






Ecological State of Soil Cover and Surface Water in the Natural and Technological Environment of Kyzyl-Zhar (Kyrgyz Republic)

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Abstract

The article presents the results of a current environmental assessment of the soil cover and surface water in the natural and man-made uranium province of Kyzyl-Zhar. Surface water in the Mailuu-Sai River is characterized by relatively high levels of mineralization, hardness, dry matter, sulfates, and chlorides. The pH level is 7.5, which is considered within normal limits. The results of measuring the chemical composition of water by quantitative mass spectrometric analysis (ICP) of 23 chemical elements in water showed a slight increase compared to the maximum permissible concentration (MPC) of the following chemical elements: Ba, Mg, Mn, Mo, Na, Pb, Se, U and F. Of these, the maximum permissible concentrations of chemical elements are: Mo, Mn and F, increased from 5 to 10 times, which requires special attention. In the studied streams, the zoobenthos is qualitatively quite poor. Aquatic invertebrates are represented only by benthic organisms and require in-depth hydrobiological analysis. The soil cover of the former uranium mine in the village of Kyzyl-Zhar is classified as Turanian gray earth soil, fine-grained in thickness, and medium in rock content. Humus content is low-quality, ranging from 50 to 140.0 t/ha. The results of spectral analysis showed that most chemical elements have low concentrations in relation to MPC and Clarke, Mn, Mo, W, Zr, Nb, In, Pb and Ag, and the following elements such as Ni, Ti, V, Cr, Cu and Y are at the background level or slightly high, but in areas they have different concentrations and differ by 2 - 4 times. The level of oil products in water varies depending on the distance of the pollution source, ex-

cept for the concentration in the river, and can fluctuate from 138 to 468 mg/l, which indicates a fairly high content of oil products, sometimes, the increase is hundreds of times (MPC 0.3 mg/dm³). Based on the soil cover, the area contaminated with oil products is the western part of the mine. (SNKJ-1), 4820 mg/kg and the lowest concentration at point SNKJ-4 content is 1380 mg/kg, in relation to the MAC, it is increased from 2 to 5 times

Keywords

Uranium Province, Soil, Pollution, Chemical Elements

1. Introduction

It is known that the Kyrgyz Republic in the mid-20th century, it was one of the largest producers of uranium ore in the USSR, which was mined until 1968. After mining ceased, a huge amount of uranium dumps remained on the territory of Kyrgyzstan. And tailings storage facilities (747.22 million m³), during the mining period, practically no attention was paid to environmental issues. In the Kyzyl-Zhar uranium province, ore was mined from 1946 to 1957. After the cessation of ore mining, no rehabilitation measures were carried out and the waste heaps remain open to this day (Djenbaev & Mursaliev, 2012; Torgoev, Aleshin, & Yu, 2009).

Currently, the mine is surrounded by a large settlement, Kyzyl-Zhar, and the village is located near the old mine. The Kyzyl-Zhar industrial zone contains waste rock heaps, unsealed mine shafts, dilapidated buildings and structures (concrete tanks, pipelines, concrete pads, metal structures, etc.), and areas contaminated with petroleum products. Therefore, the goal was to study the current state of the soil and aquatic environment in this province and adjacent areas.

Given the above data, it is important to determine the purity of surface waters through physical, chemical, and hydrobiological analysis. It is known that the degree of pollution by both organic and chemical components can be characterized using the aquatic organisms inhabiting a reservoir (Bakanov, 1999; Severinenko et al., 2023; Solodukhin et al., 2020).

The study area contains only flowing water bodies; other types of aquatic ecosystems are absent. Geographically, the Mailuu-Sai catchment area belongs to the Naryn River basin and is a transboundary river. The valley in which the river catchment is formed is located at an altitude of approximately 800 m above sea level. Given Kyrgyzstan's mountainous nature, this difference in elevation within the valley determines the nature of the bottom, water flow velocity, color, chemical and temperature regimes, which, in turn, influence the species composition of fauna, its quantitative development, and distribution in various sections of the watercourse. The main sources of water for all watercourses are precipitation—rain, seasonal meltwater, groundwater, and small glaciers (Bakanov, 1999; Djenbaev & Mursaliev, 2012).

