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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy
(Doctor of Science)

TECHNOLOGICAL AND ECOLOGICAL EVALUATION OF MINING INDUSTRY WASTES

Specialty: 3312.01 – “Materials Technology”

Field of Science: Technical Sciences

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BAKU – 2025

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İmza təsdiq edirəm
“Azərbaycan Texniki Universiteti” Publik Hüquqi Şəxsin Elmi Katibi
t.e.n. Dzayeva V.M.

GENERAL CHARACTERISTICS OF THE WORK

Relevance of the topic and degree of development. A fairly powerful metallurgical and mining complex operates in the Republic of Azerbaijan. According to approximate data, more than 1.5 million tons of steel are currently produced in the country. An important element of the metallurgical complex is the mining industry. Ore extraction is the beginning or raw material base of metallurgical production.

Enrichment of mineral raw materials and metallurgical processes are accompanied by the formation of a huge amount of technogenic waste. Currently, only a certain part of all mineral resources extracted in the world is used as a useful product, the rest is disposed of as waste in a changed form and does not find any application.

The world's production of mineral raw materials currently amounts to almost 80-100 billion tons per year, and the area of lands remaining under waste landfills and withdrawn from economic turnover is 10 million hectares. For many years, waste from mining, metallurgy, petrochemical and energy industries of various origins has been dumped in landfills.

Billions of tons of waste from mining alone have already been collected in the world. They can be recycled and used as non-ore raw materials in a number of industries, for example, in metallurgy or the production of construction materials.

Another important source of recycled raw materials is ash and tailings from the energy complex. Currently, more than 1.2 billion tons of this technogenic raw material have been accumulated in landfills. Due to their properties, these wastes can be used as recycled raw materials in construction materials and products, as well as in metallurgy, mechanical engineering and other industries.

Currently, only 10% of tailings and ash, 4% of enrichment waste, 20% of metallurgical tailings, and only up to 2% of mining complex waste are used in various industries.

Millions of tons of various wastes are generated in Azerbaijan every year, about 10% of which is used, and almost 100,000 hectares of agricultural land remain under landfills. More than 10 million tons of solid waste have been polluting the environment for many years by remaining in landfills.

A significant part of solid waste belongs to the mining, energy and metallurgical industrial complex. According to preliminary estimates, at least 10,000 tons of mining waste are generated in the country annually, while the share of used waste is only 5-8%.

True, in 2010-2024, waste utilization increased by almost 10%, but this indicator is small even compared to the former USSR, when this indicator was 29 %. Compared to world experience, this is a significantly lower indicator. In Western Europe (France, Germany, Italy, England) this indicator is 58 %, in North America (USA, Canada) 63 %, in Japan 87 %, and in China 40%.

The reuse of technogenic waste from mining, metallurgical, energy and other industries is a serious problem not only for Azerbaijan, but also for any country pursuing economic development. Experience shows that it is in these areas that a large amount of waste is generated and they are a source of serious environmental danger. Suffice it to say that the amount of mineral technogenic waste of “Dashkasan Filizsaflashdirma” OJSC exceeds 90 million. tons.

The problem is also relevant because recently a great revival has been observed in the non-oil sector of industry in the country. New industrial enterprises are being launched and their production capacity is constantly increasing. Modern equipment and technologies open up new opportunities for more efficient and ecologically rational use of recycled resources and production waste.

Thus, the mastering of product production in relevant areas from technogenic waste of the mining industry can be assessed as an important scientific and technical problem of materials technology.

The purpose of the study is to determine the possibilities of producing environmentally safe materials and products for various purposes from mining industry waste on the basis of effective technical and technological developments.

This goal is aimed at reducing the technogenic impact on the environment and ensuring the efficient use of recycled resources based on complex studies of the composition and properties of mining waste and involves solving the following scientific and practical problems:

- Analysis of the current state of the Azerbaijani mining industry and Dashkesan Filizsaflashdirma OJSC, conducting a literature review on the technological and ecological aspects of the use of mineral raw materials and technogenic waste;
- Selection and justification of research methods for the composition, structure and physicochemical properties of technogenic mineral waste;
- Study of the chemical and mineral composition, granularity and phase composition, radioactivity characteristics and microelement composition of mining and metallurgical waste;
- Thermodynamic, technological and ecological assessment of technogenic waste and study of changes in physicochemical properties;
- study of the energy consumption of mining waste recycling processes;
- putting forward proposals and recommendations on the application of the main scientific and experimental results obtained in the production of construction materials and products.

The hypothesis of this work is that, based on effective technical and technological developments, mining and metallurgical waste can be used as recycled raw materials in the production of various materials and products.

The main provisions put forward for defense:

• chemical and mineral composition, granularity and phase composition, radioactivity characteristics and microelement composition of mining and metallurgical waste;

• assessment of the thermodynamic, technological and ecological aspects of technogenic waste and the variability of physicochemical properties;

• justification of the energy consumption of mining industry waste recycling processes as a synergetic indicator;

• scientifically substantiated practical proposals on the use of mining and metallurgical wastes as raw materials.

Scientific novelty of the research:

• the use of mathematical models to describe the distribution of physicochemical and technological properties of technogenic wastes is substantiated;

• the thermodynamic parameters of chemical reactions in the targeted synthesis of wastes are calculated and the conditions for dispersion of wastes are determined;

• energy capacity is substantiated as a synergetic technological and ecological indicator characterizing waste recycling processes.

