ELMİ İŞ Beynəlxalq Elmi Jurnal. İyun 2026, Cild: 20, Sayı: 4, s. 292−302
SCIENTIFIC WORK International Scientific Journal. June 2026, Volume: 20, Issue: 4, pp. 292−302
DOI: https://doi.org/10.36719/2663-4619/128/292-302

Study Of Technogenic Pollution Of Soil And Waters in Abandoned Fields on the North-Eastern Slope of the Lesser Caucasus

Anvar Aliyev[1*], Natig Babayev[1], Yegana Kuliyeva[2]

Abstract. *Pollution has direct and indirect effects on the nutrient and organic matter content of soils. Due to a lack of air in the waste from old copper mines with a highly acidic environment (pH 1.6–2.0), the mineralization of organic matter ceases, making direct use of the waste in agriculture impossible. Considering that this figure will increase as a result of the commissioning of new deposits in the Dashkasan region, where 51.5% of the territory is subject to pollution, it is important to pay special attention to the use of new, more modern technologies. The* Z_{total} *contamination level often exceeds 128, indicating extreme levels. Concentrations of heavy metals, such as lead, can exceed the maximum permissible concentration by 12.7 times. Approximately 4.3% of the surveyed areas (according to monitoring data for 2022–2025) are classified as hazardously contaminated with heavy metals, a significant portion of which are located in former industrial zones. Further downstream there are reservoirs, the infiltration waters of which reduce the pH of the water to 3–3.5. It was found that in the area affected by copper ore processing waste, significant exceedances of maximum permissible concentrations of several elements were observed. The results of environmental monitoring, including water and sediment sampling, sample preparation, and quantitative analysis of sample composition are proof of the results. The article notes that developing measures for the removal and recycling of mining and processing waste will significantly reduce the anthropogenic impact on surface waterways.*

Keywords: *technogenesis, heavy metals, pollution, anthropogenic factors, degraded landscapes, soil erosion*

---

[1]Institute of Geography, Ministry of Science and Education of the Republic of Azerbaijan, PhD in Geographical Sciences, Baku, Azerbaijan
[2]Institute of Geography, Ministry of Science and Education of the Republic of Azerbaijan, Baku, Azerbaijan
[*]Corresponding author. E-mail: anveraliyev840@gmail.com
Received: 19 March 2026; Accepted: 25 May 2026; Published online: 22 June 2026

Kiçik Qafqazın şimal-şərq yamacındakı tərk edilmiş mədənlərdə torpaq və suyun texnogen çirklənməsinin öyrənilməsi

Ənvər Əliyev[1*], Natiq Babayev[1], Yeganə Quliyeva[2]

Xülasə. *Çirklənmə torpaqların qida və üzvi maddələr tərkibinə birbaşa və dolayı təsir göstərir. Köhnə mis mədənlərinin yüksək turşulu tullantılarında hava çatışmazlığı (pH 1.6–2.0) səbəbindən üzvi maddələrin minerallaşması dayanır və bu da birbaşa kənd təsərrüfatında istifadəni qeyri-mümkün* *edir. Ərazinin 51.5%-nin çirklənməyə məruz qaldığı Daşkəsən rayonunda yeni mədənlərin istismara verilməsi ilə bu göstəricinin artacağını nəzərə alsaq, yeni, daha müasir texnologiyaların istifadəsinə xüsusi diqqət yetirmək vacibdir. Ümumi çirklənmə səviyyəsi çox vaxt 128-i keçir ki, bu da həddindən artıq dəyərləri göstərir. Qurğuşun kimi ağır metalların konsentrasiyası icazə verilən maksimum konsentrasiyanı 12.7 dəfə aşa bilər. Tədqiq olunan ərazilərin təxminən 4.3%-i (2022–2025-ci illər üçün monitorinq məlumatlarına görə) ağır metallarla təhlükəli şəkildə çirklənmiş ərazilər kimi təsnif edilir ki, bunların da əhəmiyyətli bir hissəsi keçmiş sənaye zonalarında yerləşir. Aşağı axında infiltrasiya suları suyun pH-nı 3–3.5-ə endirən iriəcmli su hövzələri var. Mis filizi emalı tullantılarının təsirləndiyi ərazidə bir neçə elementin icazə verilən maksimum konsentrasiyalarından əhəmiyyətli dərəcədə artıq olduğu müşahidə edilmişdir. Ətraf mühitin monitorinqinin nəticələri, o cümlədən su və dib çöküntülərindən nümunələrin götürülməsi, nümunənin hazırlanması və nümunə tərkibinin kəmiyyət təhlili təqdim olunur. Məqalədə qeyd olunur ki, mədən və emal tullantılarının çıxarılması və təkrar emalı üçün tədbirlərin hazırlanması yerüstü su yollarına antropogen təsiri əhəmiyyətli dərəcədə azaldacaq.*

Açar sözlər: *texnogenez, ağır metallar, çirklənmə, antropogen amillər, deqradasiyaya uğramış landşaftlar, torpaq eroziyası*

---

[1]Azərbaycan Respublikası Elm və Təhsil Nazirliyinin Coğrafiya İnstitutu, coğrafiya elmləri üzrə fəlsəfə doktoru, Bakı, Azərbaycan

