ГИАБ. Горный информационно-аналитический бюллетень /
MIAB. Mining Informational and Analytical Bulletin, 2024;(3):55-69
ОРИГИНАЛЬНАЯ СТАТЬЯ / ORIGINAL PAPER

УДК 628.511 DOI: 10.25018/0236_1493_2024_3_0_55

АНАЛИЗ ВЛИЯНИЯ ОТВАЛОВ БОКСИТОВ НА ОКРУЖАЮЩУЮ ПРИРОДНУЮ СРЕДУ И ЗДОРОВЬЕ НАСЕЛЕНИЯ

Б.А. Есенбаев[1], А.С. Колесников[1], А.С. Наукенова[1], Ш.К. Шапалов[1], Л.И. Раматуллаева[1], Г.К. Ивахнюк[2]

[1] Южно-Казахстанский университет им. М. Ауэзова, Шымкент, Республика Казахстан, e-mail: kas164@yandex.kz
[2] Санкт-Петербургский государственный технологический институт, Санкт-Петербург, Россия

Аннотация: Приведен анализ мировых запасов бокситового сырья и темпы роста добычи бокситов. Приведена статистика запасов бокситового сырья в мире и его мировая добыча и производство. Приведено сравнение химических составов бокситов различных месторождений мира. Рассмотрена характеристика низкокачественного бокситового сырья в частности, различных месторождений Казахстана. Рассмотрен качественный и количественный состав по содержанию основных компонентов в бокситах, приведены минералы, в том или ином количестве присутствующие в бокситах и бокситовых породах казахстанских месторождений. Рассмотрены некондиционные отвалы бокситов конкретного месторождения и их влияние на окружающую природную среду и население региона. Приведены и отражены климатические характеристики региона, отражен химический состав ряда месторождений бокситов. Рассмотрено негативное антропогенное влияние отвалов некондиционных бокситов на здоровье населения региона и окружающейся природной среды под воздействием природно-климатических воздействий. В ходе проведенного анализа установлено, что пылевые загрязнения твердыми частицами являются одной из глобальных проблем по данным всемирной организации здоровья (ВОЗ), которую необходимо решать с целью улучшения качества жизнедеятельности населения и окружающей среды. По результатам исследований сформулировано заключение о поиске технологических решений утилизации отвалов некондиционного боксита путем их комплексной переработки в качестве вторичного минерального сырья.

Ключевые слова: горно-металлургическое сырье, запасы и добыча бокситов, отвальные некондиционные бокситы, техногенное воздействие, пылевое загрязнение, твердые частицы пыли, воздействия на здоровье населения, техносферная безопасность, защита и охрана окружающей среды.

Для цитирования: *Есенбаев Б. А., Колесников А. С., Наукенова А. С., Шапалов Ш. К., Раматуллаева Л. И., Ивахнюк Г. К.* Анализ влияния отвалов бокситов на окружающую природную среду и здоровье населения // Горный информационно-аналитический бюллетень. – 2024. – № 3. – С. 55–69. DOI: 10.25018/0236_1493_2024_3_0_55.

Analysis of the impact of bauxite dumps on the environment and public health

B.A. Yessenbayev[1], A.S. Kolesnikov[1], A.S. Naukenova[1], Sh.K. Shapalov[1], L.I. Ramatullaeva[1], G.K. Ivakhniyuk[2]

[1] M. Auezov South Kazakhstan University, Shymkent, Kazakhstan, e-mail: kas164@yandex.kz
[2] Saint-Petersburg State Institute of Technology, Saint-Petersburg, Russia

Abstract: This article provides an analysis of the world reserves of bauxite raw materials and the growth rate of bauxite production. The statistics of reserves of bauxite raw materials in the world and its global production and production are given. A comparison of the chemical compositions of bauxite from various deposits of the world is given. The characteristics of low-quality bauxite raw materials, in particular, various deposits of Kazakhstan, are considered. The qualitative and quantitative composition of the content of the main components in bauxite is considered, minerals present in varying amounts in bauxite and bauxite rocks of Kazakhstani deposits are given. Substandard bauxite dumps of a particular deposit and their impact on the environment and the population of the region are considered. The climatic characteristics of the region are given and reflected, the chemical composition of a number of bauxite deposits is reflected. The negative anthropogenic impact of dumps of substandard bauxite on the health of the population of the region and the surrounding natural environment under the influence of natural and climatic influences is considered. The analysis revealed that dust pollution by solid particles is one of the global problems according to the World Health Organization (WHO), which must be addressed in order to improve the quality of life of the population and the environment. Based on the results of the research, a conclusion was formulated on the search for technological solutions for the disposal of substandard bauxite dumps through their complex processing as secondary mineral raw materials.

Key words: mining and metallurgical raw materials, reserves and extraction of bauxite, dump substandard bauxite, anthropogenic impact, dust pollution, solid dust particles, effects on public health, technosphere safety, protection and environmental protection.

For citation: Yessenbayev B. A., Kolesnikov A. S., Naukenova A. S., Shapalov Sh. K., Ramatullaeva L. I., Ivakhniyuk G. K. Analysis of the impact of bauxite dumps on the environment and public health. *MIAB. Mining Inf. Anal. Bull.* 2024;(3):55-69. DOI: 10.25018/0236_1493_2024_3_0_55.

Introduction

High rates of industrial production growth and technological progress in all areas of material production lead to the active use of natural resources. More than 70% of these resources are accounted for by mineral raw materials.

Over the past 30—40 years, more minerals have been extracted than in the entire previous history of mankind. Bauxite production has also increased, and has now exceeded the billion-dollar milestone.

However, the world's mineral reserves are extremely unevenly distributed, and in the world, only the Russian Federation fully provides itself with its own raw materials [1, 2].

The Republic of Kazakhstan is largely developing on its own raw material base and does not depend on imports of mineral raw materials from other countries. However, this does not mean that we can use natural resources indefinitely, as they tend to run out. It is important to ensure the comprehensive and full use of mineral deposits and extracted mineral resources. It is necessary to look for ways to increase resources and reduce unit costs, as well as to prevent environmental pollution from industrial waste [3—10].

The integrated use of mineral resources plays an important economic role. In large-scale production, when it is necessary to extract more than 2 billion cubic meters of mineral resources to meet the needs of the economy, spend more than 100 billion kilowatt-hours of electricity, about 8 billion cubic meters of natural gas, approximately 25 million tons of conventional fuel, 3 billion cubic meters of water, almost 2 billion cubic meters of oxygen and millions of tons of various materials savings due to lower operating costs can amount to a significant amount. According to the data of leading enterprises, the sale of associated products obtained as a result of the integrated use of raw materials in the process of its complex processing provides from 27 to 51% of the total profit.

The problem of integrated use of raw materials is of great importance, since it is associated with the need to protect the subsoil and the rational use of natural resources of our country.