2. Materials and Methods of Data Processing

Field studies on collection and identification of hydrobiological material were carried out according to the methods (Zhadin, 1960; Kustareva & Lemzina, 1997). Aquatic invertebrates (zoobenthos) were collected using a quantitative frame measuring 50×50 cm with a trapping net made of #52 mill gauze. The frame was installed on the bottom so that the trapping net was straightened by the water current. Animal organisms were washed off the rocks and soil limited by the frame. The wash was transferred to a bucket, filtered through a #52 wash sieve, placed in a container with 2% formalin and provided with a label indicating the time and place of collection. At each point 1 m^2 of bottom area was caught. Office processing of the collections was carried out in the laboratory of ichthyology and hydrobiology of the Institute of Biology of the National Academy of Sciences of the Kyrgyz Republic. In the laboratory, fixed organisms were selected from the sample using an OXTL-101B microscope, classified into groups and identified, if possible, to species level. In some cases, such identification was not possible due to insufficient systematic study of individual families and genera of invertebrates inhabiting the watercourses of the Central Asian region (Bakanov, 1999; Dzhailoobaev, Neronova, Nikolaenko, & Mirkhashimov, 2009; Lepneva, 1966; Tsalolikhin, 1994-1999, 2001).

Hydrobiological samples were collected above and below the main tailings. Office processing of the samples was carried out in the Laboratory of Ichthyology and Hydrobiology of the Institute of Biology of the National Academy of Sciences of the Kyrgyz Republic. Scientific work was carried out in the summer period on the territory of the following watercourses: Mailuu-Sai N $41^{\circ}16.658'/E 72^{\circ}00.123'$ and Mailuu-Sai N $41^{\circ}16.665'/E 72^{\circ}00.130'$. The current of the Mailuu-Sai river is weak the water is transparent, the bottom is sandy and rocky, the river bed is large, but there is little water (Figure 1 and Figure 2).



Figure 1. Above the tails of the Mailuu-Sai River.



Figure 2. Below the tails of the Mailuu-Sai River.

During the study, water samples were collected for chemical analysis, then delivered to the laboratory, where they were prepared for analysis. Chemical analysis was carried out in the laboratory (GOST 23268.5-78; GOST 4011-72; GOST 33045.2014, etc.) of the Ministry of Natural Resources, Ecology and Technical Supervision of the Kyrgyz Republic (Karpov, 2003; Lepneva, 1966; Methodology for Oil Products in Water, 2000; Quantitative Chemical Analysis of Water, 1998).

Soil samples were taken from the upper horizons (0 - 20 cm), where nutrients and chemical pollutants are mainly concentrated, and from adjacent areas. To complete the task, 15 points were established on the surveyed site; 15 samples were taken for chemical analysis of natural fertility, 15 samples for heavy metals, and for pollution with oil products. Soil survey and collection of soil samples were carried out according to the “Practical guide for a soil scientist for compiling soil maps, cartograms, and writing essays” and in accordance with GOST 17.4.3.01-83 “General requirements for soil sampling”, GOST 53123-2008 (2009) (Arinushkina, 1975; United Nations Environment Programme, 2025; Levit, Ya., Kartasheva, Narbutaev, et al., 1988; Minkina, 2006).

Chemical analyses for fertility were performed using methods published in the following works: “Manual of Chemical Analysis of Soils” (Aleksandrova & Naidenova, 1967; Arinushkina 1975) namely: Determination of humus, according to the method of Tyurin and Kononova as modified by Simakov et al. (Grishina & Orlov, 1978; Systematic List of Soils of Kyrgyzstan, 1995). Elemental analysis of biospheric objects was carried out using a well-known highly sensitive analytical technology for determining the elemental composition of ICP methods (inductively coupled plasma) and spectral analysis was used (Figure 3).

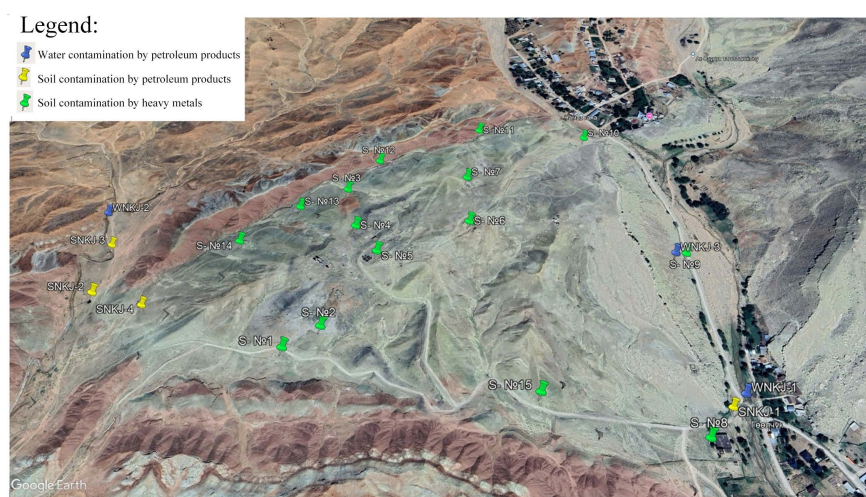


Figure 3. Schematic diagram of sampling.