[2]Azərbaycan Respublikası Elm və Təhsil Nazirliyinin Coğrafiya İnstitutu, Bakı, Azərbaycan

[*]Məsul müəllif. E-poçt: anveraliyev840@gmail.com

Daxil oldu: 19 Mart 2026; Qəbul edildi: 25 May 2026; Onlayn dərc edildi: 22 İyun 2026

Introduction

With the development of industrial society, soils are increasingly exposed to various anthropogenic factors, which disrupt their functionality, including impacting the productivity, growth, and development of flora and fauna. In areas where mining and processing industries operate, monitoring soil changes and their overall ecological status is particularly important. The formation of anomalous areas with high heavy metal content in soils leads to a change in soil types and, consequently, to the loss of their economic potential (Aristovskaya, 1988; Akbarova, 2024). During mineral exploration, the main sources of pollution are gases and noise emitted into the atmosphere by stationary heat sources from the equipment used, various drilling rigs, and other machines and engines. Atmospheric pollution is also caused by emissions of gases and dust of varying diameters generated during blasting operations, although not continuously, but periodically (Akhundova 2025; Ali, 2026). Gas and dust emissions into the atmosphere, mineral dust pollution during mountain road construction, blasting operations and crushing of rock by machines, and the withdrawal of fertile land from cultivation in large areas where rock waste accumulates in the surrounding area are the main sources of man-made pollution resulting from wind erosion of these waste piles. Furthermore, during the mining operations, water sources here are contaminated with various minerals, particularly heavy and radioactive metals, leading to contamination of surface and groundwater (Ali, 2025; Ahmadova, 2025).

Over long periods of time, for example, during the development of deposits, beginning with geological exploration, the natural and geographic components of the area are subject to contamination in various ways (Ahmad, 2026). Furthermore, sometimes during the mining process, during their opening and subsequent exploitation, along with the enormous waste heaps, large pastures, forests, and arable lands are contaminated by rock fragments that break off from them and occupy vast areas. As a result, sometimes during the mining process, an area many times larger than the deposits themselves is filled with their waste, known as "dumps." This also greatly increases the damage to nature (Allahverdi, 2026; Bahram, 2025; Guliyeva, 2023). The Lesser Caucasus natural region borders the Republic of Armenia to the southwest, the Republic of Georgia to the northwest, the right-bank plains of the Kura River to the northeast, and the left-bank plains of the Araz River to the southeast (Gahramanova, 2026). The natural region encompasses the physical-geographical areas of Ganja, the Karabakh Mountains, the Karabakh Volcanic Plateau, and Hakkari. It is distinguished primarily by its diverse natural conditions and wealth of natural resources. The northeastern part of the territory, along with its unique natural landscape, is also the main region of our Republic, rich in minerals, especially ore minerals (Hasanova, 2023; Ibrahimova, 2023). Man-made changes occurring in the mountainous meadow landscape of the region have dramatically altered the natural environment and completely weakened its recreational potential (Ibrahimova, 2024).

Given that this will lead to an increase in ecological stress zones, intensified man-made landslides, and the destruction of fertile land in the future, iron ore and alunite mining, as well as the reclamation of unusable landscapes, are important issues (Ikhtiyar, 2026). Samples were collected and analyzed from the control zone of the site, from the base of the waste, from a height of 20 and 70 meters above it, as well as from the soil layer at depths of 0–5 cm, 5–10 cm and 10–30 cm to study the impact of waste on the soil cover (Ismayil, 2025; Ismayilova, 2025a). Open-pit mining has caused significant structural damage to the environment. In 1985 alone, the Dashkasan mines produced $2.631 \cdot 10^6$ t of iron ore, and the processing plant produced $1.346 \cdot 10^6$ t of concentrate. $1.285 \cdot 10^6$ t of solid waste were discharged into the environment. One of the partially developed industrial regions of our republic is home to iron ore reserves, the primary raw material for the ferrous metallurgy industry the Dashkasan ore region (Ibrahimova, 2025; Ismayilova, 2025b). The Dashkasan, South Dashkasan, Demir, and Dardar ore deposits were discovered here. The ore has a rich mineral composition. Due to these properties, Dashkasan ore belongs to the Fe_3O_4 group of the most valuable iron ores. In addition to magnetite (up to 70%), the ore contains pyrite, hematite, arsenic-pyrite, titanium, copper, silver, zinc, nickel, cobalt, chromium, antimony, vanadium, molybdenum, and others (Khudaverdi, 2025; Mammadova, 2024; Mammadova, 2026).

