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Satbayev University

ХАБАРЛАРЫ

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ
НАУК РЕСПУБЛИКИ
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STUDIES OF WASTE FROM THE MINING AND METALLURGICAL INDUSTRY, WITH THE DETERMINATION OF ITS IMPACT ON THE LIFE OF THE POPULATION

Abstract. This article presents physicochemical studies of technogenic waste of mining and metallurgical industry - tails from enrichment of ores of non-ferrous metals. In particular, the modern state of the mining and metallurgical industry, problems of technogenic waste formation, sampling of technogenic raw materials in the form of tailings from enrichment of nonferrous metal ores at a technogenic mineral structure are considered. Methods of examination of technogenic wastes are presented, the techniques of particle size distribution (using sieve analysis), chemical, electron-microscopic (using scanning electron microscope JSM-6490LV) and X-ray phase analysis (using X-ray diffractometer ARL X’TRA) are described. As a result of a series of researches were established coordinates of angular points of a geological allotment of the tailings dump, at carrying out of physical and chemical methods of the analysis of technogenic wastes from enrichment of mining - metallurgical industry, defined the granulometric composition of tails from enrichment of nonferrous metals ores by means of sieve analysis, determined the elemental and chemical composition of samples of tails from enrichment of nonferrous metals ores, determined chemical and mineralogical composition of wastes from enrichment of mining - metallurgical industry. According to the results of the research the granulometric, chemical, elemental and mineralogical composition of the studied waste from

the enrichment of nonferrous metal ores was established and determined. On the basis of the received results number of conclusions and inferences are formulated in relation to anthropogenic effects of industrial wastes in the form of nonferrous metal ores dressing tailings on the environment and human life safety and possibility of using industrial wastes as a secondary technogenic raw material for a number of industries and manufactures.

Key words: enrichment waste, anthropogenic impact, human safety, nonferrous metals, environment, tailings, and recycling.

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ТАУ-КЕН МЕТАЛЛУРГИЯ ӨНЕРКӘСІБІНІҢ ҚАЛДЫҚТАРЫНЫҢ ХАЛЫҚ ӨМІРІНЕ ӘСЕРІН ЗЕРТТЕУ

Аннотация. Бұл мақалада тау-кен металлургия өнеркәсібінің техногендік қалдықтарының – түсті металл кендерін байытудан алынған қалдықтарының физикалық-химиялық зерттеулері келтірілген. Атап айтқанда, тау-кен металлургия өнеркәсібінің қазіргі жай-күйі, техногендік қалдықтардың пайда болу мәселелері, түсті металл кендерін байытудан қалған қалдықтар түріндегі техногендік шикізаттың техногендік минералдық құрылымдарында сынамаларды іріктеу т.б. Техногенді қалдықтарды зерттеу әдістері келтірілген, гранулометриялық (елек талдауын қолдана отырып), химиялық, электрондық-микроскопиялық (JSM-6490LV растрлық электрондық микроскопын қолдана отырып) және рентгенофазалық (ARL X ‘ TRA рентгендік дифрактометрін қолдана отырып) талдаулар әдістемелері сипатталған. Жүргізілген бірқатар зерттеулер нәтижесінде қалдық қоймасын геологиялық бөлудің бұрыштық нүктелерінің координаттары анықталды, тау-кен металлургия өнеркәсібін байытудан қалған техногендік қалдықтарды талдаудың физикалық-химиялық әдістерін жүргізу кезінде елек талдауының көмегімен түсті металдар кендерінің байытудан қалған қалдықтардың гранулометриялық құрамы анықталды, түсті металдар

