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K.T. Abdraimova, *G.B. Toychibekova, G.S. Shalabaeva, A.M. Seytmetova
Khoja Akhmet Yassawi International Kazakh-Turkish University (Turkistan, Kazakhstan)

MECHANICAL COMPOSITION, DYNAMICS OF PHYSICAL PROPERTIES OF SOIL CONTAMINATED WITH POLYMETALLIC COMBINE WASTE

Abstract. This article highlights the problems associated with heavy metal contamination of the soil near the Kargalinka tailings dam and the village of Kyzylzhol. This points to the problem of reclamation and the importance of solving this pressing problem. Soil pollution near tailings dumps, where mining waste is stored, poses a serious problem for the environment and public health, especially if the tailings dumps are saturated with heavy metals. The increased concentration of heavy metals in the soils near the tailings dam was ***Pb*** 55,9; ***Cu*** 6,8; ***Zn*** 45,2; ***Cd*** 4,7; ***Ni*** 8,2; ***As*** 5,1; ***Hg*** 4,8; ***Cr*** 13,7 mg/kg. Soil contamination with heavy metals can have long-term effects on ecosystems, agriculture, and human health. In many cases, these heavy metals are difficult to reclaim, which makes their effects long-term. As a result, soil pollution near tailings dumps has become one of the most acute environmental problems in the southern region of Kazakhstan, related to the consequences of the mining industry.
Key words*: mechanical composition, soil, heavy metals, toxic effect, accumulation, fertility.*

Полиметалл комбинатының қалдықтарымен ластанған топырақтың механикалық құрамы, физикалық қасиеттері мен динамикасы

Аңдатпа. Мақалада Қарғалы қалдық қоймасы мен Қызылжол ауылының маңындағы топырақтың ауыр металдармен ластануына байланысты проблемалар баяндалады. Бұл өзекті мәселені шешудің маңыздылығын қалпына келтіру мәселесін көрсетеді. Тау-кен қалдықтары сақталатын қалдық қоймаларының жанындағы топырақтың ластануы қоршаған ортаға, халықтың денсаулығына, әсіресе қалдық қоймалары ауыр металдармен қаныққан болса, үлкен проблема тудырады. Қалдық қоймасына жақын топырақтағы ауыр металдардың жоғары концентрациясы ***Pb*** 55,9; ***Cu*** 6,8; ***Zn*** 45,2; ***Cd*** 4,7; ***Ni*** 8,2; ***As*** 5,1; ***Hg*** 4,8; ***Cr*** 13,7 мг/кг құрады. Топырақтың ауыр металдармен ластануы экожүйелерге, ауыл шаруашылығына және адам денсаулығына ұзақ мерзімді әсер етуі мүмкін. Көптеген жағдайларда бұл ауыр металдарды қалпына келтіру қиын, бұл олардың әсерін ұзақ уақытқа созады. Нәтижесінде қалдық қоймалар маңындағы топырақтың ластануы тау-кен өнеркәсібінің салдарымен байланысты Қазақстанның оңтүстік өңірінің ең өткір экологиялық проблемаларының біріне айналды.
Түйінді сөздер: *механикалық құрам, топырақ, ауыр металдар, токсикалық әсер, аккумуляция, құнарлылық.*

Механический состав, динамика физических свойств почвы, загрязненной отходами полиметаллического комбината

Аннотация. В статье освещаются проблемы, связанные с загрязнением почвы вблизи хвостохранилища Каргалинка и села Кызылжол тяжелыми металлами. Это указывает на проблему рекультивации важности решения насущной проблемы. Загрязнение почвы вблизи хвостохранилищ, где хранятся отходы горнодобывающей промышленности, представляет серьезную проблему для окружающей среды, здоровья населения, особенно если хвостохранилища насыщены тяжелыми металлами. Повышенная концентрация тяжелых металлов в почвах вблизи хвостохранилища составляла: ***Pb*** 55,9; ***Cu*** 6,8; ***Zn*** 45,2; ***Cd*** 4,7; ***Ni*** 8,2; ***As*** 5,1; ***Hg*** 4,8; ***Cr*** 13,7 мг/кг. Загрязнение почвы тяжелыми металлами может иметь долгосрочные последствия для экосистем, сельского хозяйства и здоровья человека. Во многих случаях эти тяжелые металлы сложно поддаются рекультивации, что делает их воздействие долговременным. В результате загрязнение почвы вблизи хвостохранилищ стало одной из наиболее острых экологических проблем южного региона Казахстана, связанных с последствиями горнодобывающей промышленности.
Ключевые слова: *механический состав, почва, тяжелые металлы, токсическое воздействие, аккумуляция, плодородие.*

Introduction

The analysis of polymetallic combine waste on the dynamics of mechanical soil components is a major environmental and engineering problem. The process of mining and processing metals can lead to emissions of harmful substances, including heavy metals and other chemical compounds that affect the environment as a whole. There are several key factors that can have an impact on the mechanical composition [1].

The study of polymetallic combine waste on the dynamics of the mechanical composition of soils is the basis for environmental and engineering phenomena, since land pollution from metal mining and processing waste can change their physical and mechanical properties [2]. Let's consider exactly how such conclusions can arise on the mechanical composition of soil: 1. Changes in the mechanical composition of the soil. 2. Waste from polymetallic plants can negatively change the mechanical composition of soil, which includes the ratios of fractions (sand, clay, silt). This can [3] be defined as follows: An increase in the proportion of small particles. Many waste plants (for example, sludge, dust) contain small particles that, once in the soil, may contain their share of small fractions (clay and silt) [4]. This leads to a decrease in the water permeability and drainage properties of the soil layers, as well as to its greater density. Soil samples were taken from the Kargalinka tailings dam located near the village of Kyzylzhol [5, 6].

