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Heavy metal content in the forest-steppe zone of the Southern Urals

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Abstract. Soil as the basis of the ecotope largely determines the macro- and microelement composition of the plants growing on it. The predominant soils in the steppe zone of the Southern Urals are chernozems, among which leached, ordinary and southern subtypes are widespread. Migration of elements in the "soil - plant" system is determined by the type of soil, properties, nature of parent rocks, as well as the specificity of the plant species and other factors. Studying the influence of geochemical features of soils on the ecological state and purity of raw materials of medicinal plants is an urgent problem. Local monitoring was carried out to study the content of chemical elements (zinc, copper, cobalt, nickel, lead, cadmium, iron) in the soils of the arable layer of the fields of OOO "Zaozerny" in the forest-steppe zone of the Southern Urals.

1 Introduction

The South Ural subregion of the biosphere was identified as an independent biogeochemical taxon based on the following factors: the presence of heterogeneous metallogenic belts – copper ore and mixed copper ore, enriching soils with such microelements as Cu, Zn, Cd, Ni, Co, Mn (which leads to different reactions of organisms to excess of these elements) and the geographical position of the subregion of the biosphere, characterized by climatic unity [1-3].

Currently, the Southern Urals zone is the most complex region of Russia in the ecological aspect, where, against the background of increased radiation, there are large objects of non-ferrous and ferrous metallurgy, metalworking, mechanical engineering, chemical industry enterprises, power plants, therefore, pollution of the external environment with heavy metals is significant, and natural and man-made biogeochemical provinces of the Urals are classified as territories with the greatest degree of ecological distress [4-6]. Growing degradation of the environment disrupts the natural balance in the food chain, which leads to the accumulation of potentially dangerous chemicals in the body of animals [7, 8].

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Heavy metals are among the most dangerous chemical pollutants (ecotoxicants) for the natural environment, which is due to the physiological and biochemical characteristics of their action and transfer along trophic chains. Pollution of the environment with heavy metals is currently becoming increasingly common, which significantly contributes to an increase in the intake of heavy metals through the food chain into the human body [9]. In connection with the growth of pollution of the biosphere, knowledge of the patterns of behavior and distribution of heavy metals in bioresources is of particular interest and great practical importance. The importance of understanding the problem of heavy metal pollution of agricultural products is determined by the fact that animals are at a higher level of the food chain, are used as food products, and also for bioindication of the state of the ecosystem by pollutants.

The environmental safety of livestock products, including horse meat, which is of great importance in the diet of the population of Bashkortostan, is one of the main factors in maintaining public health.

In this regard, this project plans to study the migration process of heavy metals in the biogeochemical chain: soil - plants - animals. The study area selected is farms located in the Bashkir Trans-Urals, which are negatively affected by mining enterprises. The background area was the Birsky District, located in the northwest and located at a considerable distance from industrial centers.

The interactions between the technosphere and the biosphere have increased in recent decades – a period that is insignificantly short compared to the period of animal evolution. Therefore, the adaptation mechanisms of living organisms, developed in the evolutionary process, are insolvent, unable to ensure homeostasis. This is manifested in a variety of violations of the integration of all processes in the body, the activity of individual systems and organs, and the development of various allergic reactions. In other words, the evolutionarily established relationships in the animal organism itself are violated. In this regard, the study of technogenic geochemical provinces is a new, extremely complex scientific task, the solution of which is necessary for a general ecological assessment of the functioning of the biosphere in the modern era and the search for more rational technologies. The complexity of the problem lies in the need to differentiate technogenic and natural flows and forms of migration of chemical elements, the interaction of technogenic factors, and the manifestation of unforeseen biological reactions in organisms [9, 10].