3. Research Results

It is known that water quality in a reservoir can be assessed using physical, chemical, and biological methods, with the best results achieved using all three. It is important to note that biological analysis allows for the detection of negative impacts on aquatic organisms in a reservoir prior to sampling and analysis, while physical and chemical methods characterize the condition of the biota at the time of sampling. However, chemical assessment is also important.

During the study, water samples were collected for chemical analysis, which were then delivered to the Ministry of Natural Resources, Ecology and Technical Supervision of the Kyrgyz Republic (MNRES), where a chemical analysis of the water was conducted. The results showed that the water in the Mailuu-Sai River has a relatively high mineralization (2012), hardness (12.75), and high dry residue (1898), as well as high sulfates (819.3) and chlorides (168.00), i.e., in terms of chemical composition, it is higher accepted norms: and the pH level is 7.5, which is considered within the normal range (**Table 1**).

Table 1. Chemical analysis of Mailuu-Sai water.

Ion	mg/dm ³	Mg-eq dm ³	% Mg-eq dm ³	Ion	mg/dm ³	Mg-eq dm ³	% Mg-eq dm ³
<i>Ca</i>	145	7.23	28	<i>Cl</i>	168	4.74	17.6
<i>Mg</i>	67	5.52	21.3	<i>SO₄</i>	819.3	17.06	63.4
<i>Na</i>	298	12.96	50.1	<i>HCO₃</i>	228	3.73	13.9
<i>K</i>	5.39	0.14	0.5	<i>CO₃</i>	18.3	0.61	2.3
<i>NH₄</i>	<0.1	-	-	<i>NO₃</i>	46.29	0.75	2.8
<i>FeO₆</i>	0.2	0.01	-	<i>NO₂</i>	0.027	0	0
<i>Cations</i>	515.59	25.86	-	<i>Anions</i>	1280	26.89	-

The analysis of the elemental composition of water was carried out using the ICP method. into 23 elements . The results of the analysis showed comparative increase from the MAC of the following chemical elements: Ba, Mg, Mn, Mo, Na, Pb, Se, U and F, low values from the MAC were shown by: Be, V, Fe, Cd, K, Co, Ca, As, Ni, Cr, As and Zn. The analyses were carried out using the ICP method (GOST 31870-2012) and the tests were carried out at 22°C air. Particular attention should be paid to the following chemical elements: Mo, Mn and F, their concentration increased from 5 to 10 times (**Table 2**).

Table 2. Results of ICP analysis of river water of Mailuu-Sai.

Indicator	Result	$\pm\Delta$	MAC
Al	0.4095	0.0982	0.5
Ba	0.0495	0.0133	0, 1
Fe	0.2411	0.0626	0.1
CD	0.0018	0.0003	0.005
TO	5,3699	0.9665	50.0
Ca	143.0	24.31	180.0
Mg	74.15	10.38	40.0
Mn	0.05	0.01	0.01
Cu	0.0015	0.0004	0.001
Mo	0.0099	0.0025	0.001
Fs	0.0169	0.0025	0.05
Na	298.31	44.74	120.0
Ni	0.0058	0.0020	0.01
Sn	0.0151	0.0040	0.01
Pb	0.0098	0.0035	0.006
Se	0.0194	0.0050	0.01
Cr	0.0119	0.0030	0.07 3
U	0.11	0.033	0.03
F	0.98	0.04	0.05

3.1. Zoobenthos of the Studied Watercourses

The hydrobiological state of the Mailuu-Sai River was studied. The species composition of benthic invertebrates in the studied water bodies is characterized by a limited spectrum. During the study period, representatives of two animal phyla were found: worms (Vermes) and arthropods (Arthropoda). **Table 3** shows that the benthic invertebrate species composition in the aforementioned watercourses is represented by 15 species.

Table 3. Species composition of benthic invertebrates of Mailuu-Sai.