The impact of polymetallic combine waste on changes in the mechanical composition of soil is a significant environmental issue. Waste generated by polymetallic extraction and processing (such as slag, tailings, smelting residues, and other by-products) can cause notable alterations in soil properties, including its mechanical composition. The mechanical composition of soil refers to the relative proportions of different particles. 1. Changes in Soil Granulometric Composition: Introduction of fine particles**:** Polhigher clay and silt content**;** soil texture degradation: The additional fine particles can cause a disruption in the natural soil structure. Soil becomes more compact and loses its original texture, resulting in reduced drainage, lower water retention capacity, and increased risk of soil erosion. 2. Changes in Soil Density and Porosity: increased soil density: Polymetallic waste, particularly heavy, dense residues such as slag or certain metal-rich particles, can increase the soil's bulk density. This higher density can reduce the porosity of the soil, decreasing its ability to retain water and oxygen. Compaction of the soil also occurs, limiting the movement of roots and making the soil less suitable for plant growth; reduced porosity: When fine metal particles from the waste fill the pores in the soil, the porosity decreases. Lower porosity means reduced water infiltration and air exchange, which can impact the soil's structural integrity and biological health. 3. Impact on Soil Strength and Stability: Alteration of cohesion: The introduction of toxic metals or other chemical compounds from the waste can disrupt the cohesive forces between soil particles, leading to reduced shear strength. This makes the soil more susceptible to erosion and landslides, particularly in sloped areas. As the mechanical stability of the soil decreases, it becomes less effective at supporting vegetation and can lead to structural failure in engineered landscapes, such as roads or construction sites; increased compressibility: The presence of waste materials can increase the compressibility of the soil. In soils with a high amount of clay or fine particles from polymetallic waste, the soil becomes more prone to settlement under load, which can cause issues for agricultural activities and construction projects [7].

The effect of polymetallic combine waste on soil mechanical composition is profound and multifaceted. By introducing fine particles, increasing soil density, altering porosity, and adding toxic metals, the waste can weaken the soil's structural integrity, reduce its water retention capacity, and increase its susceptibility to erosion [8]. These changes can significantly degrade soil quality, limiting its use for agriculture and other land-based activities. Long-term management strategies, including the treatment and remediation of contaminated soils, are essential to mitigate these effects and restore the soil's natural mechanical properties [9, 10].

The presence of heavy metals in soil and their remediation using bioremediation methods is one of the pressing contemporary issues. Data on the analysis of soils from recreational and mining complexes located near non-ferrous metallurgy enterprises in the Turkestan region are presented. The dependence of the chemical composition of soil samples, collected from various points in the Turkestan region and the city of Shymkent, on the distribution of heavy metals is demonstrated [11].

Materials and Main Methods

The soil samples required for analysis were collected using a titanium-made soil drill. Samples were taken three times at depths of 0–5, 5–20, 20–30, 30–40, and 40–50 cm from five points (the corners and the center of a 5 x 5 m square). The collected samples were mixed on a plastic sheet, and a subsample of no less than 400 g (on a dry matter basis) was taken. For storage and transportation, the samples were placed in cotton bags.

In the laboratory, the soil samples were dried under dry-air conditions and then ground. They were sieved through a mesh with a diameter of 1 mm. The samples were carefully spread on thick paper and cleaned of stones, glass, plant roots, and other debris.

To determine the content of heavy metals, the soil samples were ground into a fine powder using an agate mortar.

For humus determination, the soil samples were cleaned of plant root residues, carefully pulverized, sieved through a 0.25 mm mesh, and analyzed using the method of I.V. Tyurin. The accuracy of the analysis results was verified by comparing the determined components with the known values in soil standards.

Results

The effect of polymetallic combine waste on the microfauna of polluted soil is an important aspect of environmental health, as the microfauna (including soil microorganisms, nematodes, microarthropods, and other small organisms) plays a crucial role in maintaining soil fertility, structure, and nutrient cycling. The presence of toxic pollutants from polymetallic waste, such as heavy metals (lead, cadmium, copper, zinc, etc.), can have profound impacts on the diversity, abundance, and activity of soil microfauna, leading to various negative ecological consequences. Toxic Effects of Heavy Metals on Soil Microorganisms-heavy metal contamination: Polymetallic wastes typically contain high concentrations of toxic metals like cadmium, lead, arsenic, copper, and zinc. These metals can accumulate in the soil and poi-

Table 1

Indicators of experimental data on the study of soil mechanical composition depending on distance 0–10 km and depth (concentration of heavy metal salts 1450 mg/kg)

Кесте 1

0–10 км қашықтық пен тереңдікке байланысты топырақтың механикалық құрамын зерттеудің эксперименттік деректерінің көрсеткіштері (ауыр металл тұздарының концентрациясы 1450 мг/кг)

Таблица 1

Показатели экспериментальных данных исследования механического состава почвы в зависимости от расстояния 0–10 км и глубины (концентрация солей тяжелых металлов 1450 мг/кг)

The horizon of the studied soil, cm	Particle sizes, mm	Structural elements of the soil	Dimensions of the structural elements, kg
0–30	5–1,5	the rocky layer	1,85
	1,5–0,75	crushed	1,98
	0,75–0,5	coarse sand	2,65
	< 0,5	stone coarse sand	2,43
31–60	0,25–0,05	medium-fine sand fine sand	1,02
	0,05–0,01	coarse dust	0,55
	0,01–0,005	medium-fine dust	1,02
	0,005–0,001	fine dust	2,37

Table 2

Indicators of experimental data on the study of soil mechanical composition depending on the distance of 11–15 km and depth (concentration of heavy metal salts 1090 mg/kg)

Кесте 2

11–15 км қашықтыққа және тереңдікке байланысты топырақтың механикалық құрамын зерттеудің тәжірибелік деректерінің көрсеткіштері (ауыр металл тұздарының концентрациясы 1090 мг/кг)

Таблица 2

Показатели экспериментальных данных исследования механического состава почвы в зависимости от расстояния 11–15 км и глубины (концентрация солей тяжелых металлов 1090 мг/кг)

