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### **Greening of innovation-technological development of Kazakhstani mining-metallurgical complex**

#### **Abstract**

**Object:** the aim is to justify and determine the algorithm of actions of greening the production processes of MMC of Kazakhstan as an effective mechanism of technological development and modernization of the industry.

**Methods:** the method of system analysis, the method of secondary information collection, the method of goal structuring were used during the study.

**Results:** comprehensive analysis on formation, accumulation and use directions of man-made mineral formations was given, the main problems of use of man-made mineral formations were identified, the main steps to determine the direction of greening of production processes in the mining-metallurgical industry were determined.

**Conclusions:** a common problem for the entire industry of the mining-metallurgical complex of the republic is the lack of a system for the regular collection and analysis of information on man-made sources of mineral raw materials. Only an approximate quantification of their levels of education can be made in the present. The study of man-made mineral formations will greatly help to create a monitoring system and a database of man-made mineral formations.

In order to green the MMC comprehensive geological and technological studies of man-made deposits (mine dumps, tailings of processing plants, slag of metallurgical plants, etc.) should be carried out with an assessment of the quality of useful man-made mineral forms, the extraction of ores that are profitable for mining, and the contouring of productive deposits.

**Keywords:** mining-metallurgical complex, technogenic mineral formations, greening, rational use of mineral resources, technological policy, environmentally safe production.

#### **Introduction**

An extensive resource base, represented by a large number of explored and potential reserves for such types of raw materials as manganese, copper, lead-zinc and iron ores, a number of key mining and metallurgical plants with an established material and technical base, and qualified workforce, are prerequisites for deepening the technological specialization of the mining industry in a number of regions of Kazakhstan, such as Kostanay, Karaganda, Pavlodar, East Kazakhstan, Aktobe regions.

One of the new approaches to the technological development of the mining-metallurgical complex is the greening of production processes and the processing of technogenic mineral formations. At present, the reserves of technogenic mineral formations are constantly reproduced in an expanded form and become comparable with the reserves of the minerals themselves.

Considering the fact that in the Republic of Kazakhstan, the problem of increasing waste from the mining and metallurgical complex is aggravated, the topic of this study is novel, since there are still not fully developed issues related to the state mechanism of control over the formation and use of technogenic mineral

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formations, the lack of interest of subsoil users in the rationality and complexity of mining operations, the aggravation of environmental problems in the republic.

### ***Literature Review***

The most relevant studies on the problems of rational use of secondary resources in developed countries over the past 10 years are:

- methodological developments of the leading international company ICF International in the field of environmental assessments, the establishment of management systems for the protection of ecological systems, the creation of technological, regulatory and financial conditions for the implementation of measures for the rational use of natural resources;
- adaptation of the «Best Available Techniques» (BAT), introduced by the EU Directive «On Integrated Pollution Prevention and Control» in the selection of production technologies;
- the concept of energy utilization of municipal solid waste (Waste-to-Energy), production of secondary fuel RDF (refused derived fuel) from non-recyclable waste (EU countries, USA, Canada);
- providing objective information support in the field of energy conservation, environmental protection, alternative energy sources of the information agency «Energy Safe»;
- methodological approaches to recycling waste of the German company TITECH GmbH;
- scientific developments of the Severtsov Institute of Ecology and Evolution of the Russian Academy of Sciences on innovative technologies for obtaining products from waste;
- Outotec's methodological approaches to energy saving, saving natural resources and capital investments in metallurgy technological processes. According to OECD definitions, about 70 % of Outotec's technologies can be classified as environmentally friendly goods and services (Berger G. et al., 2001, Glotov V.V., Postnikova O.V., 2015, Jakob M., Edenhofer O., 2014).

At present, in Western countries, a technology that has not passed the examination for compliance with the criteria of «environmentally friendly production» no longer has prospects in the future. When licensing, experts compare the technology proposed for use in production with «Best available technology» (BAT), as well as «Best possible technology» (BPT).

In relation to the mining and metallurgical industry, the rational use of mineral resources is substantiated in domestic and foreign economic literature. Rational use of mineral resources is determined by the completeness of extraction of minerals from the subsoil during mining, as well as useful components during technological redistribution, characterized by the following indicators:

- percentage of extraction of minerals from the subsoil during mining;
- the percentage of extraction of useful components from the extracted mineral raw materials during enrichment;
- percentage of extraction of useful components from ore raw materials during technological conversion;
- percentage of use of production waste (overburden, slags from beneficiation and metallurgical slags.) (Ivantera V.V., 2017, Kovalev Yu.Yu., 2016).