The combined reserves of the Dashkasan iron ore deposits amount to $275.5 \cdot 10^6$ t. Until recently, only the Dashkasan deposit was being developed, with a design capacity of 26,500 t per year. In 1932, a decision was made to establish a metallurgical plant in Dashkasan by importing coal from another republic. However, in 1940, Moscow decided to build the plant in Rustavi rather than Dashkasan. In 1945, construction began on an ore processing plant in Dashkasan, which was commissioned in 1954. After iron ore is mined, the rock is purified using large quantities of water in the ore processing plants located on the plant's grounds. In addition to washing the iron ore, the iron is separated from the soil by exposure to a strong electromagnetic field (Mammadzada, 2025; Mirzezadeh, 2025). After crushing, the purified iron ore is transported via a 6 km cableway between Dashkasan and the Gushchu Bridge, and then via a 35 km railway from Alabashli to Rustavi to the final processing plant. In the 1990’s, an average of $3.5\text{-}4 \cdot 10^6$ t of iron ore were mined and processed at the Dashkasan deposit. After processing this amount of rock, only $1 \cdot 10^6$ t of iron ore concentrate (with an iron content of 60%) was obtained. The remaining $2.5\text{-}3 \cdot 10^6$ t of waste remained in the region. As a result, the natural environment of these areas, which are unique mountain-meadow zones, was significantly damaged. The mining deposits that developed as a result of the development of the Dashkasan iron ore and marble, as well as the allenite reserves of Zeyli, play a significant role in the anthropogenic destruction of the mountain-meadow landscapes (Mammadova, 2024). The mountain-meadow cover in these areas, rendered unusable by the waste from the Alunit Mountain mining industry, has formed four large hills. Unused rock forms a cover here ranging from several meters to 15 meters thick. Currently, alunite waste covers an area of approximately 250 hectares.

Methods

One of the pressing and priority tasks of modern soil science is the search for and development of effective methods for cleaning contaminated soils. Therefore, detailed studies are needed to reflect and characterize the specific behavior of pollutants in soils. The anomalous content was calculated based on the criteria of metal distribution only in the upper soil layer of gray-humus horizons at a depth of 0–17 cm and the lower illuvial horizons adjacent to the parent rock at 70–80 cm, as horizons that most clearly reflect the degree of input and the nature of migration of heavy metals in the soil. The mathematical processing and calculation method for the anomaly threshold were performed according to a lognormal distribution law (Mammadova, 2025). The content of mobile forms of heavy metals in it was determined by generally accepted methods (GOST 26213-91; GOST 26207-91; GOST 26107-84; GOST 26483-85; M-MVI-80-2008). The formation of anomalous areas of heavy metals in the soil in the study area is determined by the intensity of the plant's man-made airborne industrial emissions, and the anomaly threshold value will be determined by a number of factors (Table 1). Element concentrations exceeding the anomalous threshold indicate the presence of geochemical anomalies and metal accumulation in the area. Geochemical anomaly maps were generated in the Golden Software Surfer 12 geoinformation system using the Radial Basis Functions method, which is considered one of the best methods for constructing distribution diagrams on a flat surface through experimental points. The total metal content of nitric acid soil extracts was determined using stripping voltammetry. The resulting data was used for data extraction, statistical processing, calculation of anomaly thresholds, and subsequent construction of anomalous area distribution diagrams overlaid on a terrain map using the radial basis function method.

Results

The northeastern slope of the Lesser Caucasus, along with its unique natural landscape, is also the main region of our Republic, rich in minerals, particularly ore minerals. Naturally, the development of these resources in these territories faces a serious problem: man-made pollution, which causes serious long-term damage to the environment. Typically, while some of this pollution is recoverable, much of it is irreversible. Thus, while resources such as water and air could be restored to their previous state after exploitation, restoring soil and vegetation is extremely difficult, and sometimes impossible. The main goal of this article is to assess the environmental conditions of existing man-made landscapes and develop a scientific basis for their optimization, taking into account the nature of the degraded natural landscape (Nazim, 2024).

Data analysis

It is necessary to scientifically study the difficulties of optimizing the degraded landscape in these areas, particularly the difficulties of land recycling, the impossibility of quickly restoring vegetation from a geobotanical perspective, and the sanitary and hygienic unsuitability of this area for habitation (Mirismayil, 2025). It is also necessary to consider the implementation of appropriate environmental protection measures based on modern technologies at mineral deposits that have been or will be developed in the area, both historically and currently (Nazim, 2026). Along with cleaning up the large volumes of anthropogenic waste accumulated in these areas, which include mountain forests and mountain meadows – priceless examples of nature – and using this waste in various fields (road construction, etc.), it is also possible to make a certain contribution to solving the problem of unemployment, which has already become a social disaster here. The process of returning these territories, some of the most unique corners of the republic, to their pristine natural environment is a very complex and multifaceted task (Novruz, 2025). In any case, one of the main problems is that the natural and geographical components of the territory have been exposed to various forms of pollution over a long period of time, beginning with geological exploration and mining operations (Fig. 1).

