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Heavy metals accumulation by the vegetation of the territory of the East Kazakhstan

Abstract: The objective of this work was study and assessment of the main regularities of distribution of forms of finding of the heavy metals: Cu, Zn, Mn, Co, Pb, Cd, in the plants of the territory of the east Kazakhstan. It was found that the same species of a plant accumulates the different number of HM on different types of soils. The vibration amplitude of content of the researched elements in species of the plants growing on various types of soils makes 1.1 – 6.3 times. Varying of the HM content in botanical plant families is in a small range. Zinc is characterized by a basipetal distribution along the morphological organs of plants, for the copper and manganese the acropetal distribution is characteristic. The coefficient of biological absorption of all elements was higher in plants of the family *Fabaceae Lindl.*

Key words: heavy metals, biogenic migration, accumulation, botanical families, coefficient of biological absorption.

Introduction

The east region of Kazakhstan includes the territories of the former nuclear test site and the areas of the reserve zone of the Abai Museum-Reserve (fig.1). Detailed studies in this area have not been carried out, therefore there is insufficient data on the background content of heavy metals in natural objects, including plants, which are used in most cases as a natural standard. Today the research of the content in the environment of toxic at high concentrations of substances is the largest social and economic issue. The most priority pollutants of the natural environment are heavy metals (HM), especially Pb, Cd, Zn, Cu. This is due to both the trends in the development of industry, and physiological and biochemical features of HM, their high level of toxicity and the ability to accumulate in living organisms.

Figure 1 – A map of Kazakhstan, highlighted in red – eastern Kazakhstan

Very important and actual problem is the development of scientific bases for monitoring the content of HM in natural objects, including plants, of great scientific and practical interest. It is necessary to control the content of HM in the environmental objects of different regions, and first of all in plants that are the main source of most chemical elements for living organisms and a highly informative indicator of their level in the biosphere. The chemical composition of the plant is a result of the selective relationship of organisms to elements of content in the soil [1, 2]. In various geochemical conditions, the chemical composition and metabolism of plants, even in the representatives of one species, can differ significantly [3]. The plant specific features, soil type, concentration, form of HM finding, soil pH, its granulometric composition, organic matter content, cation absorption capacity in soil, availability of technogenic sources of ecosystem pollution has impact on flow of HM into plants [4-6]. The distribution of HM in the plant is in turn dependent on the physiological functions performed by the various organs of the plant, their morphological structure and the physiological functions performed by the chemical elements. Due to selective absorption, the chemical elements enter the plant in favorable for life proportions.

The work aim was determination of the regional background level of accumulation of HM by different species, morphological organs and families of wild vegetation of the study area.

Experimental

In this work the zonal typical plants of the steppe and desert-steppe zone were studied, in total 100 plant samples, 18 species from six families, were studied. For tests were taken samples of all of the genetic horizons of the soil profile. The samples of all of the genetic horizons of the soil profile were taken for investigations. Definition of macrocomposition of all tests of soils (pH, a humus, CO_2 of carbonates, granulometric composition) was carried out by standard methods. The content of heavy metals in the explored soils was determined on the KFK-3 device by a photocolorimetric dithizone method by G.Ya. Rin'kis's recipe [6-10]. The reproducibility of the method was equal to ± 4.2%. Selection of fractions of Pb and Zn was carried out by method of parallel extraction. All analytical data were processed by mathematical analysis and mathematical statistics in soil science according to E.A. Dmitriev [7].

Results and discussion

It has shown (Table 1), that the same plant species accumulates different amounts of HM on different soil types [7, 11-15]. The content of the investigated elements in plant species growing on different types of soils varies: copper – 1.1 – 3.5 times, zinc – 1.1 – 3.2 times, manganese – 1.1 – 2.5 times, cobalt – 1.1 – 2.0 times, lead – 1.1 -3.3 times, cadmium – 1.1 – 6.3 times. Differences in the accumulation of HM by the same species on different soil types are due to both the biological characteristics of plants and the ecological condition-differences in the content and bioavailability of the elements in the soils [12-14].

