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ASSESSMENT OF ECOLOGICAL SAFETY OF PLANT RAW MATERIALS OF CULTIVATED MEDICINAL PLANT SPECIES IN THE FOOTHILL ZONE OF ZAILIYSKY ALATAU

In the field of plant biodiversity conservation, the primary task is to create collections of living plants that ensure the preservation of the gene pool and serve as a scientific basis for conducting comprehensive experimental research. The ecological conditions of the cultivated medicinal plant plot of the Main Botanical Garden (Almaty), located in the steppe zone of the Zailiysky Alatau range within the North Tien Shan Mountain province, can indirectly influence the processes of organogenesis and the chemical composition of plants through the pollution of the atmosphere, soil, and water. One manifestation of anthropogenic impacts on plants is the presence of heavy metals in them, especially lead (Pb), cadmium (Cd), and mercury (Hg). Therefore, the issue of the ecological purity of medicinal plants is relevant, necessitating research to determine the content of heavy metals in the soil and plant raw materials. Soil and plant raw material samples were analyzed using generally accepted methods for chemical analysis of soils and plant raw materials. The article provides data on the morphogenetic properties of cultivated soils and plant raw materials of six cultivated medicinal plant species from the Lamiaceae family: *Betonica betoniciflora*, *Leonurus turkestanicus*, *Salvia deserta*, *Mentha longifolia*, *Thymus marschallianus*, *Ziziphora clinopodioides* regarding the content of toxic (Pb, Cd) and mineral (Zn, Cu) elements. It was found that the concentrations of heavy metals (Cd, Pb, Zn, Cu) in the soils of the plot are within the maximum permissible concentrations (MPC), and in the studied samples of plant raw materials do not exceed the MPC for food plants and plant-based biologically active supplements

Key words: Zailiysky Alatau, medicinal plants, morphogenetic properties of soils, heavy metals, ecological safety.

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Іле Алатауының тау бөктері аймағындағы дәрілік өсімдіктердің өсірілетін түрлерінің өсімдік шикізатының экологиялық қауіпсіздігін бағалау

Өсімдіктердің биологиялық әралуандылығын сақтау саласында генофондтың сақталуын қамтамасыз ететін және кешенді эксперименттік зерттеулер жүргізу үшін ғылыми негіз болатын тірі өсімдіктердің коллекцияларын құру бірінші кезектегі міндет болып табылады. Солтүстік Тянь-Шань таулы провинциясы, Іле Алатауы жотасының дала аймағында орналасқан Бас ботаникалық бақтың (Алматы қ.) өсірілетін дәрілік өсімдіктер учаскесінің экологиялық жағдайлары атмосфераның, топырақтың және судың ластануы арқылы жанама түрде өсімдіктердің органогенез процестері мен химиялық құрамына әсер етуі мүмкін. Өсімдіктердің құрамында ауыр металдардың, әсіресе қорғасынның (Pb), кадмийдің (Cd) және сынаптың (Hg) болуы, антропогендік әсердің көрінісі айқын байқалады. Осыған байланысты дәрілік өсімдіктердің экологиялық тазалығы проблемасы өзекті, ол өсімдік шикізатындағы және топырақтағы ауыр металдардың мөлшерін анықтау үшін зерттеулер жүргізуді қажет етті. Топырақ сынамалары мен өсімдік шикізатын талдау, топырақ және өсімдік шикізатын химиялық талдау бойынша жалпы қабылданған әдістерге сәйкес жүргізілді. Мақалада учаскенің мәдени топырағының морфогенетикалық қасиеттері және *Lamiaceae* тұқымдасы дәрілік өсімдіктерінің өсірілетін 6 түрінің: *Betonica betoniciflora, Leonurus turkestanicus, Salvia deserta*, *Mentha longifolia, Thymus* дік шикізатының уытты (Pb, Cd) және минералды (Zn, Cu) элементтер құрамы бойынша талдау нәтижесінің деректері келтірілген. Учаске топырағындағы ауыр металдардың (Cd, Pb, Zn, Cu) концентрациясы ШРК шегінде, ал зерттелген өсімдік шикізаты сынамаларында тағамдық өсімдіктер мен өсімдік негізіндегі биологиялық белсенді қоспалар үшін ШРК-дан аспайтындығы анықталды

Түйін сөздер: Іле Алатау, дәрілік өсімдіктер, топырақтың морфогенетикалық қасиеттері, ауыр металдар, экологиялық қауіпсіздік

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Оценка экологической безопасности растительного сырья культивируемых видов лекарственных растений в предгорной зоне Заилийского Алатау