The object of the research is the composition, properties of wastes of the mining and metallurgical industry of our country and the mutual relationships between them.

The subject of the research is the technological processes of production of various products that ensure rational efficiency and environmental safety of wastes.

Research methods and tools. General scientific theoretical and experimental research methods were used in the research. General scientific methods such as analysis and synthesis, induction and deduction, and special methods, such as modern physicochemical research methods of structure and properties, were used.

To study the mineral composition and physicochemical properties of waste, detailed studies were conducted at the Analytical Center of the Institute of Geology and Geophysics of ANAS. The studies were carried out using modern equipment and methods in accordance with international standards.

The accuracy of the results is confirmed by the justified use of modern methods and tools of materials technology. The adequacy of the models developed on the basis of laboratory experiments indicates the correctness of the results. The results of experimental tests confirm the correctness of the proposed technical solutions.

The practical significance of the work consists in the development of justified proposals and recommendations that ensure the efficient use of technogenic waste and recycled resources. Rational technological developments on the application of mining and metallurgical waste as raw materials for construction materials are aimed at the efficient use of recycled resources and reducing the harmful impact on the environment.

The information sources of the study are theoretical-methodological and technological foundations of materials, metallurgy, recycling and ecological technologies. Monographs and articles in relevant fields, as well as materials published in periodical scientific and technical publications were used.

The theoretical-methodological basis of the study is the theory and practice of materials technology, metallurgy and materials science, recycling and ecological technologies, theoretical and technological provisions.

Application of the results of the work. Rational technological processes for the efficient use of technogenic waste were proposed in the conditions of Dashkesan Filizsaflashdirma OJSC, Baku Steel Company LLC and Baku Electric Casting OJSC. Some of the results of the research were recommended for application in the production of construction materials at "AZER KMI" LLC. Theoretical-methodological provisions on waste recycling can be used in the educational process for the specialty of Materials Engineering at AzTU.

Approbation of the results of the work. The main content of the dissertation work was discussed and approved at the following international and republican conferences and seminars:

International scientific-technical and scientific-practical conferences:

1. Azərbaycan xalqının Ümummilli lideri H.Əliyevin anadan olmasının 93 illiyinə həsr olunmuş Gənc tədqiqatçıların IV Beynəl-xalq elmi konfransı, – Bakı: Qafqaz Universiteti, – 5-7 may, – 2016
2. Metallurgiya və metalşünaslığın problemləri mövzusunda 2-ci Beynəlxalq elmi-texniki konfrans, – Bakı: AzTU, – 28-30 noyabr, – 2017
3. Professor B.S.Sərdarovun xatirəsinə həsr olunmuş "Inşaat materiallarının istehsal sahələrinin aktual problemləri və həlli yolları" mövzusunda Beynəlxalq elmi konfrans, – Bakı: AzMİU, – 26-27 noyabr, – 2018

4.“Ölçmə və keyfiyyət: problemlər, perspektivlər” mövzusunda Beynəlxalq elmi-texniki konfrans, – Bakı: AzTU, – 10-12 noyabr, – 2018.

5.“Su nəqliyyatının problemləri” mövzusunda XIV Beynəlxalq elmi-texniki konfrans, – Bakı: ADDA, – 15-18 may, – 2019

6. Материалы VI Международной конференции “Актуальные проблеми розвитку свитовой науки”, – Киев: – 20-22 февраля, – 2020

7.“İnşaatın müasir problemləri” mövzusunda Azərbaycan Memarlıq və İnşaat Universiteti İnşaat fakultəsinin 100 illiyinə həsr olunmuş Beynəlxalq elmi-praktiki konfrans, – Bakı: AzMİU, – 20-23 fevral, – 2020

8.Международная научно-практическая конференция “Development of Education, Science and Business: Results”, – Дніпро (Украина): – 25-28 май, – 2020

9.Международная научно-практическая конференция «Машины, агрегаты и процессы. проектирование, создание и модернизация». Санкт-Петербург, - 28 январь, - 2025

Republican scientific and technical conferences:

10.Doktorantların və gənc tədqiqatçıların XX Respublika elmi konfransının materialları, – Bakı: ADNSU, – 23-25 noyabr, 2016.

11.Azərbaycan xalqının Ümummilli lideri H.Əliyevin anadan olmasının 94-cü ildönümunə həsr olunmuş Respublika elmi-texniki konfransı, – Bakı: AzTU, – 3-5 may, – 2017.

12.“Təhsil-tədqiqat-istehsalat mexanizminin qurulması” mövzusunda Respublika elmi-texniki konfransı, – Bakı: AzTU, – 4-5 aprel, – 2018

13.“Tikinti istehsalatında texnoloji maşınların istifadəsinin müasir problemləri” mövzusunda Respublika elmi-praktiki konfransı, – Bakı: AzMİU, – 18-20 may, – 2019

14.Scientific seminars of the "Metallurgy and Materials Technology" department of AzTU, 2018-2024.