Currently, one of the most intensively developed types of minerals is bauxite. The quality of bauxite as a raw material is determined by the content of Al_2O_3 and SiO_2 and their mineralogical forms. Bauxite with a high mass ratio is processed abroad: Al_2O_3:SiO_2 ⩾ 9—11 (silica modulus μSi). This mainly applies to gibbsite (Guinea, India) and gibbsite-boehmite (Jamaica) types. In the CIS countries, bauxites with μSi = 2.6 are used. Only the North Ural diasporic kaolin ores, which are mined in Russia, are of high quality. The remaining North Onega, gibbsite-kaolin, Middle Timanian, hematite-chamotte-boehmite and Vistula bauxites are of low quality. In Kazakhstan, the gibbsite-kaolinite bauxite mined is also of low quality. Therefore, in the process of developing bauxite deposits in Kazakhstan, a large amount of nonconforming bauxite with a μSi⩽2.6 is obtained. Which, according to technological requirements, is substandard bauxite — a man-made waste product of the mining industry. Substandard bauxite amounts to millions of tons and is not used in industry, it is stored in a dump, while having a negative anthropogenic impact on the environment and public health [8—14].

In this regard, the purpose of these studies is to review and analyze the world reserves of bauxite raw materials and the growth rate of bauxite production, the characteristics of low-quality bauxite raw materials from various deposits and technologies for the disposal and processing of unused, low-grade bauxite, which is stored in dumps. With the prospect of searching for and developing a new, integrated technology for the disposal of bauxite dumps by processing it as a secondary mineral raw material while reducing the anthropogenic load.

Results and discussion

Global reserves of bauxite raw materials and the growth rate of bauxite production

According to the US Geological Survey (USGS), the global reserves of bauxite left to man amount to 55—75 billion tons, and the base reserves are 30 billion tons. According to the calculation of production of 300 million tons per year, bauxite can be mined for at least 100 years, and it is a mineral with large reserves.

In modern industry, one of the most important metals is aluminum. It occupies the second place in terms of production and consumption after iron and the first place among non-ferrous metals due to its universal properties: low density, high electrical conductivity, plasticity, mechanical strength, corrosion resistance, which has led to its widespread use in all branches of engineering. It is widely used in the aviation and automotive industries, construction and mechanical engineering, electrical industry, packaging production and so on.

The main material for the production of aluminum is bauxite. Bauxite is a complex rock that is an important source of aluminum and underlies the global aluminum industry. Currently, bauxite mining is carried out in several ways around the world: openly and underground. However, most mining is conducted in an open-source

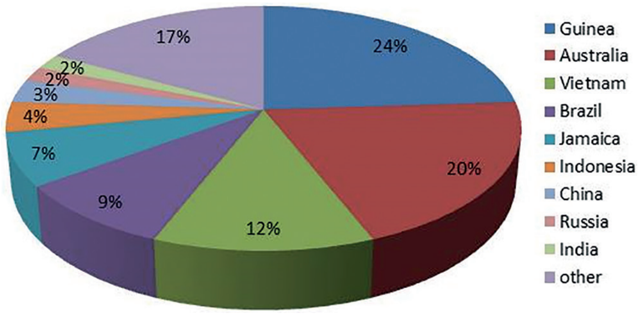

Fig. 1. Distribution of global bauxite reserves as of 2021
Рис. 1. Распределения мировых запасов бокситов по состоянию на 2021 г.

manner. The extraction method is selected depending on the type of aluminum deposit and the geological features of the ore veins. The main types of aluminum deposits include: laterite-type bauxite deposits (for example, deposits in Guinea, Belgorod region and India), bauxite lenses and sedimentary deposits (for example, in Australia, Russia, Suriname, Guyana and Guiana) and bauxite sedimentary deposits of carbonate formations (for example, in the Urals, Jamaica, France, Hungary and Greece). Bauxite layers of deposits of the third type have a significant extent, often inclined occurrence and therefore are mined underground. Deposits of the fourth type are confined to karst craters, have an unstressed capacity, lie near the surface, but may be overlain by later deposits. Their development is carried out most often in an open way [15].

In 2021 terms of the distribution of global bauxite reserves, Guinea, Australia and Vietnam have large reserves of bauxite. These three countries account for 56% of the world's reserves. Among them, Guinea has the world's largest reserves of bauxite. Guinea's main bauxite reserves amount to about 7 billion tons, which is 24%. Bauxite resources in Australia amount to 5.84 billion tons, which is 20%, which ranks second. Vietnam's bauxite reserves amount to 3.5 billion tons, which is 12%, ranking third (Figure 1).

In terms of production distribution, global bauxite production in 2021 amounted to about 390 million tons, mainly in Australia, China and Guinea. The production of the three countries amounted to 281 million tons, which is 71.9% of the global total. Among them, Australia is the largest producer of bauxite in the world, accounting for 28.2% of global production. Although China ranks seventh in terms of bauxite reserves, its production ranks third in the world, accounting for

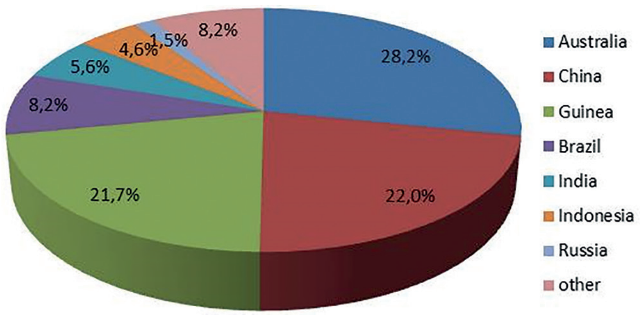

Fig. 2. Distribution of global bauxite production as of 2021
Рис. 2. Распределения мирового производства бокситов по состоянию на 2021 г.