В области сохранения биоразнообразия растений первоочередной задачей является создание коллекций живых растений, обеспечивающих сохранение генофонда и служащих научной базой для проведения комплексных экспериментальных исследований. Экологические условия участка культивируемых лекарственных растений Главного ботанического сада (г. Алматы), расположенного в степной зоне хребта Заилийский Алатау в пределах Северо-Тяньшанской горной провинции, опосредованно через загрязнение атмосферы, почвы и воды могут оказывать влияние на процессы органогенеза и химический состав растений. Одним из проявлений антропогенных воздействий на растения является присутствие в них тяжелых металлов, особенно свинца (Pb), кадмия (Cd) и ртути (Hg). В связи с этим проблема экологической чистоты лекарственных растений актуальна, что послужило необходимостью проведения исследований по определению содержания тяжелых металлов в почве и растительном сырье. Анализ почвенных проб и растительного сырья проводился по общепринятым методикам по химическому анализу почв и растительного сырья. В статье приведены данные морфогенетических свойств окультуренных почв участка и растительного сырья 6 культивируемых видов лекарственных растений из семейства Lamiaceae: *Betonica betoniciflora*, *Leonurus turkestanicus*, *Salvia deserta*, *Mentha longifolia*, *Thymus marschallianus*, *Ziziphora clinopodioides* на содержание токсических (Pb, Cd) и минеральных (Zn, Cu) элементов. Установлено, что концентрации тяжелых металлов (Cd, Pb, Zn, Cu) в почвах участка находятся в пределах ПДК, а в изученных пробах растительного сырья не превышают ПДК для пищевых растений и биологически активных добавок на растительной основе

Ключевые слова: Заилийский Алатау, лекарственные растения, морфогенетические свойства почв, тяжелые металлы, экологическая безопасность.

Introduction

One of the long-term objectives of the Global Strategy for Plant Conservation, as defined by Decision X/17 of the 19th Conference of the Parties to the Convention on Biological Diversity, is to "…conserve at least 75% of threatened plant species in *ex-situ* collections, preferably in the country of origin, and ensure the availability of at least 20% for recovery and restoration programs" [1].

In the field of conservation, particularly of medicinal, ornamental, and other beneficial plants, the primary task is to create collections of living plants that ensure the preservation of the gene pool and serve as a scientific basis for conducting comprehensive experimental research. The main activity of botanical gardens, tasked with the mission of *ex-situ* plant conservation, is associated with the mobilization and preservation of plant genetic resources [2–5].

The deterioration of the environment and climate change are universally and significantly transforming the productivity of Kazakhstan's plant cover, both natural and introduced flora. In this regard, research on the cultivation of economically valuable plants from natural habitats with predetermined valuable qualities, determining their ecological plasticity and ability for self-renewal in new growing conditions, is relevant. Such research has comprehensive significance for addressing theoretical questions of biomorphology, ecology, evolution, and plant introduction, and ultimately for ensuring the country's food and environmental security [6–9].

Purpose of Research: assessment of ecological safety of plant raw materials of medicinal plant species growing in urbanogenic conditions of the Main Botanical Garden (MBG, Almaty) in the foothill zone of the Zailiysky Alatau.

Materials and methods

The research objects were six plant species from the Lamiaceae family, cultivated in the medicinal plant plot of the MBG: *Betonica betoniciflora* (O. Fedtsch. & B. Fedtsch.) Sennikov, *Leonurus turkestanicus* V.I. Krecz. & Kuprian., *Salvia deserta* Schangin, *Mentha longifolia* (L.) L., *Thymus marschallianus* Willd., *Ziziphora clinopodioides* Lam. [10].

The research material included plant raw materials of the cultivated medicinal plant species and samples of the dark chestnut foothill soils of the medicinal plant plot of the MBG, located in the steppe zone of the Zailiysky Alatau range, subzone of the dark chestnut foothill soils (at an altitude of 750–850 (900) meters above sea level) within the North Tien Shan Mountain province [11].

The ecological conditions of the medicinal plant plot, indirectly through the pollution of the atmosphere, soil, and water, can influence the processes of organogenesis and the chemical composition of plants. One manifestation of anthropogenic impacts on plants is the presence of heavy metals in them, especially lead (Pb), cadmium (Cd), and mercury (Hg). In environmentally unfavorable areas (urban environments), plants accumulate toxic trace elements. Therefore, the issue of the ecological purity of medicinal plants is relevant, necessitating research on the content of heavy metals in them.

Soil research was conducted to determine the taxonomic affiliation of the soils in the plot, identify patterns of their formation under the conditions of medicinal plant cultivation, and assess the current state of the soil cover. Studies of edaphic conditions determine the relationship between the level of pollution or its absence in the soil-plant system.