The emergence of new technologies in the extraction of mineral resources predetermines the growth of interest of subsoil users in technogenic mineral formations (Byun, J., Sung, T.-E., & Park, H.-W., 2017, Leheza Y., Surilova O., 2019).

Environmentally oriented scientific and technological progress is capable of if not completely avoiding anthropogenic load, then, in any case, limiting its harmful effect on nature as much as possible. During this period, as well as today, scientific and technological progress directly determines the economic and social development of society, is a decisive factor in its renewal. Technique, technology, in essence, are identified with socio-economic structures. The theories of industrial, postindustrial, superindustrial, technotronic, informational societies, etc. were created on the principle of technological determinism.

The priority goals of the economy greening and environmental policy of the enterprise at this stage were to reduce the man-made load, preserve the potential of natural resources based on maintaining natural processes in nature and the development of self-recovery processes, the use of mineral extraction technologies that allow using the latter as efficiently as possible, the introduction of waste-free technologies and waste processing technologies, as well as reduction of losses.

According to the definition of the EU Commission, «waste-free technology (clean technology) implies the use of such a method of production that allows the most efficient use of energy and raw materials, the

key elements of which are to reduce the volume of pollution released into the environment and waste generated during the production and use of finished products». (Măgureanu A.F., 2014, Uzarowicz Ł. et al., 2018).

The definition of a waste-free production technology has some limitations. Its essence lies in the fact that this is a theoretical model of ideal production, and it is practically impossible to implement it in reality, it can be realized only partially. Therefore, such a concept as low-waste technology arose, suggesting that with the advancement of scientific-technical ideas, this technology will be brought to a perfect model. Therefore, it is not possible to exclude waste and their impact on the environment. Thus, such systems should be classified as low-waste, allowing not to disturb the balance in the ecological situation in the region and to strengthen the self-cleaning properties of the ecosystem.

Extraction of minerals production and optimal consumption of wood, building materials, metals are precisely those sectors of the national economy in which technologies of waste-free and low-waste production should be implemented as a priority.

In this case, it is necessary to comply with a number of conditions (Kabdybay A.K. et al., 2020):

- reduce the list of constituent parts of any raw material that are classified as waste, since there are no technologies for extracting and processing the areas of application of these raw materials components;
- when implementing projects it is necessary to take into account the peculiarities of the environmental situation as much as possible, without violating its internal balance (transfer of fertile lands or suitable for other purposes for waste disposal, emissions into water bodies, soil, atmosphere);
- inclusion of resources that were not used in the past in the economic process;
- the introduction of at least one newest operation into the technological process requires the modernization of the entire technological system of production;
- improvement of working conditions by reducing the elements of production associated with the release of dust and harmful gases;
- exclusion of toxic components, such as catalysts and intermediate production products.

The problem of the rational use of secondary resources and the greening technologies are at the intersection of industries, therefore, to solve it, it is necessary to involve specialists from different industries and make inter-industry decisions.

### **Methods**

Taking into account the constant growth of varieties of technogenic mineral formations, a wide range of conditions for their occurrence and further storage in order to increase the rationality and efficiency of use, it is necessary to solve the following tasks:

- systematization of technogenic mineral formations by types, development of their classification;
- research and disclosure of the peculiarities of their appearance;
- development of a methodology for geological and technological research of technogenic raw materials and methods of accelerated assessment;
- assessment of technogenic mineral formations;
- study of the possibility of extracting minerals from the tailings of concentration plants (Leheza Y., Surilova O., 2019, Petlovanyi M. et al., 2019, Pugachev A.V., 2014, Mel'nikov N.N., Busyrev V.M., Churkin O.Ye., 2018).

Obviously, the role of technological research in assessing technogenic mineral formations is very high. It is necessary to carry out extended technological surveys at the initial stages of geological assessment, namely, during the revision and appraisal work, in order to determine the entire range of assessment parameters and make the choice of technical means of exploration. When choosing methods of geological and technological assessment and technical means of exploration, it is necessary to take into account the probable method of mining technogenic raw materials.

### **Results**

A huge number of technogenic mineral formations of mining enterprises have been accumulated on the territory of the republic. Taking into account the places of storage and, accordingly, the possibility of use, the classification of technogenic mineral formations should be considered in the following form:

- technogenic mineral formations of the mining industry;
- technogenic mineral formations of concentration production;
- technogenic mineral formations of metallurgical production.