The horizon of the studied soil, cm	Particle sizes, mm	Structural elements of the soil	Dimensions of the structural elements, kg
0–30	5–1,5	the rocky layer	1,75
	1,5–0,75	crushed	1,89
	0,75–0,5	coarse sand	2,54
	< 0,5	stone coarse sand	2,12
31–60	0,25–0,05	medium-fine sand fine sand	1,01
	0,05–0,01	coarse dust	0,33
	0,01–0,005	medium-fine dust	1,03
	0,005–0,001	fine dust	2,21

Table 3

Indicators of experimental data on the study of soil mechanical composition depending on the distance of 16–20 km and depth (concentration of heavy metal salts 910 mg/kg)

Кесте 3

16–20 км қашықтыққа және тереңдікке байланысты топырақтың механикалық құрамын зерттеудің тәжірибелік деректерінің көрсеткіштері (ауыр металл тұздарының концентрациясы 910 мг/кг)

Таблица 3

Показатели экспериментальных данных исследования механического состава почвы в зависимости от расстояния 16–20 км и глубины (концентрация солей тяжелых металлов 910 мг/кг)

The horizon of the studied soil, cm	Particle sizes, mm	Structural elements of the soil	Dimensions of the structural elements, kg
0–30	5–1,5	the rocky layer	0,97
	1,5–0,75	crushed	1,23
	0,75–0,5	coarse sand	1,75
	< 0,5	stone coarse sand	1,02
31–60	0,25–0,05	medium-fine sand fine sand	0,92
	0,05–0,01	coarse dust	0,30
	0,01–0,005	medium-fine dust	0,94
	0,005–0,001	fine dust	1,97

son microorganisms, such as bacteria, fungi, and protozoa, which are critical for the soil's biological processes [12]. The influence of lead sulfate ($PbSO_4$) concentration on the mechanical composition of soil near the tailings dump of a polymetallic plant can be significant. Lead sulfate, which is a common component of mining and smelting waste, has a toxic impact on the soil environment and its physical properties, especially in areas close to mining sites like tailings dumps. Here's how lead sulfate can affect the mechanical composition of soil in such environments. The influence of zinc salt (such as zinc sulfate, $ZnSO_4$) concentration on the mechanical composition of soil near the tailings dump of a polymetallic plant can significantly affect the soil's physical properties and its capacity to support plant life and soil organisms. Zinc is a heavy metal commonly found in mining waste, and its presence in high concentrations can alter the granulometric composition, structure, porosity, density, and stability of the soil.

In this study, soil samples were taken from various depths (0–60 cm), depending on the distance of the tailings dump. The distance ranged from 0–15 km with concentrations of heavy metal salts of 1450 mg/kg of the studied soil.

Table 4

Indicators of experimental data on the study of soil mechanical composition depending on the distance of 21–25 km and depth (concentration of heavy metal salts 387 mg/kg)

Кесте 4

21–25 км қашықтыққа және тереңдікке байланысты топырақтың механикалық құрамын зерттеудің тәжірибелік деректерінің көрсеткіштері (ауыр металл тұздарының концентрациясы 387 мг/кг)

Таблица 4

Показатели экспериментальных данных исследования механического состава почвы в зависимости от расстояния 21–25 км и глубины (концентрация солей тяжелых металлов 387 мг/кг)

The horizon of the studied soil, cm	Particle sizes, mm	Structural elements of the soil	Dimensions of the structural elements, kg
0–30	5–1,5	the rocky layer	0,95
	1,5–0,75	crushed	1,11
	0,75–0,5	coarse sand	1,54
	< 0,5	stone coarse sand	1,09
31–60	0,25–0,05	medium-fine sand fine sand	1,02
	0,05–0,01	coarse dust	0,54
	0,01–0,005	medium-fine dust	1,87
	0,005–0,001	fine dust	1,64

Table 5

Indicators of experimental data on the study of soil mechanical composition depending on the distance of 26–30 km and depth (concentration of heavy metal salts 65 mg/kg)

Кесте 5

26–30 км қашықтыққа және тереңдікке байланысты топырақтың механикалық құрамын зерттеудің тәжірибелік деректерінің көрсеткіштері (ауыр металл тұздарының концентрациясы 65 мг/кг)

Таблица 5

Показатели экспериментальных данных исследования механического состава почвы в зависимости от расстояния 26–30 км и глубины (концентрация солей тяжелых металлов 65 мг/кг)

The horizon of the studied soil, cm	Particle sizes, mm	Structural elements of the soil	Dimensions of the structural elements, kg
0–30	5–1,5	the rocky layer	1,06
	1,5–0,75	crushed	1,27
	0,75–0,5	coarse sand	1,69
	< 0,5	stone coarse sand	0,93
31–60	0,25–0,05	medium-fine sand fine sand	0,76
	0,05–0,01	coarse dust	0,75
	0,01–0,005	medium-fine dust	1,72
	0,005–-0,001	fine dust	1,46

Similar samples were also taken at a distance of 15–30 km from the experimental soil with a heavy metal salt content of 65 mg/kg.

Studying the dynamics of changes in soil moisture capacity and density depending on the composition of heavy metals and seasons is important for assessing the state of ecosystems and developing environmental protection measures. To gain a deeper understanding of these processes, field studies were conducted and data analysis was obtained, which helped identify patterns and develop recommendations for improving soil conditions (table 6).