Plant raw material samples for chemical analysis were collected during the flowering or early flowering phase of the plants. There were no external signs of environmental pollution effects on the plants (such as changes in color, size, or shape of vegetative organs). Chemical analysis of plant raw material samples was conducted for heavy metal content (Cd, Pb, Zn, Cu).

The fieldwork methodology included laying out soil profiles with morphological descriptions of the profile, sampling soil for chemical-analytical research. The depth of the soil profiles was determined by the depth of the parent rocks [12]. The soil profile description included: the sampling point number; the position of the profile relative to macro-, meso-, and micro-relief; description of the plant community; soil surface characteristics; description of genetic horizons. Genetic horizons were identified and described based on the following morphological indicators: horizon thickness; color and nature of the coloration; moisture; structure; composition; porosity; granulometric composition; neoplasms; inclusions; root system development. Taxonomic determination of soil type, subtype, and variety was performed according to the accepted classification [13, 14].

The main diagnostic features of the soils were determined by the following indicators: humus content, total nitrogen, mobile forms of nitrogen, phosphorus, and potassium, soil solution reaction (pH), absorption capacity (sum of absorbed bases), water-soluble salt content, granulometric composition, content of mobile forms of heavy metals. Soil samples were taken from genetic horizons characterizing the soil profile to determine the main physicochemical indicators of the soils and taxonomic determination of the type. To sample for heavy metal content (Cu, Cd, Pb, Zn), the envelope method was used at depths of 0–5 and 5–20 cm [15, 16] to identify the degree of possible contamination. Soil sample analysis was conducted using standard methodologies in a chemical-analytical laboratory. The assessment of analysis results was performed according to the methodology for chemical analysis of soils [17, 18].

Results and discussion

The Main Botanical Garden (MBG) in Almaty represents a complex of artificially created ecosystems, where to some extent, the negative impact of the urban environment is mitigated, and a high level of biodiversity is formed. The combination of a conservation regime and prolonged anthropogenic impact has led to the formation of dark chestnut cultivated soils with a set of characteristics and properties that differ from their natural counterparts [19–21].

The long-term cultivation of medicinal plants involves the use of agricultural techniques: planning the plot area, plowing, organizing planting sites, applying organic fertilizers, and a care system that includes loosening, weeding, irrigation, and more. The use of agricultural practices in creating medicinal plant plantations has led to the transformation of the soil profile. A characteristic feature of the identified soils is the alteration of the composition and structure of the upper part of the profile, due to the formation of planting beds with protective ridges, the extended humus horizon, and deep leaching from carbonates as a result of irrigation. With the prolonged use of agricultural techniques and medicinal plant cultivation, natural soils have acquired characteristics and properties that signify changes in the composition and structure of the morphological profile, physicochemical properties, determining their classification position. According to morphogenetic indicators, the soils of the medicinal plant plot are classified as normal cultivated dark chestnut foothill soils [15, 22].

The morphological characteristics of the foothill dark chestnut cultivated soils in the medicinal plant plot are presented in the description of the soil profile (Table 1), which was established on August 27, 2022, in the area with cultivated medicinal plant species.

The humus content in the upper arable horizon is low, ranging from 3.21% to 3.77%, gradually decreasing with depth to 1.68% to 2.44% (Table 2).

Table 1 – Morphological description of soils

Soil Profile	Horizon Thickness, cm	Morphological Characteristics
	0–4	Grayish-brown, moist, loose, weakly cloddy, medium loamy with plant roots
	4–14	Brownish-brown, moist, compacted, weakly cloddy-bouldery, medium loamy with plant roots
	14–30	Brownish-brown, dark, moist, compacted, cloddy-bouldery, medium loamy with small yellowish spots of the rock, rare plant roots
	30–50	Brownish-brown, yellowish with yellow clay spots, moist, compacted, bouldery with small gravel inclusions
	50–60	Yellowish-brown, wet, dense, bouldery, light loamy

Table 2 – Chemical properties of soils

Sample Depth, cm	Humus, %	Total Nitrogen, %	CO_2, %	pH	Absorbed Bases, mg-eq/100 g soil				
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	∑
0–4	3.21	0.169	0.34	7.6	13.60	3.20	0.50	0.28	17.58
4–14	3.77	0.186	0.34	7.5	14.40	3.20	0.52	0.11	18.23
30–40	2.44	0.125	0.37	7.5	13.60	3.20	0.65	0.10	17.55
50–60	1.68	0.084	1.09	8.4	15.20	1.60	0.57	0.13	17.50

The total nitrogen content varies within the range of 0.084% to 0.186%. The carbon to nitrogen ratio is wide at C:N=11–11.8, which characterizes low nitrogen availability in humus. The soils are leached of carbonates down to a depth of 60 cm, with a carbonate content not exceeding 0.34% to 1.09%, which is characteristic of foothill soils developing under conditions of periodic irrigation. The soil solution reaction is slightly alkaline (pH = 7.5–7.6) in the upper part of the profile, and alkaline (pH = 8.4) in the lower part. The sum of absorbed bases is low, ranging from 17.5 to 18.2 mg-eq per 100 g of soil, with uniform distribution of values by depth. The absorbed bases are predominantly calcium cation (77–87% of the total absorbed bases) with a minor contribution from magnesium cation (9–18% of the total). The availability of nitrogen in easily hydrolyzable compounds (2.6–3.5 mg/100 g) is very low to low (Table 3).