Table 1

Chemical and mineralogical composition of bauxite mined in different countries of the world
Химико-минералогический состав бокситов добываемых в разных странах мира

State	Basic chemical compounds, %							Psi	Mineralogical type of bauxite
	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	CaO	Loss calcination	Ga 1000		
1	2	3	4	5	6	7	8	9	10
Australia	43.7	3.6	16.4	1.9	–	21.3	6.0	12.1	Gibbsite + boehmite
India	49.2	2.8	16.1	6.4	0.1	25.1	7.0	17.6	Gibbsite
China	66.1	7.9	5.5	3.3	0.4	13.8	6.0	8.4	Diasporic
Jamaica	44.3	1.5	18.2	–	–	25.0	6.0	29.5	Gibbsite
Russia	53.5	3.7	22.5	2.0	3.8	12.5	5.0	14.5	Diasporic
Urals	45.4	8.8	19.4	2.2	7.0	–	–	5.2	Diasporic
Tikhvin	45.4	15.9	13.4	0.3	1.3	15.0	5.0	2.9	Boehmite + kaolinite
Brazil	49.4	4.5	14.6	1.4	0.3	24.0	5.0	11.0	Gibbsite
Suriname	54.5	3.8	8.7	2.6		26.0	8.0	14.2	Gibbsite
Greece	56.6	3.8	21.6	2.5	0.8	12.6	3.0	14.9	Diasporic
Kazakhstan	42.6	11.6	18.4	2.3	0.8	20.5	5.0	3.7	Gibbsite + kaolinite
Vengria	53.1	4.8	18.8	2.8	–	19.5	3.0	11.1	Boehmite + gibbsite
Rumma	63.7	3.6	9.7	–	–	–	3.0	17.7	Diasporic
Guinea	56.7	2.7	7.4	3.6	0.2	26.4	3.3	21.0	Gibbsite
Yugoslavia (until 1990)	50.9	4.9	22.0	2.9	0.6	18.5	3.0	10.4	Bemite
Turkey	57.4	7.0	18.1	–	–	12.0	4.0	8.12	Diasporic

22%. Guinea is the third largest producer with production of 85 million tons, which is 21.7% (Figure 2). Bauxite mining in other countries is relatively small. Almost all alumina produced in the world is obtained from bauxite from different deposits and with different mineralogical composition. Most of the processed bauxite belongs to the category of easily opened gibbsite bauxite. Some of them belong to the diasporic type, which is more difficult to open. Such bauxite is mined in Romania, Greece, China, Hungary, Turkey, and in the Urals in Russia.

The chemical and mineralogical composition of bauxite mined in different countries of the world is presented in Table 1. The approximate chemical composition of these deposits is shown in Table 1.

High-quality raw materials include gibbsite bauxite from Jamaica, Guinea, India and Suriname, as well as double-porcelain type bauxite from Greece. The average quality level of bauxite from Hungary, Australia, Brazil and Montenegro [15, 16].

Most alumina plants around the world, except for some Chinese and Russian plants, use the same basic technology for processing bauxite, namely the Bayer method. Table 2 shows the current and projected production capacities of alumina production in the world [16—19].

Characteristics of low-quality bauxite raw materials from various deposits in Kazakhstan

Bauxites are the result of the hydrolytic decomposition of aluminosilicate mine-

Table 2

Alumina production in the world at three levels of capacity

Производство глинозема в мире по трем уровням мощности

Rating level, project capacity	The state producing alumina	Production capacity, million tons/year			The presence of a bauxite processing plant in the state, pcs.
		project	operating production for 2000	projected production	
1	2	3	4	5	6
1	Australia	14.550	14.071	18.370	6
2	India	7.410	2.020	8.760	10
3	USA	6.975	4.191	6.100	7
4	China	4.940	4.680	7.580	8
5	Jamaica	4.450	3.324	6.600	5
6	Brazil	3.670	3.190	5.390	5
7	Russia	2.950	2.856	3.256	6
8	Venezuela	2.500	2.000	3.000	1
9	Suriname	1.700	1.100	1.700	1
10	Greece	1.450	0.640	1.900	2
11	Irish	1.400	1.400	1.500	1
12	Ukraine	1.314	1.314	1.750	2
13	Germany	1.276	1.276	1.276	3
14	Canada	1.200	1.250	1.400	1
15	Kazakhstan	1.200	1.100	1.500	1
16	Spain	1.100	1.000	1.300	1
17	Italy	0.950	0.555	1.000	1
18	Japan	0.925	0.688	0.925	3
19	Hungary	0.920	0.590	0.590	3
20	Indonesia	0.900	0	0.900	1
21 – 33	All other countries	4.835	2.633	5.715	17
	Total	66.615	49.878	80.062	84

rals during weathering. They include ore elements in the form of various aluminum hydroxide hydrates — gibbsite, boehmite, diaspore, as well as aluminum oxide — corundum. The ratio of these elements can vary significantly. Most of these minerals include aqueous aluminosilicates, among which kaolinite is the most common, as well as other representatives of its group, although other minerals are also found [3, 17, 18].

The mineralogical composition of bauxites is complex. They can contain up to one hundred minerals in various combinations, which contain up to 42 chemical elements [3, 17, 18].

The ratio of minerals of these groups in bauxites is very diverse and varies significantly even within a single deposit [3, 17, 18]. The latter is especially typical for deposits of alumina ores in Kazakhstan.

Bauxite deposits in the territory of the Republic of Kazakhstan are grouped into seven bauxite-bearing regions: Vostochno-Torgaysky (Amangeldinsky), Zapadno-Torgaysky, Tsentralno-Torgaysky, Mugodzharsky, Tselinogradsky (Akmola), Ekibastuzsky, Prichimkent. The bauxites of the first three regions, which contain 96% of the geological reserves of bauxite of the Republic of Kazakhstan, are suitable in quality and technological properties for processing at the Pavlodar Aluminum Plant. All bauxite deposits — Mesozoic in age — belong to the platform, continental type and are represented by gibbsite ores. The flint modulus of bauxite varies and averages 3—4 units.

The raw material base of JSC Aluminum of Kazakhstan was two districts — Zapadno-Torgaysky and Amangeldinsky. The following deposits belong to the West Torgai bauxite-bearing area: Ayatskoye, the remains of its geological reserves are estimated at 12.0 million tons, Belinskoye — at 28.5 million tons, Krasnooktyabrskoye — more than 100 million tons. It should be noted that part of the bauxite reserves of the Krasnooktyabrskoye field is enriched with organic compounds, these are the so-called lignite inclusions.

The reserves of lignite raw materials in existing quarries have been calculated, and during extraction they are stored in special dumps, which somewhat reduces the importance of the deposit. Krasnooktyabrsky bauxites differ from the design raw materials by a high content of carbonates, sulfates, and organic compounds, which makes it difficult to process it according to the classical Bayer-sintering scheme.

The Vostochno-Torgai bauxite-bearing area — the Torgai ore management — has only about 6 million tons of geological reserves with low quality indicators (flint module 2.8—2.9 units).

The mineralogical composition of all deposits of gibbsite bauxite in Kazakhstan differs mainly only in the quantitative ratio of minerals. Bauxites are crystallized to varying degrees; most often they contain a cryptocrystalline or amorphous mass of gibbsite and kaolinite impregnated with iron oxides. Relatively large crystals form secondary minerals that fill cracks, voids and pores.

The following minerals can be named, which are present in varying amounts in Kazakhstani bauxite and bauxite rocks:

- containing alumina — gibbsite, corundum;
- containing iron — hematite, goethite, magnetite, siderite, chlorites, pyrite and marcasite, iron hydroxides;
- silicon-containing — kaolinite, hydrosludes, quartz, galloisite, chalcedony, feldspar;
- containing titanium — ilmenite, anatase, rutile, leucoxene, sphen;
- containing calcium — calcite, gypsum.

