

The environmental condition in the area of rock dumps at the Vostochny section of the Republic of Kazakhstan

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Abstract. The article analyzes the state of environmental components in the area of the Pribortovoy and Festival overburden rock dumps at the Vostochny section. During the research, a slightly elevated content of elements such as arsenic, copper, lead, and others was noted, allowing them to be grouped as associative elements. Based on statistical data, the authors present the results of chemical analyses of samples for the content of water-soluble and mobile metal compounds in soils that are part of the association of pollutants. It is concluded that, at present, wind transport of particles from overburden dumps does not significantly affect the state of the soil cover. The analysis shows that the pollution level of the region's ecosphere is mainly determined by harmful waste from industrial enterprises and transport.

1 Introduction

Mining in open pits is accompanied by the formation of significant amounts of industrial waste in the form of overburden and host rocks [1, 2]. For various quarries, the overburden coefficient (the ratio of the volume of dump rocks to useful ore) can range from 0.5 to 12.5. Overburden and host rocks are stored in waste storage facilities (dumps) located both within the quarry (internal) and outside (external).

The waste storage facilities of the Vostochny section of the Eurasian Energy Corporation Open Joint-Stock Company are located within the industrial zone of the Ekibastuz bituminous coal deposit and include the Pribortovoy and Festival dumps. The Ekibastuz bituminous coal deposit is situated in the Bayanaul district of the Pavlodar region of the Republic of Kazakhstan [3]. In orographic terms, the deposit is located in the transition zone between the typical Kazakh Uplands and the Irtysh Plain of the West Siberian Lowland. The coal-bearing deposits of the Ekibastuz bituminous coal basin form a 24 km long and 8.5 km wide basin.

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A characteristic feature of the area is the absence of rivers with constant flow. The nearest surface watercourses – the Chiderty River and the Irtysh River are located at a distance of 45 and 130 km, respectively, from the city of Ekibastuz [4].

Due to the flat-hilly terrain with numerous depressions, many shallow lakes filled with salty or brackish water are formed. The water balance of these lakes is unstable; they are replenished by floodwater runoff in the spring and precipitation. Many of them dry up by the end of summer. These lakes are generally devoid of organic life and are unsuitable for agricultural use. Ichthyofauna is absent in such lakes.

The Irtysh-Karaganda Canal runs 7–10 km north of the deposit, within which the Ekibastuz Reservoir is located. The canal is the main source of drinking and technical water supply in the district [5].

2 Methods

While working on the article, the authors analyzed scientific reports from the Kazakh Republican Board of the Scientific and Technical Society of Non-ferrous Metallurgy of the Republic of Kazakhstan. A set of scientific methods (analysis, synthesis, and critical verification of the data obtained) allowed for the study of the environmental components in the area of the Pribortovoy and Festival overburden rock dumps of the Vostochny section.

3 Discussion and results

It should be noted that, from an ecological and geochemical point of view, there is a potential danger of environmental pollution with some chemical elements in the area of dumps of the Vostochny Section LLP, since their content in production waste (overburden rocks) is quite high [6]. Overburden rocks contain very significant amounts (from 0.5 to 5.0 g/kg) of barium, manganese, titanium and phosphorus.

The content of boron, vanadium, cobalt, copper, arsenic, lead, strontium and zinc is much lower (from tens to hundreds of mg/kg). The content of the remaining elements does not exceed 10 mg/kg. It is noteworthy that a number of chemical elements are contained in overburden rocks in concentrations not exceeding those in the soils of alluvial-deluvial and lacustrine sediments.

Based on the research results, it was concluded that arsenic poses the greatest danger, as its content in overburden rocks is significantly higher than the standard for soil. Additionally, special attention should be paid to the levels of vanadium, copper, lead, and zinc in the environmental components [7].

3.1. Groundwater

The design of the rock dumps of the Vostochny section and the nature of their operation exclude the presence of other waters in the occupied territories, except for those associated with precipitation. At the same time, the main role of rock dumps in this case is the redistribution of surface runoff due to the redevelopment of the natural relief and, as a result, a change in the groundwater supply regime. Since, as already noted above, the amount of precipitation in the area of the Ekibastuz deposit is small, accordingly, the influence of rock dumps in this regard is minimal.