According to the results of the research, the content of HM in the plants of the botanic families studied is distributed in the following order of decrease (Table 2):

- on Cu: *Chenopodiaceae > Asteraceae > Cyperaceae > Poaceae, Limoneaceae > Fabaceae;*
- on Zinc: *Limoneaceae > Chenopodiaceae > Cyperaceae > Poaceae > Asteraceae > Fabaceae;*
- on Mn: *Cyperaceae > Fabaceae > Chenopodiaceae > Asteraceae , Limoneaceae > Poaceae;*
- on Co: *Poaceae > Fabaceae > Chenopodiaceae > Asteraceae , Limoneaceae > Cyperaceae;*
- on Pb: *Poaceae > Chenopodiaceae > Fabaceae > Asteraceae , Cyperaceae > Limoneaceae;*
- on Cd: *Asteraceae > Fabaceae > Limoneaceae > Chenopodiaceae > Cyperaceae, Poaceae.*

Varying the HM content in the various botanical families of plants is in a small range and amounts to an average: copper – 35.0%, zinc – 19.0%, manganese – 34.8%, cobalt – 46.7%, lead – 43.3%, cadmium – 51.5%. Due to selective absorption, chemical elements enter the plant in favorable proportions for life [8-10]. This is especially evident in various plant organs, where chemical elements have their specific function.

The distribution of HM content by plant organs is presented in Table 3. It has been found that zinc is characterized by a basipetal distribution over the organs of plants, for copper and manganese it is acropetal. Cobalt, lead, and cadmium are differently distributed over the morphological organs of plants. They are characterized by the greatest accumulation in the roots with a decrease in leaves and stems. The stems contain a minimum number of them.

Table 1 – HM content in the plant species growing on various types of soils

Type of soil	Cu	Zn	Mn	Co	Pb	Cd
Artemisia terrae-albae Krasch						
Ch_1	1.4/0.1	13.6/0.8	84.2/0.1	0.9/0.2	1.3/0.1	0.24/0.53
M_1	1.1/0.1	14.5/0.6	61.1/0.1	0.6/0.1	0.6/0.05	0.46/0.56
S	3.8/0.2	4.6/0.2	153.9/0.2	1.2/0.2	2.0/0.2	0.2/0.1
Carex melanostachya Bieb. Ex. Wiild						
Ch_1	1.9/0.2	11.8/0.7	146.5/0.2	0.7/0.1	1.6/0.2	0.44/1.02
M_1	1.7/0.1	13.2/0.7	118.2/0.1	1.2/0.2	1.2/0.1	0.07/0.08
Goniolimon speciosum (L.) Boiss						
Ch_1	1.0/0.1	15.2/0.8	89.1/0.1	1.4/0.2	0.4/0.04	0.64/1.49
S	1.6/0.1	16.4/0.8	155.8/0.2	2.3/0.3	0.4/0.04	0.73/0.37
Limonium gmelini (Willd) O. Kuntze						
Ch_1	0.7/0.1	15.2/0.8	84.3/0.1	0.6/0.1	1.0/0.1	0.3/0.7
S	2.0/0.1	14.8/0.7	132.2/0.2	0.7/0.1	1.2/0.1	0.32/0.16
Salsola tamariskina Pall						
Ch_1	2.9/0.2	15.1/0.8	107.5/0.1	1.0/0.2	1.1/0.1	0.43/1.00
S	4.0/0.3	16.6/0.8	133.8/0.2	1.8/0.3	2.6/0.2	0.46/0.23
Stipa capillata(L.)						
Ch_1	1.7/0.1	9.4/0.5	9.4/0.01	1.7/0.2	2.2/0.2	0.19/0.72
S	3.0/0.2	10.6/0.5	10.6/0.01	1.8/0.2	4.0/0.3	0.37/1.5

Note: Ch_1 – light chestnut normal soils, M_1 – meadow light soils, S – solonchaks; in the numerator – the content of the element in the plant, mg / kg, in the denominator – the coefficient of biological absorption (CBA).

Table 2 – The content of heavy metals in various botanical families of plants in the study area

Plant family	n	Cu	Zn	Mn	Co	Pb	Cd
Asteraceae Dumort. Asters	20	2.3±0.4 1.1-4.0 (53)	11.3±1.5 3.6-15.8 (42)	114.8±25.4 97.3-997.1 (70)	1.0±0.1 0.4-1.7 (44)	1.4±0.3 0.4-3.8 (64)	0.69±0.20 0.18-2.07 (90)
Chenopodiace-ae Vent. Chenopodiaceae	12	3.3±0.2 2.6-4.1 (18)	15.0±0.8 14.7-17.0 (13)	116.4±11.3 82.1-150.9 (24)	1.3±0.4 0.6-2.9 (69)	1.6±0.3 0.8-2.9 (51)	0.43±0.02 0.35-0.53 (15)
Cyperaceae Juss. Sedge	14	2.1±0.2 1.6-2.9 (24)	12.3±0.4 10.4-13.4 (9)	130.1±14.1 103.0-197.8 (29)	0.7±0.1 0.4-1.2 (39)	1.4±0.2 0.9-2.0 (30)	0.42±0.07 0.07-0.64 (45)
Fabaceae Lindl. Beans	18	1.6±0.1 1.1-2.0 (25)	10.7±0.7 7.8-14.1 (20)	128.4±13.9 91.2-188.7 (33)	1.5±0.2 0.8-2.6 (40)	1.5±0.1 1.0-2.2 (27)	0.56±0.15 0.12-1.63 (81)
Limoneaceae Lincz. Thrift	18	1.9±0.4 0.5-4.9 (66)	15.3±0.3 14.5-16.5 (6)	114.6±14.3 70.0-194.8 (37)	1.0±0.2 0.6-2.3 (55)	0.9±0.1 0.4-1.4 (44)	0.44±0.06 0.28-0.73 (42)
Poaceae Barnhart The bluegrass	18	1.9±0.2 1.4-3.0 (26)	11.5±0.8 7.7-15.9 (21)	11.3±0.6 10.3-13.8 (16)	1.6±0.2 0.6-2.3 (33)	2.0±0.3 1.2-4.0 (44)	0.42±0.05 0.19-0.73 (36)

