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The main causes of soil contamination with heavy metals (Pb, Cd, Hg) on the northeastern slope of the Lesser Caucasus of the Republic of Azerbaijan

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ABSTRACT

Problems Statement and Purpose. The subject of discussion is soil pollution - a type of anthropogenic degradation in which the content of chemicals in soils subject to anthropogenic impact exceeds the natural regional background level. The population of the earth is growing rapidly. Population growth requires food supply and meeting their consumption. At this time, the environment is polluted. Industry and agriculture especially cause soil pollution. For this reason, its research is an urgent issue. We also analyzed environmental pollution during the study. The research area is located in the Lesser Caucasus physical-geographic region, where the most important industrial enterprises in our country are located. The region is located in the western part of Azerbaijan, in an area rich in minerals. Both non-ferrous and ferrous metals are rich here. The natural conditions are also favorable for the development of industry in the area. Its richness in mineral deposits makes large-scale research of the area relevant. Therefore, our research is dedicated to the actual topic.

Data and Methods. For analysis, soil samples were taken from the research area and analyzed in the laboratory. Soil samples were taken from different soil types in the Lesser Caucasus. Based on the results of these analyses, comparisons were made for soil types.Then calculations were made based on mathematical and statistical methods. During the study, the results of previous studies in the area were also used.

Results and Discussion. As a result of the research, the influence of man-made emissions of lead, cadmium and mercury on various soil types on the northeastern slope of the Lesser Caucasus was studied, and the mechanisms that determine the state and behavior of heavy metals in background and soils subject to contamination were investigated. Ganja aluminum plant and Dashkasan ore refining plant located in the study area play a special role in soil pollution.

Conclusion. It has been noted that the excess content of certain chemicals (Pb, Hg, Cd) in the human environment (compared to natural levels) due to their receipt from anthropogenic sources has a negative impact on the environment. The process by which uncharacteristic microelements appear in the soil, characterized by a toxic effect and affecting the properties of the soil, is called soil contamination with heavy metals. It has been established that soil contamination with such chemical elements as lead, cadmium, and mercury poses a particular environmental hazard.

Keywords: *Heavy Metals (HM), EAC (eluvial-accumulative coefficient), Clark concentration (CC), Lesser Caucasus, chernozem, meadow turf soils.*

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Introduction. The use of chemical substances in the economic activities of people and their involvement in the cycle of anthropogenic transformations in the environment is constantly increasing [42]. A characteristic feature of the intensity of extraction and use of chemical elements is technophily - the ratio of annual production or production of an element to tons of lithosphere [33].

Another quantitative characteristic of anthropogenic participation in the global cycle of chemical elements on the planet is the mobilization coefficient or anthropogenic enrichment coefficient [25], which is calculated as the ratio of anthropogenic flow of a chemical element to its natural flow [44]. The level of the man-made enrichment factor [24], as well as the technophilicity of the elements, is not only an indicator of their mobilization from the lithosphere to the surface natural environments [43], but also a reflection of the level of release of chemical elements into the environment together with industrial waste [27].

Heavy metals are the most common pollutants [26]. They pollute the land heavily, especially in old cities with a long industrial history [28]. Airborne heavy metals are dispersed over long distances around metallurgical plants [29], coal-burning thermal power plants and other facilities, and settle on nearby agricultural land [36]. Heavy metals enter agricultural soils from organic and mineral fertilizers, ameliorants and plant protection products [35].

Heavy metals, as a special group of elements, are highlighted in soil chemistry due to the toxic effect they have on plants at high concentrations [30]. There is no clear definition of heavy metals [32].

When the concept of “Soil Pollution” is limited to the participation of anthropogenic substances, significant areas of soil located in the territory of positive natural geochemical anomalies [41], the agricultural use of which, in some cases, is dangerous for animals and humans, fall out of the attention of soil scientists and ecologists [40]. Meanwhile, abroad the concept of “soil pollution” is considered much more widely [37]. To denote a pollutant, two words are used: pollutant and contaminant, and the meaning of the second term is broader [28]. With its participation, two different concepts are denoted: “anthropogenic contaminant” - an anthropogenic pollutant and “natural contaminant” - a natural pollutant [45]. Accordingly, a distinction is made between anthropogenic and natural pollution [29].

Heavy metals are found in soil, water, air and food, and pose a serious environmental and public health problem [27].

Currently, heavy metal pollution is becoming an increasingly pressing problem [31]. The spread of industrialization and the use of oil, coal and other resources lead to the release of large quantities of toxic substances [43]. When these metals enter the soil through emissions from factories or the use of pesticides, these metals can remain in the soil layer for a long time [23]. They are then transported by precipitation or underground flows, thus ending up in groundwater and surface water systems [42].