Species composition	Mailuu-Sai river
Type Vermes-worms	
Class Nematoda-nematodes	
Phylum Arthropoda-arthropods	
Class Insecta-insects	
<i>Squad Diptera-diptera</i>	<i>Squad Coleoptera</i>
T.1	T.2
<i>Family Chironomidae</i>	<i>Family Gyrimidae</i>
<i>Subfamily Tanytopodinae</i>	<i>Gyrinus (s. str)</i>
<i>Genus Ablabesmyia</i>	<i>Squad Ephemeroptera-mayflies</i>
<i>Ablabesmyia monilis</i>	<i>Family Baetidae</i>
<i>Family Simuliidae</i>	<i>Genus Baetis</i>
<i>Genus Simulium</i>	
<i>Simulium sp.</i>	<i>Baetis sp.</i>
<i>Family Limoniidae</i>	
<i>Dicranota robusta sp</i>	
Total species: 15	

Zoobenthos is represented by dipteran and mayfly larvae. The dominant species in the river are dipteran larvae. Mayfly larvae were found in isolated numbers. Chironomids were found in all sections of the river. Their presence is likely related to its current and temperature. Since this is a small river, water temperatures vary. Furthermore, the river flows near a populated area where livestock graze daily. It is important to remember that midges feed on plant sap, but to produce eggs, the female requires protein, which she obtains from the blood of hosts, sometimes flying over 100 km in search. Individual species have preferred hosts, but there is no strict specialization: females feed on the blood of humans, horses, other farm animals, wild animals, and birds. Mosquitoes are known to lay eggs in ponds, puddles, water containers or pits, ditches, and depressions filled with water.

The species diversity of aquatic invertebrates in streams is very poor, characterized by the absence of certain species of worms, mayflies, stoneflies, caddisflies, and dipterans. Such fluctuations are typical of streams with an unstable hydrological regime, such as the river we studied (**Figure 1** and **Figure 2**). Streams can dry up in the summer and disappear in the winter, which negatively impacts the development of zoobenthos. It is also known that in many mountain streams with low water flow, the greatest invertebrate species diversity and their mass development are observed in the spring (March-April), when mass maturation of larvae and the emergence of adults into the air occur.

3.2. Soil Cover

Soil is a vital component of an ecosystem. Being the product of the combined influence of many factors, including climate and vegetation, soil most fully reflects the specific ecological and biogeochemical characteristics of an area.

According to literary data, southern Kyrgyzstan is part of the Turanian facies, located at absolute altitudes of 500 - 3000 m above sea level. The soil-forming rocks of the intermontane valleys, on which the Turanian gray-earth soil formed, are loess-like loams, conglomerates, and pebbles of the Quaternary period, which contain carbonates and other readily soluble salts (Djenbaev & Mursaliyev, 2012; Djenbaev, Dzhamanbaeva, Zholboldiev, et al., 2024; Mamytov et al., 1994).

During fieldwork, soil cover was described on-site and samples were collected for laboratory analysis. Sample preparation and analysis were then conducted in the laboratory. A total of 15 points were identified in the study area.

3.2.1. Quality Condition of the Soil Cover

The humus content (Table 4) is as follows: in the 0 - 25 cm layer it fluctuates within the range of 0.42% - 3.90%, CO₂, 0.44% - 1.32%, total nitrogen, 0.015% - 0.150%, total phosphorus, 0.092% - 0.255%, total potassium, 1.09% - 1.89%, mobile phosphorus, 4.0 - 100.0 mg/kg. The reaction of the soil solution from slightly acidic to alkaline, 5.40 - 8.29. The mechanical composition is presented taking into account the content of physical clay (particles < 0.01 mm in size) according to the Kachinsky classification.

Table 4. Results of agrochemical analysis.

No #	Depth cm	pH	Humus %	CO ₂ %	General N %	Gross form of P %	Gross form of K %	Movable form P ₂ O ₅ mg/kg
SKJ-1	0 - 20	7.35	1.20	3.52	0.115	0.210	1.74	21.0
SKJ-2	0 - 15	7.85	1.46	2.82	0.065	0.246	1.86	90.0
SKJ-3	0 - 25	7.65	0.57	0.96	0.050	0.132	1.62	21.0
SKJ-4	0 - 15	7.35	2.08	0.88	0.075	0.250	1.74	60.0
SKJ-5	0 - 15	7.50	0.57	1.32	0.015	0.255	1.50	4.0
SKJ-6	0 - 25	7.50	1.04	0.88	0.100	0.210	1.68	66.5
SKJ-7	0 - 25	5.40	0.94	0.80	0.070	0.210	1.92	70.0
SKJ-8	0 - 15	8.12	3.28	8.62	0.120	0.212	1.20	100.0
SKJ-9	0 - 15	7.90	1.04	12.32	0.052	0.212	1.09	13.0
SKJ-10	0 - 15	7.70	1.04	2.64	0.065	0.189	1.33	70.0
SKJ-11	0 - 25	8.60	0.42	5.28	0.075	0.112	1.62	7.0
SKJ-12	0 - 25	7.90	0.73	2.72	0.050	0.092	1.56	5.0
SKJ-13	0 - 25	8.00	0.57	4.14	0.080	0.100	1.92	4.0
SKJ-14	0 - 25	7.65	3.90	3.52	0.150	0.189	1.56	34.0
SKJ-15	0 - 20	8.29	0.68	8.36	0.047	0.212	1.68	9.0

Fraction gradations.