кендерін байытудан қалған қалдықтар сынамаларының элементтік-химиялық құрамы анықталды, түсті металдар кендерін байытудан қалған қалдықтар сынамаларының рентген-құрылымдық талдау көмегімен тау-кен металлургия өнеркәсібін байытудан алынған қалдықтардың минералогиялық құрамы анықталды. Зерттеу нәтижелері бойынша түсті металл кендерін байытудан қалған қалдықтардың гранулометриялық, химиялық, элементтік, минералогиялық құрамы анықталды. Алынған нәтижелер негізінде түсті металл кендерін байытудан қалған қалдықтарды қалдықтар түрінде өнеркәсіптік қалдықтардың антропогендік әсерінің қоршаған ортаға, адам өмірінің қауіпсіздігіне және бірқатар өнеркәсіптер мен өндірістер үшін қайталама техногендік шикізат ретінде өнеркәсіптік қалдықтарды пайдалану мүмкіндігіне қатысты бірқатар тұжырымдар мен қорытындылар жасалды.

Түйін сөздер: байыту қалдықтары, антропогендік әсер, адам өмірінің қауіпсіздігі, түсті металдар, қоршаған орта, қалдықтар қоймасы, кәдеге жарату.

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ИССЛЕДОВАНИЯ ОТХОДОВ ГОРНО-МЕТАЛЛУРГИЧЕСКОЙ ПРОМЫШЛЕННОСТИ С ОПРЕДЕЛЕНИЕМ ИХ ВЛИЯНИЯ НА ЖИЗНЬ НАСЕЛЕНИЯ

Аннотация. В настоящей статье приведены физико-химические исследования техногенных отходов горно-металлургической промышленности – хвостов от обогащения руд цветных металлов. В частности, рассмотрено современное состояние горно-металлургической промышленности, проблемы образования техногенных отходов, пробоотбор на техногенном минеральном сооружении техногенного сырья в виде хвостов от обогащения руд цветных металлов. Приведены методы исследования техногенных отходов, описаны методики гранулометрического (с применением ситового

анализа), химического, электронно-микроскопического (с применением растрового электронного микроскопа JSM-6490LV) и рентгенофазового (с применением рентгеновского дифрактометра ARL X'TRA) анализов. В результате проведенного ряда исследований были установлены координаты угловых точек геологического отвода хвостохранилища, при проведении физико -химических методов анализа техногенных отходов от обогащения горно - металлургической промышленности, определен гранулометрический состав хвостов от обогащения руд цветных металлов при помощи ситового анализа, установлен элементно- химический состав проб хвостов от обогащения руд цветных металлов, определен химический и минералогический состав отходов от обогащения горно-металлургической промышленности при помощи рентгено - структурного анализа. По результатам исследований установлены и определены гранулометрический, химический, элементный, минералогический составы исследуемых отходов от обогащения руд цветных металлов. На основании полученных результатов сформулирован ряд выводов и заключений относительно антропогенного воздействия промышленных отходов в виде хвостов от обогащения руд цветных металлов на окружающую среду и безопасность жизнедеятельности человека и возможности применения промышленных отходов в качестве вторичного техногенного сырья для ряда промышленностей и производств.

Ключевые слова: отходы от обогащения, антропогенное воздействие, безопасность жизнедеятельности человека, цветные металлы, окружающая среда, хвостохранилище, утилизация.

Introduction. The mining and metallurgical industry is Kazakhstan's most important industry, accounting for 15.2 percent of total industrial output. Many mining and metallurgical industries are city-forming, so the development of the mining and metallurgical complex (hereinafter - MMC) is the development of cities, jobs for over 200 thousand people, and the accumulation of massive waste from enrichment (Kolesnikov et al., 2021). The total volume of mined solid minerals in the CIS is about 3.5 billion m3 per year, and taking mining and enrichment works into account - about 5 billion m3, i.e. 1.5 billion m3 of rocks are mined by-products (the majority of which after enrichment are stored in dumps and tailings), to provide extraction of basic minerals from the earth.

The message of the First President of the Republic of Kazakhstan - the Leader of the Nation, N.A. Nazarbayev to the people of Kazakhstan dated January 10, 2018 "New Opportunities for Development in the Fourth Industrial Revolution" notes that the modern world, as before, continues to require resources that will play a separate role in the development of the global economy and the economy of our country in the future. However, it is also necessary to critically rethink

the organization of the resource industries, and specific approaches to natural resource management. Actively implementing integrated information and technological platforms for natural and man-made raw materials is required. And significantly increase the requirements for industrial energy and resource efficiency.