The danger of heavy metals lies not only in their direct contact with nature [34], but also in the possibility of them entering the human body through food [14]. Fish, seafood [22], vegetables and fruits may contain some heavy metals that have been absorbed by plants or animals from the environment [19]. Continuous consumption of such foods can lead to the accumulation of these substances in the human body and cause serious illness [29].

Soil pollution changes its chemical composition, physical and biological state, and deteriorates its structure [18]. Therefore, improper agricultural activities, poor waste disposal [46], active industrial production and lack of work to reduce harmful emissions lead to negative consequences [30].

Soil is the first level of filtration of drinking water [47]. From contaminated soil, harmful substances and toxins enter groundwater, accumulate in the tissues of plants that feed animals on pastures, and then end up in human food [35]. Pollutants and heavy metals can lead to diseases ranging from diarrhea to cancer [29].

Most antibiotics used in agriculture and medicine enter the environment after being excreted from the body [40]. They can filter into the soil and spread, leading to the formation of antimicrobial-resistant bacteria and reducing the effectiveness of antibiotics. Every year, about 700 thousand deaths are caused by bacteria resistant to antimicrobial drugs [42].

Contaminated soils become less fertile, leading to serious economic costs. Soil is directly or indirectly needed to produce 95% of the planet's food [26].

Soil degradation leads to drainage and desertification: about 35% of wetlands have been lost since 1970, they are disappearing faster than forests. If the situation does not change, by 2050 about half of the world's population will live in dry areas with poor soils [19].

The danger lies in the fact that soil pollution is an invisible process. Right now, about a third of the Earth's soils are degraded due to erosion, salinization, chemical pollution and other reasons [18]. And it takes about a thousand years to form just one centimeter of fertile layer. If action is not taken, the health and quality of life of future generations could be seriously jeopardized [20]. By the end of 2020, soil degradation had already affected at least 3.2 billion people – that’s 40% of the world’s population [23].

Heavy metals (HM) already occupy the second place in terms of danger [12], inferior to pesticides and significantly ahead of such well-known pollutants as carbon dioxide and sulfur. In the future, they may become more dangerous than waste from nuclear power plants and solid waste [2]. Pollution with heavy metals is associated with their widespread use in industrial production [19]. Due to imperfect purification systems, heavy metals enter the environment [17], including the soil, polluting and poisoning it [13]. HM are special pollutants, monitoring of which is mandatory in all environments [3]. Soil is the main environment into which heavy metals enter, including from the atmosphere and the aquatic environment [20]. It also serves as a source of secondary pollution of surface air and waters that flow from it into the World Ocean [11]. HM are absorbed from the soil by plants, which then enter food [5].

Soil pollution is one of the main environmental threats in the world, affecting natural processes and the ecosystem as a whole [6]. In particular, such soils are a secondary source of emissions of pollutants into the air, surface and ground waters, and then into the ocean [7].

Mercury, lead, and cadmium are ubiquitous [8]. In any doses, they are alien to the human body and animals and, with an increase in the maximum permissible concentration, lead to a variety of metabolic abnormalities [9]. Lead and cadmium are poorly excreted from the body of warm-blooded animals [21]. They are capable of accumulating in tissues of humans and animals, causing disorders of cardiovascular activity, carcinogenesis, and others [16]. In humans, consumption of 10 mg of cadmium is accompanied by symptoms of poisoning [10].

Material and methods. During the research, samples were taken from chernozem and mountain meadow turf soils common in the Lesser Caucasus

(Dashkasan, Gadabay, Ganja, Shamkir). These samples were analyzed in the laboratory. The amount of Pb, Cd, Hg elements in these soils was studied, determined in the laboratory using atomic absorption spectrophotometry methods. Data was processed using mathematical statistical methods. Their Clark coefficient, eluvial-accumulative coefficient were calculated. For this purpose, different depths are taken as a basis. Depths of 0-19, 19-26, 26-52, 52-78 cm were chosen for chernozem soils, 0-6, 6-27, 27-47, 47-65 cm for mountain meadow turf soils. Analyzes were carried out at these depths and the results are presented in tables.

Results and discussion. We determined the mercury content in soils by atomic absorption (AA) spectroscopy using an experimental analyzer (AA), and the content of lead and cadmium in the soils of the study area using a spectrophotometer (AA).

On the northeastern slope of the Lesser Caucasus, as a result of human industrial activity, the natural state of landscapes is currently being disrupted [14]. Many natural components are subject to degradation, especially soil cover. The study area is rich in mineral resources. In places where igneous rocks are closely located or have outcrops on the surface of the earth, ore minerals are common, such as iron ore (Dashkesan), alunites (Zeylik Alunitdag), polymetals (Mekhmana), mercury (Shorbulag, Agyatag), copper, molybdenum, and in other territories, deposits of marble, building materials, and mineral waters are of great economic importance (in the Kelbajar region of Istisu, in Shusha Shirlan and Turshsu).

