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MODERN GEOCHEMICAL SITUATION IN THE AREA OF MINING FACILITIES OF KURSK MAGNETIC ANOMALY (BY THE EXAMPLE OF MIKHAILOVSKY GOK)

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Abstract:
They provided the results of geochemical situation analysis in the KMA region over the past 10 years on the basis of literature data and the materials of author's studies on the example of the Mikhailovsky ore mining and processing enterprise are presented. The statistical analysis of pollutant distribution dependencies is performed within the ore mining and processing enterprise impact zones, the areas of element dispersion were estimated, the indices of industrial and agro-industrial background have been calculated using the example of a model territory. A detailed analysis of the geochemical situation in the region made it possible to formulate the main principles and directions for the migration of macro- and microelements as a result of technogenic emissions. The ranking of pollutant elements was carried out and the groups of chemical compounds with the dependent dynamics of their content in the soils of the region under study were identified.

Key words: *landscape geochemistry, ore mining and processing enterprise, heavy metal contamination, Kursk magnetic anomaly (KMA), Mikhailovsky Ore Mining and Processing Plant (MGOK), technogenic landscapes.*

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INTRODUCTION:

Mikhailovsky Ore Mining and Processing Plant (MGOK) is one of three largest open iron ore mining enterprises in the KMA basin. Mining industrial landscapes occupy more than 6,000 hectares (2.8% of the area) in the area of 20 km, which creates an intensive technogenic background along with a high degree of population [1-3]. A common landscape background is formed by man-made, residential and agro-landscapes [4]. The factors of geochemical problems determining the threat to human health and the ecosystems of the region are the following ones: 1) the dusting of rock piles - atmochemical transfer; 2) the filtration of water from ponds-sedimentation tanks and tailing dumps - hydrochemical transfer; 3) the environmental impact of communications (product pipelines and roads surrounding industrial zones).

The main share of atmospheric emissions is released into the air from chimneys and ventilation ducts, during the dusting of magnetic separation tailings, tailing dumps, the explosions in a quarry and the transfer of already deposited particles by the wind, as well as during transportation. Most of these emissions are deposited near the plant. According to [1, 5], outside the sanitary protection zone of MGOK (300-500 m from the boundaries of the enterprise), the influence of atmospheric chemical transfer is weakly expressed unlike hydrochemical transfer.

MATERIALS AND METHODS:

The study of the geochemical situation around industrial enterprises was carried out according to a standard procedure. Profiles were laid from the object of research, in accordance with the wind rose and the terrain features. The test was carried out from the surface layer by the "envelope" method (a mixed sample on the area of 25 m2) to the depth of 0-5 and 5-20 cm, the selection was carried out at the normative distance from highways. The analysis of soil samples was carried out in accredited laboratories.

The review of MGOK area geochemical study results over the past 15 years [1] shows that the content of nitrates, fluorides, toluene, xylene, benzene in the soils of ore mining and processing enterprises does not exceed normative indicators, or these components are absent. As a rule, the content of petroleum products, benzapyrene, radioactive components does not exceed the maximum concentration limit. The location of maximum concentrations of ^{137}Cs, ^{40}K, ^{226}Ra, ^{232}Th and Aeff is not related to the industrial facilities located in the area. Be, Se, Sb, Mo, Ba, Zr have an insignificant content with a uniform distribution, not related to economic objects.

The content of V, Cd, As, Zn, Pb shows a moderate concentration gradient in the direction of motor roads - 1.2-1.4 times. A similar concentration gradient is established for Ni and Cr in the direction of the overburden piles. On the contrary, their content is slightly less in the tailing dump soil - by 1.3-1.5 times. The marked concentration gradient in soils (in 1.5-2.5 times) is established for Co in the direction of loose overburden and rocky rock piles. The samples of rocks and the soil of tailing dump are characterized by a significantly large (25 times on average) content of Pb, but no significant effect of this factor was detected on the adjacent areas. The content of Cu, Sr in dumps and tailing is slightly higher than the background (in 1.3-1.5 times), but there is no pronounced gradient of their concentration in the direction of industrial facilities on the adjacent territories. The content of mobile iron, as well as Cu and Sr is 1.5-5 times higher in technical soils, which nevertheless does not create a pronounced gradient of their concentrations in the soils of adjacent territories.