Discussion

Improving the quality of soil contaminated with heavy metal ions is crucial for maintaining soil health and preventing further environmental damage. There are several strategies that can help reduce heavy metal contamination and restore soil quality. Here are a few approaches-Phytoremediation: This involves using plants to remove, stabilize, or degrade heavy metals in the soil. Some plants, known as hyperaccumulators, are capable of absorbing heavy metals through their; Common plants used for phytoremediation include sunflowers. This involves the use of microorganisms (bacteria, fungi, or algae) to

Table 6

Ratios of the data obtained on changes in soil moisture capacity and density

Кесте 6

Ылғал сыйымдылығы мен топырақ тығыздығының өзгеруі бойынша алынған мәліметтердің арақатынасы

Таблица 6

Соотношения полученных данных по изменению влагоемкости и плотности почвы

Interval and concentration of heavy metals	soil moisture indicators, %			The solid phase of the soil, y/cm^3		
	summer	spring	autumn	summer	spring	autumn
0–10 km, 1450 mg/kg	24,1	35,7	27,7	2,14	1,98	2,02
11–15 km, 1090 mg/kg	25,9	37,1	31,9	1,95	1,87	1,89
16–20 km, 910 mg/kg	35,9	48,3	43,4	1,82	1,82	1,83
21–25 km, 387 mg/kg	47,2	56,8	56,1	1,38	1,38	1,36
26–30 km, 65 mg/kg	58,5	63,7	64,8	1,17	1,17	0,99

degrade, transform, or immobilize heavy metals. Some bacteria can break down pollutants into less harmful forms or help precipitate metals out of the soil in a less toxic state.

Polluted soil, especially when contaminated with heavy metals, can have significant and far-reaching effects on the trophic chain (the sequence of organisms that eat one another in an ecosystem). Here's a breakdown of how polluted soil affects various trophic levels-primary producers: impact: plants are often the first organisms impacted by soil pollution. Heavy metals such as lead, mercury, cadmium, and arsenic can accumulate in plant tissues through the roots; effect on plants: these metals can interfere with the plant's nutrient uptake, hinder growth, cause chlorosis (yellowing of leaves), reduce photosynthesis, and even lead to plant death in extreme cases; trophic impact: since plants are the base of most trophic chains, contamination directly affects primary productivity and can limit the amount of food available for herbivores.

The presence of heavy metals in soil can have significant effects on both soil moisture capacity and soil density, which in turn affects the soil's overall health and its ability to support plant growth. Here's how heavy metal contamination can influence these soil properties-Compaction: heavy metals can cause soil particles to bind together, leading to increased soil compaction. Compacted soil has reduced pore space, which decreases the soil's ability to retain water. This leads to a lower soil moisture capacity, as water cannot be stored in the smaller pore spaces.

Reduced Aggregation: soil aggregates (clumps of soil particles held together by organic matter and microbes) are essential for maintaining pore spaces that allow water infiltration and retention. Heavy metals can disrupt soil aggregation by interfering with soil microbial activity and organic matter decomposition, leading to a decline in aggregate stability and water-holding capacity. Heavy metals like cadmium (***Cd***) and lead (***Pb***) can interfere with the soil's cation exchange capacity (CEC), which is the soil's ability to hold onto and exchange essential nutrients, including water. When CEC is disrupted, soil may lose its ability to retain water, leading to quicker drainage and less moisture available for plants. Some heavy metals can also affect the hydrophobicity of the soil, causing the soil to repel water. For instance, mercury and zinc can make soil particles less water-attractive, leading to poor water retention and potentially waterlogged conditions on the surface, while deeper layers may remain drier.

Determination of heavy metals in the soil

Determining heavy metals in soil is crucial for assessing soil quality, environmental contamination, and potential risks to human and ecological health. There are several methods commonly used for the analysis of heavy metals in soil.

Environmental Standards and Safety Limits

Regulatory bodies such as the U.S. Environmental Protection Agency (EPA), World Health Organization (WHO), and other regional organizations provide soil quality guidelines and safety limits for various heavy metals, based on their toxicity and environmental persistence.

After determining the concentrations of heavy metals, a risk assessment can be conducted to evaluate the potential environmental or human health risks posed by the contaminants. This can include evaluating exposure pathways (e.g., through crops, water, or direct contact with soil).

The heavy metal content in the soil near a polymetallic plant is a crucial factor for understanding environmental contamination, potential risks to human health, and the health of the ecosystem. Polymetallic plants typically process multiple metals (such as lead, zinc, copper, cadmium, arsenic, and others), and their waste may contain high concentrations of these metals. These heavy metals can leach into the soil, affecting its quality and making it hazardous for both plants and animals, including humans who depend on the land for agriculture or other activities.

Polymetallic plants usually process ore that contains a combination of metals. Consequently, the waste from such plants (e.g., tailings, slag, or other byproducts) can result in contamination of several metals in the surrounding soil. Some of the most common heavy metals found near these plants include:

1. Lead (***Pb*****)**: Lead is toxic, especially to the nervous system, and can contaminate the soil, water, and crops grown in the vicinity.

2. Cadmium (***Cd***): Cadmium is highly toxic and can accumulate in plants, entering the food chain. Long-term exposure can cause kidney damage and bone issues.

3. Zinc (***Zn***): Zinc, while essential in small amounts for plant growth, can be toxic in larger concentrations, causing growth inhibition and other plant issues.

4. Copper (***Cu***): Copper is another essential micronutrient for plants, but in high concentrations, it can be toxic to both plants and soil microorganisms.

5. Arsenic (***As***): Arsenic is a potent carcinogen and neurotoxin. Soil contaminated with arsenic can lead to long-term health risks for humans and wildlife.

6. Nickel (***Ni***): Nickel can accumulate in the soil near smelting or mining operations. It can be toxic to plants and soil organisms if present in excessive amounts.

7. Chromium (***Cr***): Chromium in its hexavalent form (Cr^{6+}) is highly toxic, and contamination can lead to soil and water pollution, affecting the ecosystem.

8. Mercury (***Hg***): Mercury can bioaccumulate in the food chain, and its presence in the soil poses long-term environmental and health risks.

In figure 1–2, it can be seen that the pH of the soil near the polymetallic combine's tailings dump ranged from 2.35 to 5.12, and the soil of Kyzylzhol village had a pH value from 3.91 to 5.41. This fact proves a noticeable acidification of the soil of the studied area. This fact can be referred to the influence of wastewater and generated tailings waste during the activities of the polymetallic combine. Reduced pH values may possibly affect the phytodavailability of some heavy metals and affect the migration and transformation of heavy metals in the soil.