Mountain brown forest leached soils in the area of our research are distributed in the Dashkesan region in the southern part of the ore processing enterprise.

With the open-pit method of mining in this region of the Republic of Azerbaijan, rocks containing toxic chemical elements, such as lead, cadmium and mercury, are opened, mixed and transported. The development of deposits is accompanied by disturbance and contamination of the soil cover. Industrial waste, having a strong polluting effect on agricultural landscapes, on the concentration of heavy metals (Pb, Cd, Hg) in soils, causes large deviations from permissible standards (PS) (Table 1) [15] and this has a very negative effect on the quality of agricultural plants, human health, and others.

Table 1

Maximum permissible limits for heavy metals in soil

Heavy metals mg/kg	EU STD mg/kg	US STD mg/kg	UK STD mg/kg	WHO mg/kg
Pb	300	300	70	0.3-10
Cd	3.0	400	1,4	0.002-0.5
Hg	-	-	-	0.001-0.04

Note: WHO = World Health Organization, STD = Standard

All this requires a comprehensive study of the behavior of heavy metals (Pb, Cd, Hg) in various soil types, since knowledge of the fate of highly toxic metals, the mechanism of their fixation and migration ability will make it possible to predict the extent of pollution and develop practical measures.

The content and distribution features of heavy metals (Pb, Cd, Hg) in soils and industrial dumps of the northeastern slope of the Lesser Caucasus have not been studied to date. The obvious insufficient amount of data on the problem under consideration determined the topic of this article; it has scientific and practical significance for studying the content of heavy metals (Pb, Cd, Hg) in various soil types and industrial dumps, which are a source of environmental pollution in this region of the Republic of Azerbaijan (Figure).

The study area covers territories from low mountains to high mountains, where the following soil types and subtypes are common.

Mountain chernozem (regur soil) leached soils. These soils in the study area are distributed mainly in the Gadabay and Dashkesan regions. The main polluting enterprises in these regions and near them are the aluminum plant, ore refining enterprises, ore extraction. For example, Dashkasan ore refining enterprise, Ganja aluminum plant, Gadabey ore extraction enterprise, etc. The waste of Dashkesan OJSC was 2.4 cubic km in 2016. This was calculated using the Triangulation method [1]. The distribution of heavy metals was studied along section 1 and is characterized by the data in Table 2. In the distribution of gross reserves of lead in leached chernozem soils, a certain relationship between Pb and humus is noted.

At the same time, the maximum amount of gross lead is observed in the more humified horizon (9.0 mg/kg) and soil-forming rock (12.0 mg/kg). The illuvial horizon is also characterized by a relatively high concentration (6.0 mg/kg). This is explained by the fact that from this horizon, during the leaching process, lead (EAC = 0.33) is carried out beyond the soil profile. The Clarke concentration (CC) of lead in the studied soils reaches a value of 0.25. If we compare the amount of Pg, Cd and Hg in the soil with the standards, the amount of Pb is 9-12 mg/kg and does not differ much from the norm (0.3-10 mg/kg). Also,

Table 2

Content of heavy metals in mountain chernozem leached soils

№ section	Depth, cm	Pb (mg/kg)			Cd (mg/kg)			Hg (mg/kg)		
		total	CC	EAC	total	CC	EAC	total	CC	EAC
1	2	3	4	5	6	7	8	9	10	11
	0-19	9,0	0,56	0,75	0,17	0,34	1,0	0,048	0,60	1,33
	19-26	4,0	0,25	0,33	0,16	0,32	0,94	0,038	0,48	1,05
	26-52	6,0	0,38	0,50	0,22	0,44	1,29	0,059	0,74	1,64
	52-78	12,0	0,75	1,0	0,17	0,34	1,0	0,036	0,45	1,0

the amount of Cd is 0.17 mg/kg, close to the norm (0.002-0.5 mg/kg). The amount of Hg is 0.036-0.048 mg/kg and does not differ much from the norm (0.001-0.04 mg/kg).

The vertical profile of these soils is characterized by a certain monotony in the distribution of cadmium; one can note a slight accumulation in the illuvial horizon - 0.22 mg/kg, where the accumulation coefficient (EAC) reaches a value of up to 1.29, and the clarke concentration (CC) of cadmium is 0. 44 (Table 1 and 2).

Mercury is characterized by differentiation in the vertical profile of mountain leached chernozem soils by two maxima. The first maximum corresponds to the accumulation of the element in the humus-eluvial horizon - 0.48 mg/kg, especially in its organic part, which is associated with the biogenic factor, and the strong sorption of mercury by humic substances in the soil contributes to the fixation of the metal. The second maximum with a higher value falls on the illuvial horizon (26-52 cm) -0.59 mg/kg. In the profile of these soils, mercury accumulates (EAC = 1.0-1.64), and its Clarke concentration (CC) in the described soil varies from 0.45 to 0.74.