The total volume of the dissertation with the indication of the volume of the structural sections of the dissertation separately. The dissertation consists of an introduction, 5 chapters, 167 pages of computer text, 46 figures, 26 graphs, 39 tables, a list of

117 references and an appendix. Cover (514 characters) and table of contents (2686 characters), introduction (12273 characters), Chapter I (57330 characters), Chapter II (21977 characters), Chapter III (50268 characters), Chapter IV (36124 characters), Chapter V (13989 characters), conclusion (3503 characters) and a list of used literature. The volume of the dissertation consists of 198667 characters, excluding figures, tables, graphs and a list of literature.

Publication rate. The main content of the dissertation has been published in 24 scientific articles and conference proceedings, 6 of which are abroad.

MAIN CONTENT OF THE WORK

The introduction substantiates the relevance of the topic, identifies the purpose of the research and the issues to be solved. The scientific novelty and practical significance of the work are formulated, the research methods used, the object and subject of the research are indicated.

The first chapter provides a general characteristic of the mining and metallurgical industry of Azerbaijan and a literature review on the technological and ecological aspects of the use of mineral raw materials and technogenic wastes is conducted.

The conducted literature review confirmed that the vast majority of mining and metallurgical industry wastes have the potential to be used in various fields, and on a larger scale in the production of construction materials as non-metallic raw materials.

It is shown that a systematic analysis of the processes of environmentally safe production of mining and metallurgical wastes can play a decisive role in the use of natural resources. Technical and technological developments on the use of mining waste should be evaluated according to technological and ecological criteria [1][1].

It has been confirmed that mining and metallurgical wastes cause serious damage to the environment, creating a critical situation around waste landfills. Currently, the volume of accumulated waste

[1] Dağ-mədən sənayesi tullantıları ilə atmosferin çirklənməsinə dair bəzi məsələlər. Kərimova G.X.

is almost equal to the demand for mineral raw materials of the construction materials industry. However, the quality of only 5...10% of the waste as raw materials meets the current technological and ecological requirements.

It has been established that one of the significant differences of mining and metallurgical wastes from traditional mineral raw materials is the variability of their chemical and mineral composition, physicochemical and technological properties over time; the second difference is the presence of impurities, minerals and elements in the composition of the waste that are not characteristic of mineral raw materials.

It is substantiated that there is a great need to develop scientifically substantiated provisions on the efficient use of mining and metallurgical waste. New recommendations for relevant areas can be developed on the basis of technological developments to determine the efficient processing regimes of waste. It is necessary to improve and develop rational technologies for the use of mining and metallurgical waste in the production of construction materials.

It is shown that the solution of this fundamentally important issue creates the basis for solving technical, technological, economic and environmental issues that ensure the efficient use of mineral resources.

It is confirmed that the Dashkesan mineral processing complex can be considered as a technological cluster for the efficient recycling of the country's mineral raw materials. The developed industrial and transport infrastructure conditions the implementation of large-scale technological projects in this region and promises great technical, economic and environmental benefits [2][2].

The second chapter is devoted to the methods of research of the composition, structure and physicochemical properties of technogenic mineral wastes. Here, the characteristics of the methods and means of research of the physicochemical and technological properties of mineral technological wastes are explained. The current

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[2] Azərbaycanda sənaye əhəmiyyətli faydalı qazıntı yataqlarının ümumi xarakteristikası. Kərimova G.X.

state of the Dashkesan Ore Refining Open Joint Stock Company is analyzed [5][3].

In order to study the mineral composition and physicochemical properties of wastes, detailed research was conducted in 2016-2024 at the Analytical Center of the Institute of Geology and Geophysics of the Azerbaijan National Academy of Sciences. The research was carried out using modern equipment (Germany, Japan, Russia, etc.) and international standards and methods.

Waste from mining, metallurgy, energy and chemical technology enterprises was taken as research objects. Numerous analyzes of the chemical and mineralogical composition of mining waste, rock, ores, minerals and technological products obtained from them were carried out in the Analytical Center. Complex studies were carried out to determine the physicochemical properties of technogenic waste from ferrous and non-ferrous metallurgy production.

To determine the mineral composition of the samples, waste samples were ground in a Herzog model mill and placed in a special cuvette in a Miniflex 600 X-ray diffractometer. A few minutes after the start, the results of X-ray structural analysis were obtained on the computer connected to the device.

To determine the chemical composition, wax was added to the ground samples and pressed into tablets in a Herzog pressing device. The tablets were placed in the cuvette of the Universal S8 Tiger X-ray spectroscope and the results of chemical analysis were read on the computer screen within 8-12 min. [6][4].

Analytical studies covered the following materials: mountain rocks, silicates and carbonates; various materials obtained from waste; polymetallic and iron ores, production waste; technological products obtained from ores; natural, technical and groundwater, sediments, graphite, metallurgical tailings, TPP ashes and dry residues.

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[3] Dağ-mədən sənayesi tullantılarının emalı vəziyyəti. Kərimova G.X., İsmayılov N.Ş.

[4] Mineral və təkrar xammalın kompleks emalının texniki-iqtisadi və ekoloji aspektləri Kərimova G.X., İsmayılov N.Ş., Həmidova O.S.

Research methods include the following: sample reception and preparation for analysis; determination of moisture content; determination of mass losses at high temperatures; chemical, mineralogical and granulometric analyses.

