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Scientific article

ASSESSMENT OF THE IMPACT OF MINING ENTERPRISES IN THE AKTOBE REGION ON THE ENVIRONMENT (USING THE EXAMPLE OF CHROMIUM DEPOSITS)

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ABSTRACT

Remote sensing (ERS) is a powerful tool for exploring quarries and assessing their environmental impact. This method provides extensive capabilities for monitoring, mapping and analyzing changes caused by mining activities. The mining industry has a significant negative impact on the environment, especially quarrying, which leads to landscape changes, contamination of water sources and deterioration of soils. In the Aktobe region of Western Kazakhstan, the mining of chromite ores around the city of Khromtau causes serious environmental problems. The study is aimed at improving the methodology for assessing the technogenic impact of a deposit near the city of Khromtau using Earth remote sensing (ERS) data. The study was based on field research conducted in 2012…2020 and data from мен Landsat-5TM (1986 y) and Landsat-8 OLI (2023 y) satellite images. Analysis of satellite images made it possible to identify and map zones of technogenic impact, assess environmental risks and determine the scale of anthropogenic disturbances. For more than 30 years, the area of quarries and disturbed areas has increased significantly, which negatively affects the ecological state of the city of Khromtau and its environs. Heavy metals such as chromium tend to bioaccumulate, which is hazardous to human health and the environment. The use of remote sensing allows you to quickly obtain up-to-date information for monitoring and managing the environmental condition, which helps improve the quality of life and preserve natural resources. The use of remote sensing in the study of quarries of chromite deposits allows not only to identify the scale and nature of technogenic impact, but also to propose measures to mitigate negative consequences for the environment.

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1. INTRODUCTION

The activities of the mining industry, engaged in the extraction and beneficiation of various types of ore raw materials, have a negative impact on the environment and human health. Mining is carried out by open and closed methods. More than 85 % of deposits are developed by the open pit method. In the open pit method, a large amount of rock is thrown out of the subsurface and large volumes of residual dumps – slag heaps – are formed. For example, in Germany, more than 400 thousand hectares were damaged by open-pit mining alone, and in the USA, dumps alone occupied developed economies, places that have become industrialized and technogenic landscapes - cause the most damage to the natural landscape, agriculture and forestry. The vast majority of mining sites are now completely closed, and even restoration work was completed many years ago, and there are now no signs of former mining waste left in their places. The Lausitz lignite basin of the 70 m high dump of the Espenhein open pit, where FRG mining operations were completed, is now used as a storage area for Creburn waste. Waste accompanying ore beneficiation, concentrated

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in spoil heaps and artificial water bodies, leads to subsidence of the ground cover and changes in the landscape. And erosion of land and water spreads environmentally hazardous chemicals over long distances. In the process of production, the ecological situation that has developed in the territories of industrial facilities location (mines, mines, processing plants) is completely or partially disturbed [2]. These changes are manifested in a set of various reverse phenomena, the most important of which are the orientation of agricultural areas to mining operations, depletion and damage to ground and surface water, flooding and waterlogging of developed lands, desiccation and salinization of soils, air pollution with harmful substances, chemical elements, hydrogeological, geochemical and microclimatic changes can be stated [3].

Similarly, Sukinda (India) – One of the most polluted places in the world, home to one of the largest chromium quarries. The number of people affected there is 260,000. The chromium content in 60 % of the drinking water is twice the international standard allowed. 87 % of deaths in the area are related to diseases caused by chromium poisoning [4].

Chrome ore (chromites) is one of the most valuable metal ores in the world. Identified chromite resources are estimated in 47 countries of the world and are valued at $15 billion tons. South Africa ranks first in terms of reserves (accounting for 76 % of proven reserves). Kazakhstan ranks second in the world (accounting for 9 % of world reserves) and the share of commodity chromium in the world economy is 15...20 % (Figure 1). In addition, chromite resources are also found in the USA, India, Philippines, Turkey, Madagascar, Brazil, Zimbabwe and the countries of the Philippines [5].

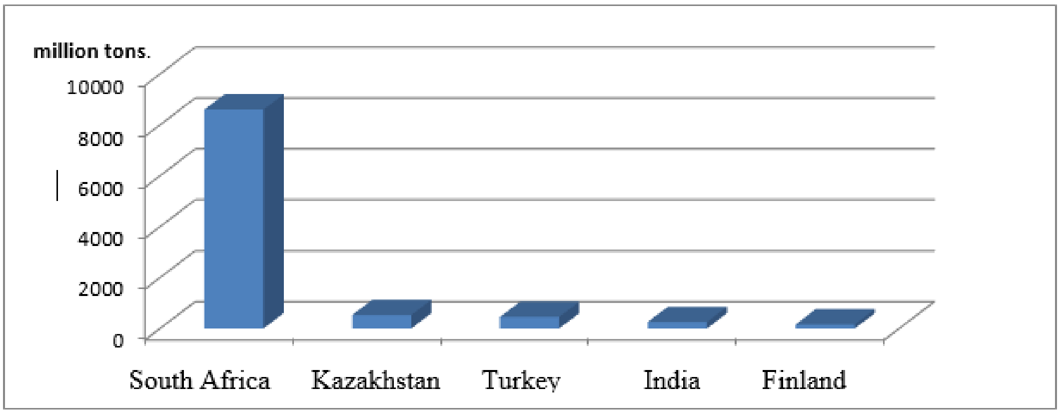

Figure 1. *Global chromium production*

Chromium mines and plants are major sources of environmental pollution. For example, Sukinda (India) – One of the dirtiest places in the world because it is home to one of the largest chrome mines. The number of people affected is 260,000, 60 % of the drinking water contains twice as much chromium as the international standard allows. 87 % of deaths in the area were caused by chromium poisoning [6].