The main mineral, gibbsite, is usually present in three forms: amorphous; fine-crystalline; coarse-crystalline. In bauxites, in which kaolinite is present in significant quantities, gibbsite is closely related to it, forming an undiscrystallized bauxite substance.

Corundum is mainly found in fresh, non-weathered stony bauxites. In general, the corundum content in Kazakhstan gibbsite bauxites is relatively low: it does not exceed 3—5% [3, 17, 18].

Silica in bauxites is present mainly in the form of kaolinite. There are three modifications of kaolinite: amorphous, fine-crystalline and coarse-crystalline. Amorphous kaolinite is the most widespread; in loose and clay bauxite differences, the content of kaolinite reaches 33—38%. Quartz is not typical for most deposits and is present in small quantities in the form of fragments, which are often replaced by gibbsite or siderite.

Chlorites usually develop from siderite and have a ferruginous composition.

Table 3

The chemical composition of bauxite processed at JSC «Aluminum of Kazakhstan», in comparison with the global average

Химический состав бокситов, перерабатываемых на АО «Алюминий Казахстана», в сравнении со средними мировыми показателями

Bauxite from various deposits	Ms, units	Content. % (by weight)						
		Al_2O_3	SiO_2	Fe_2O_3	CO_2	SO_3	$C_{орг}$	Cl
Turgai	2.9	44.0	15.0	15.7	0.14	0.28	0.15	0.18
Krasnooktyabrsky	4.8	43.0	9.0	19.6	3.7	0.80	0.35	0.35
Ayatsky	4.3	43.7	10.1	20.4	1.3	0.35	0.25	0.13
Belinsky	4.5	41.6	9.2	21.8	1.6	0.54	0.19	0.90
Russia (SUBR)	14.5	53.5	3J	22.5	–	0.16	0.10	–
Australia	12.1	43.7	3.6	16.4	следы	0.20	–	–
Brazil	11.0	49.4	4.5	14.6	0.1	–	–	–

According to X-ray diffraction analysis, they mainly belong to shamosite, which is widespread in the bauxites of the Krasnooktyabrsky deposit [3].

The main mineral forms of iron in the bauxites of the deposits under consideration are hematite, hematogel and amorphous iron hydroxides impregnating the bauxite substance. Goethite in association with hematite forms zonal collomorphic structures and rarely fine-needle crystals.

Siderite is extremely unevenly distributed and without any regularity, even within a single bauxite deposit. The largest amount of it is found in the bauxites of the Krasnooktyabrsky deposit, where the content of this mineral sometimes reaches 30%, and on average for the deposit it is about 6%.

Pyrite and its colloidal variety, melnikovite, are most characteristic of gray and carbonaceous bauxites, however, they are also found in red differences – in ore bodies lying not far from lignite clays.

Calcite is present in all deposits, but in small amounts. Gypsum is noted much less frequently.

The quality of bauxite raw materials is assessed by its content of Al_2O_3, SiO_2 and their mineral forms. Bauxite with a SiO_2 content of no more than 5% is usually processed abroad, which corresponds to a silicon module from 9 to 11 and above. [3, 19].

In Kazakhstan, bauxite with a very high SiO_2 content is considered an industrial raw material, which, according to the international classification, belong to bauxite clays or clay bauxites. In addition, the quality of bauxite is influenced by the amount of impurities in the form of sulfur compounds, iron, carbonates, chlorides and organic compounds.

Table 3 shows the chemical composition of bauxite processed at JSC Aluminum of Kazakhstan, in comparison with the global average.

It can be seen from the above table that bauxites from different deposits differ significantly in their qualitative composition and quantitative content of components, therefore, different processing methods or methods are used for them.

Turgai bauxite deposit and its impact on the environment and the population of the region

In Kazakhstan, bauxite processing is carried out at the Pavlodar Aluminum Plant (PAP), which is part of the structure of JSC Aluminum of Kazakhstan. The plant was designed for processing bauxite from the Turgai deposit, the quarry of which is located in Turgai village near Arkalyk. The deposits are located in the steppe zone of Northern Kazakhstan. The climate of the area is sharply continental: with hot and dry summers and frosty winters. The territory of the Kostanay (Turgai) region is accessible to the dry air masses of the deserts of Kazakhstan and the cold Arctic winds. A special role in the climate of the area is played by the wind, which sometimes has a speed of more than 20 m/sec. Precipitation falls mainly from April to October. Their nature is short-term, the number varies in different years from 66 to 359 mm. Evaporation is more than 2 times the amount of precipitation. This causes the intensive formation of salt marshes and salt flats on saline soil-forming rocks. In the study area, most lakes have waters with varying degrees of salinity. The type of salinity is bicarbonate-chloride-sodium and chloride-sulfate-sodium. The deposit is located in the subzone of the dry Tipchak-kovyl steppes. The natural vegetation is mainly represented by xerophytic turf grasses and (tipchak, hairy grass, reddish and Sarepta, grasshopper, desert oatmeal), there are wormwood (Austrian, saltpetre, cold, Marshall) and dry-loving grasses (Tatar breast, narrow-leaved carnation, stemless lapchatka, pyrethrum Kazakhstansky). The closeness of the herbage is about 60% , height 20–30 cm. Bauxite deposits were formed in the Mesozoic era, namely in the Cretaceous period. Lignite and multicolored clays can be found in the immediate vicinity of the ore. The Cretaceous deposits are covered with Paleogene rocks of the Cenozoic era. These include light gray or brown flake clays and glauconite Quartz sands and sandstones of the Tasaran formation. Closer to the surface there are Chegan grayish-green and olive-green fatty, dense, thin-layered clays, desalinated clays and fine-grained obliquely layered quartz sands of marine origin, Oligocene coarse-grained quartz sands and calcified sandstones of yellow-brown and red-brown color, as well as variegated — continental; The deposits of Quaternary age are of continental and lacustrine origin, greenish-gray and yellowish-brown in color. Modern Quaternary rocks are represented by lacustrine (fresh and saline) fine-grained quartz greenish-gray and gray sands, silty clays with remnants of lake vegetation, with fading salts of sodium chloride composition, as well as loess-like brown-gray and yellowish-brown sandy loams and loams.

The reserves of Turgai bauxite were depleted, their quality deteriorated and bauxites from other deposits began to be involved in processing: Ayatsky, Belinsky and Krasnogorsky [19–22].

The Turgai bauxite mine has been operating in Arkalyk since 1956. During this time, the company's employees have worked out more than 1.5 billion m^3 of rock mass, extracted more than 80 million tons of bauxite and 20 million tons of refractory clay [23–24].