To prevent element losses, samples were prepared for analysis in special analytical autoclaves - Sineo MBES-86 microwave ovens. Phase analysis of waste was carried out using the Miniflex 600 X-ray diffractometer using qualitative and quantitative phase analysis methods. In these devices, the degree of crystallinity of substances, crystallite sizes, distortions of the crystal lattice and parameters were clarified. The structure of materials was clarified and the molecular structure was determined by the Rietveld method. X-ray spectral analysis was carried out using the S8 Tiger device and according to the HCAM №439PC methodology.

The chemical, elemental and mineralogical compositions of samples taken from the studied Dashkesan Filizsaflashdirma OJSC and the alunite deposit were analyzed using appropriate methods and the results are shown in Table 1-3 and Figure 1-2.

Table 1

Chemical composition of test samples

S/s	Sample conventional name	Chemical composition, % by mass												
		Na_2O	**MgO**	**Al_2O_3**	**SiO_2**	**P_2O_5**	**SO_3**	**K_2O**	**CaO**	**TiO_2**	**MnO**	**Fe_2O_3**	**Cl-**	**YTİ**
1	Dashkesan – 1	1,13	3,06	9,64	32,47	0,09	0,18	0,83	18,39	0,46	0,704	30,70	0,04	2,17
2	Dashkesan– 2	0,44	2,59	8,20	30,82	0,14	0,22	0,54	23,41	0,38	0,724	29,36	0,01	2,96
3	Dashkesan – 3	1,47	3,67	10,84	42,10	0,14	0,63	1,00	16,45	0,45	0,490	18,13	0,03	4,36
4	Dashkesan – 4	2,35	3,83	11,74	45,40	0,23	0,26	0,99	15,91	0,62	0,443	13,53	0,05	4,50

Note: VOC – indicates the amount of volatile components at 950^0C.

Table 2

Elemental composition of test samples

S/s	Sample conventional name	Elemental composition, % by mass													
		Zn	**Ba**	**Cr**	**V**	**Sr**	**Cu**	**Zr**	**Ni**	**As**	**Rb**	**Co**	**Tb**	**Mo**	**Cd**
1	Dashkesan – 1	0,022	0,02	0,05	0,02	0,01	0,007	0,009	0,009	0,001	0,0024	0,0001	0,0002	0,0001	0,00005
2	Dashkesan – 2	0,041	0,02	0,03	0,03	0,01	0,092	0,008	0,004	0,014	0,0023	0,0001	0,0002	0,0001	0,00114
3	Dashkesan – 3	0,018	0,02	0,05	0,04	0,03	0,05	0,012	0,011	0,008	0,0025	0,0001	0,0001	0,0001	0,00019
4	Dashkesan – 4	0,023	0,03	0,06	0,02	0,03	0,011	0,011	0,008	0,003	0,0043	0,0001	0,0002	0,0060	0,00025

Table 3

Mineralogical composition of test samples

S/s	Sample Conventional name	Mineralogical composition, % by mass							
		SiO_2 (α-quavarts)	Alunite	Hematite	Kaolinite	Pyrope ($Mg_3Al_2(SiO_4)_3$)	Maqnetite (Fe_3O_4)	Albite	İllit
1	Daşkəsən – 1	7	-	-	15	38	32	8	-
2	Daşkəsən – 2	9	-	-	18	40	30	3	-
3	Daşkəsən – 3	15	-	-	22	32	19	12	-
4	Daşkəsən – 4	15	-	-	20	27	15	20	3

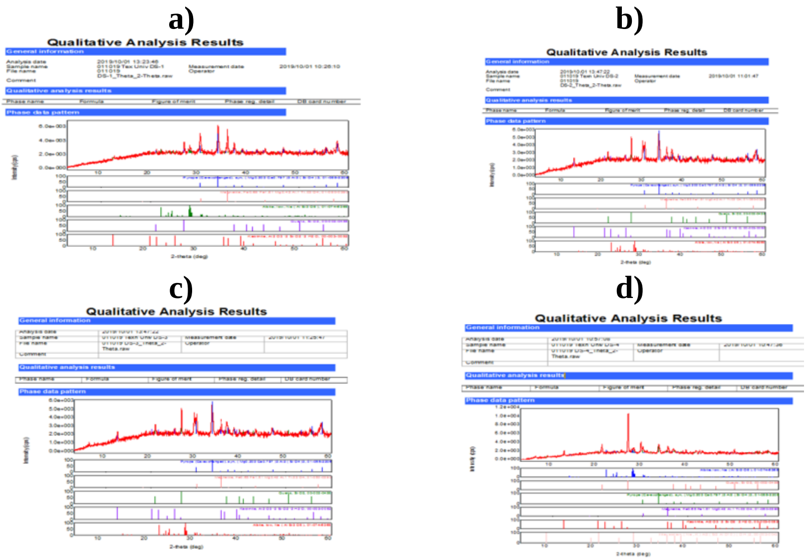

Figure 1. Diffractogram of samples obtained from Dashkesan Ore Refinery OJSC:
a)sample - 1, b) sample - 2, c) sample - 3; d) sample – 4

During the detailed studies of technogenic waste, the shape dimensions of grains and phases, the distribution of chemical elements, the phase composition of the samples, as well as chemical heterogeneity in the transparent section area were studied using a JEOL JSM 6610-LV scanning electron microscope [12][5].