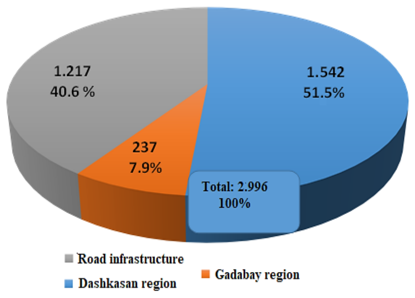
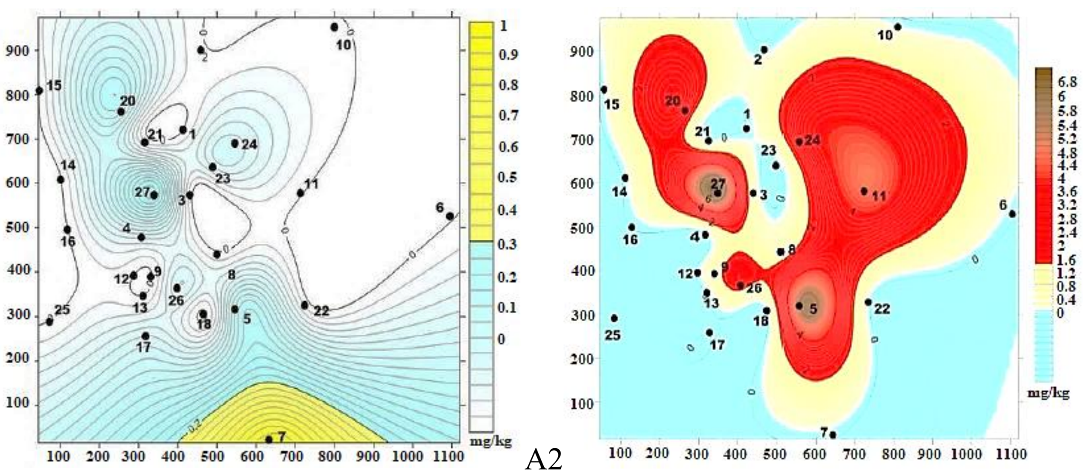


Figure 1

Percentage indicators of anthropogenic pollution in the main study areas

Anthropogenically disturbed areas by soil samples

In the study area, exceedances of the anomaly threshold were recorded in the area of sections No. 2, 3, 4, 9, 12, and 14. Low radial differentiation values, an acidic pH, and low competitive adsorption capacity characterize the migration potential of this metal within the soil profile and its presence in the lower part of the profile. In these anthropogenically disturbed areas, active aeolian processes facilitate additional mass transfer of finely dispersed fractions. In the lower part of the profile, in illuvial horizons at a depth of 70–80 cm, the anomalous threshold is several times lower than in the gray-humus horizons, at 15.8 mg/kg. Nevertheless, anomalous dispersion halos are forming in the area of profiles No. 3, 4, 12, 13, 16, and 24. The formation of these anomalous zones is likely related to active migration of humic acids down the profile (Fig. 2 A–D). Background concentrations were calculated by identifying the distribution law and further data sampling, followed by calculation of the root-mean-square logarithms of deviations for the parent rock and for the upper 0–17 cm soil layer. The background content in the parent rock is (mg/kg): Fe = 15.9; S = 0.009; Pb = 14.1; Cu = 23.1 (Fig. 3). The formation of anomalous zones with high heavy metal concentrations is largely due to various exogenous processes, along with the plant's abundant technogenic emissions. Migration, for example, results in the mass transfer of heavy metal compounds from the upper soil horizons to the illuvial horizons. Heterogeneity among the studied chalcophile elements is observed in the formation of geochemically anomalous zones. Cadmium and zinc are highly concentrated in gray-humus horizons, likely due to similarities in their electron orbital structure and bond formation. These metals partially replace divalent ions from the soil-absorbing complex. Lead and copper largely form organomineral complexes and, as a result, can migrate to a greater extent within the profile, along with humic acids, forming anomalous zones in the illuvial horizons.