At the moment, due to the depletion of valuable metals in ores and the increasing amount of difficult-to-enrich raw materials (Kolesnikov et al., 2021), (Alshanov et al., 2004), it is economically feasible and necessary to process both poor, substandard, and difficult-to-access mineral raw materials and man-made materials, particularly those found in dumps and tailings in Kazakhstan, Uzbekistan, Russia, Finland, Poland, Ukraine, Canada, and Argentina.

It is known that the main resources in the production of various materials were previously provided by the traditional mineral raw materials. In the new economic realities, this approach is qualitatively changing, and industrial wastes act as secondary raw materials (Kolesnikov et al., 2021:), (Alshanov et al., 2004), (Nadirov et al., 2017), (Evdokimov et al., 2014), (Sergeeva et al., 2016). The cost of such raw materials is much lower, and the conditions of processing are often simple. These features of economic development insistently require qualitative study of all kinds of accumulated and unused waste. One of such wastes is lead-zinc wastes (Abdraimova et al., 2010) of the mining, processing, and metallurgical industries - stockpiled in a tailings dump (Kanaev et al., 2016) near the settlement of Bayaldyr (Figure 1) in the Turkestan region of Kazakhstan (Kalmakhan, 2022). Bayaldyr tailings dump is a complex of special structures and equipment designed for storage of waste tailings of lead-zinc ore enrichment, called tailings. At the beneficiation plant concentrate was produced from the incoming mined lead-zinc ore, and the processing waste was transferred to the tailings dump. At present, according to different data, about 136-150 million tons of waste from enrichment are stored there (Bekebaeva et al., 2019), (Kalmakhan, 2022). At the same time, the tailings dump occupies a significant area of land in the southwestern part of the Kentau region and amounts to about 333.0 hectares.

The geological structure of the Bayaldyr tailings dump is represented by the object of storage of tailings of flotation enrichment of polymetallic ores of non-ferrous metals by the Kentau and Mirgalimsay processing plants. The surface plan of the Bayaldyr tailings dump at the time of construction is shown in Figure 2.

The tailings dump was built in 1961. The bottom (sole) of the Bayaldyr tailings dump is composed of quaternary loam with a capacity of 0.5 to 15 m.

Figure 1- Photo of a part of Bayaldyr tailings dump for waste from lead-zinc ore processing in Turkestan region