With the development of new technologies that allow for the expansion of industrial development, modern machinery and equipment, the process of mining is constantly increasing, which in turn increases the anthropogenic-technogenic impact on ecosystems [7]. the main factor of environmental change is technogenic processes arising from the exploitation of various forms of mining. In this regard, the Law of RK “On Environmental Protection” stipulates: “local executive bodies of oblasts regulate nature management on issues of land protection from depletion, desertification, water and wind erosion, sedimentation, waterlogging, soil salinization” [8]. In addition, as of January 1, 2016, the world officially launched the Sustainable Development Agenda, an active reconstruction plan for 2030. The plan is based on the 17 Sustainable Development Goals, which are integrated and indivisible and balance the three pillars of sustainable development: economic, social and environmental. In this regard, this study is in line with the following Sustainable Development Goals: 3-health and well-being; 6-sanitation with clean water; 11-sustainable cities and towns; 12-production with responsible consumption and 15-conservation of terrestrial ecosystems [9].

In the mining industry, remote sensing of the Earth by satellite (RS) is becoming an increasingly necessary method due to the ability to cover large areas associated with mining, identify surface features, and monitor landscape changes [10]. In addition, the use of remote sensing technologies provides unique opportunities for comprehensive assessment of the environmental impact of mining. In addition, monitoring using remote sensing helps in the identification and digital assessment of environmental changes, development of effective measures related to the management of natural resources and reduction of negative environmental impact. The introduction of these technologies will also create conditions for sustainable development of the mining industry and protection of ecosystems [11].

One of such mining enterprises with a negative impact on the environment is the extraction of chromite ores located in the Aktobe region of Western Kazakhstan (Figure 2).

Figure 2. *Chrome deposits near the city of Khromtau*

The mining industry plays an important role in the economic development of Aktobe region, being one of the main sources of income and employment in the region. Chromium deposits, which have been mined for many years, are considered particularly important. Intensive extraction of natural resources and changes in environmental and social conditions occur in parallel, so it is very important to study and assess them accurately [12].

The world's largest reserves of chrome ore are located in Aktobe region, which is the reason for the high activity of mining enterprises. The development of chrome deposits has a significant impact on various components of the environment: air, water, soil, plants and animals. At the same time, on the one hand, the socio-economic situation of the local population improves: jobs are created, infrastructure is updated, on the other hand, due to environmental problems there are also negative consequences associated with the deterioration, reduction of living conditions of the population [13...14].

The research work will be devoted to the identification and analysis of environmental and social impacts of mining in the Aktobe region, based on space images, as well as assessment of the environmental impact of chrome mining enterprises, development of proposals to minimize the impact and ensure sustainable development of the region. They will be aimed at developing strategies and measures aimed at reducing environmental risks and ensuring harmonious development of the mining region. We hope that the studies will contribute to improving mineral management practices and promoting sustainable development of the Aktobe region, striking a balance between economic growth and environmental protection.

In this regard, the purpose of our study is to improve the methods for assessing the anthropogenic impact of deposits near Khromtau using remote sensing data.

2. MATERIALS AND METHODS

It is important for Kazakhstan to extract valuable raw materials, as it ranks 1st in the world in terms of ore quality and has a high value on the world market, which is set by counterparties [7]. Donskoy Mining and Processing Plant is a city-forming enterprise and contributes to the economic growth and development of the region and the country as a whole. In addition, the mining and processing of chrome ores provides jobs for thousands of Kazakhstani people. Kazakhstan is one of the world's leading chrome producers and actively cooperates with other countries in trade and technology. This will help strengthen international economic ties and enhance the country's standing on the world stage. The presence of large chrome deposits is a strategic advantage for Kazakhstan. It ensures the country's stability and independence in providing basic materials for various industries.

The object of the study is chrome ore deposits located near the town of Khromtau (Figure 1). Khromtau city is a city of district significance and the administrative center of Khromtau district. It is 95 kilometers from the city of Aktobe. The city is inhabited by 30,2 thousand people (2023). The area of the city is 97,7 km^2 [15].

There are 3 enterprises of state importance in the city: the main enterprise - Donskiy Mining and Processing Combine (hereinafter referred to as DMPC) – a branch of TNK Kazchrome JSC; the second – Aktobe Copper Company JSC for processing of copper-zinc ores and the third - Voskhod Oriel LLP, engaged in extraction and processing of chrome. The Geophysical IX deposit is located in Khromtau district of Aktobe region, in the South Kempirsay Ore Massif on the north-eastern border of Khromtau city.

The social and economic situation of the city is directly related to the prospects of development of the mining and processing plant, which produces almost all volumes of chrome ore in Kazakhstan.