Sand-particle size content, 1 - 0.05 mm.

Coarse dust (loess-like fraction), 0.05 - 0.01 mm;

Fine + medium dust, 0.01 - 0.001 mm,

Total particle size, <0.01 mm (physical clay).

The mechanical composition (Table 5) is represented by the following fractions: sand content in the 0 - 15 - 25 cm layer is 0.74% - 25.91%; coarse dust is 11.68% - 76.76%; fine + medium dust is 0.48 - 37.00; the sum of particles (<0.01 mm) is 7.22% - 69.52%.

Table 5. Mechanical composition of soil.

No. Samples	Fraction content % (particle size mm)						Sum particles <0.01
	1.0 - 0.25	0.25 - 0.05	0.05 - 0.01	0.01 - 0.005	0.005 - 0.001	<0.001	
SKJ-1	1.75	8.25	17.8	10.76	25.28	36.16	7.22
SKJ-2	3.02	13.62	11.68	11:32	23.64	36.72	71.68
SKJ-3	12.75	13.41	65.96	0.76	1.20	5.92	7.88
SKJ-4	7.77	25.91	28.60	29.28	6.92	1.52	37.72
SKJ-5	6.45	11.43	76.76	0.48	1.88	3.00	5.36
SKJ-6	6.89	19.03	17.12	26.64	35.08	5.24	66.96
SKJ-7	9.62	10.90	12.32	9.64	37.00	20.52	67.12
SKJ-8	15.38	32.30	22.36	4.32	12:32	13.32	29.96
SKJ-9	15.87	15.81	10:00 PM	23.88	3.76	18.68	46.32
SKJ-10	21.72	23.52	22.84	3.60	4.00	24.32	31.92
SKJ-11	3.85	16.71	16.60	22:56	23.80	16.48	62.84
SKJ-12	6.41	13.15	39.80	8:44 PM	9.68	10.52	40.64
SKJ-13	0.74	15.42	14.32	10:00 PM	23.20	24.32	69.52
SKJ-14	7:30	20.3	17.52	1.96	22.60	30.32	54.88
SKJ-15	3.12	15.37	13:00	22.32	35.24	10.96	68.52

In these soils, shallow soils with rocky-pebble deposits occurring at a depth of 25 - 50 cm predominate. The qualitative condition of the soil cover in the study area, taking into account the data from the analysis of the fertility of the humus content, is determined as low-quality soils, with humus reserves in the soil within the range of 50 - 140.0 t/ha.

Human economic activity results in environmental pollution with heavy metals. To accurately assess the extent of soil contamination with heavy metals, it is necessary to know their background concentrations. It is important to note that the background concentration of heavy metals in soils depends on their content in the parent material (the chemical clay content < 0.01 mm) and on soil acidity,

which increases the mobility of heavy metals and their removal by plants.

It is known that the behavior of heavy metals in soils is influenced by organic matter, clay minerals, oxides, hydroxides of Fe, Mn, Si, Al, which vary depending on the conditions of soil formation (Mamytov & Voronov, 1994; Minkina, 2006). The degree of soil pollution with heavy metals is considered when their background (natural) content increases by 2 - 3 times (Vodyanitsky et al., 2010). If we evaluate the existing 4 categories of progressive pollution (Dobrovolsky, 1998). **Table 6**, the results of our studies showed that the main pollutant metal in the upper horizon of the soil cover of this province is stable and belongs to the 1st category of increase. In the second category, moderate (average) increase in metal concentration is characterized by an increase from 10% to 40% of the geochemical background value per year.

Table 6. Concentration of metal pollutants in the upper soil horizon.

Categories	Soil metal concentration increase category	Indicators of increase in the average concentration of metal in the soil as a percentage of the geochemical background per year
1	Stable condition	<10
2	Growth: moderate	10:40
3	Fast	41 - 100
4	Very fast	>100

The results of spectral analysis showed that most chemical elements have low concentrations in relation to MAC and Clarke - Mn, Mo, W, Zr, Nb, In, Pb, Ag and the following elements such as Ni, Ti, V, Cr, Cu and Y are at the background level or slightly high, but in different areas they have different concentrations and differ by 2 - 4 times.

