Materials Today: Proceedings 33 (2020) 1187–1191

Contents lists available at ScienceDirect

Materials Today: Proceedings

journal homepage: www.elsevier.com/locate/matpr

Heavy metals accumulation in plants of the dry-steppe zone of the East Kazakhstan region

L.R. Sassykova [a], Y.A. Aubakirov [a], M. Sh. Akhmetkaliyeva [a], A.R. Sassykova [b], S. Sendilvelan [c], M. Prabhahar [d,*], S. Prakash [d], Zh.Kh. Tashmukhambetova [a], T.S. Abildin [a], A.K. Zhussupova [a]

[a] Al-Farabi Kazakh National University, 71, al-Farabi ave., Almaty 050040, Kazakhstan
[b] Almaty College of Economics and Law, 9, Nauryzbay Batyr str., Almaty 050004, Kazakhstan
[c] Department of Mechanical Engineering, Dr.M.G.R. Educational and Research Institute, University, Chennai 600095, Tamilnadu, India
[d] Department of Mechanical Engineering, Aarupadai Veedu Institute of Technology, VMRF, Chennai 603104, Tamilnadu, India

ARTICLE INFO

Article history:
Received 11 July 2020
Received in revised form 25 July 2020
Accepted 29 July 2020
Available online 11 September 2020

Keywords:
Heavy metals
Accumulation
Coefficient of biological absorption
Geochemical specialization
East Kazakhstan

ABSTRACT

In this article data of a long-term research of the main regularities of distribution of heavy metals (Cu, Zn, Mn, Co, Pb, Cd) in plants of dry-steppe zone of the East Kazakhstan region are described. The field under study is of considerable scientific significance, as it includes the former nuclear plant of Semipalatinsk, as well as the protected area of the Abai Museum-Reserve. Zone typical plants of a steppe and desert-steppe zone were investigated; all 100 tests of plants, 18 views from 6 families were studied. It is shown that the wild vegetation of the study region contains much higher amounts of lead than cobalt. A significant scatter in the content of heavy metals in wild plants is characteristic. The maximum change in heavy metals is observed in cadmium (72%) and manganese (62%), the minimum change in zinc (25%). For the researched region by the level of biological absorption by plants, copper, manganese, cobalt, lead belong to the group of elements of average absorption; zinc, cadmium – to a group of elements of intense absorption. For zinc and cadmium, biogenic migration, apparently, can act as the main factor in the migration of these elements in the landscape. For zinc a basipetal distribution in various parts of plants is shown, and for copper and manganese an acropetal distribution in various parts of plants is revealed. Cobalt, lead and cadmium are characterized by the greatest accumulation in the roots of plants, while the content of these heavy metals in plant stems is minimal.

Selection and Peer-review under responsibility of the scientific committee of the International Conference on Future Generation Functional Materials and Research 2020.

1. Introduction

Regulation of environmental quality is impossible without an adequate assessment of its current state. Obtaining such information based on the background study, evaluation and forecast of the state of natural objects, including plants, is the main task of the global environmental monitoring system. Information on these issues will help to predict the accumulation of these toxicants in products of plant origin, normalize their admission to the trophic migration chain and develop measures to limit this income in order to produce environmentally friendly products [1–4]. In connection with the growth of human impact on the biosphere, a real danger of its negative consequences on the environment has been created. The most important pollutants in the atmosphere, water and soils are heavy metals (HM) [5–9]. HM are special pollutants, so determining their content in the environment and monitoring their transformations in air, water and soil are mandatory and systematic. HM take the second place by degree hazards, second only to pesticides and well ahead of well-known pollutants such as carbon dioxide and sulfur. It is possible that they may become more dangerous in the future than waste from nuclear power plants and solid waste. Heavy metal pollution is associated with their widespread involvement in industrial production. Methods of cleaning industrial enterprises from the products of their activities are imperfect, so heavy metals fall into the environment, including the soil, polluting and poisoning it.

The establishment of theoretical bases for regulating the quality of HM in natural objects is an especially significant and urgent challenge because of the rise in the rate of industrial production

* Corresponding author.
E-mail address: mprabhahar@gmail.com (M. Prabhahar).

https://doi.org/10.1016/j.matpr.2020.07.660
2214-7853/
Selection and Peer-review under responsibility of the scientific committee of the International Conference on Future Generation Functional Materials and Research 2020.