Due to the depletion of bauxite reserves in 2021, the Turgai Bauxite Ore Management (TBRU), which was part of JSC Aluminum of Kazakhstan, the aluminum division of ERG, ceased its work [25–26]. A result of the development, operation and extraction of bauxite at the Turgai deposit, which was carried out in an open-pit manner, over 65 years of continuous operation, more than 40 million tons of substandard bauxite have accumulated, which have been going into dumps all these years.

The dumps are located near the residential areas of Turgay and Arkalyk, and having SiO_2 (8–27%), Al_2O_3 (11–40%), Fe_2O_3 (3–25%), sulfur compounds and impurities of non–ferrous metals, in particular zinc and lead, under the influence of natural and climatic conditions, have a negative impact on the environment. In particular, by occupying agricultural land for landfills, spreading silicate dust containing solid particles (PM) in windy weather, penetrating into soil, surface and groundwater, thereby polluting soil, water and air.

Air pollution negatively affects both the state of the environment in general and human health in particular. It is one of the main causes of death and morbidity worldwide. According to the World Health Organization, 4.2 million premature deaths worldwide are associated with atmospheric air pollution, mainly from cardiovascular diseases, stroke, chronic obstructive pulmonary disease, lung cancer and acute respiratory diseases in children.

Particulate matter (PM) is of particular concern because of its health effects: some PM can penetrate deep into the respiratory tract. A large number of epidemiological and toxicological studies have shown an association of PM exposure with mortality and morbidity [27 — 29]; with lung cancer [30, 31]; with cardiovascular diseases [32, 33].

In developed countries, the level of particulate air pollution is decreasing, while in most developing countries it is increasing. Concentrations of fine particles (PM2.5) in sub-Saharan Africa and Asia are significantly higher than in Europe, the eastern United States and western South America [34]. The main form of influence of mining enterprises on air quality is atmospheric pollution by their emissions, which release dangerous pollutants into the air in the form of particles with a high content of heavy metals, carbon monoxide, sulfur dioxide or nitrogen oxides [35].

Dust in mining areas has a great impact on the environment and public health.

Bauxite dumps are the largest mining resource that has been in operation for 65 years and is currently having a negative anthropogenic impact on the region.

WHO provides worldwide guidelines on thresholds and maximum permissible levels of major gaseous air pollutants and particulate matter. The pollutants with the most convincing evidence of negative effects on human health include particulate matter (PM), nitrogen dioxide (NO_2), ozone (O_3) and sulfur dioxide (SO_2).

Particulate pollution is one of the global problems. They serve as carriers of several toxic substances and can penetrate deep into the respiratory tract. Depending on their diameter, it is possible to distinguish between coarse particles (PM10) with a diameter of less than 10 microns; and fine particles (PM2.5) with a diameter of less than 2.5 microns.

Air pollution from certain particulate matter has health effects even at very low levels of concentration.

Many studies have linked high morbidity and mortality rates to air pollution. According to a global study, deaths from air pollution are prevalent in East Asia (35%) and South Asia (32%), followed by Africa (11%) and Europe (9%). Meta-analyses indicate an average 11% increase in mortality from cardiovascular diseases with prolonged exposure to PM2.5 and an annual increase of 10 micrograms/m^3 [36].

Research by scientists has shown that air pollution can affect the development of the fetus during pregnancy, lead to premature birth, low birth weight, and subsequently stunted growth, respiratory and cardiovascular diseases, an increase in the risk of weight loss at birth by 35%, as well as an increase in stillbirths by 29% [37].

Conclusions

A result of the analysis of the current development of the global aluminum industry, in particular, the extraction of bauxite and their processing with the formation of dumps of substandard bauxite from the Turgai deposit, the following conclusions and conclusions can be drawn that:

• There is a high demand for aluminum in the form of metal in the global community, which, in turn, automatically entails a demand for the development and extraction of bauxite and, accordingly, an increase in mining waste in the coming years at the deposits;

• During the continuation of bauxite mining around the world, the number of dumps of substandard bauxite, which have an anthropogenic impact on the environment and human health, will increase;

• Dumps of substandard bauxite, containing in their composition such chemical compounds as SiO_2, Al_2O_3, Fe_2O_3, sulfur compounds and impurities of non-ferrous metals are toxic waste that require finding ways to comprehensively dispose of them in order to reduce the anthropogenic impact on the environment and human health;

• One of such ways of recycling dumps of substandard bauxite can be their complex processing as a secondary mineral raw material.

We express our gratitude to the M. Auezov South Kazakhstan University and Saint-Petersburg State Institute of Technology for the opportunity to conduct research.

СПИСОК ЛИТЕРАТУРЫ

1. *Sehnke E. D., Bond A. R.* Russian bauxite resources: Current assessment // International Geology Review. 1993, vol. 35, no. 11, pp. 1052—1061. DOI: 10.1080/00206819309465575.

2. *Govorova L. P., Vakalova T. V., Shvagrukova E. V.* Features of chemical-mineralogical composition and processing properties for medium-ferrous bauxites // MATEC Web of Conferences. 2016, vol. 85, article 125563. DOI: 10.1051/ matecconf/20168501025.

3. *Dyussenova S., Abdulvaliyev R., Akcil A., Gladyshev S., Ruzakhunova G.* Processing of low-quality gibbsite-kaolinite bauxites // Metals. 2022, vol. 12, no. 6, article 1030. DOI: 10.3390/met 12061030.

4. *Klyuev A. V., Kashapov N. F., Klyuev S. V., Lesovik R. V., Ageeva M. S., Fomina E. V., Ayubov N. A.* Development of alkali-activated binders based on technogenic fibrous materials // Construction Materials and Products. 2023, vol. 6, no. 1, pp. 60—73. DOI: 10.58224/2618-7183-2023-6-1-60-73.

5. *Smith P.* The processing of high silica bauxites — Review of existing and potential processes // Hydrometallurgy. 2009, vol. 98, pp. 162—176.

6. *Abdulmunhsin S. S.* Investigating the relationship between air pollutants and meteorology: A canonical correlation analysis // Polish Journal of Environmental Studies. 2022, vol. 31, no. 6, pp. 5841—5849.

7. *Authier-Martin M., Forté G., Ostap S.* The mineralogy of bauxite for producing smelter-grade alumina // JOM. 2001, vol. 53, no. 12, pp. 36—40. DOI: 10.1007/s11837-001-0011-1.

8. *Sarvut T. O.* Circumpolar aspect in the development of urban environment organization in Russian cities // Construction Materials and Products. 2023, vol. 6, no. 5, pp. 8. DOI: 10.58224/2618-7183-2023-6-5-8.

9. *Jumasheva K., Syrlybekkyzy S., Serikbayeva A., Nurbaeva F., Kolesnkov A.* Study the composition and environmental impact of sewage sludge // Journal of Ecological Engineerin. 2023, vol. 24, no. 3, pp. 315—322.