Geomorphologically, the city and adjacent territories belong to parts of Mugalzhar Mountain, which is represented as an eluvial-deluvial sloping plain consisting of fine gravel of bedrock formed by loams, clayey sands. The relative elevation is 300…350 meters. In the southeast of the city there are hills 380...440 m high.

The city and adjacent territories are located in the dry steppe zone. The steppe zone consists of chestnut-brown soils, where sand and rocks are found. The climate of the region is sharply continental, with the Siberian anticyclone acting over the territory in winter and subtropical desert air blowing in summer. The temperature rises to 20...22 °C in winter and to +20 +25 °C in summer. The average amount of precipitation is 350...450 mm. The average wind speed is 8 m/s.

Tributaries of the Ilek River – Karagash, Akzhar, Sarymyrza, Zharly-bulak, etc. – flow through the study area.

The basis for the study of the deposit is 2012...2020. the results of field studies of the authors [16…18] were obtained. In addition, we analyzed the materials of researchers who considered the problem of the impact of mining on the environment, many of whom believe that the main sources of destruction and pollution of various components of the natural environment are technogenic massifs located near the enterprise, which have a significant ecological impact on the environment [2, 10, 19…23]. One thing should be noted here: open-pit mining, compared to underground mining, the surface of the land, the area of which reaches hundreds and even thousands of hectares (at large enterprises) [19], is significantly destroyed, which, in turn, is partially or completely destroyed in the process of mining [24…25].

There are different methodological approaches to the study of the territorial impact of the mining-industrial complex on ecosystems. In this regard, we reviewed some works on the methodology of using remote sensing data to identify the objects of study [26…27].

Nowadays, remote sensing techniques are widely used, as the development of this technique has made it possible to obtain high quality images of the Earth's surface with high capabilities and in different color spectra. The use of satellite imagery in the study of the impact of mining on ecosystems offers new opportunities related to the identification, mapping, monitoring of anthropogenic impact zones and environmental risk assessment. In addition, RS imagery can be viewed in conjunction with other cartographic sources, especially topographic maps and extensive material collected during field surveys.

Earth remote sensing data will help to consider the problems of localization of areas subject to anthropogenic impact when assessing the categories of environmental risks, i.e. identification of objects associated with the release and exchange of rock mass (quarry-fill formation, etc.), soil-soil and water channel impact, creation of artificial water bodies.

During the writing of the article, data on the indicators of the mining industry were obtained from the Ministry of Industry and Construction of the Republic of Kazakhstan [28] and the website of the Committee on Statistics of the Republic of Kazakhstan [29]. High spatial resolution (30 m) images from the U.S. Geological Survey (USGS) [30] were used for mapping to assess the dynamics and development of the territories. The cloud-free Landsat-5 TM (13.07.1986) and Landsat-8 OLI (20.08.2023) satellite images were processed in ArcMap 10.8, resulting in the creation of maps. Based on the analysis of these satellite images, changes in the landscape and natural environment were identified. The primary focus of our research is to identify anthropogenic factors, their consequences, and to consider their impact on the ecological condition of the city of Khromtau.

The analysis of the geo-ecological state of the city of Khromtau based on various temporal satellite images is a significant study aimed at identifying environmental changes over the years. The informational content of images taken at different times varies not only depending on the issue being addressed but also on the region and season of the shooting. Since each type of landscape in a particular geographical zone is characterized by its own interconnections and patterns, natural objects also possess local decoding features [31…32]. The data and results obtained allowed for an assessment of the impact of anthropogenic factors on the landscape and resources of the city, identification of areas with specific environmental problems, and the proposal of measures to address them. The use of satellite images is an effective tool for monitoring and managing the environmental condition of the city and its surroundings, helping to improve the quality of life of its residents and preserve the environment.

The cartographic method, implemented through the ArcGIS program, allows for the integration of various types of information and the conduct of spatial analysis, taking into account numerous factors [33…35]. Maps created based on satellite images enable the visualization of disturbed landforms and the assessment of the environmental condition of an area [11].

The study of the geo-ecological condition of the city of Khromtau using periodic satellite images offers several advantages and methodological features compared to other known methods. Periodic satellite images provide highly accurate data with precise imagery, facilitating a more detailed analysis of changes in the landscape and natural environment.

The use of periodic images allows for the monitoring of environmental changes over extended periods, enabling the identification of trends and the prediction of possible future scenarios. This ability to track changes over time is critical for understanding long-term environmental impacts and developing strategies to mitigate negative effects.

Therefore, the application of satellite imagery and GIS technology for studying the geo-ecological condition of Khromtau offers high accuracy, broad coverage, and the ability to monitor changes over time. These methods, combined with cross-verification of results, ensure the reliability and validity of conclusions, contributing to effective environmental management and the improvement of the population's quality of life.

3. RESULTS AND DISCUSSION

All chromite resources in Kazakhstan are located in the Aktobe region, with reserves totaling 300 million tons in the Kempirsai Massif.

The history of the chromite industry in this region dates back to 1938, when the Donskoy Mining and Processing Plant began operating, coinciding with the development of the Kempirsai chromite deposit. During this time, the town of Khromtau and the Aktobe Ferroalloy Plant were established to support the mining workforce. By 1959, the mines “Vostochny” and “Komsomolsky” had produced over 1 million tons of ore. In 1968, the Ferak Ferroalloy Plant began operations, followed by the first processing plant at the Donskoy Processing Plant in 1973. The development of the “Molodezhnaya” mine started in 1974, and the “Central” mine in 1978 (Figure 3).