As can be seen from the data in Table 1, the volume of hazardous waste generation in dynamics since 2016 growing in 2019 amounted to 180.5 million tons. This determined the growth of waste generation per capita from 8.5 in 2016 up to 9.7 tons per capita in 2019.

Table 1 — Dynamics of hazardous waste generation in the Republic of Kazakhstan

	2015	2016	2017	2018	2019
Hazardous waste generation, thousand tons	251 565,6	151 390,1	126 874,6	149 962,4	180 506,7
Including hazard levels					
«red»	2,2	8,4	1,7	2,1	1,9
«amber»	72 996,5	19 231,1	4 108,8	4 129,1	4 165,3
«green»	178 566,9	132 150,5	122 764,1	145 831,2	176 339,5
Recycling, recycling of hazardous waste (including incineration), thousand tons	74 553,4	33 657,8	190 785,6	29 992,8	36 645,3
The share of recycling, recycling of hazardous waste,%	29,6	22,2	150,4	20,0	20,3
Hazardous waste generation per unit of GDP, kg / USD USA, in prices of 2015	2 587,5	1 539,9	1 239,4	1 407,6	1 621,3
Hazardous waste generation (all hazard levels) per capita, kg	14 340,1	8 507,9	7 033,8	8 205,2	9 749,9

Note: compiled by the author on the basis (Bureau of National statistics, 2021)

It should be emphasized that the share of processing in comparison with education is not high enough, at the end of 2019 it was 20.3 %. This figure is inferior to foreign achievements.

As can be seen from Figure 1, most of the hazardous waste is generated in the mining industry (73 %).

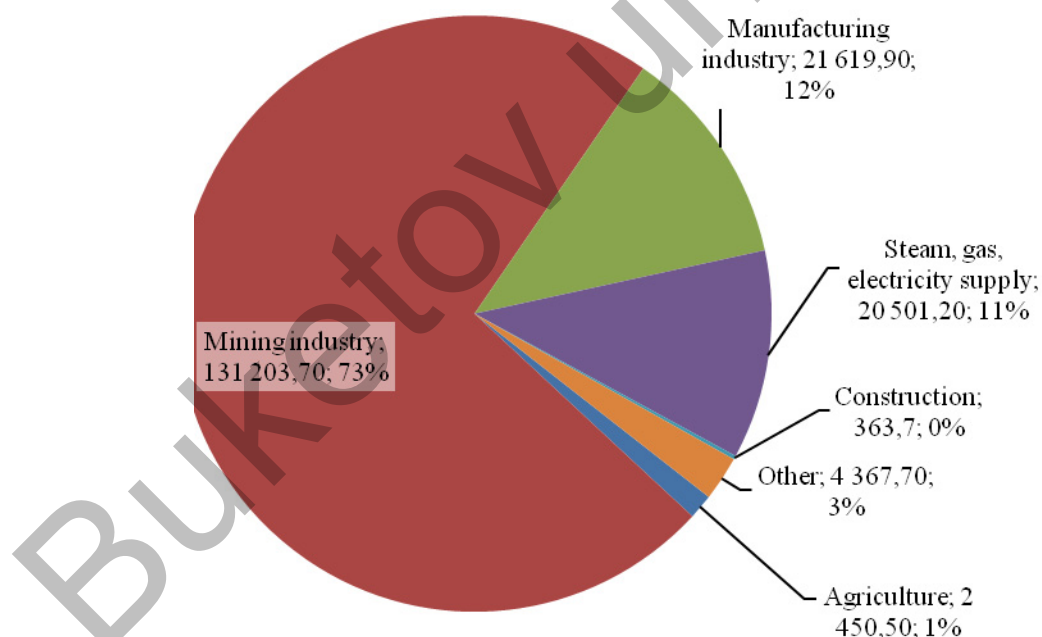


Figure 1. Generation of hazardous waste by economic activity

Note: compiled by the authors

Almost all of their volume is represented by toxic waste (99.9 %) located on the territory of industrial enterprises. They belong to waste of IV hazard class (metal slags and sludge). The III hazard class includes other wastes (wash water), which make up 60.2 % (55.3 thousand tons) of the generated waste. Taking into account that historically the accumulation of waste has continued since Soviet times, more than 2.6 billion tons of hazardous waste have already been accumulated on the territory of the country (Table 2). In general, there are 1406 technogenic deposits in the republic, with a total accumulation of 47.4 billion tons. At the

same time, according to the Deputy Executive Director of the Republican Association of Mining and Metallurgical Enterprises of Kazakhstan M. Kononov, waste processing for mining enterprises is not of economic interest (Kenzhaliyev B. K. et al., 2020; Zhalgassuly N. et al., 2020).