Considering that agricultural ecosystems are the main source of production of food products of plant and animal origin, and the productivity of animals and the quality of livestock products largely depend on the features of the biotic cycle in the agroecosphere and the geochemistry of agricultural landscapes, the aim of the work was to study the contamination of soils with heavy metals in OOO Zaozerny, Varna District, Chelyabinsk Region. The district is agricultural, but has its own geochemical features associated with copper ore zones. The Mikheevskoye porphyry copper ore deposit in the Varna District, Chelyabinsk Region, is one of the largest copper deposits in Russia: the international independent analytical consulting group CRU included the deposit in the top 50 largest copper deposits in the world. In addition, the territories of OOO Zaozerny border on the Kartalinsky District, where gold is mined by open-pit mining (45 mines). Gold mining waste (so-called tailings), mixed with hazardous reagents and metals, occupy large areas, having a negative impact on the environment.

2 Materials and methods

During the study, local monitoring was carried out to study the content of chemical elements (zinc, copper, cobalt, nickel, lead, cadmium, iron) in the soils of the arable layer.

Soil samples were taken in the upper arable layer (depth20 cm), according to GOST 17.4.3.01-83 "Soils. General requirements for sampling". For the soil study, 6 sample plots (SP) were selected: 1 PP - corn field; 2 PP - oat field; 3 PP - wheat field; 4 PP - barley field; 5 PP - vetch-oat field; 6 PP - natural forb field. Soil samples were collected and dried under natural field conditions.

The content of chemical elements in soils was determined by atomic absorption spectrophotometry on an AAS-30 spectrophotometer in accordance with Methodological Guidelines RD 52.18.191-89 "Methodological Guidelines. Methodology for Measuring the Mass Fraction of Acid-Soluble Forms of Metals (Copper, Lead, Zinc, Nickel, Cadmium) in Soil Samples by Atomic Absorption Analysis" and GOST 17.4.4.02-84 "Environmental Protection. Soils. Methods of Sampling and Preparing Samples for Chemical, Bacteriological, and Helminthological Analysis." To identify local geochemical features, concentration clarkes (CC) were calculated, showing deviations from the average content of chemical elements in the lithosphere.

The methodology of soil analysis for heavy metal content includes several key stages, starting with preparation and ending with interpretation of the results. First of all, it is necessary to determine the objectives of the study by selecting specific heavy metals such as lead, cadmium or mercury, as well as sampling areas. The study requires collecting information about the geographical and ecological features of the region, as well as possible sources of pollution.

Soil sampling is carried out using specialized equipment such as shovels, containers, and gloves. It is important to select sampling points based on preliminary analysis and contamination maps. Samples should be taken to a depth of 0-20 cm and 20-40 cm to assess the vertical distribution of metals. To obtain an average sample, combine several samples from different points. Packaging and labeling of samples are also important: each sample must be placed in a clean container and clearly marked.

After sampling, the samples should be prepared for analysis. The samples are dried at room temperature or in a drying cabinet, then crushed and sieved through a sieve with a mesh size of 2 mm to obtain a homogeneous mass. Methods such as atomic absorption spectroscopy (AAS) and atomic emission spectroscopy (AES) are used in the laboratory to determine the content of heavy metals. The samples are dissolved in acids to obtain the analyzed solutions, which are then subjected to quantitative analysis.

The data obtained is analyzed and calibrated based on standard samples. It is important to compare the results with acceptable levels of heavy metals in soils in order to assess the level of contamination and potential risks to human health and ecosystems. The final stage includes the preparation of a report describing the methods, results, and recommendations. All data should be stored for further monitoring and research, which allows for a reliable assessment of the environmental situation and the development of environmental protection measures.

3 Results and discussion

The results of the studies showed that the iron concentration in the surface soil layer of all fields exceeded the permissible levels (Table 1). The highest iron level (1.93 MAC) was found in the soils of the field where oats grow (2 PP), and the lowest iron level, which exceeded the MAC by 46.27%, was found in the soil layer of the field sown with vetch-oats (5 PP). A similar pattern was found for copper, the content of which in the soil of the field under oats (2 PP) exceeded 1.5 times, and in the soils of the field where vetch-oats grow (2 PP) - 1.3 times.