Industrial-scale chromite deposits are located in the Western Kazakhstan Complex (WKC), with over 20 of these deposits concentrated in the Kempirsai range, which stretches for 80 km in length and 30 km in width. This region contains more than 120 chromite deposits at depths of up to 1400 meters. Over the past 80 years, 226 million tons of ore have been extracted from more than 20 mines and quarries in this area. The annual production volume is approximately 6 million tons. The ore reserves are sufficient for several generations, as new deposits continue to be discovered and developed, making this an important focus for large companies.

In the Khromtau region, extensive geological work has been carried out, leading to the discovery of rich chromite ore deposits with chromium oxide content as high as 55 %. For instance, at the “Geological” deposit, 1 million tons of reserves have been identified, with an additional 3 million tons of ore planned for extraction. New ore bodies are currently being explored at the “Geological-2” and “Geophysical-7” sites. Intensive efforts are now underway to develop the secured reserves at these deposits, which has adversely affected the environmental situation in the city of Khromtau and quarries surround surrounding areas, as the city. In 2023 alone, 300,000 tons were extracted from the Dubersay quarry and 150,000 tons from the Mirny quarry [7].

Figure 3. *Chrome industry*

In the vicinity of Khromtau and the surrounding areas, there are several large deposits. One of the largest quarries is located to the south of the city, just 300 meters from residential areas and 50 meters from an abandoned sector (see Figure 2). The size of the quarry is 900×500 meters, with a depth of 150 meters (see Figure 4). In the southwestern part, approximately 800 meters from the city, there are two enormous quarries measuring 800…900×400…500 meters with a depth of 100…150 meters. In the northeastern part of the city, about three kilometers away, there are two more large quarries, each approximately 900 meters in length and over 1 kilometer in width, with widths ranging from 500 to 900 meters (see Figure 2). At the bottom of all the quarries, artificial lakes have formed, measuring 300…500×150…200 meters.

We focused exclusively on the quarries where chromite ore is extracted (see Figure 4). There are several large deposits located in the suburbs and surrounding areas.

Figure 4. *A large quarry near the city of Khromtau*

The terrain of the deposits and the surrounding areas is characterized by its location on the eastern slope of the Or-Ilek watershed, forming a ridge elongated in a submeridional direction. The slightly ridged surface is covered with numerous temporary water valleys. The land is dissected by erosional ravines with relative heights ranging from 5…10 meters to 15…50 meters. This region manifests as a denudation-accumulation plain, which has been significantly altered due to the industrial activities of the Donskoy Mining and Processing Plant. The average elevation of the area is approximately 400…450 meters, with the northwestern part reaching up to 480 meters in absolute height. The slopes behind the erosional ravines generally descend several meters over a distance of 1 kilometer. The steepest slopes, ranging from 50…100 %, are typical of riverbeds and ravines. In the upper reaches of the Oysylkara River basin, there are numerous depressions with an area of 300 square meters and a depth of 2,0 meters.

The slopes of the quarries are very steep, conical, and elongated, with gravity-driven sliding processes occurring in many places (see Figure 5). Near the quarries, waste dumps (slag heaps) have formed, consisting of the worked-out rock and soil excavated during the quarrying process. The height of the slopes in various quarries reaches 50…100 meters, with lengths ranging from 60 to 150 meters (see Figure 6).

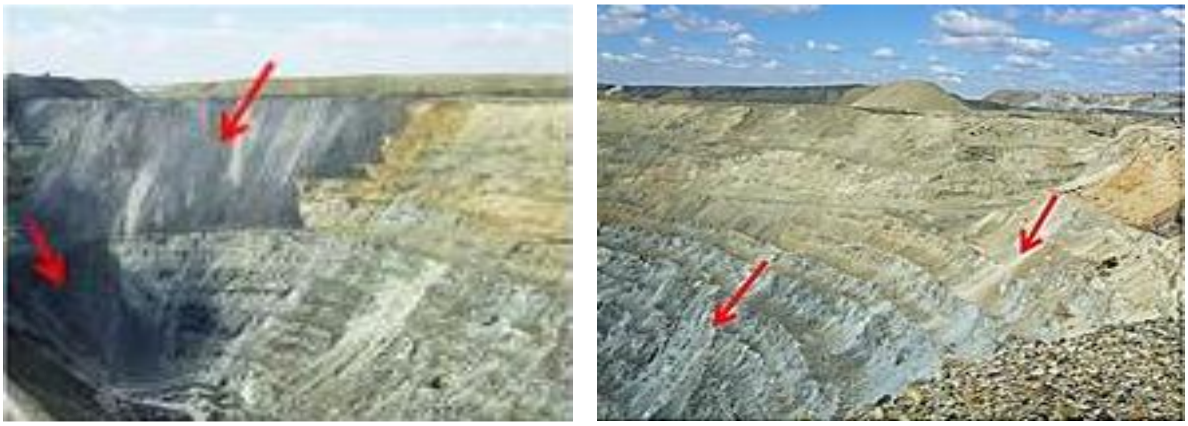

Figure 5. *Gravity-raw processes*

Figure 6. *Artificial dumps formed by chrome residue*

Open-pit mining processes involve drilling, blasting, crushing, and overburden removal using new technologies. Special drilling machines and specific quantities of explosives are used for blasting operations, which include:

– This is done with specialized equipment that uses circular motions to break up the soil layer and penetrate deeper into the ground (Loosening of soil layers).