Within the framework of systematic observations over the geoecological situation in the locations of large mining enterprises, we conducted soil-geochemical observations in the area of MGOK location:

1. The residential and agricultural zone adjacent to the northeastern borders of the enterprise extends along a strip of wastelands and arable lands, includes the forest belt and agro-dark grey forest soils. The samples 1-2 were selected in the forest belt within 2.9 km from MGOK at the depths of 0-5 and 5-20 cm, respectively; the index of samples is in the table and on Fig. 1-2 - "Fb", the area type - agricultural land (ag). The samples 3-4 were taken from arable land (2.6 and 2.4 km from MGOK, respectively), the depth of selection makes 0-20 cm, it was not separated into sublayers due to arable mixing; the index in the tables is "Ar", the land type is "Ag". The samples 5-6 characterize the weed deposit in 2 km from MGOK at the depths of 0-5 and 5-20 cm, respectively, the index is "Me", the land type is "Ag".
2. The industrial zone 1 - the slope area, including the mosaic of preserved dark gray forest soils and soil-like bodies with a mechanically disturbed (removed) top layer, with the self-growth for 15-20 years in close proximity from production facilities (washing, road for freight motor transport), a few further - the quarry and other industrial facilities. The samples 7-8 were selected on a local site of mechanically undisturbed gray forest soil, the index - "L1", type of land - industrial lands (Il). The samples 9-10 - on the site with a partially mechanically transformed soil layer, under woody and shrubby vegetation near the

road with a heavy traffic of trucks; the index is "R*".

3. Industrial zone 2 - a dump, a section of mixed dump from overburden with crushed rock particles near the zone No. 1 under self-growth with wood and grass vegetation in 15-20 years. Samples 11-12; the index in the table is "pile"

RESULTS AND DISCUSSION:

The average results of geochemical sampling of soil samples are presented in Table 1. The results of the cluster analysis are shown in the form of the dendrograms on Fig. 1-2. The grouping of samples (programmed on the basis of [6]) was carried out in terms of gross component content (metal oxides and nonmetal oxides) and microelement composition (heavy metals and other chemical elements).

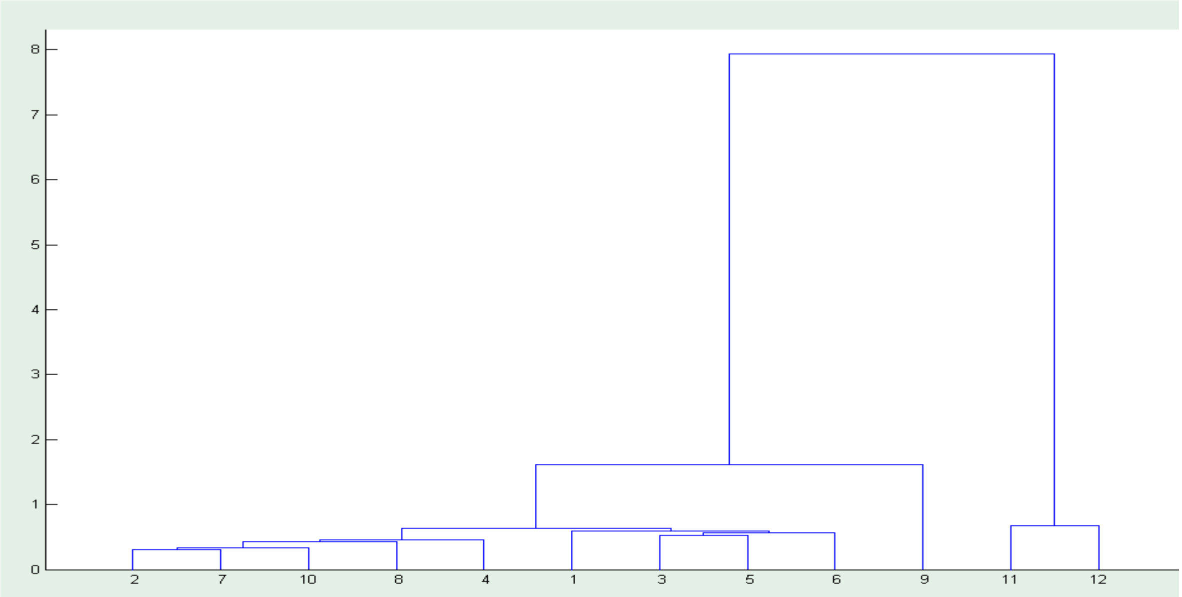
According to the results of the grouping by gross indicators, the sample 11 and 12 are singled out regularly, which are the artificial grounds of mixed rocks from MGOK. The sample 9 is also differentiated (partially mechanically damaged and cluttered topsoil on the industrial site); Other samples are differentiated slightly, including those related to different depths of sampling.