Table 1. Content of chemical elements in soil samples of land use of OOO Zaozerny, Varna district, Chelyabinsk region (M±m; mg/kg; n=18).

Chemical eleme	Iron	Copper	Zinc	Cobalt	Lead	Nickel	Manganese	Cadmium
1 PP	7511.12±8.43	136.24±0.32	46.54±0.15	11.97±0.07	27.53±0.05	58.42±0.79	257.2±0.76	7.13±0.04
2 PP	8112.31±14.12	150.86±0.41	58.67±0.08	8.78±0.04	29.61±0.17	56.61±0.09	342.16±1.52	6.59±0.03
3 PP	7431.76±17.54	138.42±0.37	51.69±0.08	17.91±0.09	31.63±0.24	54.27±0.38	305.12±0.61	6.18±0.04
4 PP	7287.11±8.97	136.24±0.53	51.87±0.09	21.65±0.06	30.98±0.06	57.47±0.75	312.23±0.12	6.32±0.05
5 PP	6142.13±11.12	129.83±0.21	53.61±0.07	9.71±0.05	31.65±0.09	63.27±0.11	365.18±1.61	6.75±0.04
6 PP	6543.49±19.48	135.29±0.41	56.42±0.19	15.84±0.09	27.38±0.14	55.31±0.35	268.26±0.79	5.78±0.03
MPC	4200,0	100,0	110.0	50.0	32.0	50.0	1500,0	5.0
Conventional world soil	3800	20	50	10	10	40	850	2
Optimal conten	1700	15-60	7-60	7-30	-	-	860	-

By comparing the values of the conventional world soil clarke with the values of the background content of chemical elements, we found that the maximum background values (Cf), amounting to 5852.16±8.57 and 93.84±2.33 mg/kg, are characteristic of iron and copper, respectively (Table 1). The high concentration of these elements is mainly due to the geochemical features of this territory, which is confirmed by the values of the concentration clarke coefficient (CC), which amounted to 1.54 for iron and 4.69 for copper.

For lead and cadmium, an increase in the background content relative to the values of the conventional world clarke was also established. Thus, the background concentrations (BC) of lead and cadmium in soils were 11.21±0.13 and 2.29±0.08 mg/kg, and the concentration clarkes (CC) were 1.12 and 1.15, respectively. The background concentrations of zinc, cobalt and nickel were close to the value of the conventional world clarke, the concentration clarkes of which were 0.70; 0.91 and 0.89, respectively. Manganese, in turn, is characterized by a reduced background content in the studied soils relative to the conventional world clarke (BC - 412.06±3.69 mg/kg; CC - 0.48).

At the second stage of the work, the obtained background average parameters of the content of chemical elements were compared with the microelement composition of the soils of Zaozerny LLC.

The analysis of the research results showed that two elements – lead and cadmium – are present in rather high concentrations, with concentration coefficients (Kc) of 2.44-2.82 and 2.52-3.11, respectively (Table 2). It should be noted that lead and cadmium are soil pollutants belonging to the first hazard class. Particularly high lead content was found in soil samples under wheat (3 PP) - 31.63±0.24 mg/kg, with a concentration coefficient (Kc3) of 2.82. The highest cadmium concentration is noted in the soil layer under corn (1 PP) - 7.13±0.04 mg/kg, which corresponds to a concentration coefficient (Kc1) of 3.11.

Four chemical elements (iron, copper, zinc and nickel) are typically found in higher concentrations in field soils relative to background values. Iron concentration coefficients are 1.05-1.38; copper - 1.32-1.60; zinc - 1.32-1.66; nickel - 1.16-1.78. In relation to the world clarke value, manganese deficiency is observed in all soils.

The content of nickel and cadmium in the soils of the land use of OOO Zaozerny amounted to an average of 1.08-1.25 MAC and 1.15-142 MAC, respectively. The content of zinc in the soils (46.54±0.15 - 58.67±0.08 mg/kg) was within the optimal level for the soil.