[5] Texnogen tullantılardan səmərəli istifadənin normativ-hüquqi təminatı məsələləri. Kərimova G.X., İsmayılov N.Ş.

During the detailed studies of technogenic waste, the shape dimensions of grains and phases, the distribution of chemical elements, the phase composition of the samples, as well as chemical heterogeneity in the transparent section area were studied using a JEOL JSM 6610-LV scanning electron microscope [12][6].

During the studies, images were obtained in a wide range of magnification in the derivative and reflected electrons, quantitative X-ray microanalysis by selecting the studied area, point, area and line, as well as spectra with a given step. Synthesis of spectra of standard samples, comparison of current spectra with those in memory, distribution map of elements and phases and X-ray microanalysis by selecting an arbitrary point were performed [7][7].

The trace element composition of the waste was determined with high accuracy using an ICP-MS 7700E inductively coupled plasma mass spectrometer, as well as 200 series Atomic Absorption Agilent technology.

The third chapter is devoted to the study of the composition and physicochemical properties of technogenic wastes of the mining and metallurgical industry. The chemical, mineral, granulometric, wastes, as well as radioactivity characteristics, were determined. The structure of technogenic wastes was thermodynamically evaluated and the variability of physicochemical properties was studied [13][8].

It was determined that technological mineral wastes (TMT) formed after the extraction of iron ore concentrate by magnetic separation at the Dashkasan enrichment plant are transported to the Goshgarchay valley, where huge mountains have formed from the waste. More than 90 million tons of waste have been generated from ore refining processes that began in 1954.

Granular waste (crushed sand) obtained during the production of sawn and crushed products based on dense mountain rocks alone

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[6] Texnogen tullantılardan səmərəli istifadənin normativ-hüquqi təminatı məsələləri. Kərimova G.X., İsmayılov N.Ş.

[7] Dağ-mədən sənayesi tullantılarının təkrar emalının qiymətləndirilməsi. Kərimova G.X., İsmayılov N.Ş.

[8] Некоторые особенности технологических отходов Дашкесанских железных руд. Исмаилов Н.Ш., Керимова Г.Х.

amounts to 25 million tons. The size of 70...90% of the granulometric composition of such waste is less than 0.3 mm, which can be used as fine sand or mineral powders in the production of various construction materials and products [8][9].

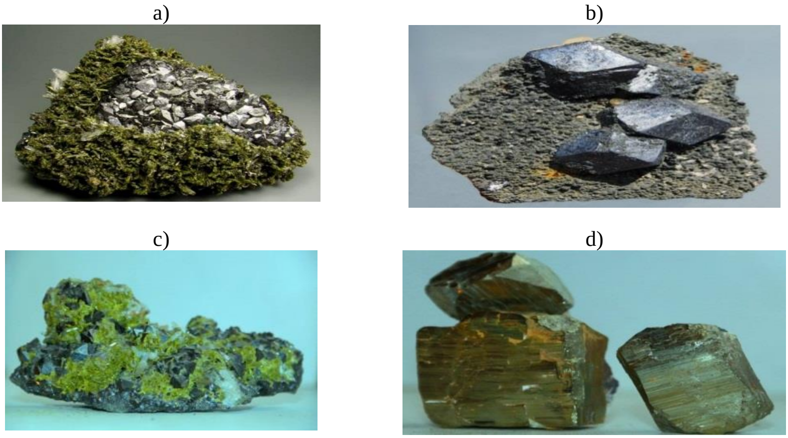

Figure 2. Minerals of an iron ore deposit and a cross-section of the deposit: a) crystalline magnetite (with epidote and quartz), b) magnetite crystals, c) magnetite, epidote and quartz, d) pyrite crystals

X-ray spectral and X-ray structural analysis of samples taken from the waste of the mining industry was performed and the corresponding diffractograms were obtained. The mineral composition of the samples of mining waste is given in Table 4. More than 10 minerals were found in the composition of TMT, with garnet, calcite, quartz, chlorite occupying the leading positions. A number of samples also contain magnetite, pyrite and plaxioglase, which indicates the rich mineral and element composition of the waste [9][10].

Mass spectrometric analysis was carried out and the microelement composition was determined. The microelement

[9] Dağ-mədən tullantılarının təkrar emalının bəzi cəhətləri. İsmayılov N.Ş., Kərimova G.X.
[10] Dağ-mədən sənayesinin tullantılarının tərkibi və xassələri. İsmayılov N.Ş., Kərimova G.X.

composition according to the results of mass spectrometric analysis revealed the following picture. It was determined by precise chemical analysis that out of 23 chemical elements that could be determined, only lithium, yttrium and rare earth elements amounted to 1 g/t.