Table 1.The average content of the main soil elements and pollutants in the soils of agricultural lands (agro-industrial background) and industrial zone (industrial background) and dumps, in the area of Mikhailovsky Ore Mining and Processing Plant (MGOK)

	Soils		Dump soil		
	Agricultural	Industrial zone	Sample № 11	Sample № 12	Is / Pl
Be	0.5			0.5	
V	33	34	26.1	0	↓ - / 2.6
V*	1.3	1.4	1	0	
Cd	0.6	0.6	0.5	0.4	↓ - / 1.3
Co	7.2	10.5	52	56	↑ 1.5 / 7.5
As	5.8	4.8	0	0	↓ 1.2 / -
Ni	20	20	22	24	↑ - / 1.1
Pb	17	23	209	230	↑ 1.4 / 13
Se	1.1	1.2	1.2	1.1	
Sb	1.2	1.1	1.1	1.2	
Cr	68.3	78	108	97	↑ 1.1 / 1.5
Mn	607	639	224	230	↓ - / 2.7
Mn*	60.3	65.9	22.1	23.6	
Cu	17.8	18	26	29	↑ - / 1.5
Mo	0.7	0.6	0.6	0.6	↓1.2 / 1.2
Zn	47	62.8	120	90	↑ 1.3 / 2.2
Fe*	222	222	212	232	
Sr	140	148	157	179	- / 1.2
Zr	1.4	1.8	1.5	1.7	↑ 1.1 / 1.1
Al*	60.9	64.1	61.3	65.2	
SO_3	62.7	62.9	66.3	66,8	
P_2O_5	0.17	0.22	0.24	0.20	
Fe_2O_3	3.19	5.13	24.64	26.24	↑ 1.6 / 8
TiO_2	0.66	0.61	0	0	↓ - / до 0
Al_2O_3	8.7	8.7	5.8	5.7	↓ - /1.5
SiO_2	70.9	67.0	46.5	45.5	↓ - /1.5
K_2O	2.08	2.01	0.73	0.67	↓ - / 3
MgO	0.90	1.05	1.57	1.5	↑ 1.2 / 1.7
CaO	1.00	1.42	2.09	2.15	↑ 1.4 / 2.1
^{40}K	232	210	148	193	↓ 1.1 / 1.4
^{226}Ra	14.0	15.2	18.2	15.7	↑ 1.1 / 1.2
^{232}Th	18.7	16.8	23.4	10.7	-
A эф	59	56	62	47	