Analysis of the research results and their comparison with the optimal content of chemical elements in soils showed a decrease in the availability of cobalt and manganese to plants. Thus, the cobalt content in the soils of fields under corn (1 PP), oats (2 PP) and vetch-oats (5 PP) was11.97±0.07 mg/kg, 8.78±0.04 mg/kg and 9.71±0.05 mg/kg, respectively, and were at the lower limit of the optimal level for plants. The concentration of manganese in the soils of all fields was 2.33-3.31 times lower than the optimal values.

The content of TM in the soils of various ecosystems has not been systematically studied. The content of elements important from an agronomic point of view and soil formation processes has been studied most widely. Studies on the accumulation and migration of heavy metals are few and limited to cadmium, zinc, copper, and lead.

The main natural compound of molybdenum is molybdenite, or molybdenum luster. MoS2 is a mineral very similar in appearance to graphite. Man-made soil contamination with molybdenum is associated with the extraction, smelting and processing of metals, oil refining, and wastewater. Metallurgical enterprises annually emit more than 1.5 thousand tons of molybdenum to the earth's surface. The amount of molybdenum in soils is also related to its content in the parent rocks. The rocks of the studied region of the Southern Urals contain from 0.13 to 3 mg/kg of molybdenum. In soils, its amount varies from 0.1 to 2.17 mg/kg and correlates at a 90% probability level. The maximum molybdenum content was found in the soils of meadow ecosystems of the Yuryuzan-Ai foothill plain (p.15-99. Voznesenka, gray forest soil - 2.17 mg/kg; p.14-2000. Arkaulovo, gray forest undeveloped soil - 2 mg/kg; p.4-2000. Voznesenka, gray forest undeveloped soil - 1.13 mg/kg), minimal - on arable soils (up to 0.25 mg/kg). Obviously, active removal of molybdenum by agricultural crops takes place in the arable land. The reserves of molybdenum in the half-meter layer reach 13.9 kg/ha. The relationship of molybdenum with organic matter is also confirmed by a high correlation coefficient (r= 0.83 at P=95%).

The concentration of copper in the earth's crust is 14.3-25 mg/kg, and in the soils of the world 30 mg/kg. Copper is one of the most mobile heavy metals, which is confirmed by the research of scientists. For copper, concentrations of less than 15 mg/kg are completely insufficient for plants and animals, 15-60 is normal, and more than 60 mg/kg is toxic, causing chlorosis and plant diseases. With agricultural plants, 50-100 g of copper is removed from 1 ha.

The copper content in the rocks of the republic varies in a wide range - from 9.1 to 325.0 mg/kg, in soils it expands to 509 mg/kg (exceeding the maximum permissible concentration by 9.3 times). The main copper reserves are concentrated in the Trans-Ural foam, in a region with a developed mining industry. The maximum concentrations were found at the Uchalinsky Mining and Processing Plant. The mine, which features a combination of open-pit and mine methods, produces copper-zinc, zinc and sulfur-pyrite ores. Thus, in the upper horizon of the sod undeveloped soil in the section of the river20-2000, located 100 m from the plant, in a layer of 5-12 cm, the copper content is 513 mg/kg, in

the AU horizon in a layer of 13-20 cm is 505 mg/kg of soil. Soil of man-made origin was studied at a distance of 150 m from this section, where the copper content in the At horizon in the 0-5 cm layer is 526 mg/kg and in the CD horizon at a depth of 6-10 cm in tuff sandstone is 325 mg/kg. There is also a positive relationship between the copper content in the soil and rocks. According to the data, the average copper content in the soils of the Novosibirsk region ranged from 10.4 to 20 mg/kg. The dumps of the Uchalinsky deposit are composed of almond-stone basalts, andesite basalts, tuffs and breccias of the main composition, gabbro, gabbro-diorites (all together 50%), 15% are rhyolites, dacites, their tuffs and lavobreccias, 20% are sericite-quartz, sericite-chlorite-quartz metasomatites with inclusions of sulfides and poor pyrite ores; 15% are clay rocks. The rocks of the landfills are sulfidized to varying degrees, the amount of sulfides in the metasomatites reaches 9%. The weighted average copper content in the dumps reaches 0.05%, the amount is 224 thousand tons, zinc - 0.12% and 565 thousand tons. tons of sulfur - 2.35% and 11.1 million tons. The total volume of accumulated stripping at Uchalinsky GOK as of 01.01.2011 amounted to more than 500 million tons.