A2

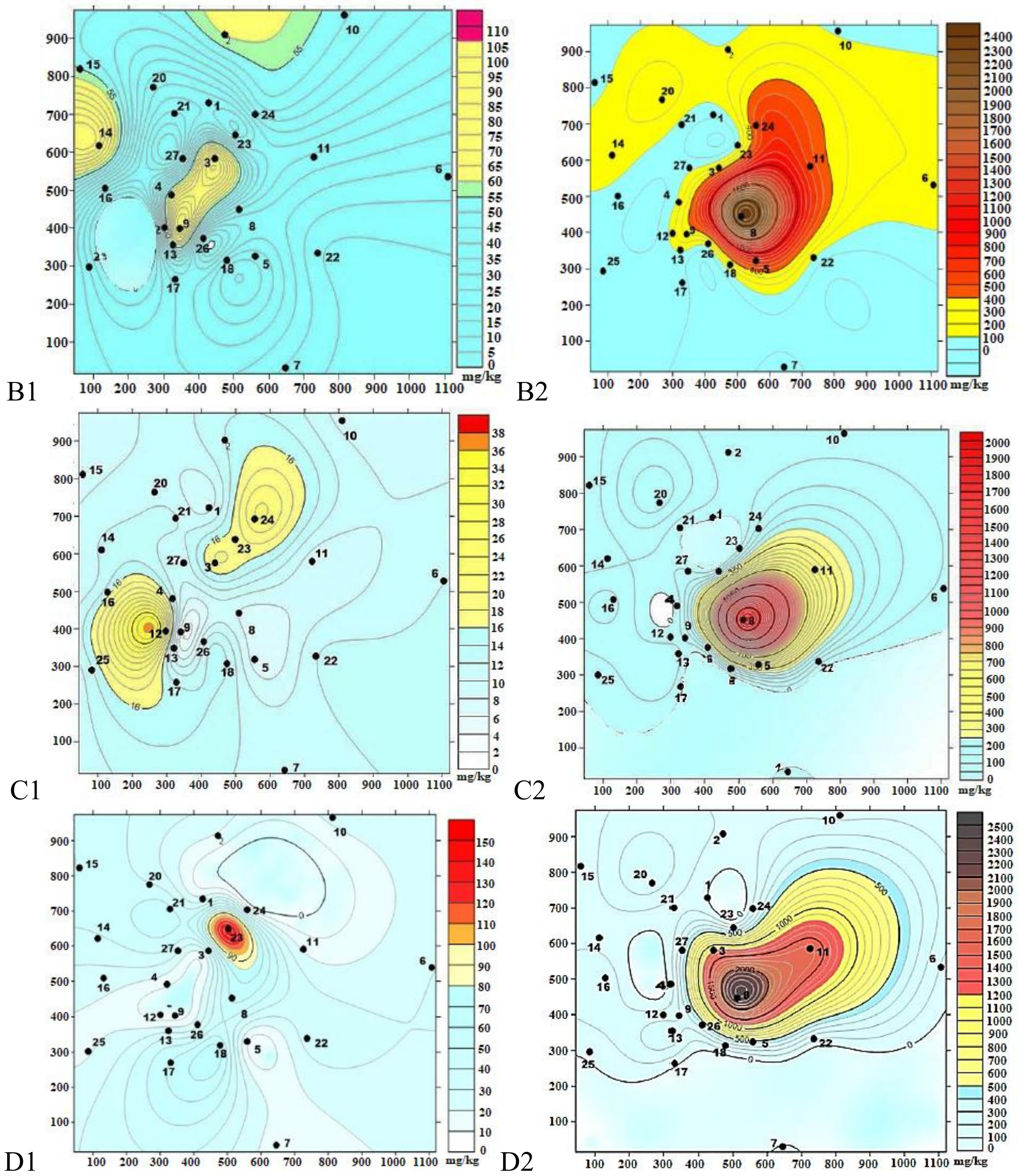


Figure 2

Geochemical anomalies: 1. illuvial horizons (70–80 cm); 2. humus-accumulative horizons (0–17 cm); S (A1–A2); Fe (B1–B2); Pb (C1–C2); Cl (D1–D2)

Small debris accumulates at the summits of terriogenic landforms formed by rock waste, while larger rocks accumulate at the base. Due to sparse vegetation, ravines with slopes of 50–60° have formed on the slopes of the waste dumps. The exploitation of the Dashkesan iron ore mines alone has rendered 1,200 ha of forest and meadow land unusable, of which 500 ha are covered by rock waste dumps. Mining waste has also chemically polluted the soil cover of mountain meadow landscapes. Analysis of soil samples taken from the waste dumps and adjacent areas shows that the content of trace elements and heavy metals in the soil is significantly higher than in natural landscapes. As a result of waste dump leaching by surface water and filtration, active chemical elements migrate and settle in the soil, contaminating it. Unused rock waste here forms a cover ranging from a few meters to 15 meters thick. The cessation of mining operations in recent years has resulted in the growth of sparse grasses and isolated shrubs on these waste heaps. As a result of the exploitation of the Zaylik and Alunitdag mines, the 20–30 meter-high waste slopes have formed terrigenous relief features with inclinations of 45–50°, sometimes reaching 700°. Currently, alunite waste covers an area of approximately 250 ha. The physicochemical composition of the waste from the former Gadabay copper mine differs from that of other mines. This waste consists of very fine particles and is quickly washed away. Therefore, river waters in this area are seriously polluted. The pH of this water ranges from 1.6 to 2. As can be seen, the composition of the mine waters of the copper mines of the Gadabay region has an acidic reaction (Fig. 1). The total amount of mineral substances is 7-8 g/l. The SO4 content in the mine waters varies from 650 mg/l to 650 mg/l. The copper content ranges from 350 mg/l to 500 mg/l. More than 80% of the microelements are readily soluble in water. The content of mobile phosphorus here is very low - 2-3 mg/l. The mine waters are richer in nitrogen - 19-30 mg/l. The potassium content in the water is 15 mg/l. These wastes are chestnut-colored in the upper layer and dark brown in the lower layer due to excess moisture. Due to the highly acidic environment, they are deprived of air, and sometimes even leak completely. This halts the mineralization of organic matter. In other words, the plant immediately dries out, as aluminization and nitrification processes cease. At the same time, since the mobile nitrogen in these wastes combines with fixed oxides, the plant cannot assimilate them. As a result, the plant dies due to phosphorus deficiency. Therefore, direct use of these wastes in agriculture is impossible. However, various researchers have demonstrated the possibility of using them in combination with mineral fertilizers and manure (Fig. 3).