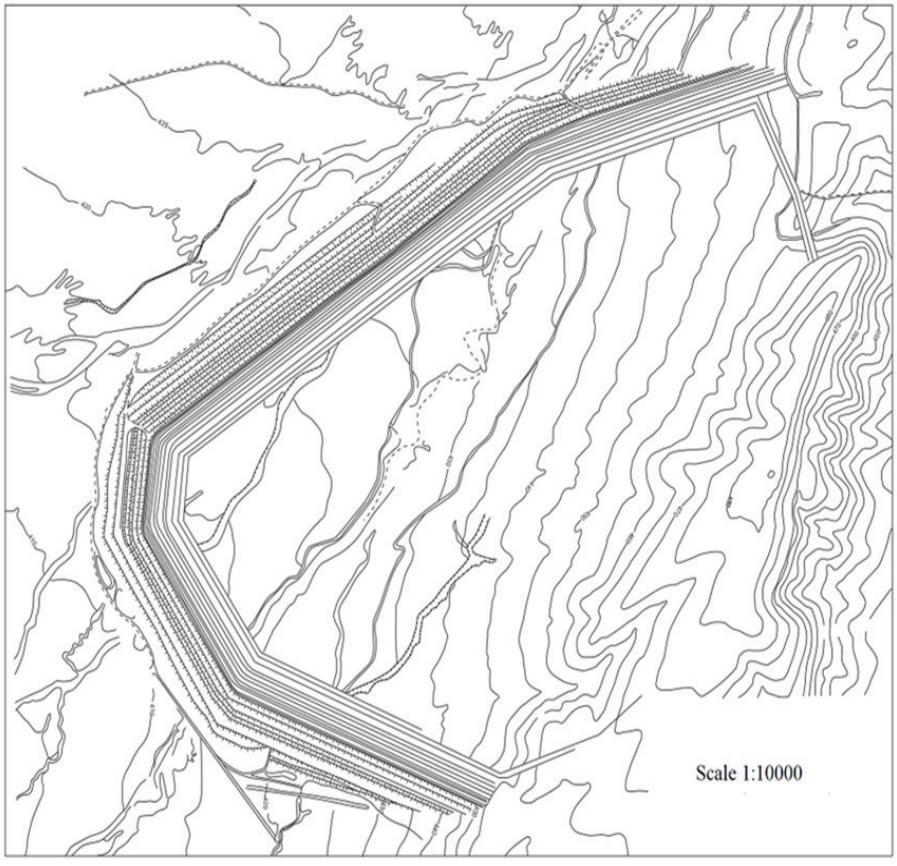


Figure 2 – Surface plan of Bayaldyr tailings dump at the time of construction

Strengthening, sealing or waterproofing of the bottom (sole) there was no tailings storage during its construction. The sides (dam) of the tailings dump are filled with unsorted rocks of the Mirgalimsay deposit – blocks (up to 1.5 m), crushed stone, gravel and loam. The composition of the stone material is limestones and dolomitized limestones. The width of the dam is 175-270m. The height of the sides (dams) is 0-45m. The Bayaldyr tailings dump was filled via a pulp pipeline connected to the northeastern side of the tailings dump and laid along the northern side of the dam. The south-western part of the tailings dump (65% of the total area) is recultivated – covered with a layer of 0.3-0.5 m of sand and gravel deposits. The surface of the tailings dump is not flooded with water, it is dry. There is no vegetation at the moment.

According to studies by a number of scientists (Kanaev et al., 2016), (Bekebaeva et al., 2019), it was found that the tailings from enrichment, located in the tailings have the following chemical and mineralogical composition, given in Table 1.

Table 1- Chemical and mineralogical composition of Bayaldir tailings waste

Elements and compounds, %													
Pb	Zn	Fe_{com}	FeS_2	MgO	CaO	Al_2O_3	SiO_2	$PbSO_4$	$PbCO_3$	PbS	$ZnCO_3$	$ZnSiO_3$	ZnS
1.8	4.9	7.13	11.25	0.45	4.89	4.64	54.75	0.32	0.52	0.95	0.73	0.33	3.84

From the chemical composition of waste from enrichment, we can see that their chemical composition contains a number of useful compounds, in particular, oxides of silicon, aluminum, and iron, as well as residual compounds of lead and zinc, which in terms of ecology and human life safety are heavy nonferrous metals, which have a negative anthropogenic impact on the environment and public health, but at the same time, they are one of the valuable non-ferrous metals for the metallurgical industry (Kalmakhan, 2022), (Ayeni et al., 2012), (Kolesnikov et al., 2022), (Chen et al., 2011),(Zhanikulov et al., 2022), (Choudhary et al., 2013), (Darweesh et al., 2014), (Zhanikulov et al., 2021) and can be used as secondary raw materials in a number of industries, such as metallurgy and chemical technology.

Unfortunately, in contrast to foreign countries with developed economies, the practice of processing tailings from enrichment is not widespread in CIS factories, despite their huge number.

Thereby, research and scientific work aimed at reducing energy consumption and specific costs of raw materials, with the involvement in the production cycle of man-made raw materials as secondary, while reducing the harmful anthropogenic effects on the environment and human safety through the recycling of man-made waste are relevant, new and require a comprehensive qualitative approach for their further development and implementation in production.