Despite the importance of copper in the formation of organic components, the functional dependence on the humus content was not reliable, which is typical for anthropogenic intake of the substance.

Chromium ranks 21st among the elements of the Earth's crust, its clarke is 122 mg/kg. The clarke of chromium in the soils of the world is 70 mg/kg (requirements). In the United States, chromium ranks third among pollutants in terms of prevalence in landfills and second after lead among inorganic compounds. The behavior of chromium in the region has hardly been studied. The chromium content in the soils of the republic ranges from 13.8 to 260 mg/kg, in metamorphosed eclogite shales of the Kiryabinka hospital (Trans-Ural peneplain) reaches 587 mg/kg. In most hospitals, the concentration of chromium in rocks is higher than in soils.

Cobalt is not widespread in nature, it occurs in combination with arsenic in the form of minerals: cobalt speiss and cobalt luster. This element enters the environment primarily with emissions from the metallurgical industry and amounts to about 800 tons per year. As is known, cobalt in trace amounts is required for the normal growth and development of plants and microorganisms, it is necessary for symbiotic nitrogen fixation. Cobalt is inherited in soils from the parent rocks.

Its content in the soil-forming and bedrock rocks of the Southern Urals varies in a relatively small range - from 1.6 to 37 mg/kg, in soils the average values are 6.8-19 mg/kg. When the cobalt content changes within these parameter boundaries, the relationship between them is reliable at a lower probability level compared to copper and chromium. At the same time, the cobalt content in the soil is closely correlated with the pH of the soil ($r = -0.80$ at $P=0.95$). The inverse relationship with the acidity of the medium corresponds to the well-known fact of increased sorption of cobalt by manganese oxides with increasing pH.

The main cobalt reserves are concentrated in the Yuryuzan-Ai foothill plain and the Trans-Ural peneplain. The accumulation of cobalt in the humus-accumulative horizons of the Trans-Ural foam is due not only to its intake from soil-forming and bedrock, but also to anthropogenic input. Thus, in the turf of the underdeveloped soil of the Akhunovo hospital (Trans-Uralsky peneplain), the cobalt content in the A1 horizon is 35 mg/kg, which is 2 times higher than in the rock. In the Yuryuzan-Ai foothill plain, its accumulation is primarily due to the natural conditions of soil formation. The supply of this element to the upper horizons of soils is provided by pumping cobalt compounds from the underlying layers by the root systems of forest and meadow vegetation. The cobalt content on the Ufa plateau and the Belebeevskaya plateau-like upland does not exceed the Clark world index.

Nickel, like cobalt, occurs in nature mainly in the form of compounds with arsenic or sulfur, for example, minerals kupernickel, arsenic-nickel gloss. Nickel is more abundant in the Earth's crust than cobalt (about 0.01%). This element is less actively fixed by soil components than cobalt. However, in micro quantities it is necessary for plants and microorganisms. Its most accessible forms, like lead and chromium, are associated with iron and manganese oxides. The sources of technogenic nickel intake into the soil are fuel combustion products, especially coal (700 tons/year in coal ash according to Bondarev, 1976), as well as waste from metallurgical enterprises. The nickel content in the soils of the Southern Urals varies in a very wide range - from 0.01 to 247 mg/kg, and in the parent rocks - from 10 to 148 mg/kg. There is a close correlation between these indicators, the correlation coefficient is g=0.96 (mountain A0) and g=0.99 (mountain AB). Studies in the soils of western Siberia have established a nickel content of 32.1-35.2 mg/kg.