10. *Kolesnikov A. S.* Thermodynamic simulation of silicon and iron reduction and zinc and lead distillation in zincoligonite ore-carbon systems // Russian Journal of Non-Ferrous Metals. 2014, vol. 55, pp. 513—518. DOI: 10.3103/S1067821214060121.

11. *Vorona-Slivinskaya L. G.* Regional plans for solid waste management: distinctive features of practice in Russia and EU countries // Construction Materials and Products. 2023, vol. 6, no. 3, pp. 98—118. DOI: 10.58224/2618-7183-2023-6-3-98-118

12. *Donaev A., Kolesnikov A., Shapalov Sh., Sarapagalieva B., Ivahnuk G.* Studies of waste from the mining and metallurgical industry, with the determination of its impact on the life of the population // News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences. 2022, vol. 4, pp. 55—68.

13. *Klyuev A. V., Kashapov N. F., Klyuev S. V., Zolotareva S. V., Shchekina N. A., Shorstova E. S., Lesovik R. V., Ayubov N. A.* Experimental studies of the processes of structure formation of composite mixtures with technogenic mechanoactivated silica component // Construction Materials and Products. 2023, vol. 6, no. 2, pp. 5 – 18. DOI: 10.58224/2618-7183-2023-6-2-5-18.
14. *Серебряков П. В.* Профессиональные заболевания органов дыхания: национальное руководство // Медицина труда и промышленная экология. – 2016. – № 7. – С. 47 – 48.
15. *Дубовикова О. А., Наумчик А. Н., Еремин Н. И.* О переработке некондиционных бокситов Казахстана // Записки Горного института. – 1978. – Т. 78. – С. 42.
16. *Сизяков В. М.* Эффективный способ комплексной переработки нефелинов на глинозем и попутные продукты // Записки Горного института. – 2001. – Т. 149. – № 5. – С. 177 – 182.
17. *Дубовиков О. А., Бричкин В. Н., Николаева Н. В., Ромашев А. О.* Исследование процесса термохимического обогащения бокситов Среднего Тимана // Обогащение руд. – 2014. – № 4. – С. 14 – 18.
18. *Bazin C., El-OuassitI K., Ouellet V.* Sequential leaching for the recovery of alumina from a Canadian clay // Hydrometallurgy. 2007, vol. 88, no. 1-4, pp. 196 – 201. DOI: 10.1016/ j.hydromet.2007.05.002.
19. *Кожахметова З. Ж., Кожахметов О. С.* О современных методах разработки бокситовых месторождений // Молодой ученый. – 2017. – № 17(151). – С. 95 – 98.
20. *Логинова В., Шопперт А. А., Чайкин Л. И., Кырчиков А. В., Доре Би И, Доре Би, Киреев А. Е.* Комплексная переработка бокситового сырья является основной задачей ближайших лет / Металлургия цветных металлов: сборник материалов IV международной научно-технической конференции, посвященной 100-летию со дня рождения С.И. Кузнецова. – Екатеринбург: УрФУ, 2018. – С. 30 – 35.
21. *Sarsenbay G., Myltykbaeva L., Abdulwalyev R., Satylganova S.* The study of method for complex processing turgay sub-standard aluminum-containing raw materials // Advances in Materials Physics and Chemistry. 2012, vol. 2, pp. 216 – 220. DOI: 10.4236/ampc.2012.24B055.
22. *Каирбеков Ж. К., Жалгасулы Н., Аубакиров Е. А.* Новые технологии добычи и переработки полезных ископаемых: Монография. – Алматы: КазНУ, 2014. – 224 с.
23. *Суюндиков М. М., Абикенова Г. К., Красных И. А., Дейграф И. Э., Суюндик Н. М.* Исследование известковой каустификации растворов процесса Байера в производстве глинозема // Труды университета. – 2022. – № 2(87). – С. 42 – 46. DOI: 10.52209/1609-1825_2022_2_42.
24. *Lippmann M., Ito K., Nadas A., Burnett R.* Association of particulate matter components with daily mortality and morbidity in urban populations // Research Report, 2000, vol. 95, pp. 73 – 82.
25. *Dominici F., Zanobetti A., Zeger S. L., Schwartz J., Samet J. M.* Hierarchical bivariate time series models: a combined analysis of the effects of particulate matter on morbidity and mortality // Biostatistics. 2004, vol. 5, pp. 341 – 360.
26. *Newell K., Kartsonaki C., Lam K. B. H., Kurmi O. P.* Cardiorespiratory health effects of particulate ambient air pollution exposure in low-income and middle-income countries: a systematic review and meta-analysis // Lancet Planet Health. 2017, vol. 1, pp. 368 – 380.
27. *Pope C. A., Burnett R. T., Thun M. J.* Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution // Jama. 2002, vol. 287, pp. 1132 – 1141.
28. *Turner M. C., Krewski D., Pope C.A. Chen Y., Gapstur S. M., Thun M. J.* Long-term ambient fine particulate matter air pollution and lung cancer in a large cohort of never-smokers // American Journal of Respiratory and Critical Care Medicine. 2011, vol. 184, no. 12, pp. 1374 – 1381. DOI: 10.1164/rccm.201106-1011OC.
29. *Brook R. D., Rajagopalan S., Pope C. A. Brook J. R., Bhatnagar A., Diez-Roux A. V., Holguin F., Hong Y., Luepker R. V., Mittleman M. A., Peters A., Siscovick D., Smith S. C. Jr., Whitsel L., Kaufman J. D.* Particulate matter air pollution and cardiovascular disease an update to the scientific statement from the American Heart Association // Circulation. 2010, vol. 121, pp. 2331 – 2378.
30. *Pope C. A., Burnett R. T., Krewski D., Jerrett M., Shi Y., Calle E. E., Thun M. J.* Cardiovascular mortality and exposure to airborne fine particulate matter and cigarette smoke shape of the exposure-response relationship // Circulation. 2009, vol. 120, pp. 941 – 948.
31. *Petkova E. P., Jack D. W., Volavka-Close N. H., Kinney P. L.* Particulate matter pollution in African cities // Air Qualite Atmosphere Health. 2013, vol. 6, pp. 603 – 614.
32. *Keita M., Traore O.* Environmental impact of open PIT mining: Case of bauxite mining in Guinea // International Journal of Applied Environmental Sciences. 2020, vol. 15, pp. 167 – 177.

33. *Assad M.* Transfert des éléments traces métalliques vers les végétaux: mécanismes et évaluations des risques dans des environnements exposés à des activités anthro-piques // TEL. 2017.

34. *Ткаченко К. А.* Китайские инфраструктурные проекты в Африке // Азия и Африка сегодня. — 2018. — № 2. — С. 41—44.