It should be noted that in this case it is difficult to separate the natural abnormal concentrations of toxic elements in the groundwater of hydrochemical anomalies from man-made pollution of groundwater. This is due to the fact that the concentrations of trace elements in groundwater vary widely and depend on the following main factors: the

lithological composition of the aeration zone of water-bearing rocks, geochemical conditions, the content of ore components in rocks and the level of anthropogenic pollution of groundwater [8].

The looseness of the soils laid in the dumps, especially in the first 4–5 years after dumping, provides high filtration properties of man-made soil mass. Filtering through the soil mass, precipitation undergoes certain changes in its chemical composition, then causing changes in the composition of groundwater. According to stock materials, there was an increased amount of fluorine in groundwater (up to 2.5 maximum permissible coefficient (MPC) and in places lead (more than 1 MPC). According to the authors, all exceedances of MPC and background concentrations (molybdenum, manganese, iodine, strontium and copper) were associated with the geochemical spectrum of water-bearing rocks.

The chemical composition of groundwater was monitored during the research. Samples were taken using existing wells after pumping. At the initial stage, a spectral analysis of the chemical composition of the selected samples was performed, which showed that almost all samples had increased mineralization (up to 16 MPC). At the same time, the metal content exceeds the MPC in only two samples. In the water sample taken from wells 113, an excess of MPC for manganese (1.5 MPC) was detected, and from wells 119 – for titanium (3.0 MPC) [1]. See Table 1.

Table 1. Results of spectral analysis of water samples.

Name of the element	Content (mg/dm ³) in sample no.:					
	well 109	well 101	well 104	well 106	well 113	well 119
Al (0.5)	0.029	0.048	0.047	0.074	0.074	0.076
Ba (0.1)	< 0.0096	< 0.012	< 0.016	not detected	not detected	not detected
Cr (0.05)	not detected	0.0048	not detected	not detected	not detected	not detected
Cu (1.0)	0.0096	0.012	0.016	0.01	0.015	0.011
Fe (0/3)	0.029	0.048	0.011	0.074	0.044	0.045
Mn (0/1)	0.0029	0.0048	0.0078	0.0044	0.15	0.045
Mo (0/25)	0.029	0.036	0.047	0.044	0.015	0.03
Ni (0.1)	0.0048	0.0048	0.0016	0.044	0.0015	not detected
Pb (0.03)	not detected	0.0072	not detected	not detected	not detected	not detected
Si (10.0)	1.44	3.0	2.34	1.85	2.22	4.54
Sr (7.0)	0.19	0.15	0.31	0.15	0.15	4.54
Ti (0.1)	0.029	0.036	0.031	0.03	0.03	0.30
V (0.1)	< 0.0096	< 0.012	< 0.016	< 0.015	< 0.015	not detected
Dry residue	960	1200	1560	1480	1480	16120

Notes: 1. The following elements were not detected during the analyses – Ag, Au, As, Be, Bi, Cd, Ce, Co, Hf, Ga, Ge, Y, Yb, In, La, Li, Nb, Pt, Sb, Sc, Sn, Ta, Th, Ti, U, Zn, Zr, W.

2. In columns 1, the MPC values for groundwater are shown in parentheses.

3. Values exceeding the MPC are highlighted in bold [1].

Then the samples were subjected to a complete chemical analysis, including for the content of trace elements. See Table 2.

Table 2. The results of a complete chemical analysis of water samples.

Element	MPC	Content (mg/dm ³) in the sample taken from the well					
		109	101	104	106	113	119
F	1.50	2.10	2.91	2.58	2.30	2.32	1.54
Ti	0.10	< 0.01	<0.01	0.05	<0.01	<0.01	<0.07
Mo	0.25	0.18	0.15	0.24	0.16	0.11	0.20
Mn	0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
As	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fe	0.30	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cu	1.0	<0.005	0.006	<0.005	<0.005	<0.005	0.10
Zn	1.0	0.018	0.081	0.043	0.017	0.023	0.075
Pb	0.03	0.048	0.029	0.031	0.044	0.036	0.067
Co	0.10	<0.05	<0.05	<0.05	<0.05	<0.05	0.08
SO ₄	500.0	245.0	179.0	231.0	323.0	392.0	1711.0

Notes: Values exceeding the MPC are highlighted in bold.