Accumulated solid waste from the tailings dump over the years led to the following indications of certain substances in the soil: the total amount of iron in the tailings dump was much higher than in the soils near the village of Kyzylzhol with a content of 202.8 mg/kg; a certain amount of organic matter (humus) averaged 4.56m g/kg in the tailings dump, and in the soils near The content of the village was 3.34 mg/kg; in the soils of the tailings dump, the content of the most common heavy metals such as lead Pb and copper ***Cu*** in the soils exceeded the maximum permissible concentration and amounted to 55.9 and 6.8 mg/kg; In addition, the content of zinc ***Zn***, cadmium ***Cd***, and nickel ***Ni*** was 45.2, 4.7, and 8.2 mg/kg; the excess of MPC in the soils of the tailings dump was also noticeable in higher concentrations of heavy metals such as arsenic ***As***, mercury ***Hg***, and chromium ***Cr*** in amounts of 5.1, 4.8, and 13.7 mg/kg.

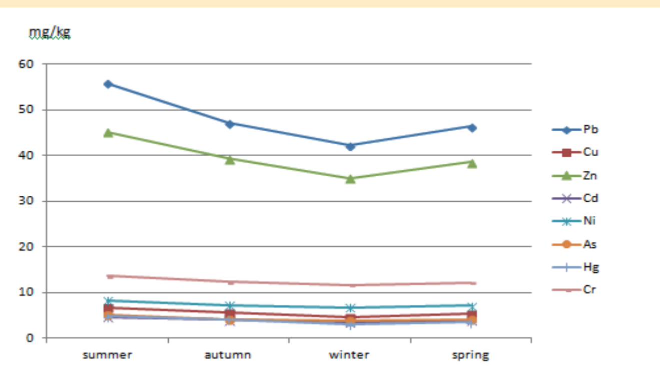

Figure 1. The content of heavy metal ions in the soil near the Kargalinka tailings dam.
Сурет 1. Қарғалы қалдық қоймасына жақын топырақтағы ауыр металл иондарының құрамы.
Рис. 1. Содержание ионов тяжелых металлов в почве вблизи хвостохранилища Каргалинка.

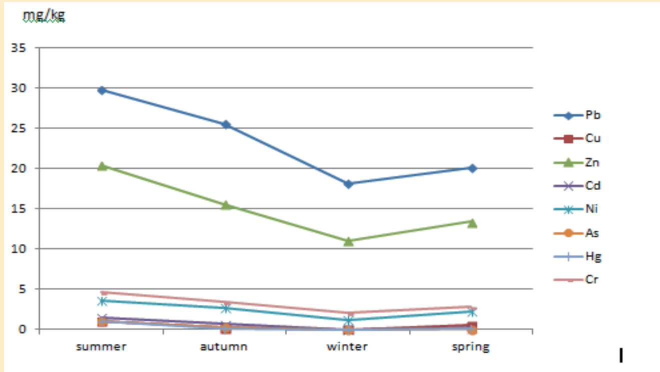

Figure 2. The content of heavy metal ions in the soil near the village of Kyzylzhol.
Сурет 2. Қызылжол ауылының маңындағы топырақтағы ауыр металл иондарының құрамы.
Рис. 2. Содержание ионов тяжелых металлов в почве вблизи села Кызылжол.

The excess concentration of heavy metals in soil can be caused by several factors, many of which are related to human activities, industrial processes, and natural phenomena. Mining activities, particularly those involving polymetallic ores, can lead to the release of heavy metals into the environment. When ores are mined, processed, and smelted, heavy metals such as lead (***Pb***), cadmium (***Cd***), zinc (***Zn***), arsenic (***As***), and mercury (***Hg***) are often left behind in the form of tailings, slag, and other byproducts. These metal-rich materials can leach into surrounding soil, water, and air. The disposal of mine tailings, which are often stored in tailings storage facilities (TSFs), can result in the contamination of nearby soil. The heavy metals in tailings can leach into the soil over time, especially if the tailings are not properly managed. When sulfide minerals (e.g., pyrite) in the soil or tailings are exposed to oxygen and water, they can oxidize and form sulfuric acid. This acid can increase the solubility of heavy metals like iron, lead, and cadmium, making them more mobile and leading to contamination of soil and water.

Dumping of industrial waste, including metal-laden byproducts, in landfills or unregulated disposal sites can cause long-term contamination of the surrounding soil. Additionally, emissions from industrial activities can settle onto the ground, contributing to heavy metal contamination.

Excessive concentrations of heavy metals in soil are primarily driven by industrial activities, mining, improper waste disposal, and agricultural practices. Natural processes can also contribute to heavy metal concentrations, but human activities have significantly amplified the risks. Monitoring, regulating industrial practices, and implementing effective waste management strategies are key to minimizing the impact of heavy metals on soil health and the environment.

Remediation of technogenically polluted tailings pond soil, especially contaminated with heavy metals, is a complex but necessary process to restore the environment and prevent further damage to the components of the agroecosystem and human health when assessing environmental quality. Tailings ponds, which are waste left over from mining and metal extraction processes, often contain high concentrations of heavy metals such as lead (***Pb***), cadmium (***Cd***), arsenic (***As***), mercury (***Hg***), and zinc (***Zn***). These metals can be toxic to plants, animals and humans, which makes the reclamation process extremely important for restoring the ecological balance of the earth and increasing its safety for future use.

Goals of Reclamation:

1) reducing the bioavailability of toxic metals in the soil to prevent uptake by plants and the food chain;

2) restoring soil fertility by improving physical, chemical, and biological properties of the soil;

3) preventing further contamination of the surrounding environment (air, water, and soil) due to leaching of metals from the tailings;

4) revegetating the area to reduce erosion and dust dispersion, and promote ecosystem restoration;

5) key steps in reclamation of polluted soil in tailings dumps.