Table 3 – Provision of soils with mobile forms of nitrogen, phosphorus and potassium

Sample Depth, cm	Mobile forms, mg/100 g soil		
	Nitrogen	Phosphorus	Potassium
0–4	3.50	2.00	20.64
4–14	3.80	2.13	28.80
30–40	3.20	1.33	15.36
50–60	2.60	0.80	12.00

The availability of mobile forms of phosphorus (8.0–21.3 mg/100 g) is average in the upper and middle parts of the profile and very low in the transition horizon to the parent rock. The availability of mobile forms of potassium (12.0–28.8 mg/100 g) is high to average. The described soils are not saline with easily soluble salts, with the total salt content not exceeding 0.034–0.046% (Table 4).

Table 4 – Content of water-soluble salts in soils (% / mg-eq)

Sample Depth, cm	The total salt content, %	Alkalinity		Cl^{-1}	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}
		HCO_3^{-}	CO_3^{-2}						
0–4	0.034	0.015 0.24	0.000 0.00	0.005 0.15	0.004 0.08	0.006 0.30	0.001 0.10	0.002 0.07	0.001 0.03
4–14	0.037	0.017 0.28	0.000 0.00	0.005 0.15	0.005 0.10	0.006 0.30	0.001 0.10	0.001 0.05	0.002 0.05
30–40	0.039	0.015 0.24	0.000 0.00	0.005 0.15	0.008 0.16	0.006 0.30	0.001 0.10	0.003 0.11	0.001 0.02
50–60	0.046	0.020 0.32	0.000 0.00	0.005 0.15	0.009 0.18	0.007 0.35	0.002 0.15	0.002 0.10	0.001 0.02

The granulometric composition of soils is medium loamy with predominance of coarse dust (27.98%) and fine sand (20.48 %) fractions (Table 5). The presence of stony fraction in the upper horizons is observed in the amount of 2.91-2.97 %, which decreases with depth to 1.58-1.69 %. The distribution of silty-dusty fractions shows a maximum of their content in the upper part of the profile.

Table 5 – Granulometric composition of soils

Sample Depth, cm	Fractional content, %, fraction sizes in millimeters on absolutely dry soil								
	Stones	Gravel	Sand		Dust			Mud	<0.01
	□3	3–1	1–0.25	0.25–0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001	
0–4	2.91	0.09	17.47	20.48	27.98	8.77	12.38	12.92	34.07
4–14	2.97	1.99	16.10	21.47	28.31	8.27	11.22	14.63	34.12
30–40	1.69	0.00	18.66	21.38	27.93	7.90	11.60	12.53	32.03
50–60	1.58	0.00	11.25	22.84	38.89	7.28	10.56	9.18	27.02

One of the most important groups of toxicants that pollute the soil are heavy metals. These include metals with a density greater than 8,000 kg/m^3 (excluding noble and rare metals): Pb, Cu, Zn, Ni, Cd, Hg, Co, Sb, Sn, Be. Almost all heavy metals are toxic. The anthropogenic dispersion of this group of pollutants (including in the form of salts) in the biosphere leads to poisoning or the threat of poisoning living organisms. In our research, we analyzed cadmium (Cd), lead (Pb), zinc (Zn), and copper (Cu).

Cadmium (Cd): The content of this element in soils, in the absence of anthropogenic influence, is determined by the composition of the parent rocks [23, 24]. In the soil solution, it forms complex ions and organic chelates. The mobility of cadmium in soils depends on the reaction environment and the redox potential. Cadmium is more mobile in acidic environments and is more available to plants. Soil contamination with cadmium is one of the most dangerous ecological phenomena due to the potential for its accumulation in plants above normal levels even at low soil concentrations.

Lead (Pb): A priority toxicant element, soluble lead compounds are poisonous. The Clarke value of Pb in the Earth's crust is 16.0 mg/kg [25]. Compared to other heavy metals, it is the least mobile, with its mobility decreasing in alkaline soil solution (pH). Mobile Pb is present as complexes with organic matter (60–80% of mobile Pb) [26]. The natural content of lead in soils is determined by the mineralogical and chemical composition of the parent rocks [27]. In urban areas, soil contamination with lead is associated with vehicle exhaust and industrial emissions.