Table 4

Mineralogical composition of mining waste

Sample №-si	Mineralogical composition, % by mass											
	Garnets	Calcites	Quartz	Chloride	Plaquioglase	Diopside	Magnetite	Pyrite	Botite	Goethite	Actionolite	Total
1	57.1	7.4	5.6	11.5	4.9	8.5	3.4	1.6	0	0	0	100
2	51.2	9.5	8.7	6.9	8.1	4.7	10.9	0	0	0	0	100
3	32.5	16.2	14.5	8.8	13.1	7.2	3.8	1.6	0.9	0	1.4	100
4												
5	52.2	7.2	8.3	6.5	5.1	6.1	6.9	3.0	0	4.7	0	100
6	39.0	14.3	10.3	8.9	12.0	5.3	8.3	1.9	0	0	0	100
7	34.3	17.6	10.0	10.3	12.8	10.5	4.0	0.5	0	0	0	100
8	30.0	24.7	9.9	17.6	6.8	6.8	1.8	2.4	0	0	0	100
9	33.3	18.1	10.5	11.0	13.8	10.0	2.1	1.2	0	0	0	100
10	40.6	13.2	12.2	7.1	11.5	9.6	4.4	1.4	0	0	0	100

The concentrations of chemical elements in monomineral fractions were determined by the mass spectrometric method. The results obtained indicate a sharply different content of elements in these minerals. Thus, high concentrations of rare earth and lithium are characteristic for sulfides, radioactive elements for calcites, and only lithium for magnetites [10][11].

Technogenic mineral wastes of the ore processing plant, as well as various samples of rocks taken from the deposit, were evaluated in terms of radiation hazard. It was determined that the radioactivity value is within 0.08-0.11 μEv/s, which is within the limits of the released norms and does not pose a radiation hazard. Thus, the radiation background of the wastes is low and they meet the requirements of industrial norms on radiation safety.

The fourth chapter is devoted to the study of thermodynamic, technological and environmental assessment of

[11] Daşkəsən filiz yataqlarının struktur-geoloji özəllikləri və faydalı qazıntılarının əsas növləri. Kərimova G.X.

mining and metallurgical waste, reduction of energy consumption of chemical synthesis and recycling processes.

It was determined that the metallurgical waste of Baku Steel Company is a highly dispersed secondary product similar to slag, and its chemical composition is SiO_2 – 28.6 %; Al_2O3 – 2.3 %; CaO – 59.96 %; MgO – 13.76 %; TiO_2 – 0.78 %; V_2O_5 – 0.3 %; FeO – 0.21 %; MnO – 0.09 %; P_2O_5 – 0.01 %.

The average chemical composition of waste generated in the ore refining process is SiO_2 – 53.7 – 83 %; Al_2O_3 – 9.6 – 16.4 %; Fe_2O_3–0.4 –5.0 % TiO_2 – 0.3 – 1.1 %; MgO – 0.15 – 0.25 %; CaO–0.3 –2.5 %; MnO_2–0.01–0.02 %; K_2O–0.2 – 0.8 %; P_2O_5 – 0.02 – 0.5%; pH varies within the range of 3-5 %.

The chemical composition of powder waste collected from metallurgical furnaces is SiO_2 – 9.9–13.7 %; Mn_3O_4 – 25.8 – 33.9 %; Fe_2O_3 – 5.86 – 14.7%; CaO – 8.15 – 9.5%; (Na_2O+K_2O) – 4.13 – 5.75%; S – 0.85 – 1.38%; Al_2O_3 – 2.85 – 2.90 %; FeO–2.15– 2.26%; P– 0.13 – 0.15%; C – 25–30%.

It was determined that the composition of mining and metallurgical waste is heterogeneous, but by implementing targeted synthesis of waste, enrichment, recycling or grinding of ore, it can be used as a valuable raw material in the production of various construction materials [3][12].

For this purpose, a sand-alkali mixture was prepared and solidified using synthesized technogenic waste in different proportions. The fine structure of the prepared samples was studied using an electron microscope (Fig. 3). It has been established that pores in waste act as gas exchange channels because their dimensions are approximately within the limits of the mean free path of molecules [16][13].

The principles and algorithms for constructing mathematical models have been developed to assess the usability of waste and ensure the efficiency of recycling processes. Mathematical models

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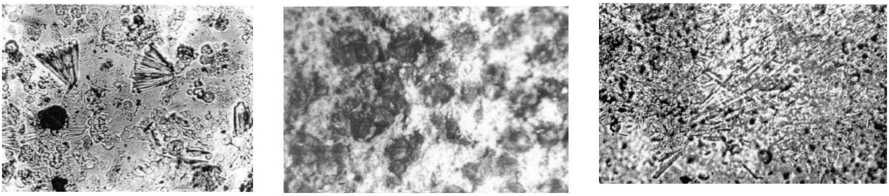
[12] Dağ-mədən sənayesi tullantılarının texnoloji və ekoloji qiymətləndirilməsi məsələsinə dair bəzi mülahizələr. Kərimova G.X.

[13] Dağ-mədən tullantıları emalının səmərəliliyinin bəzi mühüm cəhətləri. Kərimova G.X.

have shown that it is possible to rationally use waste as recycled raw materials. By changing the parameters of this model and conducting numerical calculation experiments on a computer, it is possible to control the nature of changes in the physicochemical properties of waste and the corresponding recycling processes [4][14].



pulp:alkaline= 90:10 (x10min) | pulp:alkaline = 88:12 (x10min) | pulp:alkaline = 88:12 (x20min)

Figure 3. Structure of silicate-alkaline stone

It is known that the waste of ore enrichment and metallurgical production of the mining industry mainly consists of solid waste. A structural diagram of the technological processes of waste recycling has been drawn up (Fig. 4).