It should be noted that chemical analyses have not confirmed the presence of elevated concentrations of manganese and titanium. At the same time, an excess of MPC for fluorine and lead was found in all samples, and an increased content of sulfates was noted for the sample taken from well 119. Taking into account the research results of Pavlodargydrogeology JSC, this excess of standards can be attributed to a regional hydrochemical anomaly.

3.2. Soil cover

Spectral analysis in depth intervals showed the presence of a number of elements in the samples, in quantities exceeding the MPC for the soil. Such elements include gallium, cobalt, copper, molybdenum and arsenic [9]. Moreover, increased concentrations were recorded for all samples, without exception, taken both from the windward and downwind sides of both dumps, regardless of the point and depth of sampling. It can be noted that of the elements included in the association of pollutants, only copper and arsenic were found in increased amounts. Such results do not allow us to draw an unambiguous conclusion about the degree of influence of the dumps of the Vostochny section on the soil cover of adjacent territories. Therefore, chemical analyses of the gross content of copper and arsenic, as well as gallium, nickel, lead, fluorine and zinc, were performed. The results of the analysis (it was performed in the chemical analytical laboratory “Kazmehanobr”) are shown in Table 3 [1].

Table 3. The content of gross forms of potentially dangerous elements in the soils of territories adjacent to rock dumps, mg/kg.

Place of sampling	As (2.0)	F	Cu (23.0)	Ni (35.0)	Zn (110.0)	Ga	Pb (32.0)
Festival Dump							
well 101	1.7	34.5	16.6	15.0	49.0	0.2	7.2
well 104	1.7	23.7	22.8	22.0	64.0	0.4	9.9
well 106	1.8	42.6	19.6	28.0	72.0	0.5	8.5
well 109	1.2	32.3	17.6	30.0	56.0	0.3	23.0
Pribortovoy Dump							
well 113	1.9	33.8	21.6	32.0	42.0	0.3	20.7
well 119	1.7	26.1	22.4	34.0	48.0	0.3	27.3

Notes. In line 1, the MPC values are shown in parentheses.

Table 3 shows that the gross content of all potentially hazardous metals in soil samples is lower than the existing MPC. It should be noted that currently there are no approved standards for the maximum permissible gross content of fluorine in the soil, and for gallium there are no standards at all for any of the forms.

At the next stage of the research, the content of water-soluble and mobile forms of potentially dangerous heavy metals in the samples was determined (Table. 4 and 5). It showed that the water-soluble forms of copper and lead are contained in amounts of 0.08–0.26 mg/kg and 2.1–3.4 mg/kg, respectively, and nickel and zinc are almost absent. At the same time, an increased content of soluble fluorine was noted, both on the windward and downwind sides of the dumps, which confirms the fact of a high background content of this element at the site under examination. There are slightly more mobile forms of heavy metals in soil samples than water-soluble ones, but, nevertheless, their concentrations remain within the normal range. The content of mobile forms of fluorine in all cases is registered in quantities exceeding the standards. The content of mobile forms of arsenic was not carried out, since there are no corresponding MPCs [1].

Table 4. The content of water-soluble forms of elements in soils, mg/kg.

Place of sampling	Cu	Ni	Zn	Pb	F (10.0)
Festival Dump					
well 101	0.08	<0.5	not detected	3.40	12.7
well 104	0.26	<0.5	1.45	2.37	23.4
well 106	0.24	1.2	3.26	3.20	17.9
well 109	0.18	0.9	not detected	1.99	16.4
Pribortovoy Dump					
well 113	0.10	<0.5	not detected	2.10	19.5
well 119	0.24	<0.5	4.52	3.09	18.6

Note. In line 1, the MPC values are shown in parentheses.

Table 5. The content of mobile forms of elements in soils, mg/kg.