Zinc (Zn): Important factors affecting the mobility of Zn in soils include the content of clay minerals and the pH level. As pH increases, Zn forms organic complexes and binds with the soil. With organic matter, Zn forms stable compounds, resulting in its accumulation in soil horizons with high humus content. Elevated zinc levels in soils can be due to natural geochemical anomalies and technogenic pollution. In garden soils, zinc can accumulate to 250 mg/kg or more [27].

Copper (Cu) is a relatively inactive metal chemically and a weakly migratory element. The amount of mobile copper depends on the chemical and mineralogical composition of the parent rock, soil solution pH, and organic matter content [25, 28]. Most of the copper in the soil is bound with iron oxides, manganese, iron and aluminum hydroxides, montmorillonite, and vermiculite. Humic and fulvic acids form stable complexes with copper. At pH 7–8, the solubility of copper is minimal. The main signs of copper deficiency in plants are the slowing and cessation of reproductive organ formation. Soil contamination with mobile forms of heavy metals was not detected. Exceeding the maximum permissible concentrations (MPC) for copper, cadmium, lead, and zinc was not observed (Table 6).

Data on the content of mobile forms of heavy metals in soils, along with agrochemical indicators, provide an understanding of the ecological state of the soil cover in the studied area.

According to the results of soil research on heavy metal contamination (Cu, Cd, Pb, Zn), exceeding the MPC [29] for these indicators was not identified (Table 6).

Table 6 – Content of mobile forms of heavy metals in soils of the plot, mg/kg

No.	Depth, cm	Cu	Cd	Pb	Zn
L–02	0–5	0.20	0.06	0.00	2.46
	5–20	0.16	0.08	0.08	1.44
MPC		3	1	6	23

As a result of the research, it was found that the foothill dark chestnut cultivated soils of the medicinal plant plot are characterized by an extended humus horizon. This is due to the processes of humus leaching into the lower horizons of the soil profile under the influence of the periodic irrigation system and deep leaching of carbonates. The differentiation into genetic horizons is unclear, the structure is loose, and the composition of the upper horizons is loose. The humus content is low to very low (1.68–3.77%) with low nitrogen availability in the humus. The absorption capacity (by the sum of absorbed bases) is low, indicating a low sorption capacity with a low content of exchangeable cations that contribute to structure formation. The soils are leached of carbonates, not solonetzic, and do not contain easily soluble salts. They are medium loamy in granulometric composition.

The analysis of results on the content of nutrition elements (NPK) in soils of the site showed low and very low provision of soils with nitrogen of easily hydrolyzable compounds (2.6–3.5 mg/100 g); average and very low provision with mobile forms of phosphorus (8.0–21.3 mg/100 g); increased and average provision with exchangeable potassium (12.0–28.8 mg/100 g). No exceeding of the maximum permissible concentrations (MPC) of heavy metals in the plot soils was found.

The chemical composition of plants is formed under the simultaneous influence of various factors, which can be combined into two groups: internal, determined by plant physiology, and external, reflecting the influence of the surrounding abiotic and biotic environment. The biogenic migration of microelements is characterized by their involvement in the small biological cycle of substances (into organisms and their transformation products), during which differentiation and selective absorption of microelements occur. Zinc, copper, and cadmium, which are elements of weak accumulation and medium capture, are absorbed to the greatest extent, while lead is element of weak accumulation and very weak capture [30]. Biological absorption of microelements varies for different plant species growing under identical edaphic conditions.

The accumulation of various toxicants in parts of plants used as medicinal raw materials is due to the impact of technogenic pollution. The soil-ecological conditions of plant growth significantly influence the variability of the chemical composition of plants. A relationship has been established between the content of certain chemical elements in the soil and the production of specific groups of biologically active substances by plants [31, 32].

The chemical composition of plants is significantly determined by the physicochemical properties of soils (pH, granulometric composition, organic matter content, etc.), which influence the availability of microelements to plants, the biological characteristics of plant species, the intensity of anthropogenic load, and the physiological role of heavy metals [33]. The absence of natural accumulation limits of microelements in plants is the main prerequisite for conducting relevant research. Currently, when assessing the contamination of medicinal plant raw materials with heavy metals, the permissible levels adopted for tea, vegetables and fruits, and plant-based dietary supplements are used as indicative criteria for ecological purity [34–36].

Cadmium (Cd): an element of high toxicity. Cadmium ions are highly mobile in soils, easily translocate into plants, and enter the bodies of animals and humans through food chains. Cadmium salts possess mutagenic and carcinogenic properties and represent a potential genetic hazard. In human and animal nutrition, cadmium is a cumulative poison. The normal content of cadmium in plants is 0.05–0.2 mg/kg of air-dry mass, with a presumed maximum of 3 mg/kg [24]. The permissible level is 1.0 mg/kg [35].