[10–12]. Data on the historical quality of HM of the observed territory's natural resources is very useful from a realistic point of view, because it offers knowledge on the resilience of habitats of relation to future temperature and geochemical shifts due to global and regional anthropogenic impacts. In fact, these data offer an ability to forecast food, animal and human epidemiological diseases [13–17]. Intake of HM into plants is influenced by factors such as plant types, soil type, concentration, soil composition, soil pH, particle size distribution, organic matter content, cation absorption ability in soil, and the presence of anthropogenic pollution sources. In addition, the distribution of HM within the plant depends on the physiological functions performed by the plant's various organs, their morphological structure and the physiological functions performed by the chemical elements [18–21]. Thus, the current selective absorption by plants of chemical elements should be viewed more broadly: not only as a collection of elements essential for metabolism, but also as an opposition to element entry. Selective absorption rates are numerous in a plant organism: from less alert (at the border of the root environment) to more rigid (in terrestrial organs, in particular at the border of stem seed (fruit). Chemical elements enter the plant in favorable proportions for life-activity due to selective absorption [22–24].

The purpose of the research was to define the level of HM accumulation by various types of wild vegetation of the East Kazakhstan region.

2. Materials and methods

East Kazakhstan region is located in the eastern part of Kazakhstan, on the border with Russia and China (Fig. 1a).

This area covers a very large variety of geological and climatic areas from the Altai in the east and eastern edges of the Kazakh steppes in the west of the region [4,25]. The flora and fauna of East Kazakhstan is amazing and diverse (Fig. 1b). About 90% of the republic's forest wealth is concentrated in the region. The study area's vegetation cover is characterized by considerable diversity and is typical of steppe, and partially desert-steppe zone [10,14,26–28].

Steppe and desert-steppe-zone typical plants were investigated in the research zonal; a total of 100 plant samples were analyzed, 18 species from 6 families. Samples of all available genetic horizons of the soil segment were taken for analyses. Standard methods were used to determine the composition of all the soil samples (pH, humus, CO_2 carbonates, distribution of particle size) [4,10]. The content of HM in the studied soils was determined on a KFK-3 device using the photocolorimetric dithizone method based on measurement of an optical density of the painted extract according to G.Ya.Rinkis's prescription [29–31]. The reproducibility of the method is ±4.2%, sensitivity of a method is 0.01 mkg/ml. The selection of fractions of heavy metals was performed by the method of parallel extraction. All analytical material is processed by the method of mathematical analysis and mathematical statistics in soil science according to the method of E.A. Dmitriev [24,30].

3. Results and discussions

The features of absorption of chemical elements by vegetation, described in the scientific literature [18,22,32–40], are mainly manifested in the study area.

The distribution of HM in vegetation has the following descending series: Mn > Zn > Cu > Pb > Co > Cd (Table 1). Wild vegetation of the studied region has a significant amount of lead than cobalt. Characteristic is a significant variation in the content of HM in wild plants. The maximum variation of HM occurs in cadmium (72%) and manganese (62%), the minimum variation in zinc (25%).

The significant variability of metals in plants is due to their genotypic specificity, their geochemical and ecological environment. To assess the geochemistry and physiological role of each chemical element, it is important to know not only its content, but also the intensity of utilization of this element by the plant [35]. As shown in Table 1 according to the value of coefficient of biological absorption (CBA), which indicates how many times the element content in plant ash is more than in the lithosphere, Cu, Co are elements of the average biological capture and weak accumulation in plants; Zn, Mn, Pb – refers to the elements of strong biological accumulation and Cd - to the elements of energetic biological accumulation (in calculating the CBA, the average content of elements in the crust was calculated by A.P. Vinogradov [34,35]).

According to the CBA level, the elements under study are in the following descending order:

Cd (45.9) > Zn (2.1) > Mn (1.2) > Pb (1.1) > Co (0.9) > Cu (0.6).

Data on the ecological regularity of the accumulation of heavy metals by the same plant species on different types of soils are shown in Fig. 2.