Table 2. Presence of hazardous waste at enterprises at the end of the year, thousand tons

	2015	2016	2017	2018	2019
The Republic of Kazakhstan	2 877 364,3	2 975 552,5	2 904 857,9	2 518 278,5	2 658 354,9
Kostanay	1 606 778,7	1 580 682,8	1 605 746,1	1 063 531,1	1 156 195,5
Karaganda	624 596,2	718 782,4	725 276,6	731 615,2	739 539,3
Pavlodar	209 542,5	226 094,6	451 261,8	585 630,4	608 570,9
Akmola	8 550,6	9 383,2	10 226,1	17 710,4	25 998,8
Aktobe	4 272,7	4 857,1	4 946,7	6 496,8	6 230,0
Almaty	3 598,9	4 058,0	4 503,2	5 027,4	5 573,7
Atyrau	29,1	86,8	179,5	425,8	658,8
West Kazakhstan	138,4	309,6	338,2	358,0	375,5
Zhambyl	6 862,6	8 325,3	12 025,1	12 429,9	12 673,7
Kyzylorda	8,0	19,3	61,9	205,8	942,7
Mangystau	527,1	268,8	187,3	216,0	203,8
Turkestan	430,4	1 126,4	1 159,0	784,0	1341,3
North Kazakhstan	34 889,5	34 717,7	35 811,9	36 988,2	38 397,6
East Kazakhstan	354 848,6	356 446,8	20 472,4	22 824,9	25 024,7
Nur-Sultan	22 288,3	24 603,3	25 932,9	27 503,2	29 092,2
Almaty city	2,7	5 790,4	6 729,2	6 082,6	7086,0
Shymkent	0,0	0,0	0,0	448,8	450,3

*Note: compiled by the author on the basis (Bureau of National statistics, 2021)*

If we consider the regional structure, then 3 regions (Kostanay, Karaganda, Pavlodar) account for about 90 % of all accumulated hazardous waste.

The main negative reasons for the storage of man-made mineral formations of the mining industry are as follows. First, at the enterprises, waste rock and off-balance ores containing valuable components are stored together, which subsequently leads to the loss of metal and causes unnecessary losses or costs.

Secondly, the specificity of mining operations with the formation of dumps of rocks from mining operations is mechanical crushing and removal of overburden and ore-containing rocks to dumps. At the same time, there is no change in the petrographic, mineralogical and chemical composition of the rocks. Therefore, the qualitative characteristics of the rocks of the dumps of associated mining production is determined by the composition of the primary rocks that make up the areas of mineral deposits.

Mineral processing tailings, occupying vast areas of land, cause significant harm to the natural environment. They intensively pollute soils and water bodies, and form dust storms near tailing dumps.

### **Discussions**

The specificity of the problem determines an individual approach to each of the technogenic mineral formations. The following suggestions are considered to be the main actions and measures for the greening of the technological development of the mining and metallurgical complex.

1. Modernization and transformation of production technologies and its equipment renewal, including:
  - transformation and/or improvement of the efficiency of existing technological regimes in order to reduce the sources of the formation of pollutants and sources of waste generation;
  - automation of technological processes and equipment modernization;
  - optimization of technological connections (equipment piping);
  - replacement of the usual reagents, materials and energy carriers; the use of waste from other industries as reagents;
  - introduction of new technology or technical update.
2. Implementation of production cycles according to the principle of a closed system:
  - processing of reagents, materials and raw materials;
  - introduction of an alternative water supply system (circulating, repeated);
  - renewal of the ventilation system of industrial premises
  - consumption of excess heat.