– The ore is mixed with chemical reagents, and chromium is extracted from the mixtures as a result of the chemical reaction (Ore processing)

– These systems are used to collect and analyze data on the state of the deposits in real-time, ensuring precise and efficient management of the mining process (Automated monitoring systems).

Rock extraction operations are carried out using excavators, which have significant environmental impacts, necessitating measures to mitigate these effects. To address this, since 2019, the plants have undergone updates and implemented the new ERGW production system. The modernization of equipment and the launch of the new ERG Green processing plant have made it possible to recycle all production slag [7].

The soil extracted from quarries (slag heaps: clay, loam, primarily gravel) is exposed to open air and undergoes various gravitational, sliding, and weathering processes. Chromium, classified as a heavy metal, poses significant environmental risks because heavy metals are prone to bioaccumulation. Bioaccumulation occurs when a chemical element concentrates in the environment and gradually builds up within a biological organism over time. These compounds accumulate in living organisms before they can be broken down or transformed, leading to absorption and storage in biological tissues. This accumulation poses long-term health risks to both the environment and living organisms, including humans, as heavy metals can have toxic effects on various biological systems.

Chromium waste heaps render the land unsuitable for agricultural use, contaminate the soil with harmful trace elements, and disperse dust into the air. These waste dumps have a significant anthropogenic impact on both the lithosphere and the atmosphere. When wind speeds reach 2 m/s over a period of 55 days, the amount of dust dispersed into the environment is approximately 5,3 tons per year. However, at wind speeds of 7 m/s (over 297 days), the amount of dispersed dust dramatically increases to 40 tons per year.

A significant environmental issue in the region is the contamination of the Ilek River and its tributaries with chromium compounds. The Ilek River is widely known as the “Chromium River” because the problem of contamination with hexavalent chromium has persisted for more than 60 years. The Aktobe Chromium Compounds Plant was launched without filtration systems in 1958, and within a year, chromium levels in the river had already exceeded permissible limits. In 1994, the maximum chromium concentration in the river's maximum allowable concentration (MAC) increased by 4,8 times, and four years later (in 1998), it increased by 18,4 times. To reduce chromium levels in the silt to acceptable levels, it is necessary to release a volume of water equal to that of the Aktobe Reservoir into the river annually. However, by 2005, the maximum chromium concentration in the silt had decreased to 8,6 times the MAC. Despite the decrease in concentration, chromium can still cause serious harm to human health.

It is known that chromium belongs to the group of heavy metals. Heavy metals are dangerous because they tend to bioaccumulate - increasing the concentration of chromium compounds in living organisms over time more rapidly than changes in the environmental concentration of the chemical element. These compounds are often collected in water along with industrial waste. It has been reported that the concentration of hexavalent chromium in 60 % of the drinking water in Khromtau exceeds the national standard by two times, affecting approximately 2,6 million people in the city [6].

To address this problem, industrial waste is being deposited into artificial depressions near the quarry (see Fig. 7), where nearby grazing cattle drink the water.

Figure 7. *Industrial waste cast into an artificial lake*

Local residents note that such occurrences happen quite often, and they have become accustomed to them, despite the fact that these conditions cause respiratory diseases, which are particularly common among children who drink cow's milk. Additionally, hexavalent chromium compounds, released into the environment through industrial waste, are part of a group of chemicals with mutagenic and carcinogenic properties, which are potentially dangerous to reproductive health. In specific environmental conditions, humans are typically exposed to a complex mix of chemical substances that interact with adverse physical and biological factors.

To map the dynamics of changes in the natural components of the deposits and monitor the changes in relief due to anthropogenic impact, satellite images from 1986 and 2023 (spanning 37 years) were obtained. The interpretation of these satellite images revealed the areas of disturbed zones from open-pit chromite mining, as well as individual large forms of technogenic relief, such as quarries, waste dumps, and waste accumulation sites (see Figure 8). The interpretation indicators were corroborated by field research results. The city of Khromtau and its surroundings, as previously mentioned, are surrounded by dumps (mine dumps) formed from the rocks extracted from the deposits. As a result, a unique pit microrelief has developed in the city. The decoding data were confirmed by the results of field research.