The soils of the Yuryuzan-Ay foothill plain, the Trans-Ural peneplain and the Belebeyevskaya plateau upland are characterized by a nickel content above the Clark of the world, but below the MPC. The arable soils of Voznesenka and Bolsheustikinskoye hospitals have a low nickel content (like copper and molybdenum), often defined as zero (0.01 mg/kg). Apparently, crops in these areas may suffer from a lack of this element.

Antimony in nature occurs, as a rule, in combination with sulfur in the form of antimony gloss, or antimonite. The antimony content in the Earth's crust is relatively low (1 mg/kg). Geochemically, antimony is similar to arsenic, and it is highly mobile in the environment. It can accumulate in soils due to the extraction of non-ferrous metals, and the antimony content reaches 200 mg/kg near copper smelting plants.

Antimony is practically absent in the soils of the Ufa plateau (the maximum content is 0.7 mg/kg at the Baikie hospital). A small amount of this element was detected in the soils and soil-forming rocks of the Yuryuzan-Ai foothill plain, where it amounts to 0.1-3.7 mg/kg and usually increases down the profile.

High concentrations of antimony were found only in the Trans-Ural mining region, which is associated with the extraction and processing of polymetallic ores. In the upper horizons of soils, the maximum antimony content was detected at the Uchalinsky GOK hospital (7.3 mg/kg) and in the soil-forming rocks of the Komsomolskoye and Kiryabinka hospitals (11 mg/kg), which is 2-3 times higher than the maximum permissible concentration.

The main carriers and concentrators of heavy metals are ore minerals, accumulations of which form deposits and which are also present as inclusions in empty rocks. The main ore minerals of pyrite deposits are pyrite, chalcopyrite, and sphalerite. Magnetite, tennantite, bornite, arsenopyrite, and pyrrhotite are present in smaller quantities. In addition to their own chemical composition, these minerals possess a certain set of impurity elements, which, under the conditions of active exposure to environmental agents, can become mobile and become involved in migration. Pale ores are carriers of arsenic, mercury, and antimony.

The study areas vary significantly in terms of the total chemical pollution index. In the cleanest area of the Ufa plateau, the total pollution index does not exceed 8.5 units. and it belongs to the category of weak and acceptable soil pollution. The main role in pollution is played by molybdenum, whose share ranges from 13.7 to 69.6%. Chromium is in second place (9.9-30.4%), followed by cobalt, nickel and copper, the amount of which varies in a close range.

In the soils of the Yuryuzan-Ai foothill plain, the overall level of exposure to elements of the 2nd class of toxicity varies markedly depending on the ecosystem. Arable soils are characterized by the lowest total pollution indicators (1.0-3.6), meadows are the highest (1.3-40.3), forests occupy an intermediate position (16.0-26.0). The main contribution to the accumulation of elements of this class in the soils of all ecosystems in descending order is made by molybdenum (13.2-64%), cobalt (4.6-41%), copper (16.7-49.3%). The chromium and nickel content is generally negligible.

In the soils of the Trans-Ural peneplain, the total pollution index varies from 1.3 to 25.9 units. The minimum values are typical for the soils of the Komsomolskoye (meadow) and Kiryabinka (forest) hospitals, the maximum values are Akhunovo (forest) and Uchalinsky GOK (forest). As expected, copper makes up almost half of the load in soils near Uchalinsky GOK among the elements of the 2nd class of toxicity. The proportion of molybdenum (18.2-27.6%) and chromium (15.9-18.2%) is also high. In the soils of Safarovo, Kiryabinka and Akhunovo hospitals chromium has the advantage (41.1-65.1%), with a relatively high content of nickel (18.3-28.5%) and cobalt (7.6-24.4%).