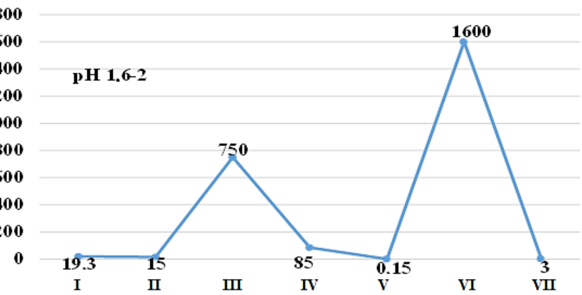


Figure 3
Agrochemical parameters of water (mg/l) in the copper mine of the Gadabay region

Note: I – Total Nitrogen; II – K; III – S; IV – Cl; V – Pb; VI – Fe; VII - P

Elemental composition of alunite landfill

The largest deposits after iron ore in the Dashkasan region are the alunite deposits in Zeylik. This deposit is considered the second largest in the world in terms of reserves, after the Fushun deposit in China. The deposit's reserves amount to $174 \cdot 10^6$ t. In addition to Al, alunite contains Na and K salts, S, and other minerals. Over time, as with other deposits in Dashkasan, open-pit mining of the alunite deposits in Zeylik led to the formation of environmentally hazardous areas, the activation of man-made landslides, and the destruction of fertile soils. As a result of the operation of the Dashkasan iron ore mines, 1,200 ha of forest and meadow lands have become unusable, of which 500 ha are covered by rock waste. Mining waste has also chemically polluted the soil cover of mountain meadow landscapes. Analysis of soil samples taken from mining waste and adjacent areas shows that the soil contains significantly higher levels of trace elements and heavy metals than in natural landscapes. As a result of waste leaching by surface water and filtration, active chemical elements migrate and settle in the soil, contaminating it. The content of these elements in soils in contact with the waste is 4–9 times higher than in natural background soils. The content of Zn, Cu, Co, Mg, B, and Hg in iron ore waste and in soils in contact with it is 4–9 times higher. As a result of the operation of the Dashkesan iron ore mines, 1.200 ha of forest and meadow land have become unusable, of which 0,500 ha are covered by rock dumps. Mining waste has also chemically polluted the soil cover of mountain meadow landscapes. Analysis of soil samples taken from mining waste and adjacent areas shows that the content of trace elements and heavy metals in the soil is significantly higher than in natural landscapes. As a result of the washing of mined rock by surface water and filtration, active chemical elements migrate and settle in the soil, contaminating it. The concentrations of these elements in soils in contact with the waste are 4–9 times higher than in natural background soils. The concentrations of zinc, copper, cobalt, and manganese in iron ore waste and in soils in contact with it are 4–9 times higher (Table 1).

Table 1
Elemental composition (%) of samples taken at different distances from alunite landfill

Elements	**Concentration**		
	Control (150m) 0-5 cm	**5-10 cm**	**10-30 cm**
Fe	0.30944 ± 0.0002	0.31765 ± 0.00122	0.31439 ± 0.00022
Co	-	0.00479 ± 0.00059	-
Rb	0.00115 ± 0.00008	0.00111 ± 0.00007	0.00110 ± 0.00007
Sr	0.00490 ± 0.00017	0.00324 ± 0.00013	0.00334 ± 0.00013
I_2	0.00063 ± 0.00005	0.00050 ± 0.00004	0.00057 ± 0.00004
Sn	0.00269 ± 0.00011	-	-
Zr	0.00093 ± 0.00008	0.00297 ± 0.00011	0.00292 ± 0.00011
Tb	-	0.00598 ± 0.00110	-
Elements	**Concentration**		
	A1 0-5cm (Bottom of the landfill)	**A1 5-10 cm**	**A1 10-30 cm**
Fe	0.29566 ± 0.00024	0.31478 ± 0.00027	0.30752 ± 0.00023
Br	0.00026 ± 0.00004	0.00026 ± 0.00005	-
Rb	0.00129 ± 0.00008	0.00135 ± 0.00009	0.00131 ± 0.00008
Sr	0.00373 ± 0.00014	0.00378 ± 0.00015	0.00332 ± 0.00013
I_2	0.00059 ± 0.00005	0.00054 ± 0.00005	0.00052 ± 0.00004
Zr	0.00267 ± 0.00011	0.00309 ± 0.00012	0.00297 ± 0.00011
Mo	-	0.00015 ± 0.00002	-
Pd	-	-	0.00037 ± 0.00004
Elements	**Concentration**		
	A2 (0-20 m) 0-5 cm	**A2 5-10 cm**	**A2 10-30 cm**
Fe	0.59115 ± 0.00029	0.46662 ± 0.00029	0.28995 ± 0.00021
Rb	0.00172 ± 0.00011	0.00148 ± 0.00010	0.00101 ± 0.00007
Sr	0.00486 ± 0.00018	0.00429 ± 0.00017	0.00328 ± 0.00012
I_2	0.00060 ± 0.00005	0.00078 ± 0.00006	0.00052 ± 0.00004
Zr	0.00393 ± 0.00014	0.00400 ± 0.00014	0.00296 ± 0.00011
Nb	-	0.00035 ± 0.00004	-
Elements	**Concentration**		
	A3 (20-70 m) 5-10 cm	**A3 0-5 cm**	**A3 10-30 cm**
Fe	0.34898 ± 0.00023	0.29394 ± 0.00111	0.86389 ± 0.00036
Rb	0.00133 ± 0.00008	0.00132 ± 0.00009	0.00249 ± 0.00014
Sr	0.00357 ± 0.00013	0.00388 ± 0.00015	0.00548 ± 0.00020
I_2	0.00054 ± 0.00004	0.00051 ± 0.00005	0.00096 ± 0.00007
Zr	0.00290 ± 0.00011	0.00329 ± 0.00012	0.00558 ± 0.00018
Tb	-	0.00566 ± 0.00109	-