Material and methods. The materials used in the present research were enrichment wastes from the Bayaldyr tailings dump. The Bayaldyr tailings dump is located near Kentau city of Turkestan region (formerly Chimkent and South Kazakhstan) 0.4 km to the east of the village of Bayaldyr. Geomorphologically, the Bayaldyr tailings dump is confined to the northern slope of the ridge separating it from Bayaldyr settlement.

Sampling was carried out manually according to GOST 28192-89. There were taken 5-point samples along the perimeter of the tailing storage facility, which were subsequently combined into a combined sample. The combined sample, consisting of an appropriate number of point samples, was numbered in accordance with the accounting system and delivered to the laboratory for sample preparation, where it was subjected to further processing (Poizot et al., 2008). The selected samples were subjected to physical and chemical methods of analysis, in particular, granulometric, chemical (Wise et al., 2015), electron microscopic analysis on a scanning electron microscope, and X-ray phase analysis.

Electron microscopic type of analysis was carried out on a scanning electron microscope JSM-6490LV (Figure 3a). With the help of an electron microscope in the field of binders we can study the following issues: the shape and size of individual crystals; processes of growth and destruction of crystals, processes occurring at the boundaries of grains, phase transformation during heat treatment and cooling and a number of other more private tasks. SEM - a device that is based on the television principle of sweeping a thin beam of electrons over the surface of a specimen under study. The electron beam falling on the surface of the sample interacts with the substance, which results in a number of physical phenomena. After that, a relief picture of the sample surface is obtained on the screen. The sample under study does not require any special preparation: it is placed on the device in the state which is necessary according to the plan of the experiment (Kannan, 2018).

A reliable experimental method for obtaining data on the structure and lattice dynamics of solids under such external influences as pressure and temperature is X-ray diffraction analysis. It has a number of important advantages. For example, the solid itself is examined in an unchanged state and the result of the analysis is a direct identification of the substance or its constituents. The main purpose of X-ray diffraction analysis (XRF) is to identify the different phases in a mixture of phases on the basis of the diffraction pattern of the sample under study. In the practice of X-ray diffraction analysis as polycrystalline bodies, the powder or Debye-Scherer method is mainly used. This method is a widespread method for X-ray structural analysis of fairly well-oxidized substances. An X-ray diffractometer ARL X'TRA (Thermo Fisher Scientific (Ecublens) SARL,

Switzerland.) was used for the X-ray structural analysis, the appearance of which is shown in Figure 3b.

a- JSM-6490LV scanning electron microscope

b- X-ray diffractometer ARL X'TRA

Figure 3- Laboratory equipment for physical-chemical methods of analysis

The ARL X'TRA X-ray diffractometer is designed to measure the intensity and diffraction angles of X-rays diffracted on a crystalline object for X-ray diffraction and X-ray structural analysis of materials. The ARL X'TRA diffractometer is a stationary, automated, floor-standing laboratory instrument. The operating principle of the instrument is based on the registration of X-ray radiation diffracted by elements of the crystal lattice of the studied sample (Bunaciu 2015).

Results. According to the results of physical and chemical investigations of samples of waste from enrichment in the Bayaldyr tailings dump, the following results were obtained, in particular, the coordinates of the Bayaldyr tailings dump were established, which are shown in Table 2.

Table 2 - Coordinates of corner points of the Bayaldyr tailings pond

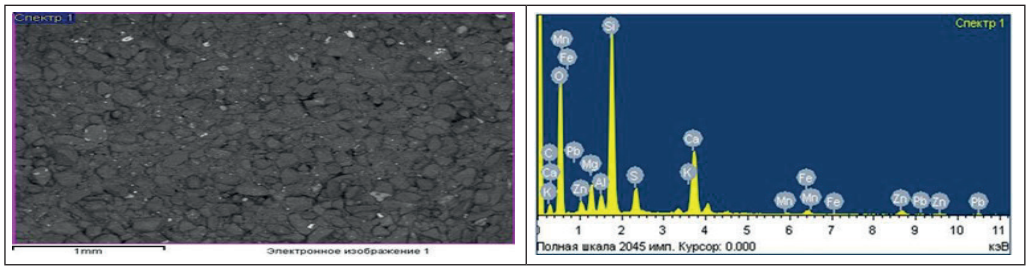
Nº points	Coordinates of the corner points of the geological allotment	
	northern latitude	eastern longitude
1	2	3
1	43⁰30'52,3"	68⁰26'45,5"
2	43⁰30'47,7"	68⁰26'44,1"
3	43⁰30'32,4"	68⁰26'58,9"
4	43⁰30'22,7"	68⁰27'31,8"
5	43⁰30'25,9"	68⁰27'46,8"
6	43⁰30'37,1"	68⁰27'48,7"