The results of this study show that the same plant species accumulates different amounts of heavy metals on different types of soils [12,13,41–43]. So, for example, the content of the heavy metals under study changes as follows: 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. It was revealed that the content of heavy metals in the families of plants of the studied area depends on both their content in the soil and the situation with the mineral nutrition characteristic of the given type of soil.

Fig. 1. East Kazakhstan: a- a map of Kazakhstan regions, East Kazakhstan region is shown by red color; b- picturesque vegetation of the East Kazakhstan. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 1
Results of determination of heavy metals content in the general vegetation population of the study area (n = 100).

Element	In dry weight of plants			In the ashes of plants			CBA
	K_v	M ± m	V	K_v	M ± m	V	
Cu	0.5–4.1	2.0 ± 0.1	43	6.6–84.0	26.4 ± 0.1	56	0.6
Zn	3.6–17.0	12.5 ± 0.4	25	41.9–401.5	171.9 ± 11.7	48	2.1
Mn	7.7–297.1	100.9 ± 8.8	62	89.6–5,932.6	1,199.1 ± 142.1	84	1.2
Co	0.4–2.9	1.2 ± 0.1	50	3.0–74.1	15.3 ± 1.9	88	0.9
Pb	0.4–4.0	1.5 ± 0.1	47	2.9–64.8	18.2 ± 1.8	71	1.1
Cd	0.07–2.07	0.50 ± 0.05	72	0.80–27.04	5.97 ± 0.69	82	45.9

Note: CBA-Coefficient of biological absorption; n is the number of samples; K_v is a range of variation, mg/kg; M ± m is the arithmetic average and its error, mg/kg; V - coefficient of variation, %.

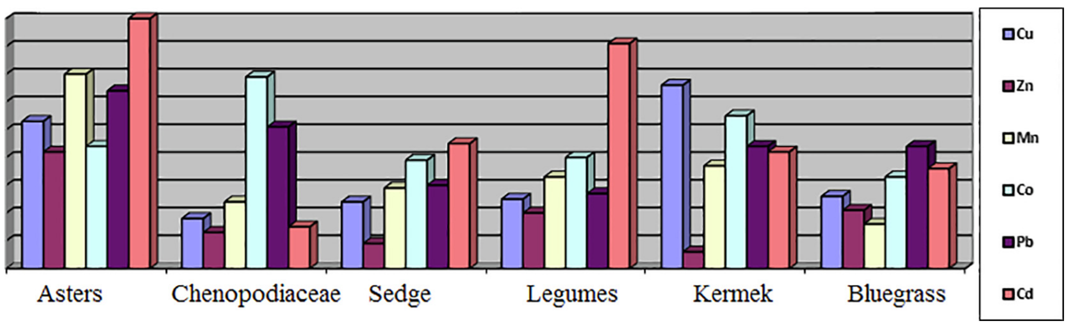

Fig. 2. The results of determining the content of heavy metals in various plant species growing on various types of soils in East Kazakhstan.

This is evidenced by the value of the coefficient of biological absorption (CBA), which allows us to indirectly judge the degree of availability of elements in the soil for plants. As a rule, the higher the CBA value, the greater the element content in the plant. Differences in the accumulation of heavy metals by the same plant species on different types of soil are related to both the biological characteristics of plants and environmental conditions, differences in the content and bioavailability of various chemical elements in soils [14,15].

The content of HM in plants of the botanical families studied is distributed in order, shown in Fig. 3.

The variation in the content of HM in the botanical families of plants in the study area is small and averages: copper-35.0%, zinc-19.0%, manganese-34.8%, cobalt-46.7%, lead-43.3%, and cadmium-51.5%. Due to selective absorption, chemical elements enter plants in favorable proportions for life [16–19]. This is especially noticeable in various plant organs, where chemical elements have a specific function.

The distribution of heavy metal content in different parts of plants is shown in Fig. 4.

Thus, it is established that zinc is characterized by a basipetal distribution in various parts of plants, and copper and manganese-by an acropetal distribution in various parts of plants. A slightly different pattern of distribution by morphological organs of plants was found for cobalt, lead and cadmium. These latter heavy elements are characterized by the greatest accumulation in the roots of plants, while the content of these heavy metals in plant stems is minimal.