Mountain meadow turf soils. These soils are located in Dashkasan region (Figure 1). The content and distribution of the studied metals (Pb, Cd, Hg) in the vertical profile of mountain meadow turf soils are presented in Table 3, Section 2.

If we compare the amount of Pg, Cd and Hg in the soil with the standards, the amount of Pb is 6-10 mg/kg and does not differ much from the norm (0.3-

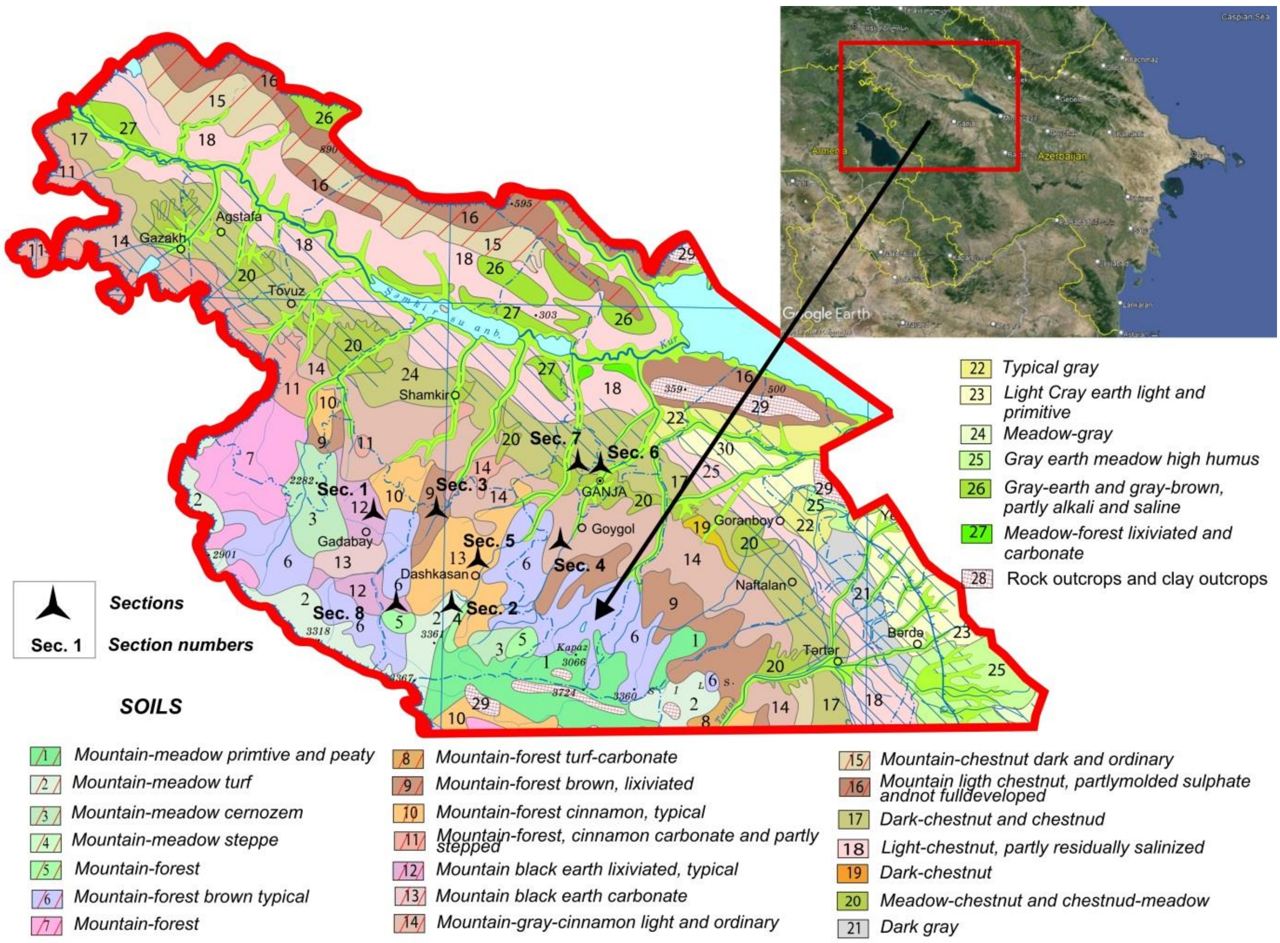

Fig. 1. Soil sections in Lesser Caucasus (investigation area)

Table 3

Content of heavy metals in mountain meadow turf soils

№ section	Depth, cm	Pb (mg/kg)			Cd (mg/kg)			Hg (mg/kg)		
		total	CC	EAC	total	CC	EAC	total	Cc	EAC
2	2	3	4	5	6	7	8	9	10	11
	0-6	6,0	0,38	0,60	0,14	0,28	0,82	0,048	0,60	2,45
	6-27	8,0	0,50	0,80	0,14	0,28	0,82	0,039	0,49	1,18
	27-47	7,0	0,44	0,70	0,16	0,32	0,94	0,16	2,0	4,84
	47-65	10,0	0,63	1,0	0,17	0,34	1,04	0,035	0,41	1,0