Note: n is the number of samples; in the numerator – the arithmetic mean and its error, mg/kg; in the denominator – the range of variation, mg / kg, in parentheses – the coefficient of variation, %.

As can be seen from these series, the CBA of all elements appeared to be higher in the plants of the family *Fabaceae Lindl.* In general, for the area under study, it is characteristic that copper, manganese, cobalt, and lead are classified as a group of elements of average absorption by the level of biological absorption of plants; zinc, cadmium – to the group of elements of intensive absorption. For the latter, biogenic migration, apparently, can act as the main factor in the migration of these elements in the landscape.

Conclusion

It was found that differences in the accumulation of heavy metals by the same species on different types of soils are due to both the biological characteristics of plants and the ecological condition – differences in the content and bioavailability of elements in a particular soil. The content of the investigated elements in plant species growing on different soil types varies: copper – 1.1 – 3.5 times, zinc – 1.1 – 3.2 times, manganese – 1.1 – 2.5 times, cobalt – 1.1 – 2.0 times, lead – 1.1 -3.3 times, cadmium – 1.1 – 6.3 times. Varying of the content of heavy metals in botanical plant families is in a small range and amounts to an average: copper 35.0%, zinc 19.0%, manganese 34.8%, cobalt 46.7%, lead 43.3 %, cadmium – 51.5%. Zinc is characterized by a basipetal distribution according to the morphological organs of plants, and acropetal distribution is typical for copper and manganese.

Table 3 – The HM content in the organs of a common set of wild plants (n = 100)

Element	Root	Stalk (stem)	Leaf
Cu	2.6±0.3 0.5-6.3 (36)	1.8±0.3 0.5-6.3 (51)	1.7±0.3 0.5-4.1 (39)
Zn	11.8±0.7 3.4-15.8 (18)	13.9±2.8 3.5-26.6 (30)	15.1±1.0 2.7-21.2 (22)
Mn	135.7±23.7 8.6-677.6 (48)	83.5±15.2 6.3-274.7 (50)	78.4±6.7 10.0-189.0 (21)
Co	1.7±0.4 0.4-4.8 (62)	0.8±0.2 0.1-3.2 (69)	1.1±0.2 0.2-3.1 (43)
Pb	2.0±0.4 0.3-7.2 (51)	1.0±0.2 0.1-4.1 (58)	1.3±0.2 0.2-3.5 (39)
Cd	0.67±0.14 0,10-2.88 (58)	0.34±0.06 0.02-1.29 (56)	0.51±0.11 0.04-2.03 (54)

Note: n is the number of samples; in the numerator – the arithmetic mean and its error, mg/kg; in the denominator – the range of variation, mg/kg, in parentheses – the coefficient of variation, %.

Cobalt, lead and cadmium are characterized by the greatest accumulation in roots with a decrease in leaves and stems (stalk). The stems contain a minimum number of them. For copper, zinc is characterized by intense absorption by stems, less leaves, roots, the coefficient of biological absorption (CBA): $CBA_{Stalk\ (stem)} > CBA_{leaf} > CBA_{root}$; for Pb, Mn – $CBA_{root} > CBA_{stalk\ (stem)} > CBA_{leaf}$; for Co, Cd – $CBA_{root} > CBA_{leaf} > CBA_{stalk\ (stem)}$. By the value of CBA Cu, Co refers to the elements of medium biological capture and weak accumulation in plants; Zn, Mn, Pb – to elements of strong biological accumulation; Cd – to elements of vigorous biological accumulation. CBA of all elements was higher in plants of the family *Fabaceae Lindl.*

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