4. Conclusion

The study of the features of heavy metals (Cu, Zn, Mn, Co, Pb, Cd) distribution in plants of dry-steppe zone of the East Kazakhstan region (Republic of Kazakhstan) have been described. The content of heavy metals in wild plants of the region is strongly dependent on their genetics, plant species. The high variability of content of heavy metals in plants is characteristic of wild-growing vegetation of the explored region. For the studied region by the level of biological absorption by plants, copper, manganese, cobalt, lead belong to the group of elements of average absorption; zinc, cadmium - to a

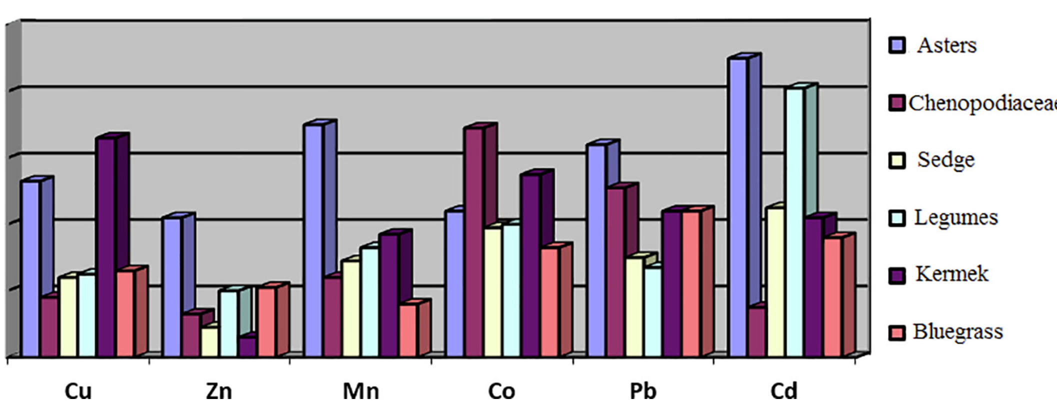

Fig. 3. Results of determining the content of heavy metals in various Botanical families of plants in the study area.

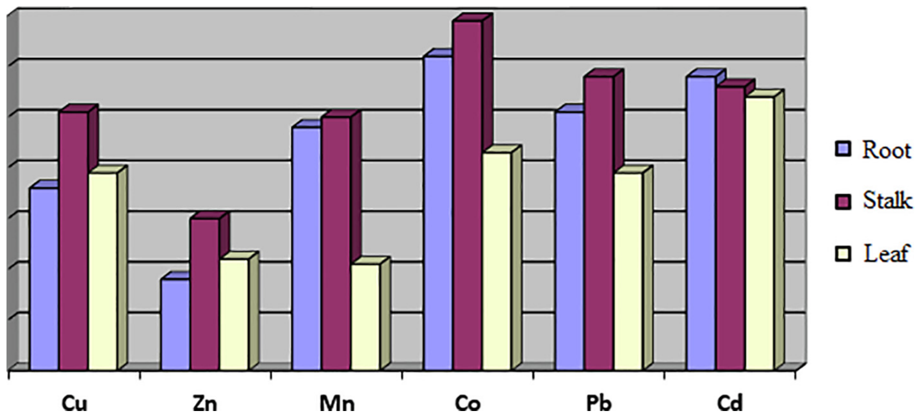

Fig. 4. Results for determining the content of heavy metals in plant parts with a total population of wild plants (n = 100).

group of elements of intense absorption. For zinc and cadmium, biogenic migration, apparently, can act as the main factor in the migration of these elements in the landscape. The variation in the content of HM in the botanical families of plants in the study area is small and averages: copper-35.0%, zinc-19.0%, manganese-34.8%, cobalt-46.7%, lead-43.3%, and cadmium-51.5%.

CRediT authorship contribution statement

L.R. Sassykova: Conceptualization. **Y.A. Aubakirov:** Software, Data curation. **M. Sh. Akhmetkaliyeva:** Writing - original draft, Visualization. **A.R. Sassykova:** Investigation, Supervision. **S. Sendilvelan:** Resources, Software, Validation. **M. Prabhahar:** Writing - review & editing. **S. Prakash:** Data curation, Editing and validation. **Zh.Kh. Tashmukhambetova:** Formal analysis. **T.S. Abildin:** Writing - original draft, Validation. **A.K. Zhussupova:** Methodology.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors are wishes to thank the management committee of Al-Farabi Kazakh National University, Almaty, Dr.M.G.R. Educational and Research Institute, University and Aarupadai Veedu Institute of Technology, VMRF for the continuous encouragement and support rendered then and there to do the research inside the campus and guiding them to do publication in this journal.