Table 1 shows that there was no significant difference in the elemental composition of the elements present here between the waste impact zone and samples taken from the control zone. Therefore, it can be concluded that the alunite waste in this area caused only mechanical pollution of the territory. It would be more effective to use this waste, consisting of various types of rock, as an important raw material base for construction work, especially in the development of road and communication systems. It would be more profitable to clear the area of waste and also to use the mountain meadow pastures for livestock farming. In the future, in the development of the region's economy, especially in the use of skilled mining labor, it would be more appropriate to use it here to strengthen the forage base for agriculture, especially livestock farming. At the same time, for the ecological safety of the territory, it is important to develop all deposits using mining methods. The cessation of mining operations in recent years has led to the formation of sparse grass thickets on these hills. Removing waste from the area, as well as using mountain meadow pastures for livestock farming, will also play a significant role in strengthening our republic's food supply. In the future, this will play an even greater role in the region's economic development, particularly in utilizing its skilled labor force in the mining industry, as well as in providing reliable supplies for agriculture in the region. The development of all deposits using mining methods is a key factor in maintaining the region's environmental integrity.

Discussion

The conducted studies revealed a number of geochemically anomalous zones containing high concentrations of the heavy metals studied. The main areas of anomalously high concentrations are localized primarily near iron ore processing plants and mines. Intraprofile differentiation is characterized by heavy metal accumulation in the upper 0–17 cm soil layer, in gray-humus horizons. In the lower illuvial-textural horizons, at a depth of 70–80 cm, the anomalous zones are significantly reduced in size and manifest themselves more locally in spatial variation. The conducted research revealed that a total of 2.996 ha, or 0.013% of the territory of the Gadabay and Dashkasan regions on the northeastern slope of the Lesser Caucasus, were subject to technogenic pollution. In the studied areas, anthropogenic geosystems man-made giant landforms, waste heaps, roads, etc., formed as a result of the use of technogenic waste have significantly altered the natural environment, disrupting the soil and vegetation cover, soil formation, and hydrogeological processes. Due to a lack of air in the waste from old copper mines with a highly acidic environment (pH 1.6–2.0), the mineralization of organic matter ceases, making direct use of the waste in agriculture impossible. Considering that this figure will increase as a result of the commissioning of new deposits in the Dashkasan region, where 51.5% of the territory is subject to pollution, it is important to pay special attention to the use of new, more modern technologies. It would be more efficient to use existing waste, consisting of various types of rocks, as an important raw material base for construction work, especially in the development of road and transport infrastructure.

References

1. Aristovskaya, T. V., Chugunova, M. V., & Zykina, L. V. (1988). Rate of soil biological reaction to addition of organic compounds as indicator of microflora ability to regulate soil environmental conditions. *Microbiology, 57*(5), 860–867.
2. Akbarova, C., & Mammadova, A. (2024). Chorological analysis and phenological observations of some species of the family *Crassulaceae* J. St.-Hil. in the Lesser Caucasus of Azerbaijan. *Advances in Biology and Earth Sciences, 9*(2), 301–309. https://doi.org/10.62476/abes9301
3. Akhundova, S., Mammadova, G., Bunyatova, L., Alakbarli, G., Ahmadova, A., Aliyev, F., Bagirova, C., & Shammadova, I. (2025). Study of the modern bio-ecological state of Absheron coastlines. *Advances in Biology and Earth Sciences, 10*(1), 168–176. https://doi.org/10.62476/abes.101168