35. *Liousse C., Galy-Lacaux C.* Pollution urbaine en Afrique de l'Ouest // La Météorologie. 2010, vol. 71, pp. 45—49.

36. *Bourdel T., Bind M., Bejot Y., Morel O., Argacha J-F.* Cardiovascular effects of air pollution // Archives of Cardiovascular Disease. 2017, vol. 110, pp. 634—642.

37. *Mannucci P. M., Franchini M.* Health effects of ambient air pollution in developing countries // International Journal of Environmental Research and Public Health. 2017, vol. 14, article 1048. ГИАБ

REFERENCES

1. Sehnke E. D., Bond A. R. Russian bauxite resources: Current assessment. *International Geology Review*. 1993, vol. 35, no. 11, pp. 1052—1061. DOI: 10.1080/00206819309465575.

2. Govorova L. P., Vakalova T. V., Shvagrukova E. V. Features of chemical-mineralogical composition and processing properties for medium-ferrous bauxites. *MATEC Web of Conferences*. 2016, vol. 85, article 125563. DOI: 10.1051/ matecconf/20168501025.

3. Dyussenova S., Abdulvaliyev R., Akcil A., Gladyshev S., Ruzakhunova G. Processing of low-quality gibbsite-kaolinite bauxites. *Metals*. 2022, vol. 12, no. 6, article 1030. DOI: 10.3390/met 12061030.

4. Klyuev A. V., Kashapov N. F., Klyuev S. V., Lesovik R. V., Ageeva M. S., Fomina E. V., Ayubov N. A. Development of alkali-activated binders based on technogenic fibrous materials. *Construction Materials and Products*. 2023, vol. 6, no. 1, pp. 60—73. DOI: 10.58224/2618-7183-2023-6-1-60-73.

5. Smith P. The processing of high silica bauxites — Review of existing and potential processes. *Hydrometallurgy*. 2009, vol. 98, pp. 162—176.

6. Abdulmunhsin S. S. Investigating the relationship between air pollutants and meteorology: A canonical correlation analysis. *Polish Journal of Environmental Studies*. 2022, vol. 31, no. 6, pp. 5841—5849.

7. Authier-Martin M., Forté G., Ostap S. The mineralogy of bauxite for producing smelter-grade alumina. *JOM*. 2001, vol. 53, no. 12, pp. 36—40. DOI: 10.1007/s11837-001-0011-1.

8. Sarvut T. O. Circumpolar aspect in the development of urban environment organization in Russian cities. *Construction Materials and Products*. 2023, vol. 6, no. 5, pp. 8. DOI: 10.58224/2618-7183-2023-6-5-8.

9. Jumasheva K., Syrlybekkyzy S., Serikbayeva A., Nurbaeva F., Kolesnkov A. Study the composition and environmental impact of sewage sludge. *Journal of Ecological Engineerin*. 2023, vol. 24, no. 3, pp. 315—322.

10. Kolesnikov A. S. Thermodynamic simulation of silicon and iron reduction and zinc and lead distillation in zincoligonite ore-carbon systems. *Russian Journal of Non-Ferrous Metals*. 2014, vol. 55, pp. 513—518. DOI: 10.3103/S1067821214060121.

11. Vorona-Slivinskaya L. G. Regional plans for solid waste management: distinctive features of practice in Russia and EU countries. *Construction Materials and Products*. 2023, vol. 6, no. 3, pp. 98—118. DOI: 10.58224/2618-7183-2023-6-3-98-118

12. Donaev A., Kolesnikov A., Shapalov Sh., Sarapagalieva B., Ivahnuk G. Studies of waste from the mining and metallurgical industry, with the determination of its impact on the life of the population. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences*. 2022, vol. 4, pp. 55—68.

13. Klyuev A. V., Kashapov N. F., Klyuev S. V., Zolotareva S. V., Shchekina N. A., Shorstova E. S., Lesovik R. V., Ayubov N. A. Experimental studies of the processes of structure formation of composite mixtures with technogenic mechanoactivated silica component. *Construction Materials and Products*. 2023, vol. 6, no. 2, pp. 5—18. DOI: 10.58224/2618-7183-2023-6-2-5-18.

14. *Serebryakov P. V.* Occupational respiratory diseases: national guidelines. *Russian Journal of Occupational Health and Industrial Ecology*. 2016, no. 7, pp. 47—48. [In Russ].

15. Dubovikova O. A., Naumchik A. N., Eremin N. I. On the processing of substandard bauxite in Kazakhstan. *Journal of Mining Institute*. 1978, vol. 78, pp. 42. [In Russ].

16. Sizyakov V. M. Efficient method of integrated processing of nepheline into alumina and by-products. *Journal of Mining Institute*. 2001, vol. 149, no. 5, pp. 177—182. [In Russ].