References

[1] B.J. Alloway, Heavy Metals in Soils, Blackie Academic and Professional, Suffolk, England, 1995, p. 368.
[2] X.S. Wang, Y. Qin, Int. J. Environ. Pollut. 33 (2008) 173, https://doi.org/10.1504/ijep.2008.019391.
[3] A. Mann, C. Reimann, P. de Caritat, N. Turner, M. Birke, Geochem.: Explor. Environ. Anal. 15 (2015) 99–112, https://doi.org/10.1144/geochem2014-279.
[4] M.Sh. Akhmetkaliyeva, L.R. Sassykova, Y.A. Aubakirov, A.S. Zhumakanova, S. Sendilvelan, News of the National Academy of sciences of the Republic of Kazakhstan, series chemistry and technology, 426(2017), pp.11-15. DOI:10.32014/2018. 2518-1491.
[5] S. Seenivasan, T.A. Anderson, N. Muraleedharan, Environ. Monit. Assess. 188 (2016) 428, https://doi.org/10.1007/s10661-016-5440-y.
[6] S.L. Welles, N.C. Ellstrand, Am. J. Bot. 103 (2016) (2016) 663–667.
[7] D.L. Sobariu, D.I. Fertu, M. Diaconu, L.V. Pavel, R.M. Hlihor, E.N. Drăgoi, S. Curteanu, M. Lenz, P.F. Corvini, M. Gavrilescu, New Biotechnol. 39 (2017) 125–134, https://doi.org/10.1016/j.nbt.2016.09.002.
[8] M. Oves, M. Saghir Khan, J. Bioremed. Biodegrad. 7 (2016) 2, https://doi.org/10.4172/2155-6199.1000334.
[9] H. Ali, E. Khan, I. Ilahi, J. Chem. 2019 (2019), https://doi.org/10.1155/2019/6730305.
[10] M.S. Akhmetkaliyeva, L.R. Sassykova, Y.A. Aubakirov, S. Sendilvelan, A.S. Zhumakanova, T.S. Abildin, A.K. Zhussupova, M.B. Amangeldi, News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geol. Tech. Sci. 429 (2018) 20–29, https://doi.org/10.32014/2018.2518-170X.
[11] Z. Li, X. Qi, X. Fan, Z. Du, C. Hu, Z. Zhao, Y. Isa, Y. Liu, Sci. Total Environ. S0048–9697 (16) (2016) 30925–30931, https://doi.org/10.1016/j.scitotenv.2016.05.020.
[12] H. Liu, H. Wang, Y. Zhang, J. Yuan, Y. Peng, X. Li, Y. Shi, K. He, Q. Zhang, Environ. Sci. Pollut. Res. 25 (2018) 16852–16863, https://doi.org/10.1007/s11356-018-1866-9.
[13] T. Chen, X. Liu, M. Zhu, K. Zhao, J. Wu, J. Xu, P. Huang, Environ. Pollut. 151 (2008) 67–78.
[14] M.S. Akhmetkaliyeva, L.R. Sassykova, Y.A. Aubakirov, S. Sendilvelan, Int. J. Biol. Chem. 10 (2017) 40–44, https://doi.org/10.26577/2218-7979-2017-10-2-40-44.
[15] L. Sassykova, A. Nalibayeva, Y. Aubakirov, Z. Tashmukhambetova, U. Otzhan, N. Zhakirova, M. Faizullaeva, Orient. J. Chem. 33 (2017) 1941–1948, https://doi.org/10.13005/ojc/330440.
[16] L.R. Sassykova, Technogenic emissions into the atmosphere: impact on the environment and neutralization by catalytic methods, Qazaq university, Almaty, 2018.
[17] Y.A. Aubakirov, L.R. Sassykova, A.M. Nalibayeva, K. Dossumov, Z.K. Tashmukhambetova, A.S. Zhumakanova, A.K. Zhussupova, N.K. Zhakirova, Orient. J. Chem. 33 (2017) 3130–3137.
[18] K. Palani, K. Balasubramanian, R.A. Kalaivani, Orient. J. Chem. 34 (2018) 3129–3133.
[19] L. Sassykova, V. Bunin, A. Nalibayeva, M. Nurakhmetova, J. Chem. Technol. Metal. 53 (2018) 537–542.
[20] X. Wang, Y. Sun, S.h. Li, H. Wang, PLoS ONE 14 (2019), https://doi.org/10.1371/journal.pone.0220409 e0220409.
[21] L.R. Sassykova, A. Ussenov, A.T. Massenova, Sh.A. Gil'mundinov, K.S. Rakhmetova, V.N. Bunin, Zh.T. Basheva, M.K. Kalykberdiyev, Int. J. Chem. Sci., 14(2016), pp.206-212.
[22] X. Zhao, J. Bioremed. Biodegrad. 7 (2016), https://doi.org/10.4172/2155-6199.1000353.
[23] M. Yemane, B.S. Chandravanshi, T. Wondimu, Food Chem. 107 (2008) 1236–1243.
[24] S.L. Mosyakin, M.G. Kholodny, Ukrainian Bot. J. 74 (2017) 409–420. https://doi.org/10.15407/ukrbotj74.05.409.
[25] https://kz.expert/en/news/analitika/525_kazakhstan_how_the_countrys_development_differentiates_its_regionsen.wikipedia.org/wiki/East_Kazakhstan_Region.
[26] http://kray.pushkinlibrary.kz/ru/priroda/priroda/361-priroda.html.
[27] https://natworld.info/rasteniya/rastenija-kazahstana-harakteristika-spisok-nazvanija-i-foto.
[28] http://zaisantour.kz/vostochno-kazakhstanskaya-oblast.
[29] G.Y. Rinkis, T.A. Kunitskaya, Bull. Acad. Sci. Latvian SSR 8 (1995) 119–123.
[30] E.A. Dmitriev, Mathematical Statistics in Soil Science, Librokom Book House, 2009.
[31] M.S. Akhmetkaliyeva, L.R. Sassykova, Y.A. Aubakirov, G.R. Kosmambetova, Int. J. Biol. Chem. 10 (2017) 89–91.
[32] Y.V. Alekseev, Heavy Metals in Soils and Plants, Agropromizdat, Moscow, 1987.
[33] I.G. Vazhenin, Methodological Recommendations for the Study and Mapping of Soil Cover by Levels of Pollution by Industrial Discharges, VASKHNIL, Moscow, 1987.
[34] A.P. Vinogradov, Geochemistry of rare and trace chemical elements in soils, M (1957) 203–207.