3. Efficient use of materials, raw materials and reagents, including:
  - analysis and assessment of the dynamics of consumption of types of raw materials, dividing into accounted and unaccounted losses;
  - application of resource-saving technologies;
  - reduction of accounted and unaccounted for losses of all types of raw materials, reagents and materials.
4. Efficient use of energy resources, including:
  - analysis and assessment of the dynamics of consumption of energy resources used, including both accounted and unaccounted losses;
  - identification of reserves of energy saving;
  - reduction of accounted and unaccounted losses of all types of energy resources.
5. Reducing the use of harmful, hazardous, poisonous materials and substances, including:
  - monitoring of the ecological situation with regard to raw and consumed materials;
  - removal of hazardous, harmful and toxic substances from industrial consumption or the search for alternative less hazardous ones;
  - reduction of consumption of hazardous and highly hazardous substances in raw materials and materials used in production.
6. Introduction of secondary raw materials and energy resources into production processes, including:
  - analysis and assessment of methods of using secondary raw materials and energy resources at the enterprise;
  - positive dynamics of growth in the use of secondary raw materials and energy resources as a percentage of the total volume consumed at the enterprise;
  - consumption of waste from the production of finished products and an increase in the percentage of use as secondary raw materials.
7. Complex consumption of energy resources and raw materials, including:
  - analysis and assessment of options, as well as alternative, complex consumption of raw materials and energy resources;
  - positive dynamics of growth of indicators of complex consumption of raw materials and materials;
  - extraction of secondary resources and additional products sent to the outside.
8. Streamlining the movement of pollutants, including:
  - reduction of the number of unorganized sources of the formation of pollutants;
  - division of organized flows of pollutants by concentration and target components;
  - separation of organized flows of pollutants to identify especially hazardous components in them.
9. Taking special measures to prevent the occurrence and progression of environmental emergencies and developing an algorithm for actions in such circumstances, including:
  - development and application of a sequence of preventive and corrective actions designed to reduce the risks of occurrence and development of environmental emergency situations;
  - regulatory and material support for personnel actions in emergency environmental situations, including the placement and disposal of waste generated during the elimination of the consequences of environmental emergencies;
  - fast and efficient response of personnel to the manifestation of environmental disasters within the framework of the developed regulations, including the placement and processing of man-made waste;
  - tightening control and preventive actions during unfavorable climatic conditions;
  - availability and use of specialized equipment and machinery to eliminate negative environmental consequences;
  - formation of plans of additional measures for damage assessment, mitigation and elimination of consequences.
10. Monitoring of sources of pollution and formation of man-made waste:
  - the use of modern means of monitoring the formation of man-made waste, their scale and volume of accumulation, as well as the sources of pollution;
  - the use of additional monitoring tools on technologies for the utilization and processing of technogenic formations.

The described measures and the algorithm of actions should be applicable, first of all, in relations between quarries and processing plants, where a significant amount of industrial waste has already been accumulated. In this case, the following can act as objects of analysis and control:

- hazardous waste, the handling of which is regulated by regulatory documents;
- wastes with problems associated with their processing;
- wastes characterized by high costs for their cleaning, processing and disposal;
- loss of raw materials, material resources during storage in a warehouse, during transportation in the technological chain, etc.

The sequence, priority and optimality of actions is determined individually in relation to each technogenic mineral formation and may include measures in the following areas:

- minimizing the reduction of sources or completely eliminating sources of pollution;
- processing of man-made waste or transfer of waste for disposal and neutralization;
- sorting and separation of man-made flows, formation and transportation of waste to appropriate landfills.

Thus, the project for the greening of processes in mining and processing industries includes, in addition to the main production process, a number of auxiliary production processes aimed at minimizing and eliminating anthropogenic impact on nature throughout the entire life cycle of the enterprise.

The choice and assessment of methods for greening production include a number of organizational, technological operations, taking into account the economic and environmental effects. It should be remembered that a gradual, economically profitable transformation of production is advisable, implying the initial implementation of low-cost actions and measures, mainly of an organizational nature, and only then medium- and large-cost investment projects related to the improvement of production processes and technologies.

### **Conclusions**

A common problem for the entire industry of the mining and metallurgical complex of the republic is the lack of a system for the regular collection and analysis of information on man-made sources of mineral raw materials. In the present, one can only make an approximate quantitative estimate of their education volumes. The study of technogenic mineral formations will largely help to create a monitoring system and a database of technogenic mineral formations.

For the purpose of greening the mining and metallurgical complex, it is necessary to carry out comprehensive geological and technological studies of technogenic deposits (dumps of mine workings, tailings of concentrating plants, slags of metallurgical plants, etc.) with an assessment of the quality of useful technogenic mineral forms, allocation of profitable ores for mining, and delineation of productive deposits.

The number of formed technogenic mineral formations should be reduced:

- in the mining industry through the use of secondary raw materials and man-made deposits of minerals in metallurgy, as well as the development of alternative energy sources, which can lead to a reduction in the production of solid fossil fuels;
- in ferrous metallurgy through the introduction of the most modern technologies aimed at improving the quality of steel, reducing its losses during casting, rolling, etc., as well as focused on energy saving;
- in non-ferrous metallurgy through to the widest possible production of secondary metals.