7	43⁰31’11,8”	68⁰27’26,1”
8	43⁰31’26,3”	68⁰28’11,1”
9	43⁰31’17,9”	68⁰28’16,5”
10	43⁰31’09,0”	68⁰28’18,5”
11	43⁰31’06,0”	68⁰28’14,4”
12	43⁰30’53,7”	68⁰28’05,4”
13	43⁰30’48,8”	68⁰27’59,8”
14	43⁰30’32,0”	68⁰27’51,8”

The granulometric composition of tailings from the enrichment of ores of non-ferrous metals during the study by fractions was the following values:

1) - 5 - 2.5mm - 0-0.7%;
2) - 2.5 - 1.25mm - 0-0.1%;
3) - 1.25 - 0.63mm - 0.0-0.7%;
4) - 0,63 - 0,315mm - 0,3-5,4%;
5) - 0,315-0,16 mm - 1,3-8,7%;
6) - less than 0.16 mm - 88.4-96.8%.

The results of the electron elemental microscopic analysis are shown in Figure 4.



The element	C	O	Mg	Al	Si	S	K	Ca	Mn	Fe	Pb	Zn	Total
Weighing %	13,24	49,11	1,99	1,41	16,23	2,45	0,49	8,99	0,35	2,41	1,01	2,32	100

Figure 4 - Elemental-microscopic analysis of tailings from the enrichment of the Bayaldyr tailings pond

The X-ray phase composition of the Bayaldyr tailings is shown in Table 3.

Table 3- X-ray phase composition of Bayaldyr tailings dump waste

№	Compounds	Name	weight. %
1	SiO_2	Silicon Oxide	54.06
2	Fe_2O_3	Common iron	5.78
3	FeS_2	Iron(II) disulfide	3.2

4	MgO	Magnesium Oxide	1.38
5	CaO	Calcium Oxide	7.78
6	Al_2O_3	Aluminum oxide (alumina)	11.02
7	$PbSiO_3$	Lead Metasilicate(II)	1.68
8	$PbSO_4$	Lead sulfate (II)	0.32
9	$PbCO_3$	Lead Carbonate(II)	0.52
10	PbS	Lead Sulfide (II)	1.95
11	$ZnCO_3$	Zinc Carbonate (Smithsonite)	0.71
12	$ZnSiO_3$	Zinc (II) metasilicate	0.33
13	ZnS	Zinc sulfide, (zinc sulphide)	2.73
14	Other		8.54

Discussion. According to the results of Table 2 with the help of the found coordinate points, it was established that the Bayaldyr tailing dump has the dimensions 1871-2375 by 569-1404m in plan and represents an area of 2.45 km^2. This area is significant and could have been a fertile area for growing various cereal crops for agriculture or plant fodder for herbivorous domestic and wild animals, acting as pastures with its own flora and habitat for wild animals and birds of the steppe.

From the results of the obtained granulometric composition of tailings from enrichment of non-ferrous metal ores, it is clear that 88.4-96.8% of the waste from the Bayaldyr tailings is represented by the dust-like fraction capable of being transported over significant distances in windy weather, which is typical for this region. The presence of up to 96% of the dust-like fraction containing inorganic silicon oxide and heavy non-ferrous metals is capable of spreading dozens of kilometers from the tailing dump, depending on the wind rose of the region, thus violating sanitary and hygienic norms of settlements and cities located in the immediate vicinity of the tailing dump, as well as contamination of soil, surface waters, and atmosphere, having a negative impact on human activity, animal and vegetation habitats of the region.