10 mg/kg). Also, the amount of Cd is 0.14-0.17 mg/kg, close to the norm (0.002-0.5 mg/kg). The amount of Hg is 0.035-0.16 mg/kg and does not differ much from the norm (0.001-0.04 mg/kg). The data that was obtained as a result of soil analyzes taken from section 2 shows that lead accumulates in the upper horizons to a lesser extent compared to the soil-forming rock. The maximum Pb content falls on the underlying horizon (47-65 cm) - 10.0 mg/kg, which is the result of leaching from the upper horizons and this is confirmed by the EAC (1.0). In this case, the clarke concentration (CC) for lead is less than 1 and varies from 0.38 to 0.63.

The cadmium content reaches the highest values in the lower horizons - 0.16-0.17 mg/kg. This is also confirmed by the concentration clarke (0.32-0.34) and the eluvial-accumulative coefficient (0.94-1.04).

The distribution of gross mercury reserves is characterized by differentiation in the vertical profile of mountain meadow turf soils with one maximum, which is noted in the horizon of 47-65 cm-0.34 mg/kg. In different horizons, the accumulation coefficient (EAC) is 1.0-4.84, and the concentration clarke varies widely: from 0.41 to 2.0.

The content and distribution of heavy metals (Pb, Cd, Hg) were studied in section 3, Table 4.

Table 4

Content of heavy metals in mountain brown forest leached soils

№ section	Depth, cm	Pb (mg/kg)			Cd (mg/kg)			Hg (mg/kg)		
		total	CC	EAC	total	CC	EAC	total	CC	EAC
1	2	3	4	5	6	7	8	9	10	11
	0-13	10,0	0,63	1,67	0,09	0,18	1,13	0,056	0,70	2,33
	13-38	7,0	0,44	1,17	0,15	0,30	1,88	0,060	0,75	2,5
	38-70	7,0	0,44	1,17	0,15	0,30	1,88	0,022	0,28	0,91
	70-93	6,0	0,38	1,0	0,08	0,16	1,0	0,024	0,30	1,0

Analysis of the data presented in Table 4 shows that **t**he vertical profile of mountain brown forest leached soils is characterized by an uneven distribution of lead. The eluvial-accumulative coefficient (EAC) for lead in various horizons is 1.0-1.67, and the clarke concentration is less than unity. This is due to its low content in the soil-forming rock and the removal of Pb from the soil profile during the leaching water regime.

In the profile of mountain-brown leached soils, cadmium is relatively distributed. No horizon with high Cd content is identified. According to the profile, its concentration varies from 0.08 to 0.15 mg/kg (EAC = 1.0-1.13). In the upper horizon and in the middle part of the soil profile, cadmium accumulates, and the degree of enrichment with the element (CC) is 0.16-0.30.

In section 3 (Figure), mercury is characterized by an uneven distribution, in which the eluvial-accumulative coefficient (EAC) is 0.91-2.5 and the change in mercury content is very pronounced, where a decrease in the concentration of the metal is observed in the direction of the underlying horizons. The largest amount is noted in the layer 13-38 cm (EAC = 2.5), and the smallest in the layer 38-70 cm (EAC = 0.91).

Chestnut soils. When comparing the lead and cadmium content in these soils along characteristic section 4 (Table 5), the highest values are observed in the upper humus horizons: Pb -20.0 mg/kg, Cd -0.56 mg/kg (Table 5).

With depth, as the amount of humus decreases and the mechanical composition of the soil transitions from medium loamy to heavy loamy varieties, a decrease in the content of Pd and Cd is observed. At the same time, active accumulation of lead and cadmium occurs in the upper horizon of chestnut soils. This is evidenced by the calculated eluvial-accumulative coefficient (EAC), which is 1.0-3.40 for lead; for cadmium 1.0-4.67. The confinement of Pb and Cd to the upper horizon is also due to the fact that in the zone of moderate-dry steppes there is a general accumulation of metals in the soil profile with some excess in the humus horizon. Clarke concentration (CC),

Table 5

Content of heavy metals in chestnut soils (mg/kg)

№ section	Depth, cm	Pb (mg/kg)			Cd (mg/kg)			Hg (mg/kg)		
		total	CC	EAC	total	CC	EAC	total	CC	EAC
1	2	3	4	5	6	7	8	9	10	11
	0-5	20	1,25	3,40	0,56	1,12	4,67	0,041	0,51	0,54
	5-18	17	1,06	4,0	0,47	0,94	3,92	0,022	0,28	0,29
	18-60	9	0,56	1,80	0,23	0,46	1,92	0,063	0,79	0,83
	60-100	5	0,31	1	0,14	0,28	1,17	0,021	0,26	0,28
	100-125	5	0,31	1	0,12	0,24	1	0,076	0,95	1

indicating the degree of enrichment in lead and cadmium, is consistently 1.25; 1.12. The maximum value exceeds the minimum value for Pb by 3, and for Cd by 2.5 times.