In these conditions it is extremely important to define the institutional environment for the revitalization of environmental entrepreneurship. The key to effective implementation of the principles of sustainable development in this system is government authorities and an enterprise that implements environmental management and, on this basis, environmental marketing.

### **Complementary Data**

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**А.Қ. Қабдыбай, Н.Д. Кенжебеков, Д.Н. Улыбышев, Е.Б. Жайлауов**

### **Қазақстанның тау-кен металлургия кешенін инновациялық-технологиялық дамытуды экологияландыру**

#### **Аңдатпа**

**Мақсаты:** Саланы технологиялық дамыту мен жаңғыртудың пәрменді тетігі ретінде Қазақстанның ТМК өндірістік процестерін экологияландыру іс-қимылдарының алгоритмін негіздеу және айқындау болып табылады.

**Әдісі:** Зерттеу барысында жүйелік талдау әдісі, қайталама ақпаратты жинау әдісі, мақсаттарды құрылымдау әдісі қолданылды.

**Нәтижелері:** Техногендік минералдық түзілімдерді қалыптастыру, жинақтау және пайдалану бағыттары бойынша кешенді талдау жасалды, техногендік минералдық түзілімдерді пайдаланудың негізгі проблемалары анықталды, тау-кен металлургия саласындағы өндірістік процестерді экологияландыру бағыттарын айқындау жөніндегі негізгі қадамдар айқындалды.

**Қорытындылар:** Республиканың тау-кен металлургия кешенінің барлық саласы үшін минералдық шикізаттың техногендік көздері туралы ақпаратты тұрақты жинау және талдау жүйесінің болмауы ортақ проблема болып табылады. Қазіргі уақытта олардың түзілімдерінің көлеміне шамамен сандық бағалауды жасауға болады. Техногендік минералдық түзілімдерді зерттеу көп жағдайда мониторинг жүйесін және техногендік минералдық түзілімдердің деректер базасын құруға көмектеседі.

ТМК-ны экологияландыру мақсатында пайдалы техногендік минералдық нысандардың сапасын бағалап, кендерді өңдеу үшін рентабельді кендерді бөле отырып, өнімнің шоғырларын контурлап, техногендік кен орындарына (тау-кен қазбаларының үйінділері, байыту фабрикаларының қалдықтары, металлургия зауыттарының шлактары және т.б.) кешенді геологиялық-технологиялық зерттеулер жүргізу қажет.

**Кілт сөздер:** тау-кен металлургия кешені, техногендік минералдық түзілімдер, экологияландыру, минералдық-шикізат ресурстарын ұтымды пайдалану, технологиялық саясат, экологиялық қауіпсіз өндіріс.

**А.К. Кабдыбай, Н.Д. Кенжебеков, Д.Н. Улыбышев, Е.Б. Жайлауов**

**Экологизация инновационно-технологического  
развития горно-металлургического комплекса Казахстана**

**Аннотация**

**Цель:** Обоснование и определение алгоритма действий экологизации производственных процессов ГМК Казахстана как действенного механизма технологического развития и модернизации отрасли.

**Методы:** При проведении исследования использованы методы системного анализа, сбора вторичной информации и структуризации целей.

**Результаты:** Дан комплексный анализ по образованию, накоплению и направлениям использования техногенных минеральных образований, выявлены основные проблемы использования техногенных минеральных образований, определены основные шаги по направлениям экологизации производственных процессов в горно-металлургической отрасли.

**Выводы:** Общей проблемой для всей отрасли горно-металлургического комплекса республики является отсутствие системы регулярного сбора и анализа информации о техногенных источниках минерального сырья. В настоящее время можно сделать лишь приблизительную количественную оценку их объемов образования. Изучение техногенных минеральных образований во многом поможет создать систему мониторинга и базу данных техногенных минеральных образований. В целях экологизации ГМК следует провести комплексные геолого-технологические исследования техногенных месторождений (отвалы горных выработок, хвосты обоганительных фабрик, шлаки металлургических заводов и т.п.) с оценкой качества полезных техногенных минеральных форм, выделением рентабельных для отработки руд, оконтуриванием продуктивных залежей.

**Ключевые слова:** горно-металлургический комплекс, техногенные минеральные образования, экологизация, рациональное использование минерально-сырьевых ресурсов, технологическая политика, экологически безопасное производство.

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