3.2.2. Mineral Part of the Soil Cover

MgO is similar in chemical properties to calcium, but its migration through the landscape proceeds differently. Magnesium is more strongly bound to the absorption complex than calcium. In the landscape, magnesium is a less active migrant than calcium, being more strongly bound in soils and the weathering crust. MgO content in soil samples ranged from 2.0 to 4.0 mg/kg soil. The highest content was observed in samples STKJ-13, STKJ-14 and STKJ-15 (0 - 15 cm) - 4.0 mg/kg (**Table 7**).

Table 7. Basic mineral content of the soil cover (%).

Number of points	SiO ₂	Al ₂ O ₃	MgO	Fe ₂ O ₃	CaO	Na ₂ O	K ₂ O
STKJ-1	50	4	2	7	3	0.3	<0.15
STKJ-2	50	5	3	7	4	0.3	<0.15
STKJ-3	50	5	3	7	3	0.3	<0.15

Continued

STKJ-4	50	5	3	7	3	0.3	<0.15
STKJ-5	50	5	3	7	4	0.3	0.3
STKJ-6	50	4	3	7	3	0.4	0.3
STKJ-7	>50	4	2	5	3	0.3	0.15
STKJ-8	>50	12	4	9	7	0.7	0.9
STKJ-9	>50	9	4	9	7	0.5	0.7
STKJ-10	>50	12	5	9	12	0.5	0.7
STKJ-11	40	5	3	5	5	0.3	<0.15
STKJ-12	50	5	3	5	7	0.3	<0.15
STKJ-13	>50	12	4	12	9	0.9	2
STKJ-14	>50	12	4	12	9	0.9	2
STKJ-15	>50	9	4	12	9	0.9	2

Sodium is present as Na_2O a typical alkali that actively participates in many plant physiological processes, readily enters water, and is carried away from the landscape. Sodium content ranges from 0.3 to 0.9 g/kg of soil. The highest content was observed in samples STKJ-13, STKJ-14, and STKJ-15: 0.9 mg/kg.

Potassium, in the form of K_2O , forms readily soluble compounds with the main anions of the lithosphere (Cl^- , SO_4^- , PO_4^- , etc.). It is characterized by weak water migration and active participation in the biological cycle. Its content ranges from <0.15 to 2 mg/kg, with the highest content noted in samples STKJ-13, STKJ-14, and STKJ-15 (0 - 15 cm) - 2.0 mg/kg.

Calcium in the form of CaO in the deposit's soils ranges from 30 - 50 g/kg of soil. Its intensive participation in biological cycles and water migration determines its important role in the biosphere. Its content ranges from 3.0 to 12 mg/kg, with the highest content observed in the STKJ-10 sample (0 - 15 cm) at 12 mg/kg.

Aluminum oxide (Al_2O_3) is the most common compound whose migration is influenced by calcium content, but it is poorly mobile in soils with a neutral and slightly alkaline soil reaction. The migration capacity of aluminum is influenced by calcium content. In the studied soils, its content ranged from 4.0 to 12 mg/kg, with the highest content observed in samples STKJ-13, STKJ-14, and STKJ-8 (0 - 15 cm), 12 mg/kg.

Iron in the form of Fe_2O_3 in the landscape determines the significant role of oxidation-reduction conditions in its migration. It migrates readily in acidic, slightly neutral, and slightly alkaline environments. Its content ranges from 7 to 12 mg/kg, with the highest content observed in samples STKJ-13, STKJ-14, and STKJ-15 (12 mg/kg).

Only oxygenated silica compounds (SiO_2) are known in the landscape, almost all of which are insoluble or poorly soluble in water. Its role in biological cycling and water migration is inferior to that of calcium and sodium. Its content in soils

reaches up to 50 g/kg of soil.

The results of the study showed that the territory near the Kyzyl-Zhar province has an average concentration of metals in the upper soil horizon and in the study area less than 10% of the natural norm (geochemical background) and a moderate increase in metal concentration from 10% to 40% per year is characterized by an increase in the average (moderate) concentration, according to estimates of the existing category of soil pollution (Djenbaev & Mursaliev, 2012; Dobrovolsky, 1998) and below the MAC in general.

3.3. Petroleum Products

It should be noted that in the Mailuu-Sai River, droplets of petroleum products are leaking from under a collapsed bridge. This product has a negative impact on the river and its inhabitants. In addition to benthic invertebrates, the reservoir is home to toad tadpoles and algae (Figure 4 and Figure 5).



Figure 4. Oil product distributed along the Mailuu-Sai River.



Figure 5. Toad tadpoles in the Mailuu-Sai River.