17. Dubovikov O. A., Brichkin V. N., Nikolayeva N. V. The middle Timan bauxites thermo-chemical treatment process study. *Obogashchenie Rud*. 2014, no. 4, pp. 14 — 18. [In Russ].
18. Bazin C., El-OuassitI K., Ouellet V. Sequential leaching for the recovery of alumina from a Canadian clay. *Hydrometallurgy*. 2007, vol. 88, no. 1-4, pp. 196 — 201. DOI: 10.1016/ j.hydromet.2007.05.002.
19. Kozhakhmetova Z. Zh., Kozhakhmetov O. S. On modern methods of development of bauxite deposits. *Young scientist*. 2017, no. 17(151), pp. 95 — 98. [In Russ].
20. Loginova V., Shoppert A. A., Chaikin L. I., Kirchikov A. V., Dore Bi And, Dore Bi, Kireev A. E. Complex processing of bauxite raw materials is the main task of the coming years. *Metallurgiya tsvetnykh metallov: sbornik materialov IV mezhdunarodnoy nauchno-tekhnicheskoy konferentsii, posvyashchennoy 100-letiyu so dnya rozhdeniya S.I. Kuznetsova* [Metallurgy of non-ferrous metals: a collection of materials of the IV International scientific and technical conference dedicated to the 100th anniversary of the birth of S.I. Kuznetsov], Ekaterinburg, UrFU, 2018, pp. 30 — 35. [In Russ].
21. Sarsenbay G., Myltykbaeva L., Abdulwalyev R., Satylganova S. The study of method for complex processing turgay sub-standard aluminum-containing raw materials. *Advances in Materials Physics and Chemistry*. 2012, vol. 2, pp. 216 — 220. DOI: 10.4236/ampc.2012.24B055.
22. Kairbekov Zh. K., Zhalgasuly N., Aubakirov E. A. *Novye tekhnologii dobychi i pererabotki poleznykh iskopaemykh*: Monografiya [New technologies of mining and processing of minerals: Monograph], Almaty, KazNU, 2014, 224 p.
23. Suyundikov M. M., Abikenova G. K., Krasnykh I. A., Deigraf I. E., Suyundik N. M. Investigation of calcareous caustification of solutions of the Bayer process in the production of alumina. *Proceedings of the University*. 2022, no. 2(87), pp. 42 — 46. [In Russ]. DOI: 10.52209/1609-1825_2022_2_42.
24. Lippmann M., Ito K., Nadas A., Burnett R. Association of particulate matter components with daily mortality and morbidity in urban populations. *Research Report*. 2000, vol. 95, pp. 73 — 82.
25. Dominici F., Zanobetti A., Zeger S. L., Schwartz J., Samet J. M. Hierarchical bivariate time series models: a combined analysis of the effects of particulate matter on morbidity and mortality. *Biostatistics*. 2004, vol. 5, pp. 341 — 360.
26. Newell K., Kartsonaki C., Lam K. B. H., Kurmi O. P. Cardiorespiratory health effects of particulate ambient air pollution exposure in low-income and middle-income countries: a systematic review and meta-analysis. *Lancet Planet Health*. 2017, vol. 1, pp. 368 — 380.
27. Pope C. A., Burnett R. T., Thun M. J. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *Jama*. 2002, vol. 287, pp. 1132 — 1141.
28. Turner M. C., Krewski D., Pope C.A. Chen Y., Gapstur S. M., Thun M. J. Long-term ambient fine particulate matter air pollution and lung cancer in a large cohort of never-smokers. *American Journal of Respiratory and Critical Care Medicine*. 2011, vol. 184, no. 12, pp. 1374 — 1381. DOI: 10.1164/ rccm.201106-1011OC.
29. Brook R. D., Rajagopalan S., Pope C. A. Brook J. R., Bhatnagar A., Diez-Roux A. V., Holguin F., Hong Y., Luepker R. V., Mittleman M. A., Peters A., Siscovick D., Smith S. C. Jr., Whitsel L., Kaufman J. D. Particulate matter air pollution and cardiovascular disease an update to the scientific statement from the American Heart Association. *Circulation*. 2010, vol. 121, pp. 2331 — 2378.
30. Pope C. A., Burnett R. T., Krewski D., Jerrett M., Shi Y., Calle E. E., Thun M. J. Cardiovascular mortality and exposure to airborne fine particulate matter and cigarette smoke shape of the exposure-response relationship. *Circulation*. 2009, vol. 120, pp. 941 — 948.
31. Petkova E. P., Jack D. W., Volavka-Close N. H., Kinney P. L. Particulate matter pollution in African cities. *Air Qualite Atmosphere Health*. 2013, vol. 6, pp. 603 — 614.
32. Keita M., Traore O. Environmental impact of open PIT mining: Case of bauxite mining in Guinea. *International Journal of Applied Environmental Sciences*. 2020, vol. 15, pp. 167 — 177.
33. Assad M. Transfert des éléments traces métalliques vers les végétaux: mécanismes et évaluations des risques dans des environnements exposés à des activités anthro-piques. *TEL*. 2017.
34. Tkachenko K. A. Chinese infrastructure projects in Africa. *Asia and Africa today*. 2018, no. 2, pp. 41 — 44. [In Russ].
35. Liousse C., Galy-Lacaux C. Pollution urbaine en Afrique de l'Ouest. *La Météorologie*. 2010, vol. 71, pp. 45 — 49.
36. Bourdel T., Bind M., Bejot Y., Morel O., Argacha J-F. Cardiovascular effects of air pollution. *Archives of Cardiovascular Disease*. 2017, vol. 110, pp. 634 — 642.
37. Mannucci P. M., Franchini M. Health effects of ambient air pollution in developing countries. *International Journal of Environmental Research and Public Health*. 2017, vol. 14, article 1048.

ИНФОРМАЦИЯ ОБ АВТОРАХ
Есенбаев Бауыржан Анварбекович[1] — докторант PhD,
e-mail: ip_esenbaevb@mail.ru,
ORCID ID: 0009-0009-8707-9543,
Колесников Александр Сергеевич[1] — канд. техн. наук,
профессор, e-mail: kas164@yandex.kz,
ORCID ID: 0000-0002-8060-6234,
Наукенова Айгуль Сагындыковна[1] — канд. техн. наук,
профессор, e-mail: n.a.s.1970@mail.ru,
ORCID ID: 0000-0003-0596-7141,
Шапалов Шермахан Куттыбаевич[1] — доктор философии (PhD),
профессор, e-mail: shermahan_1984@mail.ru,
ORCID ID: 0000-0002-3015-5965,
Раматуллаева Ляззат Имамадиновна[1] — канд. техн. наук,
доцент, e-mail: ramatullaeva_l@mail.ru,
ORCID ID: 0000-0003-1771-9903,
Ивахнюк Григорий Константинович — д-р хим. наук,
профессор, Санкт-Петербургский государственный
технологический институт (технический университет),
e-mail: fireside@inbox.ru,
ORCID ID: 0000-0002-3983-2328,
[1] Южно-Казахстанский университет им. М. Ауэзова,
Шымкент, Республика Казахстан.
Для контактов: Колесников А.С., e-mail: kas164@yandex.kz.

INFORMATION ABOUT THE AUTHORS
B.A. Yessenbayev[1], PhD Student,
e-mail: ip_esenbaevb@mail.ru,
ORCID ID: 0009-0009-8707-9543,
A.S. Kolesnikov[1], Cand. Sci. (Eng.), Professor,
e-mail: kas164@yandex.kz,
ORCID ID: 0000-0002-8060-6234,
A.S. Naukenova[1], Cand. Sci. (Eng.),
Professor, e-mail: n.a.s.1970@mail.ru,
ORCID ID: 0000-0003-0596-7141,
Sh.K. Shapalov[1], PhD, Professor,
e-mail: shermahan_1984@mail.ru,
ORCID ID: 0000-0002-3015-5965,
L.I. Ramatullaeva[1], Cand. Sci. (Eng.),
Assistant Professor, e-mail: ramatullaeva_l@mail.ru,
ORCID ID: 0000-0003-1771-9903,
G.K. Ivakhniyuk, Dr. Sci. (Chem.), Professor,
Saint-Petersburg State Institute of Technology,
190013, Saint-Petersburg, Russia,
e-mail: fireside@inbox.ru,
ORCID ID: 0000-0002-3983-2328,
[1] M. Auezov South Kazakhstan University, 160012, Shymkent, Kazakhstan.
Corresponding author: A.S. Kolesnikov, e-mail: kas164@yandex.kz.

Получена редакцией 09.12.2023; получена после рецензии 15.01.2024; принята к печати 10.02.2024.
Received by the editors 09.12.2023; received after the review 15.01.2024; accepted for printing 10.02.2024.