The minimum content of the element was found in *Menta longifolia* plants, and the maximum in *Betonica betoniciflora* and *Salvia deserta* plants.

Lead (Pb): Under natural conditions, lead is present in all plants, but its role in metabolism has not been identified. Lead is one of the main components of chemical environmental pollution and is toxic to plants. Lead enters plants through two pathways: absorption by roots and leaves. Normal lead concentrations in plants are considered to be 0.1–5 mg/kg of air-dry mass, with a presumed maximum of 10 mg/kg [24]. The permissible lead concentration level is 6.0 mg/kg for plant-based dietary supplements [35].

The minimum content of the element was found in *Menta longifolia* plants, максимальное – в растениях *Ziziphora clinopodioides, Betonica betoniciflora* and *Salvia deserta* plants (Table 7).

Table 7 – Standardization of microelements content in plants, mg/kg dry matter according to V.B. Ilyin [24]

Element	Cd	Pb	Zn	Cu
Content				
Deficient	–	–	<20	<5
Normal	0-0.5	2–14	25–250	6–15
Toxic	>100	–	>400	>20
Average in the vegetation of continents [37]	0.035	1.25	30	8.0

Zinc (Zn): The primary functions of zinc in plants are associated with the metabolism of carbohydrates, proteins, and phosphates, the formation of auxin, DNA and ribosomes. The content in plants varies between 15–150 mg/kg dry matter. In industrial areas, zinc levels in plants can exceed background levels. The presumed maximum zinc content in plants is 300 mg/kg air-dry mass [24]. Plants that produce carbohydrates selectively absorb Zn. Zinc has weak phytotoxicity, which manifests with a significant increase in its soil content. Signs of zinc toxicity in plants appear when its content in tissues reaches 300–500 mg/kg dry matter [28].

The minimum content of the element was found in *Betonica betoniciflora* и *Salvia deserta* plants, while the maximum was found in *Menta longifolia* and *Leonurus turkestanicus* plants (Table 7).

Copper (Cu): In plants, copper is involved in photosynthesis, respiration, nitrogen reduction, and fixation processes. Copper is a component of oxidase enzymes such as cytochrome oxidase, ceruloplasmin, superoxide dismutase, urate oxidase, and others, and participates in biochemical processes as part of enzymes that catalyze substrate oxidation reactions with molecular oxygen. Plants that produce alkaloids selectively absorb Cu. The normal content of copper in plants is 3–40 mg/kg air-dry mass, with a presumed maximum of 150 mg/kg. Copper content in vegetation rarely exceeds 10 mg/kg [28].

The minimum content of the element was found in *Betonica betoniciflora* and *Salvia deserta* plants, while the maximum was found in *Menta longifolia* plants (Table 7).

The content of cadmium (Cd) and lead (Pb) in all plant raw material samples is not deficient, is considered normal, is not toxic, and is within average values for continental vegetation, not exceeding the maximum permissible concentrations (MPC) for dietary supplements and tea (Table 7).

The content of zinc (Zn) in plant raw material samples (*Betonica betoniciflora, Salvia deserta*) is slightly deficient, below normal, non-toxic, and below average values for continental vegetation. In plant raw material samples from *Leonurus turkestanicus, Menta longifolia, Thymus marschallianus, Ziziphora clinopodioides*, zinc content is not deficient, considered normal, non-toxic, and above average values for continental vegetation (Table 7).

The copper (Cu) content in all plant raw material samples is not deficient, is considered normal, is not toxic, and is within average values for continental vegetation, not exceeding the maximum permissible concentrations (MPC) for tea (Table 7).

No exceedance of the maximum permissible concentrations in plant raw materials was found (Table 8). Changes in the chemical composition of plants begin to occur with a tenfold increase in the total amount of heavy metals compared to the background content.

Table 8 – Heavy metal content in plants, mg/kg dry matter

Name of plant	Element			
	Cd	Pb	Zn	Cu
Betonica betoniciflora (O. Fedtsch. & B. Fedtsch.) Sennikov	0.0729	0.5017	2.1068	17.1223
Leonurus turkestanicus V.I. Krecz. & Kuprian.	0.0374	0.4578	2.1682	38.6319
Mentha longifolia (L.) L.	0.0108	0.2467	2.5611	49.2217
Salvia deserta Schangin.	0.0729	0.5017	2.1068	17.1223
Thymus marschallianus Willd.	0.0422	0.4038	2.3072	34.0608
Ziziphora clinopodioides Lam.	0.0623	1.0567	2.1326	32.0269
MPC for dietary supplements	1.0	6.0	–	–
MPC for tea	1.0	10.0	–	100.0

Conclusion

The first assessment of ecological safety of plant raw materials of six cultivated species of medicinal plants of *Lamiaceae* family on the content of toxic (Pb, Cd) and mineral (Zn, Cu) elements, as well as the results of soil analysis of the collection plot of medicinal plants of the Main Botanical Garden (Almaty), indicate that their content depends on the species of plants. The results of assessment of ecological safety of plant raw materials of medicinal plants species tested in the conditions of MBG of

Almaty can be used for further studies of ecological purity of medicinal plant raw materials.