The scheme shows that the processes of ore enrichment and metallurgical waste processing can be characterized by energy intensity. It was found that it is possible to save total energy consumption by spending part of this energy on the processing of technogenic waste [13][15].

The fifth chapter is devoted to the study of the possibility of using mining and metallurgical waste in the production of construction materials. Technological developments on the use of technogenic waste as raw materials for the production of various construction materials and products are described.

Initially, the possibility of using technogenic waste as raw materials in the production of sand-silicate bricks was studied. The

[14] Daşkəsən filiz yataqlarının işlənməsinin əsas xüsusiyyətləri. İsmayılov N.Ş., Kərimova G.X.

[15] Оценка технологических отходов обогашения Дашкесанских железных руд. Исмаилов Н.Ш., Алиев М.Х., Керимова Г.Х.

mixed pulp mortar: alkaline activator with a density of 1.5 g/cm^3: quicklime: crushed sand (waste) = (12-16) : 0.5 : (4-6) : remainder was prepared and processed [18][16].

A mixed composition was prepared based on liquid glass as an adhesive material for preparing a concrete mixture: heptane: pulp = (18-26) : (0.3-0.5) : remainder. The addition of heptane is intended to extend the setting time of the mixture. The possibility of obtaining concrete based on this type of adhesive material has been determined.

One of the areas of application of technogenic waste is the technology of obtaining heat-insulating materials. The proposed waste can be a source of raw materials for the preparation of such materials and products. It is proposed to prepare semi-cylindrical products for pipe insulation based on the obtained heat-insulating material.

It is proposed to prepare an acid-resistant composite material based on technogenic waste. This composite material can provide corrosion protection and can be applied in the construction of buildings and structures where chemicals are used.

Acid-resistant composite material is proposed based on the test results of experimental samples prepared on the basis of liquid glass, diabase slag and ore refining waste slag.

The advantage of the proposed composite material with this composition is related to the possibility of aesthetic design of the product (coatings) and improvement of working conditions (no exposure of workers to fluorine compounds).

It is proposed to use calcium sulfate slurry formed in the production of ferroalloys in the production of fiberglass coatings. According to the conducted research, hydrated calcium sulfate slurry contains 8% iron oxide, up to 5% other metal oxides and no more than 0.5% sulfuric acid. Currently, this waste from the ferroalloy plant is not used, pollutes the environment and requires additional costs for its storage.

[16] Optimization of technological processes of mineral waste processing Dashkesenskyh ores. Kerimova G.X.

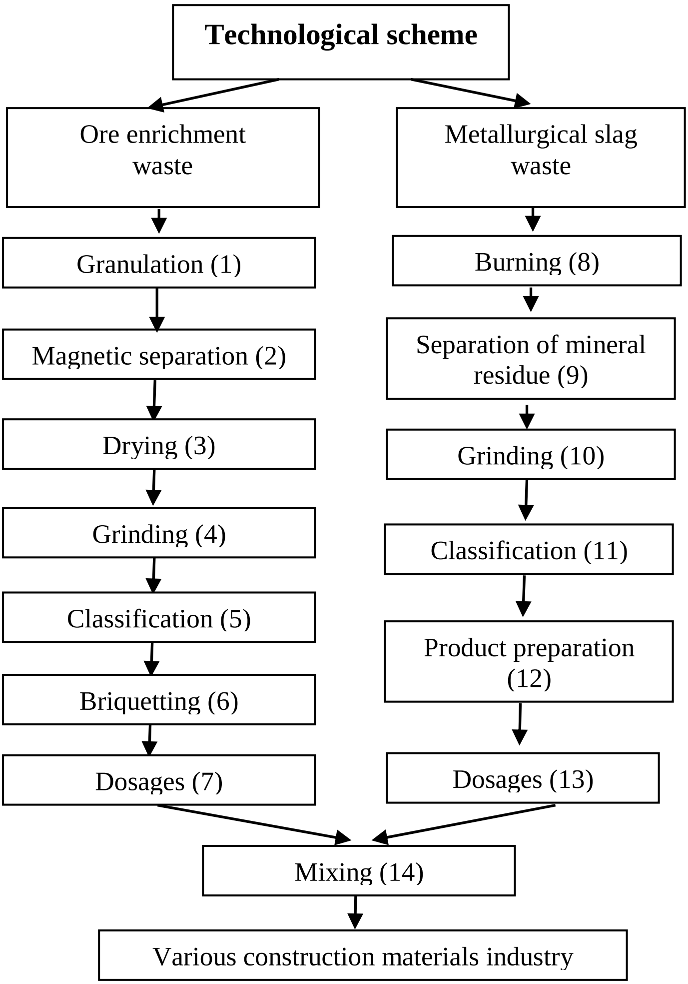


Figure 4. Technological scheme of ore enrichment and metallurgical tailings waste recycling

The test results showed that this proposed waste can be used in the production of fiberglass coatings. The durability of products made using this type of waste can be increased, its resistance to the atmosphere can be increased, and the technological and ecological efficiency of production can be increased.

It is proposed to prepare a plaster mixture using waste from the mining and metallurgical industries. The mixture is intended to include crushed quicklime, ground metallurgical slag, crushed mountain sand and calcium salt. The homogeneity of the mixture is ensured by subsequent molding and solidification of the aqueous suspension solution [17][17].