Assessment and Monitoring of Contamination: before beginning reclamation, an assessment of contamination levels in the soil and surrounding environment is necessary. This includes measuring the concentration of heavy metals in the soil at various depths, assessing the pH, organic matter content, and soil structure, as well as evaluating the surrounding water and air quality. Mapping the distribution of contamination within the tailings dump helps in planning targeted remediation efforts.

Removal or Containment of Contaminated Materials: excavation and Removal; in some cases, it may be feasible to excavate contaminated soil and remove it to a controlled disposal site or waste management facility.

Containment: where removal is not practical, a containment approach is used to limit the spread of contamination. This can involve creating impermeable barriers, such as caps or liners, to prevent leaching of heavy metals into groundwater and surrounding areas.

Stabilization and Immobilization: stabilizing or immobilizing the metals in place is a common strategy in the reclamation of polluted soils. This can reduce the bioavailability of metals and prevent their migration.

Chemical Stabilization: the addition of amendments such as lime, phosphate compounds, or organic matter can bind heavy metals in the soil, reducing their solubility and making them less available for plant uptake. For example, adding phosphates can convert soluble forms of metals like cadmium and lead into insoluble, less toxic compounds.

Soil Amendments: adding organic matter, such as compost or biochar, can help stabilize the soil, improve its structure, and encourage the formation of stable metal-organic complexes that reduce the mobility of heavy metals.

Conclusion

In summary, heavy metals have a detrimental impact on soil moisture capacity and density by altering soil structure, disrupting biological activity, and reducing the ability of the soil to retain and supply water to plants. These changes lead to decreased soil fertility, poor plant growth, and reduced ecosystem productivity. Understanding and mitigating these effects are critical for managing contaminated soils and promoting ecosystem restoration.

Reclamation of heavy metal-contaminated soils in tailings dumps is a complex process that requires a combination of physical, chemical, and biological techniques.

Effective reclamation strategies should focus on reducing metal mobility, restoring soil fertility, and promoting ecological recovery. While the process can be challenging and resource-intensive, successful reclamation not only improves soil health and ecosystem stability but also helps protect human health by mitigating the risks of metal exposure through soil, water, and food sources.

REFERENCES

1. *Velasquez E. Soil macrofauna as an indicator for evaluating soil based ecosystem services in agricultural landscapes. / Velasquez E., Lavelle P. // Acta Oecologica. 2019. V. 100. Art. № 103446 (in English)*
2. *Evangelista S.J. A proposal for the assessment of soil security: Soil functions, soil services and threats to soil. / Evangelista S.J., Field D.J., McBratney A.B., Minasny B., Ng W., Padarian J., Dobarco M.R., Wadoux A.M.J.-C. // Soil Security. 2023. V. 10. Art. № 100086 (in English)*
3. *Imashev A. Research of possible zones of inelastic deformation of rock mass. / Imashev A., Suimbayeva A., Zholmagambetov N., Takhanov D., Abdimutalip N. // News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences. 2018. V. 2. P. 177–184 (in English)*
4. *Creamer R.E. The life of soils: Integrating the who and how of multifunctionality. / Creamer, R.E., Barel J.M., Bongiorno G., Zwetsloot M.J. // Soil Biology and Biochemistry. 2022. V. 166. Art. № 108561 (in English)*
5. *Shafea L. Microplastics effects on wettability, pore sizes and saturated hydraulic conductivity of a loess topsoil. / Shafea L., Felde V.J.M.N.L., Woche S.K., Bachmann J., Peth S. // Geoderma. 2023. V. 437. Art. № 116566 (in English)*
6. *Wagg, C. Soil biodiversity and soil community composition determine ecosystem multifunctionality. / Wagg C., Bender S.F., Widmer F., van der Heijden M.G.A. // Proc. Natl. Acad. Sci. U.S.A. 2014. Vol. 111 (14). P. 5266–5270 (in English)*
7. *Lin Y. Adaptation of soil fungi to heavy metal contamination in paddy fields – a case study in eastern China. / Lin Y., Xiao W., Ye Y., Wu C., Hu Y., Shi H. // Environmental Science and Pollution Research. 2020. V. 27. P. 27819–27830 (in English)*
8. *Baibotayeva A. Study of the effect of heavy metals on soil cover and methods of their bioremediation control. / Baibotayeva A., Kenzhalieva G., Zhantasov K., Zhantasova M., Kocherov E. // Series of Geology and Technical Sciences. 2021. V. 445. P. 52–57 (in English)*

9. Wall L. Changes of paradigms in agriculture soil microbiology and new challenges in microbial ecology. / Wall L., Gabbarini L., Ferrari A., Frene J., Covelli J., Reyna D., Robledo N. // Acto Oecologica. 2019. V. 95. P. 68–73 (in English)
10. Gonmadje C. Environmental filtering determines patterns of tree species composition in small mountains of Atlantic Central African forests. / Gonmadje C., Dourmenge C., Sunderland T., McKey D. // Acta Oecologica. 2019. V. 94. P. 12–21 (in English)
11. Palansooriya K.N. Soil amendments for immobilization of potentially toxic elements in contaminated soils: A critical review. / Palansooriya K.N., Shaheen S.M., Chen S.S., Tsang, Daniel C.W., Hashimoto Y., Hou D., Bolan N.S., Rinklebe J., Ok Y.S. // Environment International. 2020. V. 134. Art. № 105046 (in English)
12. Tang W. Heavy metal contamination in the surface sediments of representative limnetic ecosystems in Eastern China. / Tang W., Shan B., Zhang H., Zhang W., Zhao Y., Ding Y., Rong N., Zhu X. // Scientific Reports. 2014. V. 4. Art. № 7152 (in English)