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Conflict of interests

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References

1.Global Strategy for Plant Conservation. The targets. 2011-2020 // URL: https://www.cbd.int/gspc/targets.shtml

2...Kunming-Montreal Biodiversity Framework Program. [Electronic resource]. URL: https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-04-ru.pdf

3. Petrisheva T.Y., Morgacheva N.V. (2020.) Biodiversity: structure, problems and conservation prospects. IOP Conference Series: Earth and Environmental Science. Vol. 548. No. 7, 072011.

4. Tkachenko K.G. Collections of botanical gardens – modern practice of preservation and study of the diversity of the plant world // Hortus bot. 2019 б. – T. 14. – P. 94–102. URL: http:// hb.karelia.ru/journal/article.php?id=6385. DOI: 10.15393/j4.art.2019.6385.

5. Tkachenko K.G. The importance of collections of useful plants in botanical gardens for the conservation of floristic diversity // Study, conservation and rational use of the plant world of Eurasia: materials of the International scientific and practical conference dedicated to the 90th anniversary of the Institute of Botany and Phytointroduction. – Almaty, 2022. – P. 674–677.

6. Proskuryakov M.A. Monitoring of variability of medicinal plants of Kazakhstan // Study, conservation and rational use of the plant world of Eurasia: materials of the International scientific and practical conference dedicated to the 90th anniversary of the Institute of Botany and Phytointroduction. – Almaty, 2022. – P. 542–552.

7. Belyaeva T.N. Biological features of ornamental dicotyledonous perennial plants during introduction in the conditions of the southern taiga of Western Siberia: dissertation abstract for the degree of Doctor of Biological Sciences: 03.02.01 . – Tomsk, 2021. – P. 49.

8. Asiminicesei D., Vasilachi I.C., Gavrilescu M. Heavy Metal Contamination of Medicinal Plants and Potential Implications on Human Health // Revista de Chimie (Rev. Chim.), – 2020. – Vol.71. – Issue 7. – P. 16–36. URL: https://doi.org/10.37358/RC.20.7.8222

9. Message of the President of the Republic of Kazakhstan to the people of Kazakhstan dated September 01, 2020. "Kazakhstan in the new reality: time for action" – VII. Ecology and protection of biodiversity // URL: https://www.akorda.kz/ru/addresses/addresses_of_president/poslanie-glavy-gosudarstva-kasym-zhomarta-tokaeva-narodu-kazahstana-1-sentyabrya-2020-g

10. Grudzinskaya L.M., Gemedzhieva N.G., Nelina N.V., Karzhaubekova Zh.Zh. Annotated list of medicinal plants of Kazakhstan: Reference publication / – Almaty, 2014, – P. 200.

11. Sokolov S.I. Soils of Alma-Ata botanical garden // Bulletin of the Academy of Sciences of the KazSSR, 1946. – No. 11 (20). – P. 59–61.

12. Soil Survey. Manual on field research and soil mapping. – Moscow: Academy of Sciences of the USSR, 1959. – P. 340.

13. Classification and diagnostics of soils of the USSR. – Moscow: Kolos, 1977. – P. 223.

14. Shishov L.L., Tonkonogov V.D., Lebedeva I.I., Gerasimova M.I. Classification and diagnostics of soils of Russia. – Smolensk: Oikumena, 2004. – P. 342.

15. GOST 17.4.3.01-83 Nature protection. Soils. General requirements for sampling.

16. GOST 17.4.4.02-2017. Interstate standard. Nature protection. Soils. Methods for sampling and preparation for chemical, bacteriological, and helminthological analysis (introduced by the order of Rosstandart dated April 17, 2018 N 202-st).

17. Arinushkina E.V. Guide to chemical analysis of soils. – Moscow: Moscow State University, 1962. – P. 491.

18. Myanina N.B., Arinushkina E.V. Methodological guide for interpreting soil chemical analysis results. – Moscow: Moscow State University, 1979. – P. 62.