The soils of the Belebeyevskaya plateau-like upland do not differ much in total chemical parameters and belong to the permissible category of pollution. At the same time, the main load on the elements falls on copper (24.4-41.2%). Next in descending order are: molybdenum (9.8-32.4%), chromium (16.1-27.6%), nickel (13.5-23%), cobalt (13.5-19.4%). Arable soils (2.2-2.7) and high forests (3.4-6.2) are characterized by the lowest total pollution indicators.

In general, the ecological situation in terms of elements of the 2nd hazard class increases in a number of geomorphological areas: Yuryuzano-Aiskaya foothill plain - Transuralsky peneplain - Ufa plateau - Belebeevskaya plateau-shaped upland.

Reserves of heavy metals (HTM) in a half-meter soil layer per unit area reflect the potential reserve used by plants in the process of their vital activity. The soils of the surveyed areas are subject to significant variation. The soils of the Yuryuzan-Ai foothill plain are characterized by high reserves of cobalt, nickel and chromium, comparable to the reserves of the Trans-Ural peneplene, where non-ferrous metals are mined (Uchalinsky GOK). The Trans-Ural foam is also characterized by an abnormally high copper content of 1293 kg/ha. The soils of the Belebeevskaya upland contain small reserves of copper, nickel and chromium compared to other areas.

Comparison of the obtained data with the values of the conventional world clarke with subsequent calculation of the concentration clarke showed that the copper content in the soils of the land use of Zaozerny LLC is 6-7.5 times higher than the conventional world clarke; lead and cadmium - 3-3.5 times; iron - 1.6-2 times; nickel - 1.5 times.

The content of heavy metals in soils is an important environmental problem, especially in regions with intensive industrial activity. Heavy metals such as lead (Pb), cadmium (Cd), mercury (Hg), nickel (Ni) and zinc (Zn) have high toxicity and the ability to accumulate in the biosphere, which leads to negative consequences for human health and the ecosystem.

In conditions of anthropogenic impact, especially in industrially developed regions, significant soil contamination with heavy metals occurs. The sources of this pollution can be emissions from industrial enterprises, road transport, the use of chemical fertilizers and pesticides, as well as unauthorized landfills. These factors contribute to the accumulation of toxic elements in soils, which raises concerns about their impact on ecosystems and public health.

Studies conducted in different regions show that the content of heavy metals in soils varies depending on the geographical location and type of land use. In urbanized areas, such as large cities, the level of soil contamination with heavy metals often significantly exceeds background values. For example, in areas adjacent to industrial facilities, concentrations of lead and cadmium can reach levels that pose a risk to human health and the ecosystem. These elements can accumulate in plants, which leads to their toxicity to animals and humans who consume contaminated products.

The environmental consequences of soil pollution by heavy metals include deterioration of the quality of soil resources, decreased fertility, and disruption of ecosystem processes. Toxic elements negatively affect the microbiological activity of the soil, which disrupts the decomposition of organic substances and biogeochemical cycles. This, in turn, can lead to a decrease in biodiversity and deterioration of ecosystems.

Various methods, including field studies and laboratory analyses, are used to assess the content of heavy metals in soils. Spectroscopic methods such as atomic absorption spectroscopy and inductively coupled plasma spectroscopy make it possible to accurately determine concentrations of toxic elements in soil samples. The data obtained is used for comparison with established norms and standards, which makes it possible to assess the level of contamination and its potential risks.

Taking into account the above, the content of heavy metals in soils is a serious environmental problem that requires an integrated approach to monitoring and management. Further research is needed to assess the long-term effects of pollution, as well as the development of effective methods for remediation and cleaning of contaminated areas. Sustainable land management and the introduction of environmentally sound technologies in industry can help reduce pollution and improve the environment. Thus, solving the problem of soil pollution with heavy metals is an important step towards ensuring public health and preserving ecosystems.

4 Conclusion

The conducted studies of soil samples under the farm's forage crops indicate a high content of iron, nickel, copper and cadmium, which, in our opinion, may be associated with deposits of iron-ammonium, copper and nickel ores.

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