Mercury has a different distribution pattern from lead and cadmium. The mercury content is 0.01 mg/kg and at the same time EAC increases to 1.0. The largest amount of this metal is observed in the bed rock - 0.076 mg/kg, which is explained by the enrichment of these rocks with mercury and exceeds its clarke content in the lithosphere (0.08 mg/kg). The mercury content in soil is closely dependent on its amount in soil-forming rocks, and the clarke concentration (CC) for mercury varies within the range of 0.26-0.95.

Impact of dumps on the environment. Rock dumps are very active sources of air, soil, and groundwater (possibly surface) water pollution. Rock dumps are sources of hazardous environmental manifestations associated with the combustion of dump masses, their fluttering, degassing and leaching. The impact of rock dumps is direct or indirect, associated with the interaction of the latter with precipitation, surface and groundwater, as a result of which the water seeping out from under the dumps is saturated with mineral salts and contaminated with harmful components [4].

Relatively more locally, but together the most intense impact on the natural environment is exerted by man-made flows of various pollutants generated from overburden dumps. This determines the need for a comprehensive study of the characteristics of geochemical changes in natural objects, the transformation of which is of great importance in soils.

It should be noted that in the area of our research there are deposits and occurrences of such ore districts as Shamkir, Dashkesan, Gadabay and others. In recent years, the extraction of various minerals from the above areas has been increasing at a rapid pace. During the development of deposits, the soil cover is disturbed and polluted, large areas of the land fund are put out of use for many years, the dynamic balance in landscapes is disrupted, the restoration of which will require many years and very large costs. Therefore, it is extremely important to study the degree of stability and response of different types of soils to such active geochemical anthropogenic load, such as mining.

In order to study the influence of dump rocks on soil conditions, sections were laid in various dumps, in background soils (control) and in areas adjacent to these soils (Figure). The results of some analyzes are presented in Table 6.

(CC) is the ratio of the content of an element in the soil horizon to its global clarke in the earth's crust.

EAC - (eluvial-accumulative coefficient) is the ratio of the content of an element in the horizon to its content in the soil-forming rock.

Analysis of the data presented in Table 5 shows that ***content of heavy metals in cobalt ore dumps and adjacent soils.*** The area occupied by cobalt ore dump rocks is 25 hectares. The thickness of the dumps ranges from 10-200 m. Ore mining here for a long time was carried out in adits and therefore the rocks of this deposit are scattered throughout the territory. Vegetation covers no more than 2-3% of the surface.

The nature of the distribution of lead, cadmium and mercury in cobalt ore dumps was studied using the example of table 4, section 3. A comparison of the data obtained as a result of the analyzes shows that the rocks of these dumps contain very high concentrations of the studied heavy metals (Pb, Cd, Hg).

The distribution of lead (section 3) in the rocks of cobalt ore dumps is characterized by two maxima. The first maximum is observed in the layer of 0-20 cm (47.0 mg/kg), and the second is confined to the layer of 80-100 cm (40 mg/kg). According to the eluvial-accumulative coefficient (EAC), during the distribution of lead in the rocks of these dumps, the accumulation of Pb is observed only in the above layers, while in the middle layers there is a significant decrease (EAC = 0.2-0.7). This is explained by the fact that the middle layers of the rock contain lead in low concentrations. The lead content in the dump rocks is 1.8-2.9 times higher than its average content in the lithosphere.

The results of the study showed that the nature of the distribution of cadmium along the conventional horizons, section 3, changes arbitrarily and

Table 6

Content of heavy metals in dumps, control soils and soils adjacent to dumps (mg/kg)