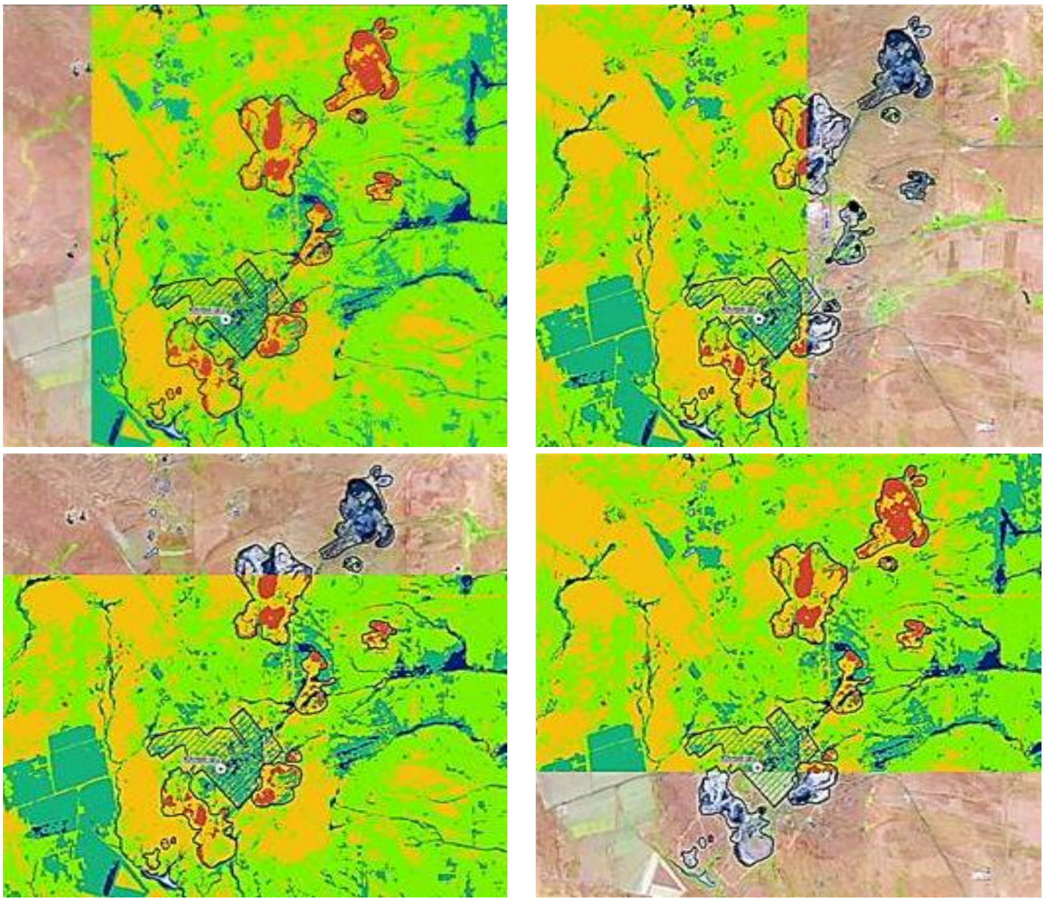

Figure 9. *The process of comparing relief shapes when decoding images*

The remote sensing method allowed for the determination of the area of technogenic disturbances, including waste dumps: the total area of disturbed land in 1986 was 115,8 square kilometers, and by 2023 it had increased to 298,3 square kilometers, an expansion of 2,5 times. The image interpretation results showed that over 37 years, the area of the city increased by 2,6 times, while the area of quarries expanded by 3 times (see Table 1).

Table 1
Dynamics of land changes in the city of Khromtau and its surroundings

Objects	1986 (sq. km)	2023 (sq. km)	Dynamics
Careers	154,2	476,4	3 >
Khromtau city square	3,6	9,4	2,6 >
The Barren lands	115,8	298,3	2,5 >
Areas with sparse vegetation	415,6	398,3	0,9 <
Dense thickets	77,5	16,0	4,8 <
Farm lands	219,3	116,2	1,9 <
Water forms	1,5	0,5	3,0 <

4. CONCLUSION

Thus, the environmental situation in the city of Khromtau and the surrounding areas is considered unfavorable. This is due to the fact that a stable chromium biogeochemical province has formed in these regions, including the city and adjacent territories, which leads to an increased movement of chromium within the biosphere along the path: soil-plants-animals-humans.

Heavy metals, including chromium, are considered hazardous compounds because they have the ability to bioaccumulate, meaning that this chemical element accumulates in a biological organism faster than it can be broken down or altered. Additionally, the soil and vegetation cover and agricultural lands are altered, with areas reduced by 1,0…4,8 times, water bodies decreasing by 3,0 times, and many small rivers being destroyed or dried up (see Figure 9).