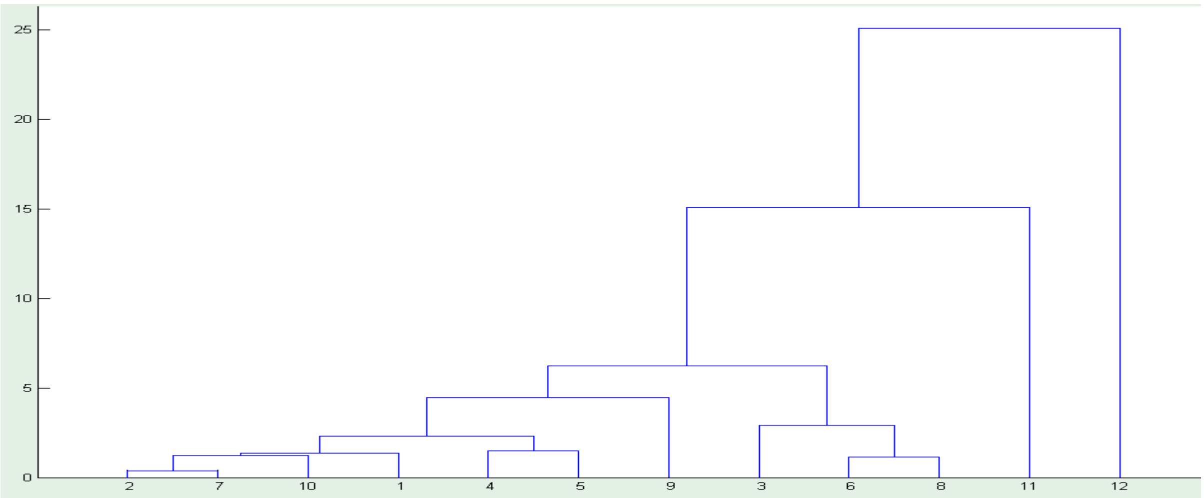
* -movable form

Note: Unit of measurement: for chemical elements and sulfur oxide - mg/kg, for oxides (except sulfur) - %, radionuclides - becquerel per kilogram. Growth ↑ or decrease ↓ dynamics of the studied ingredient concentrations is shown as the multiplicity factor for soils at the industrial site (Is) and for pile (Pl) relative to the soils on agricultural lands.



Sample №	2	7	10	8	4	1	3	6	5	9	11	12
Sampling depth	5-20	0-5	5-20	5-20	0-20	0-5	0-20	5-20	0-5	0-5	0-5	5-20
Kind of land	Fb	L1	R*	L1	Ar 3	Fb	Ar 2	Me	Me	R*	pile	pile
Type of land	Ag	Il	Il	Il	Ag	Ag	Ag	Ag	Ag	Il	Il	Il

Fig. 1 Dendrogram according to the indicators of macroelement component content.



Sample №	2	7	10	1	4	5	9	3	6	8	11	12
Sampling depth	5-20	0-5	5-20	0-5	0-20	0-5	0-5	0-20	5-20	5-20	0-5	5-20
Kind of land	Fb	L1	R*	Fb	Ar 3	Me	R*	Ar 2	Me	L1	pile	pile
Type of land	Ag	Il	Il	Ag	Ag	Ag	Il	Ag	Ag	Il	Il	Il

Fig. 2 Dendrogram according to the indicators of microelement content values (heavy metals)

The results of clustering by microelement composition differ from the clustering by macrocomponents: the samples 11-12 are also isolated here, but according to the "similarity level" the characteristics of sample 11 are significantly removed from the sample 12 and approach to the set of properties of the remaining samples. This, in our opinion, is related with the washing water regime of the upper layer of soil on the dump and the accompanying biochemical processes, since under the conditions of self-growth for many years the intensive soil-forming processes take place [7-9]. The remaining samples are differentiated less, without clearly defined patterns of distribution. We can assume some differentiation according to the depth of sampling and an even less pronounced differentiation tendency into forest and non-forest areas.

With the exception of loose soil samples, there are no clear differences between the soil samples selected on the territory of MGOK and on agricultural lands outside the enterprise. This is due to the relatively leveled macro-component composition of soils and a high proportion of road transport infrastructure, both on the territory of an industrial enterprise and on agricultural lands.

The dynamics of geochemical indicators allows us to note the trends associated with the production activities of the mining facility. First of all, this is the increased content of some heavy metals and other elements and their compounds in technogenic soils in relation to the agro-industrial background: Pb - 13 times, Co - 7.5, Cr - 1.5, Zn - 2.2, Cu - 1.5, Fe_2O_3 - 8, CaO - 2.1 and MgO - 1.7. Some increase of these components content in soil samples is characteristic only of the point located close to the areas of bulk soil at the road for heavy vehicles on the industrial site of MGOK (samples 9, 10), especially for sample 9, characterizing the topsoil (0-5 cm) : Pb - 1.4 times, Co - 1.5, Cr - 1.1, Zn - 1.3, Fe_2O_3 - 1.6, CaO - 1.4. This indicates a moderate atmochemical effect of industrial facilities in the form of dust, actively settling along the production motor transport communications at the distance of up to 50 m; at the distance of 100 m such geochemical anomalies are not detected.

Some components - V, As, Mn, TiO_2, Al, Si, K - are contained by technogenic soils in much smaller quantities than in soil samples, or even absent.