Thus, the possibility of producing construction materials and products for various purposes using technogenic waste from metallurgy, mining, chemistry, energy and other industries has been determined.

The use of such waste ensures the technical, economic and environmental efficiency of the manufactured product. The application of new technologies is intended to meet the regulatory requirements by increasing the physical and mechanical properties of the products obtained. The proposed technological developments allow significantly reducing the harmful impact on the environment [19][18].

In order to increase the activity of cement produced by the application of steelmaking slag of the metallurgical industry, it is proposed to produce clinker using ore refining waste - a sand-clay mixture. The optimization of the composition was studied by the method of mathematical planning of experiments.

Three variable factors affecting the activity of cement in the clinker were assumed: X_1 – the amount of SiO_2, %; X_2 - the amount of FeO, %; X_3 - dispersity, mm.

Based on the analysis of the experimental results, a mathematical model of the increase in cement activity (Y, %) was obtained, that is, a regression equation:

$$Y = 42,413 - 0,008 \cdot X_1 + 0,125 \cdot X_1 \cdot X_2 \cdot X_3 - 0,092 \cdot X_1^2 - 0,092 \cdot X_2^2$$

[17]Исследование проблемы использования техногенных отходов горно-металлургической промышленности Азербайджана Керимова Г.Х.

[18] Tullantэlarэn texnoloji emal proseslərin optimallaюdэrэlmasэ vэ enerji tutumunun dinamikasэ. Kэrimova G.X.

The usefulness of the regression equation coefficients was determined according to the Student criterion. The adequacy of the mathematical model was checked based on the Fisher criterion. Based on the obtained statistical model, the optimal amount of influencing factors was determined: X_1= 32,8; X_2= 6,3; X_3= 2,1.

Thus, technogenic wastes of the mining and metallurgical industries can be used as an efficient and ecologically rational source of mineral raw materials in the production of construction materials and products, and simple technologies can be developed using such wastes. The physical and mechanical properties of products obtained on the basis of these technologies meet the established regulatory requirements. Technological developments allow achieving technical, economic and environmental efficiency, and significantly reducing the technogenic impact on the environment [24][19].

MAIN RESULTS

1. It is substantiated that it is necessary to improve the technologies for the production of various materials from technogenic wastes of the mining and metallurgical industries. It is shown that one of the priority directions of efficient use of waste is the identification of opportunities for the use of technogenic waste as recycled raw materials in the construction sector.

2. Technogenic wastes are classified and the technological principles of their reuse in various fields are determined. The technological and ecological characteristics of waste generated at mining, metallurgy, thermal power and chemical industry enterprises are determined.

3. The results of studies of the physicochemical and mineralogical properties of mineral wastes of “Dashkesan Ore Refining” OJSC confirmed the prospects for re-enrichment of wastes, separation of useful elements, and their use as recycled raw materials, and it is justified that they promise great technical and economic benefits to the country's mining industry.

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[19] Эффективность переработки отходов горнодобывающей промышленности: некоторые важные аспекты. Керимова, Г.Х.

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4. The sources of technogenic waste in the mining industry, its characteristic features and harmful effects have been systematized. It has been established that when technogenic waste remains in landfills for a long time, its physicochemical and technological properties change sharply, and over time, the waste loses its consumer properties and its harmful effect on the environment increases.

5. It has been established that the difference between mining waste and traditional raw materials for construction materials is their chemical and mineral composition, variability of physicochemical and technological properties. The presence of impurities in the composition of mining waste that are not characteristic of traditional raw materials requires a special approach when developing their recycling technologies.

6. It was determined that the analysis of the recycling of mining and metallurgical waste is based on the principles of modeling physical processes. The efficiency of waste recycling processes should be based on technological and environmental assessments. The energy intensity of technogenic waste recycling processes is presented as a complex synergistic indicator and it is shown that its minimum can be taken as an optimal criterion.

7. Efficient technical and technological developments for the production of construction materials from mining and metallurgical waste are proposed. The proposed technologies for the preparation of various construction materials and products allow saving mineral raw materials and reducing the technogenic impact on the environment.

8. Technologies for the production of construction materials and products from mining and metallurgical waste are substantiated. Regression models expressing the rational composition and properties of construction mixtures for various purposes based on technogenic waste have been built. Production tests at “AZER KMI” LLC have confirmed the efficiency of using technogenic waste as recycled raw materials. The proposed developments allow for certain technical, economic and environmental benefits.

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The author's personal participation in the past centuries:

[1,2,3,4,10,16,17,18,19,21,24] were executed independently by the plaintiff.

In the works [5,6,7,8,9,11,12,13] the statement of the problem, empirical research and conclusions are devoted to the claimant.

[14,15,20,22,23] number of works have been completed by the authors.

The dissertation defense will be held on September 17, 2025 at 12:00 at the meeting of the BFD2.09. One-time dissertation council, established on the basis of the FD2.09 Dissertation Council operating under the PLE "Azerbaijan Technical University"

Address: AZ1073, Baku, H.Javid Avenue, 25.

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Electronic versions of the abstract is avialable on the official website (www.aztu.edu.az) of the Azerbaijan Technical University PLE.

Abstract was sent to the requered addresses on 30 July 2025.

Signed for print: 01.07.2025
Paper format: A5
Volume: 40294
Number of hard copies: 100