4. Ali, R. S., Farman, N. A., Israphil, G. M., Gudrat, V. I., Allaheverdi, T. H., & Madnee, M. (2026). Current state of production of alternative energy on the Absheron Peninsula. *International Journal of Applied Power Engineering, 15*(1), 37–45. https://doi.org/10.11591/ijape.v15.i1.pp37-45
5. Ali, R. S., Kichmirza, M. N., Eyvaz, G. I., Israphil, G. M., Allahverdi, T. H., & Madnee, M. (2025). Modern research on the use of alternative energy resources in Azerbaijan. *International Journal of Advances in Applied Sciences, 14*(3), 907–915. https://doi.org/10.11591/ijaas.v14.i3.pp907-915
6. Ahmadova, M. A., Mustafaev, M. G., Gafarbayli, K. A., et al. (2025). Diagnostic specifics of the chemical elemental composition of the meadow-gray soils in the Mughan Steppe, Azerbaijan. *SABRAO Journal of Breeding and Genetics, 57*(5), 2139–2146. https://doi.org/10.54910/sabrao2025.57.5.34
7. Ahmad, P. S., Latifaga, A. R., Mirismayil, M. A., Nazim, R. M., Ikhtiyar, A. N., Telman, V. M., Aghayeva, T. S., & Shirinova, G. F. (2026). Eco-biological features of mountain gray-brown soils development in the Karabakh steppe (Republic of Azerbaijan). *International Journal of Agriculture and Biosciences, 15*(4), 1691–1699. https://doi.org/10.47278/journal.ijab/2026.063
8. Allahverdi, T. H., Musa, A. J., Maharram, S. H., Gudrat, V. I., Israphil, G. M., Madnee, M., & Farhad, G. A. (2026). Modeling humus stocks and introducing a saturation coefficient to assess soil organic carbon capacity in forest soils of the Sheki-Zagatala Region, Azerbaijan. *International Journal of Agriculture and Biosciences, 15*(5), 210–223. https://doi.org/10.47278/journal.ijab/2026.116
9. Bahram, F. V., Allahverdi, T. H., Eyvaz, M. I., Yusif, E. H., Elshad, T. J., & Farhad, G. A. (2025). Bioecological characteristics of modern soil cover in subtropic regions of Azerbaijan. *International Journal of Advances in Applied Sciences, 14*(4), 1200–1207. https://doi.org/10.11591/ijaas.v14.i4.pp1200-1207
10. Guliyeva, Y. (2023). Diagnostics of soils in the south western part of Absheron Peninsula on the basis of aerospace materials. *Bulletin of Science and Practice, 9*(7), 118–127. https://doi.org/10.33619/2414-2948/92/17
11. Gahramanova, A. Y., Mammadova, R. N., Hasanova, T. A., Alakbarli, G. Y., Mammadova, G. I., & Asgarova, G. F. (2026). Studies on gray-brown soils with rapeseed (*Brassica napus* L.) as a forage crop in the Sheki region of the Greater Caucasus. *SABRAO Journal of Breeding and Genetics, 58*(1), 432–441. https://doi.org/10.54910/sabrao2026.58.1.40
12. Hasanova, T., & Mammadova, G. (2023). The impact of changes in soil moisture indicators on biological activity in recent years on the southern slope of the Greater Caucasus. *Nature and Science, 5*(3), 7–12. https://doi.org/10.36719/2707-1146/30/7-12
13. Ibrahimova, L. (2023). Influence of the climate factor on the development of mountain geosystems and emerging environmental problems. *News of the Tula State University. Sciences of Earth, 3*(1), 68–79. https://doi.org/10.46689/2218-5194-2023-3-1-68-79
14. Ibrahimova, L., Zeynalov, L., & Asadov, H. (2024). Assessment of regional factors for sustainable development of agrocenoses based on GIS and remote sensing. *Comptes Rendus de l'Académie Bulgare des Sciences, 77*(6), 849–857. https://doi.org/10.7546/CRABS.2024.06.08
15. Ikhtiyar, A. N., Gudrat, V. I., Islam, R. M., Yarish, A. G., Novruz, L. B., Israphil, G. M., Allahverdi, T. H., Farhad, G. A., & Nazim, R. M. (2026). Changing the biological activity of soil in sunflower crops. *Comptes Rendus de l'Académie Bulgare des Sciences, 79*(1), 145–156. https://doi.org/10.7546/CRABS.2026.01.18
16. Ismayil, A. I., Alakbar, R. H.-B., Gudrat, V. I., Islam, R. M., & Allahverdi, T. H. (2025). Soil salinization in Ujar region of Azerbaijan with index application and comparison of various methods. *Comptes Rendus de l'Académie Bulgare des Sciences, 78*(6), 946–954. https://doi.org/10.7546/CRABS.2025.06.18

17. Ismayilova, A. A., Mirzezadeh, R. I., Bunyatova, L. N., Mammadova, G. I., Hasanova, T. A., Asgarova, G. F., & Madnee, M. (2025a). Biomass and enzymatic activity assessment of the coniferous-deciduous forests in Azerbaijan. *SABRAO Journal of Breeding and Genetics, 57*(6), 2584–2595. https://doi.org/10.54910/sabrao2025.57.6.31
18. Ibrahimova, L., & Imanov, H. (2025). The role of landscape in the formation of river flow in the Nakhchivan Autonomous Republic. *Visnyk of V. N. Karazin Kharkiv National University Series: Geology. Geography. Ecology, 62*(1), 184–193. https://doi.org/10.26565/2410-7360-2025-62-14
19. Ismayilova, A., Shukurov, S., Hasanaliyeva, L., Osmanova, S., Asgarova, G., & Hasanova, T. (2025b). Modern soil cover of natural cenoses and agrocenoses landscapes of the Kur-Araz plain. *Advances in Biology and Earth Sciences, 10*(2), 314–325. https://doi.org/10.62476/abes.102314
20. Khudaverdi, S. S., Azer, A. I., Ali, R. S., Javanshir, M. K., Allahverdi, T. A., & Farhad, G. A. (2025). Determination of soil salinization by hyperspectral remote sensing in the Shirvan Plain. *International Journal of Advances in Applied Sciences, 14*(3), 662–670. https://doi.org/10.11591/ijaas.v14.i3.pp662-670