19. Sokolov S.I., Assing I.A., Kurmangaliyev A.B., Serpikov S.K. Soils of the Alma-Ata region. // Soils of the Kazakh SSR. – Alma-Ata: Academy of Sciences of the Kazakh SSR, 1962. – Issue 4. – P. 423.

20. Rappoport A.V., Lysak L.V., Marfenina O.A. The relevance of soil-ecological research in botanical gardens (on the example of Moscow and St. Petersburg). // Bulletin of the Moscow Society of Nature Researchers. Biological Department, 2013. – Vol. 118, No. 5. – P. 45–56.

21. Grigoryev, Fridland, 1964; Grigoryev G.I., Fridland V.M. On the classification of soils by the degree of cultural transformation. // Soil Science, 1964. – No. 5. – P. 1–4.

22. Permitina V.N. Formation of soil cover under the conditions of the introduction of tree species in the botanical garden. // Soil Science and Agrochemistry, 2016. – No. 2. – P. 17–26.

23. Mukherjee, S., Chatterjee, N., Sircar, A.et al.A Comparative Analysis of Heavy Metal Effects on Medicinal Plants //Appl. Biochem. Biotechnol. – 2023. – Vol. 195. – P. 2483–2518. URL: https://doi.org/10.1007/s12010-022-03938-0

24. Ilyin V.B. Heavy metals in the soil-plant system. – Novosibirsk: Nauka, 1991. – P.151.

25. Vinogradova, N., Glukhov, A., Chaplygin, V., Kumar, P., Mandzhieva, S., Minkina, T., Rajput, V.D. The Content of Heavy Metals in Medicinal Plants in Various Environmental Conditions: A Review // Horticulturae. – 2023. – No. 9. – P. 239–246. URL: https: // doi.org/10.3390/horticulturae9020239

26. Kalimoldina L.M., Sultangazieva G.S., Suleimenova M.Sh. Contamination of soils with heavy metal in the urban area of Almaty // Soil science and agrochemistry. – 2022. – No.3. – P. 38–45. https://doi.org/10.51886/1999-740X_2022_3_38

27. Kiran, Bharti R., Sharma R. Effect of heavy metals: An overview // Materials Today: Proceedings. – 2022. – Vol. 51. Part 1. – P. 880–885. https://doi.org/10.1016/j.matpr.2021.06.27828.

28. Naimanova A., Akhmetova S., Issayeva A., Vyrakhmanova A., Alipbekova A. Phytoaccumulation of Heavy Metals in South Kazakhstan Soils (Almaty and Turkestan Regions): An Evaluation of Plant-Based Remediation Potential // International Journal of Design & Nature and Ecodynamics. – 2024. – Vol. 19. –No. 2. – P. 451– 464.

29. Maximum Permissible Concentrations of Chemical Substances in Soil (MPC). – No. 3.01.056.97. Approved by the Chief State Sanitary Doctor of the Republic of Kazakhstan E.E. Durumbetov on November 29, 1997.

30. Rymbekova G.N., Akhmetova S.O. "Morphological Characteristics and Features of Soil Pollution in Almaty" // Scientific Collection «Inter Conf». – 2023. – No.182. – P. 167–170.

31. Rashid, Abdur, Brian J. Schutte, April Ulery, Michael K. Deyholos, Soum Sanogo, Erik A. Lehnhoff, and Leslie Beck. 2023. "Heavy Metal Contamination in Agricultural Soil: Environmental Pollutants Affecting Crop Health" Agronomy 13, no. 6: 1521. https://doi.org/10.3390/agronomy13061521

32. Ivanov V.B., Aleksandrova V.V., Tsyganova V.I. Assessment of Heavy Metal Accumulation in Plants. // Global Problems of Scientific Civilization, Ways of Improvement. Materials of the XV International Scientific and Practical Conference. – Stavropol: Paragraph Publishing House LLC, 2022. – Vol. 1. – P. 423–429.

33. Kamanina I.Z., Kaplina S.P., Salikhova F.S. Heavy Metal Content in Medicinal Plants. // Scientific Review. Biological Sciences, 2019. – No. 1. – P. 29–34.

34. Maximum Permissible Concentrations of Heavy Metals and Arsenic in Food Raw Materials and Food Products. URL: https://files.stroyinf.ru/Index2/1/4293731/4293731790.htm

35. SanPiN 2.3.2.1078-01. Hygienic Requirements for the Safety and Nutritional Value of Food Products. Moscow, 2001.

36. SanPiN 2.3.2.560-96. Hygienic Requirements for the Quality and Safety of Food Raw Materials and Food Products. – Moscow, 1996.

37. Kashin V.K. Content of Microelements in Couch Grass in Western Transbaikalia // Agrochemistry, 2020. – No. 3. – P. 55–61. DOI: 10.31857/S0002188120030072

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