Petroleum products are produced in this province and the surrounding area. Oil is a common environmental pollutant, causing long-term disruption of the normal functioning of the soil ecosystem, deteriorating soil fertility, and altering the intensity of oxidation-reduction processes.

Oil and petroleum products are recognized as a priority among biosphere pollutants. The negative impact of oil on soil occurs through the movement of petroleum hydrocarbons through the soil profile. Oil primarily impacts the upper soil horizons, and can penetrate to depths of 1 - 2 meters. Oil and petroleum products are most deeply present in soils with a light mechanical composition—sand, gravel, sandy loam, and fissured rock, which is characteristic of the soils studied. The good permeability of well-drained sandy and sandy loam soils ensures deep penetration of the pollutant into the soil and parent rock. According to scientists [Davydova and Tagasov \(2004\)](#), starting with a pollutant concentration of 50 l/m², traces of oil are detected at depths of 100 cm or more. At doses of 1.5 l/m² and less, they are permeable to oil, therefore, at doses of 20 l/m², the preservation and rate of restoration of the living soil cover on loam is higher than on sandy soil.

The rate, depth, and nature of oil penetration, as well as the extent of contamination, depend not only on the physicochemical properties of the oil itself but also on the soil and climatic conditions of the region. Oil contaminants alter the physical condition of the soil, disrupting the air-water balance, structural condition, and carbon-nitrogen balance. No studies have been conducted in the republic on the negative impact of oil and petroleum products on soil fertility and soil properties, so accumulated international research data is provided for comparison.

3.3.1. Oil Products in the Soil

According to most researchers, soils exhibit reduced absorption capacity, altered soil pH, deterioration of soil water and air conditions, decreased water-holding capacity, structural degradation, a lack of oxygen, which affects plant development, and a deterioration in the availability of mobile nitrogen and phosphorus. To quantify the degree of soil pollution, a scale of soil pollution by oil and petroleum products, proposed by Russian scientists, is used ([Dzhailoobaev, Neronova, & Nikolaenko, 2009](#); [Ibragimova, Evseeva, Yudin, & Vodyanova, 2025](#); [Sokolov, 1975](#)).

The main sources of soil contamination are production pipelines, crude and commercial oil collection points (collectors), and storage facilities. A site investigation in Kyzyl-Zhar revealed that, in addition to uranium mining, small-scale oil production had occurred there. The presence of old oil storage facilities suggests that the oil was discovered at a uranium mine. Since only two shafts led into the mine and there was no separate oil drilling nearby, the crude oil residue must have been part of the uranium mine. A circular crude oil tank is located approximately 70 meters east of the mine's administrative building. The tank has concrete walls and a concrete roof with two hatches. Its outer diameter is 7.8 meters. Additionally, a tank measuring 18 meters × 4.6 meters × 2 meters is located on the site. The middle section of the tank contains oil residue.

Soil samples were collected for analysis for oil product contamination from 4 sites. Sampling is being carried out at the following areas:

- 1) Point No. 1, (sample code: SNKJ-1), the area of the dilapidated building, (coordinates E - 41°16'39.31", N - 72°00'07.09");
- 2) Point No. 2, (sample code: SNKJ-2) western part of the mine, (coordinates E - 41°16'49.74", N - 71°59'23.85");
- 3) Point No. 3, (sample code: SNKJ-3) western part of the mine, (coordinates E - 41°16'53.41", N - 71°59'24.29");
- 4) Point No. 4, (sample code: SNKJ-4) western part of the mine, (coordinates E - 41°16'48.31", N - 71°59'27.91");



Point No. 1 Area of the dilapidated building Point No. 4 Western part of the mine

The analysis showed that the oil product content in the water fluctuates depending on the distance from the pollution source, particularly in the western part of the mine, where the oil product reservoir is located, and the concentration level in the upper soil layer varies. It should be noted that the soil most contaminated with oil products is in the western part of the mine, where severe oil product contamination of up to 4820 mg/kg (0 - 20 cm layer) was noted in the area of the destroyed building near foot of the mountain slope (SNKJ-1); then section SNKJ-2 – 3460 mg/kg, on the western side of the mine (SNKJ-2) and then section SNKJ-3 content, 1980 mg/kg and point SNKJ-4 content, 1380 mg/kg (**Table 4**). It is known that MAC of oil products in soil less than 1000 mg/kg is permissible norm, at the same time from 1000 - 2000 mg/kg is low; 2000 - 3000 mg/kg is average; 3000 - 5000 mg/kg is high. If we compare with literary data on the level of pollution of soil cover with oil products, the concentration level of this province is increased from 2 to 5 times (**Table 8**).

