики. Выявлено возрастание внимания к проблеме отходов, которые из объектов, сопутствующих минеральным ресурсам, превращаются постепенно в объекты приоритетной значимости. Данная тенденция подтверждается изменениями в концептуальных положениях, сменяющих друг друга в историческом аспекте, ролью техногенных месторождений в расширении минерально-сырьевой базы, а также возможностью улучшения экологической ситуации за счет ликвидации ТМО при их использовании.

Заключение. Учет выявленных изменений в обращении с ТМО при формировании минерально-сырьевой базы страны, региона позволяет повысить достоверность прогноза геологоразведочных работ, в том числе геологического изучения ТМО.

***Ключевые слова*:** концепции, временной аспект, природные ресурсы, техногенные минеральные образования, приоритеты.

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Статья поступила в редакцию 10 января 2024 года