[35] G.B. Udintsev, L.V. Dmitriev, A.P. Vinogradov, Philos. Trans. Royal Soc. LondonSeries A 268 (1971) 653–659.
[36] R. Zinkute, I. Bauziene, K. Dilys, J. Mazeika, J. Taminskas, R. Taraskevicius, Geochemistry 15 (2015) 293–318, https://doi.org/10.1144/geochem2013-245.
[37] S.K. Reddy, C.S. Reddy, G.V.S. Reddy, Orient. J. Chem. 34 (2018) 1078–1090.
[38] V.V. Ivanov, Geochemistry of trace elements Ga, Ge, Gd, In, Tl in hydrothermal deposits, Moscow, 1966.
[39] K.A. Hudson-Edwards, Mineral. Mag. 67 (2003) 205.
[40] C.M. Rice, R.J. Herrington, Mineral. Mag. 67 (2003) 233–234.
[41] J. Duan, J. Tan, Atmos. Environ. 74 (2013) 93–101.
[42] S.S. Huang, Q.L. Liao, M. Hua, X.M. Wu, K.S. Bi, C.Y. Yan, B. Chen, X.Y. Zhang, Chemosphere 67 (2007) 2148.
[43] K. Sharipov, A. Kirgizbayeva, K. Omirzakova, A. Batyrbayeva, A. Toktabayeva, J. Chem. Technol. Metal. 52 (2017) 962–968.