Table 8. Results of soil tests for oil contamination.

Name of ingredients	Depth cm	Data by points (mg/kg)			
		SNKJ-1	SNKJ-1	SNKJ-1	SNKJ-1
Petroleum products	0 - 20	4820 ± 456	3460 ± 321	1980 ± 264	1380 ± 243

3.3.2. Petroleum Products in Water

In order to study the oil pollution of water in the Mailuu-Sai River, samples were

collected at three sites for analysis. Sampling was carried out at the following points in areas contaminated with oil products: point #1 (sample code: WNKJ-1), near a dilapidated building (coordinates E - 41°16'39.95", N - 72°00'08.23"); point #2 (sample code: WNKJ-2), on the western side of the mine (coordinates E - 41°16'56.03", N - 71°59'23.31"); point No. 3, (sample code: WNKJ-3), western side of the mine (coordinates E - 41°16'49.03", N - 72°00'07.09") (Table 5). The analysis was carried out using the method of measuring the concentration of petroleum products in samples of natural waters using fluorimetric methods (PNDF 14.2:4:128.98). The maximum permissible concentration (MPC) of petroleum products in water bodies of domestic and drinking water use and cultural and household water use is 0.3 mg/dm³ in waters of water bodies of fishery importance is 0.05 mg/dm³. However, it should be noted that according to the requirements of SanPiN 1.2.3685-21, the concentration of petroleum products in any water, except technical water, should not exceed 0.1 mg/dm³ (Mamytov & Voronov, 1994; Nekrasova & Kamenetskaya, 2024).

As is typical, oil concentrations in contaminated water vary widely, from exceeding standards (more than 0.1 - 0.3 mg/L) to several hundred or thousands of mg/L in industrial discharges. The results show that in this province, the Mailuu-Sai River has oil product levels reaching up to two hundred mg/L, representing concentrations hundreds of times higher than accepted standards, necessitating urgent action (Table 9).

Table 9. Results of water tests for oil product contamination.

Name of ingredients	Data by points (mg/l)		
	WNKJ-1	WNKJ-2	WNKJ-3
Petroleum products	168.40 ± 32	152.00 ± 19	194.00 ± 41

Soil is a vital component of an ecosystem. Being the product of the combined influence of many factors, including climate and vegetation, soil most fully reflects the specific ecological and biogeochemical characteristics of an area.

According to literary data, the south of Kyrgyzstan is part of the Turanian facies, located at absolute altitudes of 500 - 3000 m above sea level. The soil-forming rocks of the intermountain valleys, where the Turanian gray-earth soil formed, are loess-like loams, conglomerates, and pebbles of the Quaternary period, which contain carbonates and other readily soluble salts.

4. Conclusion

In Kyrgyzstan, two systems of standards for the main chemical elements are used to assess water quality: environmental standards, expressed in maximum permissible concentrations, and discharge standards, expressed in maximum permissible discharges.

Methods for analyzing (determining) the content of substances in surface and waste waters are developed by competent organizations, approved and recom-

mended for use by the sanitary-epidemiological supervision and environmental protection authorities of the Kyrgyz Republic, respectively.

The results of water analysis in the Mailuu-Sai River showed that water quality does not meet required standards. Relatively high mineralization, hardness, and dry residue were determined, along with high sulfate and chloride levels. A pH of 7.5 is considered within normal limits.

Elemental analysis of water in the river according to ICP showed a comparatively weak increase from the MPC of chemical elements: Ba, Mg, Mn, Mo, Na, Pb, Se, U and F, and the following chemical elements: Mo, Mn and F, increased in relation to the MPC from 5 to 10 times, which requires special attention.

The qualitative composition of zoobenthos in the studied streams was found to be quite poor. Aquatic invertebrates are represented only by benthic organisms and require in-depth hydrobiological analysis.

According to laboratory analysis results, the highest levels of chemical elements were found in samples STKJ-13, STKJ-14, and TKJ-15 of all soil samples. The study confirms that elevated concentrations of individual heavy metals in the soil exceed the MPC in the tailings and industrial areas, while in lower areas they are at background levels.

The level of petroleum products in the water varies depending on the distance from the pollution source. The concentration of petroleum products in the river fluctuates between 138 and 468 mg/L, indicating sufficiently high levels of petroleum products, hundreds of times higher than the maximum permissible concentration, requiring urgent remediation measures. In terms of soil cover, the most contaminated area with petroleum products is the western part of the mine. at the foot of the mountain slope (SNKJ-1) and the lowest concentration at SNKJ-4, and in relation to MPC, the levels of pollution of the soil cover with oil products in this province are increased.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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