The results of pairwise correlation analysis of chemical component content in soils are presented in Table 2. They excluded the data on the elements for which no close relationship with the content of the remaining elements is revealed. In this group, a significant relationship is shown: ^{40}K-^{232}Th (r = 0,90); *Sb-Al**(r = –0.73). With regard to the distance to economic objects, due to their complex and mosaic combination in the study area, there is no strong dependence on the indices of chemical ingredient concentrations, the maximum (by module) values are for motor vehicles: Pb (-0.76), Sr (-0.67), Al* (-0.72), for production facilities: Al* (-0.68).

The absence of relation for the indicators of gross and mobile forms of Al* and Fe* (r = 0.32 and -0.19, respectively) indicates a predominant effect on their mobility, made not by a stock of gross forms, but by a set of indicators such as acid-base conditions, redox potential and the availability of other promoters or inhibitors of oxides solubility [10-11]. At the same time, the concentrations of mobile forms V* and Mn* have a strong dependence on the concentrations of gross forms (r = 0.92 and 0.97, respectively). Due to a high similarity of correlation ratio estimation results with the rest of the ingredients, the calculation indices for the mobile forms of these elements are not shown in the table.

By the distribution of statistically significant correlation coefficients, several groups of chemical elements and their compounds can be distinguished: 1) the group of silicon, potassium, titanium oxides and similar microelements As and Ni; 2) the group of calcium, iron and phosphorus oxides, with similar microelements: Zn, Co, Pb, Cr, Sr, Se. The components of these groups often have significant positive correlation coefficients within the groups and negative ones between the groups.

Table 2. Correlation coefficients of ingredient concentration pairwise comparison in the soils of MGOK region. The values for dependent and highly dependent elements are highlighted in boldface

	SiO_2	K_2O	TiO_2	As	Ni	Al_2O_3	Cu	Mn	Cd	V	Se	Sr	Cr	Pb	Co	Zn	P_2O_5	Fe_2O_3	CaO
SiO_2		**0.79**	**0.69**	0.61	0.52	0.15	0.23	0.06	0.03	-0.28	-0.46	-0.58	-0.46	-0.45	**-0.66**	**-0.77**	**-0.89**	**-0.75**	**-0.89**
K_2O	**0.79**		**0.71**	**0.71**	**0.81**	0.43	0.37	0.40	0.01	-0.31	**-0.65**	**-0.74**	-0.63	-060	**-0.72**	**-0.81**	**-0.73**	**-0.79**	**-0.81**
TiO_2	**0.69**	**0.71**		**0.70**	0.59	0.62	0.55	0,00	-0.28	-0.63	**-0.66**	-0.51	-0.55	-0.21	-0.46	-0.59	**-0.78**	-0.63	**-0.71**
As	0.61	**0.71**	**0.70**		**0.68**	0.44	0.44	0.21	-0.27	-0.54	**-0.73**	-0.37	**-0.89**	-0.51	**-0.63**	**-0.66**	-0.53	**-0.74**	**-0.69**
Ni	0.52	**0.81**	0.59	**0.68**		0.61	0.62	**0.70**	-0.03	-0.26	-0.54	**-0.78**	-0.63	-0.57	-0.45	-0.58	-0.49	-0.57	-0.54
Al_2O_3	0.15	0.43	0.62	0.44	0.61		**0.89**	0.59	-0.63	**-0.77**	-0.61	-0.41	-0.21	0.10	0.10	-0.10	-0.33	-0.15	-0.26
Cu	0.23	0.37	0.55	0.44	0.62	**0.89**		0.58	**-0.64**	**-0.78**	-0.35	-0.25	-0.13	0.25	0.26	0.07	-0.23	0.02	-0.13
Mn	0.06	0.40	0.00	0.21	**0.70**	0.59	0.58		-0.17	-0.16	-0.30	-0.53	-0.12	-0.25	0.06	-0.10	-0.05	-0.08	-0.11
Cd	0.03	0.01	-0.28	-0.27	-0.03	-0.63	**-0.64**	-0.17		**0.84**	0.18	-0.29	0.04	-0.54	-0.30	-0.23	-0.02	-0.14	-0.03
V	-0.28	-0.31	-0.63	-0.54	-0.26	**-0.77**	**-0.78**	-0.16	**0.84**		0.53	-0.04	0.19	-0.35	-0.11	001	0,31	0.10	0.28
Se	-0.46	**-0.65**	**-0.66**	**-0.73**	-0.54	-0.61	-0.35	-0.30	0.18	0.53		0.58	0.60	0.50	0.53	**0,.64**	**0.65**	**0.71**	**0.74**
Sr	-0.58	**-0.74**	-0.51	-0.37	**-0.78**	-0.41	-0.25	-0.53	-0.29	-0.04	0.58		0.41	**0.71**	0.56	**074**	**0.73**	**0.69**	**0.71**
Cr	-0.46	-0.63	-0.55	**-0.89**	-0.63	-0.21	-0.13	-0.12	0.04	0.19	0.60	0.41		**0.72**	**0.80**	**0.76**	0.41	**0.82**	0.63
Pb	-0.45	-0.60	-0.21	-0.51	-0.57	0.10	0.25	-0.25	-0.54	-0.35	0.50	**0.71**	**0.72**		**0.85**	**0.84**	0.46	**0.82**	**0.65**
Co	**-0.66**	**-0.72**	-0.46	-0.63	-0.45	0.10	0.26	0.06	-0.30	-0.11	0.53	0.56	**080**	**0.85**		**096**	**0.63**	**0.95**	**0.81**
Zn	**-0.77**	**-0.81**	-0.59	**-0.66**	-0.58	-0.10	0.07	-0.10	-0.23	0.01	**0.64**	**0.74**	**0.76**	**0.84**	**0.96**		**0.80**	**0.99**	**0.93**
P_2O_5	**-0.89**	**-0.73**	**-0.78**	-0.53	-0.49	-0.33	-0.23	-0.05	-0.02	0.31	**0.65**	**0.73**	0.41	0.46	**0.63**	**0.80**		**0.79**	**0.94**
Fe_2O_3	**-0.75**	**-0.79**	-0.63	**-0.74**	-0.57	-0.15	0.02	-0.08	-0.14	0.10	**0.71**	**0.69**	**0.82**	**0.82**	**0.95**	**0.99**	**0.79**		**0.93**
CaO	**-0.89**	**-0.81**	**-0.71**	**-0.69**	-0.54	-0.26	-0.13	-0.11	-0.03	0.28	**0.74**	**0.71**	0.63	**0.65**	**0.81**	**0.93**	**0.94**	**0.93**	