From figure 4, which reflects the results of the elemental-microscopic analysis of the tailings from the enrichment of the Bayaldyr tailings dump, the elemental analysis is given, which is represented by the following chemical elements: C-13.24%; O-49.11%; Mg-1.99%; Al-1.41%; Si-16.23%; S-2.45%; K-0.49%; Ca-8.99%; Mn-0.35%; Fe-2.41%; Pb-1.01%; Zn-2.32%. Based on the elemental composition we can see the presence of heavy non-ferrous metals in the form of lead and zinc, as well as sulfur, manganese, and iron, which can have a negative impact on both the natural environment and human activities.

Table 3, which shows the chemical and mineralogical composition of the enrichment waste, shows that the waste from enrichment is represented by the

following minerals: SiO_2- 54.04%; Fe_2O_3-5.78%; FeS_2-3.2%; MgO-1.38%; CaO-7.78%; Al_2O_3-11.02%; $PbSiO_3$-1.68%; $PbSO_4$-0.32%; $PbCO_3$-0.52%; PbS-1.95%; $ZnCO_3$-0.71%; $ZnSiO_3$-0.33%; ZnS-2.73%; other-8.54%. The presence of the above-mentioned compounds, some of which are toxic and under the influence of climatic conditions have been contributing to pollution of ground and surface waters, soils of the adjacent area, and atmospheric air for several decades, having a toxicological and negative impact on the safety of life activities of people living in settlements near and near the tailing dump, as well as on the flora and fauna of the region, violating sanitary and hygienic standards. For example, heavy metals in the form of lead and zinc can migrate from soil to plants, from plants to animals, and from animals to human organisms through the food chain, having the ability to accumulate in human organisms causing different kinds of diseases and abnormalities.

Since the collapse of the Soviet Union, the tailing dump stopped receiving timely and necessary maintenance and upkeep, having a harmful impact both on the ecological situation of the region and on sanitary-hygienic norms and human health. According to the doctor Mukhtar Turisbekov, the health curve of Kentau region's residents has significantly decreased due to the presence of the tailing dump and its anthropogenic impact on people, fauna, and flora located in the region. The doctor also connects the statistics of cancer diseases in neighboring settlements and Kentau city with the influence of the tailing dump. Today, environmental problems of the region are raised by the head of the Department of Ecology of Turkestan region Kalmakhan K.K. [9], so, in the article of Kanat Kalmakhanovich, it is noted that: "In the region (Turkestan region) there are large-tonnage wastes of mining production - these are dumps, tailings dumps. These wastes must be processed and the territory must be released from them. Subsequently, the released land can be given to other needs. For example, according to scientists' estimates, there is a lot of zinc at the Bayaldir tailing dump that can be processed. And for that, an investor is needed".

Thus, the wastes of enrichment of ores of non-ferrous metals, stored at Bayaldyr tailings dump, having a harmful anthropogenic impact on the environment and human life safety, based on the content of various chemical elements and compounds in their composition, it is possible to consider these wastes in the context of secondary man-made raw materials for a number of industrial sectors and industries. In particular, it can be the enterprises of metallurgical, binder, and construction production facilities.

Conclusions. As a result of the physicochemical studies of enrichment wastes deposited at the Bayaldyr tailings dump depository, the following conclusions and conclusions can be made:

- the enrichment waste located at the Bayaldyr tailings dump by its chemical

and mineralogical composition can have a negative impact on the environment and life safety of people living in the immediate vicinity;

- the tailings contain non-ferrous metals in the form of lead and zinc, reaching the following intervals of 1.01-2.1 and 2.32-2.6% respectively, which practically corresponds to the currently extracted lead-zinc ores

- the stored wastes of the mining-metallurgical industry of the Bayaldyr tailings dump, based on their chemical composition, can be considered secondary technogenic raw materials for the chemical, metallurgical, and construction industries.

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