№ section	Depth, cm	Pb (mg/kg)			Cd (mg/kg)			Hg (mg/kg)		
		total	CC	EAC	total	CC	EAC	total	CC	EAC
1	2	3	4	5	6	7	8	9	10	11
Cobalt ore dumps										
3	0-20	47,0	2,9	1,2	2,2	4.4	0,5	2,05	25,63	1,3
	20-40	28,0	1,8	0,7	10,0	20,0	2,2	2,02	25,2 5	1,2
	40-60	37,0	2,3	0,9	3,5	7,0	0,8	1,97	24,63	1,2
	60-80	30,0	1,9	0,2	14,0	28,0	3,0	1,52	19,0	0,9
	80-100	40,0	2,5	1,0	4,6	9,0	1,0	1,63	20,38	1,9,
Mountain brown forest leached soils (control)										
4	0-20	9,0	0,56	1,8	0,13	0,26	2,2	0,018	0,23	0,8
	20-40	7,0	0,44	1,4	0,16	0,32	2,7	0,015	0,19	0,9
	40-60	6,0	0,38	1,2	0,09	0,18	1,5	0,021	0,26	0,2
	60-80	6,0	0,38	1,2	0,09	0,18	1,5	0,011	0,13	0,5
	80-100	5,0	0,31	1,0	0,06	0,12	1,0	0,024	0,30	1,0
In places where soils adjoin waste dumps										
5	0-20	24,0	1,5	2,4	0,61	1,22	1,6	0,26	3,25	1,2
	20-40	19,0	1,19	1,9	0,54	1,08	1,4	0,30	3,75	1,4
	40-60	16,0	1,0	1,6	0,42	0,84	1,1,	0,21	2,63	1,0
	60-80	16,0	1,0	1,6	0,26	0,52	0,7	0,19	2,38	0,9
	80-100	10,0	0,63	1,0	0,38	0,76	1,0	0,21	2,63	1,0

ranges from 2.2-14.0 mg/kg, with a concentration clarke of 4.4-28.0. The value of CC clearly shows the excess content of cadmium in the rocks of these dumps.

In the distribution of mercury in the dump rocks, there is a decrease in its content from the upper layers to the 60-80 cm horizon, where it reaches a value of 1.52 mg/kg. Due to the accumulation, its content increases in the 80-100 cm layer (1.63 mg/kg). The data presented clearly indicate that mercury is in elevated concentrations in the rocks of the studied dumps. Compared to its average content in the lithosphere (0.08 mg/kg), the dump rocks contain 19-25 times more mercury.

The study of the content of heavy metals in soils (section 5, located 100 m from the dump) located at the junction of cobalt ore dumps (Figure) with natural soils in comparison with control section 4 shows that if the lead content in background (control) soils ranges from 5.0 to 9.0 mg/kg; then in soils mixed with dump rocks it varies within 10.0-24.0 mg/kg. The cadmium content in background soils is 0.06-0.16 mg/kg, in soils mixed with dumps 0.26-0.61 mg/kg, and mercury in background soils is 0.011-0.024 mg/kg, and in mixed with dumps 0.19-0.30 mg/kg.

A comparison of the data presented shows that contamination with lead and cadmium affects only the upper layers of the soil and there is 2.7 times more lead and 4.7 times more cadmium than in background soils (control). The accumulation of these metals in the upper layer of soil is explained by their washing away by surface water from dumps and transfer into the soil. Unlike Pb and Cd, mercury contamination covers the entire vertical profile of the studied soils.

At the same time, soils under the influence of dumps contain 8.8 times more mercury than background soils and the clarke concentration index is 2.4-3.8 times higher than its average content in the lithosphere.

Content of heavy metals in aluminum smelter dumps and adjacent soils. The aluminum plant is located on the northern outskirts of Ganja. The production of this enterprise operates on the basis of the Dashkesan alunite deposit and mainly produces alumina. Over the course of 20-25 years, as a result of the use of imperfect technology, production dumps were formed on the southern side of the plant, covering an area of about 20 hectares, which had a strong impact on the environment and resulted in its pollution.

The distribution of lead, cadmium and mercury in the dumps of the Ganja aluminum smelter is shown in the most complete form in Table 4. The presented analytical data shows that the samples of these dumps contain heavy metals in high concentrations.

The lead content decreases with depth. The upper layers of dumps are especially enriched with this metal, where Pb is: 0-20 cm - 190.0 mg/kg; 20-40 cm – 170.0 mg/kg. In terms of concentration, the lead content exceeds the clarke value by up to 12 times. All layers of dump rocks are characterized by the accumulation of lead (EAC = 1.0-5.4).

The results of the determinations show that in the conventional horizons of the dumps, the cadmium content decreases towards the underlying layers. At the same time, high concentrations of this metal are observed in the 0-20 cm layer (1.3 mg/kg). Relatively low concentrations are observed at a depth of 80-100 cm (0.70 mg/kg). In general, the cadmium content in the dumps is 2.6 times higher than its average content in the lithosphere. Cadmium accumulates (EAC= 1.0-1.9).

Dump samples are characterized by a very high mercury content - 5.09-0.84 mg/kg. Its concentration exceeds the clarke content in all horizons by 10.5-63.6 times. An increase in the eluvial-accumulative coefficient to 6.06 indicates the accumulation of mercury in these dumps.