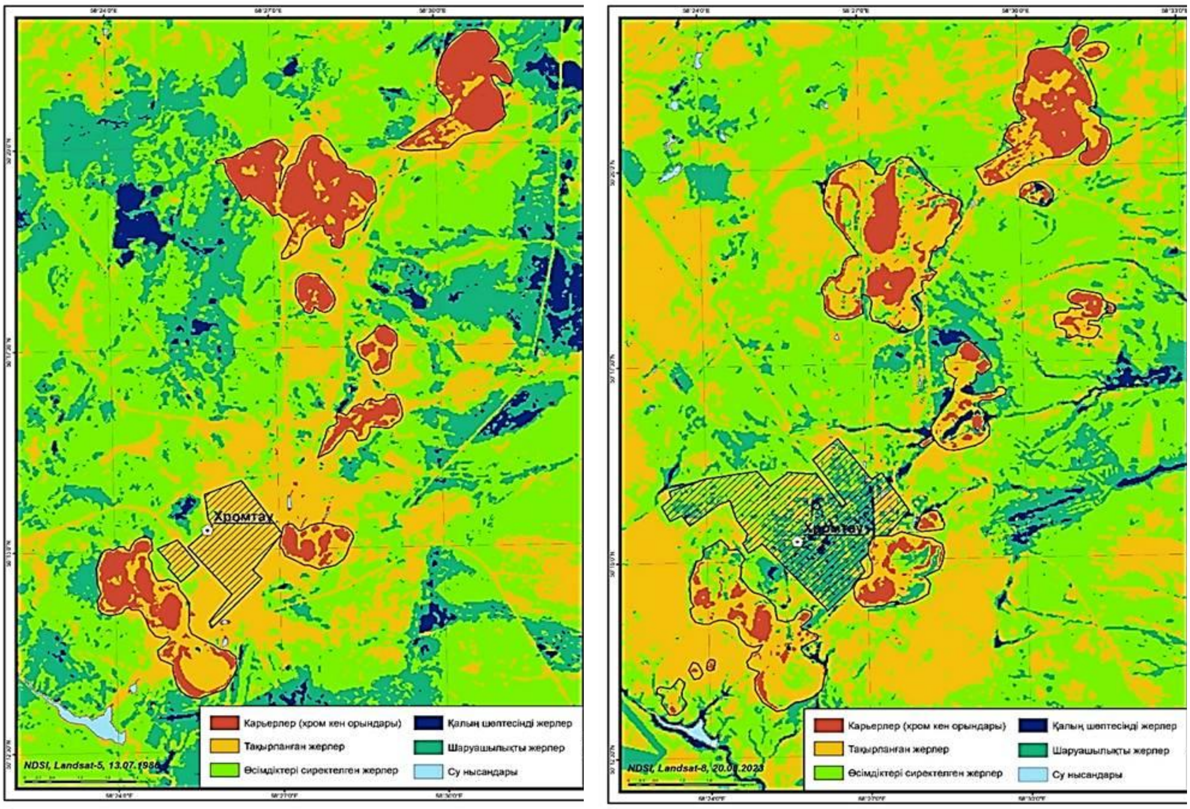

Figure 9. *Anthropogenic disturbance of the terrain in the area of the city of Khromtau*

The impact of chromite mining is evident in the depletion of land, contamination of soil with harmful trace elements, and the excessive release of dust into the atmosphere, leading to an imbalance in natural components and environmental pollution.

Satellite imagery plays a significant role in assessing changes in the environmental conditions and topography resulting from mineral extraction. Through the interpretation of these images, maps showing the changes (dynamics) in the topography of the mining area have been created (see Figure 7), and the extent of disturbed lands has been determined (see Table 1).

All of the aforementioned points necessitate qualified intervention, ranging from environmental assessments to direct impacts on the entire natural complex. The application of rapid Earth remote sensing methods has enabled the acquisition of precise and up-to-date information on the environmental conditions of natural and mountain-technical systems. The effective integration of information obtained from remote ssing data and other sources, including field expedition data, demonstrates efficient mechanisms for addressing a wide range of both practical tasks and theoretical research.

The data and research findings can be utilized to provide informational support for decision-making in the fields of environmental protection and sustainable development. The results of the study contribute to improving the quality of life for the population in the city of Khromtau and other regions by providing measures to enhance the environmental situation.

Thus, the following general conclusions can be drawn from the above:

1)The extraction and processing of ore materials, particularly chromite ore, in mining and processing plants are the primary sources of environmental pollution and pose significant risks to human health.

2) The development of chromite ore extraction processes, including gravitational, landslide, wind, and water erosion, as well as the collapse of the earth's surface, destruction of soil and vegetation cover, soil salinization, and intensification of desertification processes, leads to anthropogenic and technogenic changes in the natural landscape.

3) The remote sensing method allows for the identification and determination of zones of anthropogenic impact, the mapping of technogenic relief zones, and the identification of areas of environmental threats.

4) The total area of disturbed land in the chromite ore mining region reached 77,470 hectares, meaning that over 37 years, this area has increased by six times.

Currently, the chromite and ferrochrome market is growing after a temporary decline during the pandemic. Large-scale projects for the development of chromium production include the construction of new mines and plants, which require strict control over production and its environmental impact. Therefore, in the coming decades, the mining industry, including chromite ore extraction, will remain an environmental risk factor not only for the living population but also for the natural components of the entire region's environment.

DATA AVAILABILITY

The data used in this study are the result of an independent analysis conducted by the authors using remote sensing technology (RS).

AUTHORS' CONTRIBUTION

Conceptualization –AK, AA, AS; resources - AK, DK, MM, AK[2]; formal analysis – AA, AK; methodology - AK, AA, AS; software - AK, AA, AS, DK, MM; supervision - AK, AA, AS, DK, MM; visualization –AK, AA, AS, DK, MM; writing—original draft preparation – AK, AA, AS; writing—review and editing - AK, AA, AK[2].