ПАЙДАЛАНЫЛҒАН ӘДЕБИЕТТЕР ТІЗІМІ

1. Веласкес Э. Топырақ макрофаунасы ауыл шаруашылық ландшафттарындағы топыраққа негізделген экожүйелік қызметтерді бағалау көрсеткіші ретінде. / Э. Веласкес, П. Лавель. // Acta Oecologica. 2019. Т. 100. Мақ. № 103446 (ағылшын тілінде)
2. Евангелиста С.Дж. Топырақ қауіпсіздігін бағалау ұсынысы: топырақ функциялары, топырақ қызметтері және топырақ қауіптері. / С.Дж. Евангелиста, Д.Дж. Филд, А.Б. МакБратни, Б. Минасны, В. Нг, Х. Падарян, М.Р. Добарко, А.МЖ-К. Ваду. // Soil Security. 2023. Т. 10. Мақ. № 100086 (ағылшын тілінде)
3. Имашев А. Тау жотасының серпімді емес деформациясының ықтимал аймақтарын зерттеу. / А. Имашев, А. Сүйімбаева, Н. Жолмағанбетов, Н. Таханов, Н. Әбдімүтәліп. // News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences. 2018. Т. 2. Б. 177–184 (ағылшын тілінде)
4. Кример Р.Е. Топырақ өмірі: көпфункционалдылықтың «кім және қалай» интеграциясы. / Р.Е. Кример, Дж.М. Барел, Г. Бонджорно, М.Дж. Цветслут. // Soil Biology and Biochemistry. 2022. Т. 166. Мақ. № 108561 (ағылшын тілінде)
5. Шафеа Л. Микропластиканың ылғалдылыққа, тері тесігінің мөлшеріне және лесс топырағының жоғарғы қабатының қаныққан гидравликалық өткізгіштігіне әсері. / Шафеа Л., B.J.M.N.L. Фельде, С.К. Boxe, Й. Бахманн, С. Пет. // Geoderma. 2023. Т. 437. Мақ. № 116566 (ағылшын тілінде)
6. Вагг К. Топырақтың биоалуантүрлілігі және топырақ қауымдастығының құрамы экожүйенің көп функционалдығын анықтайды. / К. Вагг, Ф. ендер, Ф. Видмер, М.Г.А. ван дер Хейден. // Proc. Natl. Acad. Sci. U.S.A. 2014. Т. 111 (14). Б. 5266–5270 (ағылшын тілінде)
7. Лин Я. Күріш алқаптарында ауыр металдармен ластануға бейімделген топырақ саңырауқұлақтары – Қытайдың шығысындағы зерттеу. / Я. Лин, У. Сяо, Й. Яньмей, В. Цифан, Х. Имин, Ш. Хаокун. // Environtental Science and Pollution Research. 2020. Т. 27. Б. 27819–27830 (ағылшын тілінде)
8. Байботаева А. Ауыр металдардың топырақ қабатына әсерін зерттеу және олардың биоремедиациялық бақылау әдістері. / А. Байботаева, Г. Кенжалиева, Қ. Жантасов, М. Жантасова, Е. Кочеров. // Геология және техникалық ғылымдар сериясы. 2021. Т. 445. Б. 52–57 (ағылшын тілінде)
9. Уолл Л. Ауыл шаруашылығындағы топырақ микробиологиясындағы парадигмалардың өзгеруі және микробтық экологиядағы жаңа сын-қатерлер. / Л. Уолл, Л. Габбарини, А. Феррари, Ж. Френе, Дж. Ковелли, Д. Рейна, Н. Робледо. // Acto Oecologica. 2019. Т. 95. Б. 68–73 (ағылшын тілінде)
10. Гонмадже К. Атлантикалық Орталық Африка ормандарындағы кішкентай тауларда ағаш түрлерінің құрамының үлгісін экологиялық сүзу анықтайды. / К. Гонмадже, Ч. Дуумене, Т. Сандерленд, Д. МакКей. // Acta Oecologica. 2019. Т. 94. Б. 12–21 (ағылшын тілінде)
11. Палансурия К.Н. Ластанған топырақтағы ықтимал улы элементтерді иммобилизациялауға арналған топырақ қоспалары: сыни шолу. / К.Н. Палансурия, С.М. Шахин, С.С. Чен, Цанг, К.В. Даниэль, Ю. Хашимото, Д. Хоу, Н.С. Болан, Дж. Ринкл, Ю.С. Ок. // Environtent International. 2020. Т. 134. Мақ. № 105046 (ағылшын тілінде)
12. Тан В. Шығыс Қытайдың өкілдік лимнетикалық экожүйелеріндегі ауыр металдардың ластануы. / В. Тан, Б. Шан, Х. Чжан, В. Чжан, Ю. Чжао, Ю. Дин, Н. Ронг, С. Чжу. // Scientific Reports. 2014. Т. 4. Мақ. № 7152 (ағылшын тілінде)

СПИСОК ИСПОЛЬЗОВАННЫХ ИСТОЧНИКОВ

1. Веласкес Э. Почвенная макрофауна как индикатор для оценки экосистемных услуг почвы в сельскохозяйственных ландшафтах. / Э. Веласкес, П. Лавель. // Acta Oecologica. 2019. Т. 100. Ст. № 103446 (на английском языке)
2. Евангелиста С.Дж. Рекомендация по оценке безопасности почвы: функции почвы, почвенные услуги и почвенные риски. / С.Дж. Евангелиста, Д.Дж. Филд, А.Б. МакБратни, Б. Минасны, В. Нг, Х. Падарян, М.Р. Добарко, А.МЖ-К. Ваду. // Soil Security. 2023. Т. 10. Ст. № 100086 (на английском языке)
3. Имашев А. Исследование возможных зон неупругой деформации горного хребта. / А. Имашев, А. Суимбаева, Н. Жолмаганбетов, Н. Таханов, Н. Абдимуталип. // News of the National Academy of

Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences. 2018. Т. 2. С. 177–184 (на английском языке)
4. *Кример Р.Е. Почвенная жизнь: интеграция многофункциональности «кто и как». / Р.Е. Кример, Дж.М. Барел, Г. Бонджорно, М.Дж. Цветслут. // Soil Biology and Biochemistry. 2022. Т. 166. Ст. № 108561 (на английском языке)*
5. *Шафеа Л. Влияние микропластика на влажность, размер пор и насыщенную гидравлическую проницаемость верхнего слоя почвы лесс. / Л. Шафеа, B.J.M.N.L. Фельде, С.К. Вохе, Й. Бахманн, С. Пет. // Geoderma. 2023. Т. 437. Ст. № 116566 (на английском языке)*
6. *Вагг К. Биоразнообразие почвы и состав почвенного сообщества определяют многофункциональность экосистемы. / К. Вагг, Ф. Бендер, Ф. Видмер, М.Г.А. ван дер Хейден. // Proc. Natl. Acad. Sci. U.S.A. 2014. Т. 111 (14). С. 5266–5270 (на английском языке)*
7. *Лин Я. Адаптация почвенных грибов к загрязнению тяжелыми металлами на рисовых полях – пример из Восточного Китая. / Я. Лин, У. Сяо, Й. Яньмей, В. Цифан, Х. Имин, Ш. Хаокун. // Environtental Science and Pollution Research. 2020. Т. 27. С. 27819–27830 (на английском языке)*
8. *Байботаева А. Исследование влияния тяжелых металлов на почвенный покров и методы их биоремедиационного контроля. / А. Байботаева, Г. Кенжалиева, К. Жантасов, М. Жантасова, Е. Кочеров. // Серия геологии и технических наук. 2021. Т. 445. С. 52–57 (на английском языке)*
9. *Уолл Л. Изменение парадигм в микробиологии почвы в сельском хозяйстве и новые вызовы в микробной экологии. / Л. Уолл, Л. Габбарини, А. Феррари, Ж. Френе, Дж. Ковелли, Д. Рейна, Н. Робледо. // Acta Oecologica. 2019. Т. 95. С. 68–73 (на английском языке)*
10. *Гонмадже К. Экологическая фильтрация определяет закономерности состава видов деревьев в небольших горах Атлантической Центральной Африки. / К. Гонмадже, Ч. Думенж, Т. Сандерленд, Д. Маккей. // Acta Oecologica. 2019. Т. 94. С. 12–21 (на английском языке)*
11. *Палансурия К.Н. Почвенные смеси для иммобилизации потенциально токсичных элементов в загрязненной почве: критический обзор. / К.Н. Палансурия, С.М. Шахин, С.С. Чен, Цанг, К.В. Даниэль, Ю. Хашимото, Д. Хоу, Н.С. Болан, Дж. Ринкл, Ю.С. Ок. // Environtent International. 2020. Т. 134. Ст. № 105046 (на английском языке)*
12. *Тан В. Загрязнение тяжелыми металлами в поверхностных отложениях репрезентативных лимнических экосистем Восточного Китая. / В. Тан, Б. Шан, Х. Чжан, В. Чжан, Ю. Чжао, Ю. Дин, Н. Ронг, С. Чжу. // Scientific Reports. 2014. Т. 4. Ст. № 7152 (на английском языке)*

Information about the authors:
Abdraimova K.T., Candidate of biological Sciences, Associate Professor Khoja Akhmet Yassawi International Kazakh-Turkish University (Turkistan, Kazakhstan), *kuralai.abdraimova@ayu.edu.kz;* https://orcid.org/0000-0002-6390-2111
Toychibekova G.B., Doctor of Ph.D, Associate Professor Khoja Akhmet Yassawi International Kazakh-Turkish University (Turkistan, Kazakhstan), *gaziza.toychibekova@ayu.edu.kz;* https://orcid.org/0000-0003-3575-3021
Shalabaeva G.S., Candidate of Technical Sciences, Associate Professor Khoja Akhmet Yassawi International Kazakh-Turkish University (Turkistan, Kazakhstan), *gulshat.shalabaeva@ayu.edu.kz;* https://orcid.org/0000-0003-3605-4708
Seitmetova A.M., Candidate of Biological Sciences, Associate Professor, Khoja Akhmet Yassawi International Kazakh-Turkish University (Turkistan, Kazakhstan), *aiman.seitmetova@ayu.edu.kz;* https://orsid.org/0000-0002-5321-9730

Авторлар туралы мәліметтер:
Абдраимова Қ.Т., биология ғылымдарының кандидаты, доцент м.а., Қожа Ахмет Ясауи атындағы Халықаралық қазақ-түрік университеті (Түркістан қ., Қазақстан)
Тойчибекова Г.Б., Ph.D, доцент м.а., Қожа Ахмет Ясауи атындағы Халықаралық қазақ-түрік университеті (Түркістан қ., Қазақстан)
Сейтметова А.М., биология ғылымдарының кандидаты, доцент, Қожа Ахмет Ясауи атындағы Халықаралық қазақ-түрік университеті (Түркістан қ., Қазақстан)
Шалабаева Г.С., техника ғылымдарының кандидаты, доцент м.а., Қожа Ахмет Ясауи атындағы Халықаралық қазақ-түрік университеті (Түркістан қ., Қазақстан)

Сведения об авторах:
Абдраимова К.Т., канд. биол. наук, и.о. доцента, Международный казахско-турецкий университет имени Ходжи Ахмеда Ясави (г. Туркестан, Казахстан)
Тойчибекова Г.Б., Ph.D, и.о. доцента, Международный казахско-турецкий университет имени Ходжи Ахмеда Ясави (г. Туркестан, Казахстан)
Сейтметова А.М., кандидат биологических наук, доцент, Международный казахско-турецкий университет имени Ходжи Ахмеда Ясави (г. Туркестан, Казахстан)
Шалабаева Г.С., канд. техн. наук, и.о. доцента, Международный казахско-турецкий университет имени Ходжи Ахмеда Ясави (г. Туркестан, Казахстан)