Presumably, for the first group this is conditioned by the participation of components in the development of clay complexes, in the second group - by the effect of such selective processes as the inability to enter clay complexes in arbitrary quantities, the biogenic complex development, in part, the similarity of these ingredients import from the outside. Such multifactority of the reasons for the grouping of the studied chemical substances leads to the fact that some components, participating to some extent in the second group as a whole, create more local groups of increased positive correlations among themselves simultaneously. For example, the group Zn, Pb, Cr, Co, or Ni, participating in the first group, is simultaneously paired with the element which is not included in the first group - Mn. There is the self-grouping of such pairs of elements as Al_2O_3-Cu; Ni-Mn; Cd-V.

During the performance of the correlation analysis for the aggregate of soil samples with the participation of two samples of man-made soil, a number of cases notes a sharp change both of the correlation coefficient value module and in its sign. This is natural, because technogenic soils contain a number of elements either in greatly increased or in lowered concentrations, and these abrupt changes in the levels of components do not depend on the patterns of chemical element distribution in soils. That is, the results of the analysis for the aggregate of data collected on genetically heterogeneous territories are unreliable.

SUMMARY:

1. The background concentration values are determined for the soil pollutants in mining and agro-industrial zones within the location of a large mining enterprise for the extraction and enrichment of iron ores in the Mikhailovsky district of the Kursk region of Russia.
2. It has been shown that the main environmental pollution by heavy metals in MGOK location area is caused by dust deposition containing elevated concentrations of lead, cobalt, chromium, zinc, and iron. At the same time, the areas of identified geochemical anomalies (in comparison with the agro-industrial background of the MGOK location) are extended to the distance of no more than 100 m from dust sources.
3. The self-growing areas of disturbed territories have intensive soil self-purification processes.
4. Two groups of chemical compounds with a dependent dynamic of their content in soils have been identified.

CONCLUSIONS:

The conducted study of the geochemical situation in the mining zone of the KMA region, using the example of the Mikhailovsky Ore Mining and Processing Plant, allows to determine the main pollutants associated with mining activities. They revealed the tendencies of polluting substance distribution within the distancing from industrial objects, which will allow to carry out the procedure of mined area monitoring and reclamation more correctly.

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