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АҚТӨБЕ ОБЛЫСЫНДАҒЫ ТАУ-КЕН ӨНДІРІСІ КӘСІПОРЫНДАРЫНЫҢ ҚОРШАҒАН ОРТАҒА ТИГІЗЕТІН ӘСЕРІН БАҒАЛАУ (ХРОМ КЕН ОРЫНДАРЫНЫҢ МЫСАЛЫНДА)

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ТҮЙІН СӨЗДЕР

АБСТРАКТ

тау-кен өнеркәсібі
техногендік әсер
Жерді қашықтан зондтау (ЖҚЗ)
экологиялық қауіп-қатерлер
қоршаған орта
Хромтау

Жерді қашықтықтан зондтау (ЖҚЗ) аумақтың экологиялық жағдайын бақылаудың қуатты құралы болып табылады, әсіресе, тау-кен өнеркәсібі аймағында. Тау-кен өнеркәсібі қоршаған ортаға айтарлықтай кері әсер етеді, әсіресе ашық әдіспен өндіру кезінде: ландшафттың өзгеруіне, су көздерінің ластануына және топырақтың нашарлауына әкеледі Батыс Қазақстанның Ақтөбе облысында Хромтау қаласының маңында хромит кендерін өндіру күрделі экологиялық проблемалар туғызуда Ұсынылып отырған зерттеу Жерді қашықтықтан зондтау (ЖҚЗ) деректерін пайдалана отырып, Хромтау қаласы маңындағы кен орнының техногендік әсерін бағалау әдістемесін жетілдіруге бағытталған. Зерттеу 2012…2020 жылдары жүргізілген далалық зерттеулер мен Landsat-5TM (1986 ж.) және Landsat-8 OLI (2023 ж.) спутниктерінің деректеріне негізделген. ArcGIS бағдарламаларын пайдалана отырып, спутниктік суреттерді талдау техногендік әсер ету аймақтарын анықтауға және картаға түсіруге, экологиялық қауіптерді бағалауға және антропогендік жерлердің ауқымын анықтауға мүмкіндік берді. ЖҚЗ мәліметтерді талдау техногендік әсер ету аймақтарын анықтауға және картографиялауға, экологиялық қауіп-қатерлерді бағалауға, антропогендік әсердің масштабын есептеуге мүмкіндік берді. Соңғы 30 жылда карьерлердің және бұзылған жерлердің ауданы айтарлықтай өсті, бұл Хромтау қаласы мен оның маңындағы экологиялық жағдайға теріс әсер етті. Хром сияқты ауыр металдар биоаккумуляция процесіне бейім, ол адам денсаулығы мен қоршаған ортаға қауіпті. Бұл жағдайда қашықтан зондтауды қолдану қоршаған ортаның жағдайын бақылау және басқару үшін өзекті ақпаратты жылдам алуға мүмкіндік береді, табиғи ресурстарды сақтауға көмектеседі. Хром кен орындарының карьерлерін зерттеуде қашықтан зондтау әдісін қолдану техногендік әсердің масштабы мен ерекшеліктерін анықтауға ғана емес, сонымен қатар қоршаған ортаға тигізетін жағымсыз салдарды азайту шараларын ұсынуға мүмкіндік береді.

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ОЦЕНКА ВОЗДЕЙСТВИЯ ГОРНОДОБЫВАЮЩИХ ПРЕДПРИЯТИЙ АКТЮБИНСКОЙ ОБЛАСТИ НА ОКРУЖАЮЩУЮ СРЕДУ (НА ПРИМЕРЕ ХРОМОВЫХ МЕСТОРОЖДЕНИЙ)

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КЛЮЧЕВЫЕ СЛОВА
горнодобывающая промышленность
техногенное воздействие
дистанционное зондирование Земли (ДЗЗ)
экологические риски
окружающая среда
Хромтау

АБСТРАКТ

Дистанционное зондирование Земли (ДЗЗ) представляет собой мощный инструмент для исследования карьеров и оценки их воздействия на окружающую среду. Этот метод предоставляет широкие возможности для мониторинга, картографирования и анализа изменений, вызванных горнодобывающей деятельностью. Горнодобывающая промышленность оказывает значительное негативное воздействие на окружающую среду, особенно при карьерной добыче, что приводит к изменению ландшафта, загрязнению водных источников и ухудшению состояния почв. В Актюбинской области Западного Казахстана добыча хромитовых руд вокруг города Хромтау вызывает серьёзные экологические проблемы. Исследование направлено на совершенствование методики оценки техногенного воздействия месторождения около г. Хромтау с использованием данных дистанционного зондирования Земли (ДЗЗ). Основой исследования послужили полевые исследования, проведённые в 2012…2020 годах, и данные спутниковых снимков мен Landsat-5TM (1986 г) и Landsat-8 OLI (2023 г) Анализ космических снимков позволил выявить и картографировать зоны техногенного воздействия, оценить экологические риски и определить масштабы антропогенных нарушений. За более чем 30 лет площадь карьерных и нарушенных территорий значительно возросла, что негативно сказывается на

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экологическом состоянии города Хромтау и его окрестностей. Тяжелые металлы, такие как хром, имеют тенденцию к биоаккумуляции, что опасно для здоровья человека и окружающей среды. Использование ДЗЗ позволяет оперативно получать актуальную информацию для мониторинга и управления экологическим состоянием, что способствует улучшению качества жизни и сохранению природных ресурсов. Применение ДЗЗ в исследовании карьеров хромитовых месторождений позволяет не только выявить масштабы и характер техногенного воздействия, но и предложить меры по смягчению негативных последствий для окружающей среды.