Place of sampling	The content of water-soluble forms of elements extracted									
	with an ammonium acetate buffer at pH=4.8					With a one molar solution of nitric acid				
	Cu(3.0)	Ni (4.0)	Zn (23.0)	Pb	F (2.8)	Cu (3.0)	Ni (4.0)	Zn (23.0)	Pb	F(2.8)
Festival Dump										
well 101	1.2	6.0	9.5	1.4	4.0	1.6	0.7	10.0	2.8	4.1
well 104	2.5	2.8	21.5	2.0	8.0	2.8	2.9	12.0	2.2	5.0
well 106	0.9	1.7	13.4	0.8	3.3	0.9	1.4	16.2	3.1	3.4
well 109	0.7	1.6	4.5	1.2	3.1	0.7	1.2	4.8	2.7	3.7
Pribortovoy Dump										
well 113	0.5	6.0	10.5	4.6	3.5	2.4	2.0	6.0	2.1	3.6
well 119	1.4	6.0	21.7	5.3	4.4	1.8	2.3	12.0	3.2	3.6

Summing up, it can be stated that the current wind transport of overburden particles from dumps does not significantly affect the state of the soil cover. That is, the influence of the Pribortovoy and Festival dumps in terms of soil pollution in this area did not go beyond the permissible limits. This is confirmed by the fact that about 5% of the total area of

dumps is subject to dusting. Basically, this is the fitting part of the freshly poured ledges of the dumps.

3.3. Atmospheric air

Dumps, like their natural counterparts, natural hills, have the ability to change the nature of their surface under the influence of wind so that the deflationary effect decreases many times. Therefore, the assessment of the intensity of deflation cannot be carried out in isolation from the study of the morphology of dumps as forms of man-made relief characterized by a certain set of geological and geomorphological processes [10-12].

It should be borne in mind that over time, the appearance of the dump surface changes. The rocks of the Ekibastuz dumps are prone to soaking and destruction under the influence of seasonal processes, as a result, the slope surface becomes more homogeneous, pieces of rock, with the exception of strong sandstones, melt away, and large blocks of carbonaceous mudstones are destroyed by moisture and seasonal temperatures. As a result of precipitation, small fractions of rocks are cemented into an eluvial crust 0.5–2.0 cm thick, which prevents the blowing of rock particles. In a short time, the deflationary destruction of surfaces is sharply reduced: a primary crust forms on the slopes and water erosion develops [13, 14].

The studies conducted at the Ekibastuz dumps allow us to conclude that the main source of dust formation on the dumps is working equipment, primarily working excavators and moving vehicles. Thus, according to experts of the Moscow center “Technology”, the main source of dust in the city's air are Ekibastuz state district power station and steppe (75–55%), the second largest pollutant are CHP plants, sections, dumps (total effect 23–25%).

At the same time, up to a wind speed of 1–12 m/s on the surface of the dump, there are no signs of dusting even in the freshly filled part of the dump tier. At this wind speed, dust begins to blow out of the freshly filled part of the dump and dust that has settled on work sites and previously filled slopes of the dump, which occurs with gusts of wind [1].

In accordance with the results of observations of the sanitary and preventive laboratory of JSC Ekibastuzpromservice, dust removal from the studied rock dumps ranges from 0.65 to 0.95 mg/m³ (Table 6).

Table 6. Annual emission and dust content in the air of dumps and at the border of the sanitary protection zone.

Name of the dump	Annual dust emission, tons	Dust content in the air, mg/m ³	
		on the dump	on the border of the sanitary protection zone
Festival	389	6.8	0.90
Pribortovoy	499	6.1	0.85

Since the main source of dust formation on the dumps is working equipment, primarily working excavators and transport, the coefficient $K_{work} = 0.20$ used in calculations, taking into account the ratio of the total area of the dump ($S_{Prib.} = 147.9$ ha and $S_{Fest.} = 264.9$ ha) to the area of work sites ($S_{Work.} = 30.0$ ha)

4 Conclusion

Thus, no trends were observed towards an increase in the concentration of trace elements included in the association of pollutants [15]. The excess standards for the total content of gallium, cobalt, arsenic, copper, and zinc noted in spectral analyses are typically not

confirmed by chemical analyses. The work carried out by the Scientific and Technical Society of Non-Ferrous Metallurgy of the Republic of Kazakhstan allowed for an objective assessment of the environmental components in the area of industrial waste storage, concluding the absence of dangerous trends in their changes. The assessment of environmental components in the area of waste storage facilities at the Vostochny section of the Eurasian Energy Corporation Open Joint-Stock Company supports the continuation of waste storage at present.

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