Let us consider the content of heavy metals in section 8 (10 km distance from dump) located at the junction of the dumps with background (control) soils in comparison with control section 7 (Table 4, Figure). In various layers of soil mixed with dumps, the content of metals (Pb, Cd, Hg) is several times higher than in control soils. This is especially typical for a horizon of 0-20 cm and is associated with their washing away by surface water from dumps and moving into the soil. Thus, in the control soil, in a layer of 0-20 cm, the lead content is 6.0 mg/kg; cadmium - 0.14 mg/kg; mercury - 0.035 mg/kg, while in places where soils adjoin waste dumps (section 28(2) - respectively Pb = 36.0 mg/kg; Cd = 0.65 mg/kg; Hg = 0.68 mg /kg.

The concentration of all metals under consideration exceeds their clarke values several times. The results of the analyzes show that pollution processes affect the entire vertical profile of the soils in the study area.

Conclusion. During field and laboratory studies, the content of lead, cadmium and mercury in the main soil types common in the study area was determined. The diversity of soil and geochemical conditions determined different contents in the distribution of metals both in arable and genetic soil horizons. It was revealed that ongoing mining operations are the main factor in the pollution of the adjacent territory in the area of our study. Based on the data obtained, maps of the gross contents of heavy metals (Hg, Pb, Cd) for the study area were compiled. It has been established that the source of environmental pollution in this region is overburden rocks from various dumps, which greatly influence the increase in the content of such hazardous metals for the environment as lead, cadmium and mercury.

Under the influence of the Ganja aluminum smelter, the soils are enriched with heavy metals and the arable horizon (0-20 cm) of the surrounding area contains 6 times more lead, 4.6 times more cadmium and 19.4 times more mercury, compared to control soils.

To improve the state of the environment and protect soils from pollution, we have proposed the following recommendations:

- Of particular danger is soil contamination with heavy metals such as mercury, lead, cadmium. Therefore, it is advisable to carry out reclamation of disturbed areas and return them to agriculture and afforestation. As a result, there will be an expansion of arable land and forest areas, which are problematic resources for this study area.
- To reduce the negative impact of pollution sources (mineral deposit dumps in the study area), it is necessary to use modern mining technology.
- Considering that mineral dumps occupy a large area in this area, it is necessary to carry out recycling of waste to obtain additional economic profit.
- It is mandatory to determine environmental and economic damage in monetary terms of negative changes in the environment of the study area as a result of its pollution, in the quality and quantity of natural resources, as well as the consequences of such changes.
- When assessing damage to the natural environment of the study region, the costs of reducing pollution must be taken into account; environmental restoration costs; additional costs due to changes in environmental quality; costs of compensating for risks to human health.

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Основні причини забруднення ґрунтів важкими металами (Pb, Cd, Hg) на північно-східному схилі Малого Кавказу Азербайджанської Республіки

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Предметом обговорення є забруднення ґрунтів – вид антропогенної деградації, при якому вміст хімічних речовин у ґрунтах, що піддаються антропогенному впливу, перевищує природний регіональний фоновий рівень. Населення Землі стрімко зростає. Зростання населення вимагає забезпечення продуктами харчування та задоволення їх споживання. У цей час забруднюється навколишнє середовище. Особливо забруднюють ґрунт промисловість і сільське господарство. Тому його дослідження є актуальним питанням. Територія досліджень розташована в Малокавказькому фізико-географічному районі, де розташовані найважливіші промислові підприємства нашої країни. Природні умови також сприятливі для розвитку промисловості району. Його багатство на родовища корисних копалин робить актуальним широкомасштабне дослідження території. Для аналізу були взяті проби ґрунту з досліджуваної ділянки та досліджені в лабораторії. Зразки ґрунту були взяті з різних типів ґрунтів Малого Кавказу. За результатами цих аналізів було проведено порівняння типів ґрунтів. Потім були зроблені розрахунки на основі математичних і статистичних методів. В результаті досліджень вивчено вплив техногенних викидів свинцю, кадмію та ртуті на різні типи ґрунтів північно-східного схилу Малого Кавказу та визначено механізми, що визначають стан і поведінку важких металів у фоновому та досліджено забруднені ґрунти. Особливу роль у забрудненні ґрунтів відіграють Гянджінський алюмінієвий завод і Дашкасанський гірничо-збагачувальний комбінат, розташовані на території дослідження. Відмічено, що перевищення вмісту деяких хімічних речовин (Pb, Hg, Cd) у середовищі існування людини (порівняно з природними рівнями) внаслідок їх надходження з антропогенних джерел негативно впливає на довкілля. Процес появи в ґрунті невластивих мікроелементів, що характеризується токсичною дією і впливає на властивості ґрунту, називається забрудненням ґрунту важкими металами. Встановлено, що особливу екологічну небезпеку становить забруднення ґрунту такими хімічними елементами, як свинець, кадмій, ртуть.

Ключові слова*: важкі метали (ВМ), ЕАК (елювіально-акумулятивний коефіцієнт), концентрація Кларка (КК), Малий Кавказ, чорнозем, лучно-дернові ґрунти.*

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