HSPI Inc. The Open Access Publisher

ACEE ISSN 2574-0350 ANNALS OF CIVIL AND ENVIRONMENTAL ENGINEERING

Short Communication

Bioaccumulation of As, Cd, Cr, Cu, Pb, Zn in *Ambrosia artemisiifolia L.* in the polluted area by enterprise for the production and processing of batteries

Ryzhenko Nataliia[1]*, El Amrani Abdelhak[1], Giltrap Michelle[2], Furong Tian[2] and Volodymyr Laptev[2]

[1]CNRS/UMR 6553/OSUR, Ecosystems - Biodiversity - Evolution, University of Rennes 1, Rue du Thabor, 35000, France

[2]School of Food Science & Environmental Health, Technological University Dublin, Dublin 7, Ireland

More Information

***Address for Correspondence:** Ryzhenko Nataliia, CNRS/UMR 6553/OSUR, Ecosystems - Biodiversity - Evolution, University of Rennes 1, Rue du Thabor, 35000, France, Email: nataliia.ryzhenko@univ-rennes1.fr

Submitted: July 06, 2022
Approved: July 12, 2022
Published: July 13, 2022

How to cite this article: Nataliia R, Abdelhak E, Michelle G, Tian F, Laptev V. Bioaccumulation of As, Cd, Cr, Cu, Pb, Zn in *Ambrosia artemisiifolia L*. in the polluted area by enterprise for the production and processing of batteries. Ann Civil Environ Eng. 2022; 6: 026-030.

DOI: 10.29328/journal.acee.1001036

ORCiD: https://orcid.org/0000-0002-1117-7544

Keywords: Metals; Bioaccumulation; Polluted sites; Soil; Plant; *Ambrosia artemisiifolia* L

Abstract

In this paper, the concentration of As, Cd, Cr, Cu, Pb, and Zn was investigated in soil and *Ambrosia artemisiifolia L*. sampling from polluted cite near the enterprises for the production and processing of batteries in the city of Dnipro in Ukraine. The obtained results of the study were provided to assess the plant species through bio-monitoring and phytoremediation. Though *Ambrosia artemisiifolia L*. is a weed that causes serious allergic reactions in humans, this plant species can also have a high bioaccumulative capacity regarding metals. The obtained results highlighted the metals' significantly higher concentration in roots than in the inflorescence part in *Ambrosia artemisiifolia L*. Among all studied metals, Zn and Cu had the highest concentration in *Ambrosia artemisiifolia L*., while lead was characterized by the highest bioavailable content available to plant forms in the soil. The various distribution of As, Cd, Cr, Cu, Pb, and Zn was found in different parts of the plant. According to plant-up-taking indexes studied elements can be ranked in the following descending order: Cu > Zn > Cr > Cd > Pb. *Ambrosia artemisiifolia L*. could be proposed for phytoremediation in Zn, Cu, Cd, and Cr contaminated soils although this species is resistant to lead soil pollution.

Introduction

Toxic metals are famous pollutants due to their toxicity, persistence in the environment, and bioaccumulative nature [1-3]. Their acute or chronic poisonings may arise through water, air, and food for humans as well as for biota. Although metals are naturally occurring elements that are found throughout the earth's crust, most environmental contamination and human exposure result from anthropogenic activities such as mining and smelting operations, industrial production and use, and domestic and agricultural use of metals and metal-containing compounds [1,4-6]. The research on the potential bioaccumulation of plants as bioindicators is an important attempt that contributes to the findings of the method of monitoring pollution as well as the processing of phytoremediation in a polluted environment, especially in industrial sites. Such contaminated sites include the areas near the enterprises for the production and processing of batteries. The city of Dnipro in Ukraine is characterized by a significant anthropogenic load and has enterprise for the production and processing of batteries [7]. In this regard, the areas near the enterprises for the production and processing of batteries have aroused interest in the study of plant bioaccumulation by revealing certain species of plants that are capable of high bioaccumulation on contaminated soils.

The ability to bioaccumulate depends on different factors, such as physicochemical properties of metal and its quantity, soil type and its buffering properties, species of plants, etc. *Ambrosia artemisiifolia L.* is an annual herb native to Central and Northern America [8, 9]. It has been accidentally introduced into Ukraine as well as others countries as a contaminant of seed and grains. *Ambrosia artemisiifolia L.* typically colonizes disturbed land where it produces a large number of seeds that can remain viable in the soil for 40 years or more. The pollen produced by species of Ambrosia is highly allergenic and can induce allergic rhinitis, fever, or dermatitis. However, this species is a powerful bioaccumulator [10-12]. The gained results of the study not only provided the environmental status in terms of metal pollution and bioaccumulation in Dnipro but also allow for assessing plants regarding bio-monitoring and phytoremediation.

The aim of the investigation was to assess the bio-accumulative availability of As, Cd, Cr, Cu, Pb, and Zn for *Ambrosia artemisiifolia L.* in polluted soil by enterprise for the production and processing of batteries. On the one hand, the study of the ability to bioaccumulate metals in polluted areas makes it possible to propose a plant species for phytoremediation or to determine the plant resistance to high elements bioavailable concentrations. On the other hand, the discovery of bioavailability patterns gives an insight into the behavior of the metal in the soil and plants, which allows for forecasting their danger in the environment.

Materials and methods

As, Cd, Cr, Cu, Pb, and Zn content in soil and plants was studied in the area of 716 m from the enterprise for the production and processing of batteries in Dnipro city in Ukraine. Soil and plants of *Ambrosia artemisiifolia L.* were sampled in July 2021 (Figure 1). The studied soil is ordinary low-humus black on heavy loess loam (pH salt 6.7; organic matter by Turin, Walkley - Black 4.4%).

Mean standard deviations, variance, minimum, maximum, and standard errors were calculated in four replicates. The experimental results were interpreted using standard statistical methods. Soil and plants were sampled in the phase of plants flowering. Analysis of soil samples (extraction with acetate-ammonium buffer pH 4.8) and plants (in the different parts as well as in total plants) (extraction with a mixture of concentrated acids $HN0_3$ and H_2SO_4) was carried out by the method of atomic emission spectrometry with inductively coupled plasma (optical spectrometer with inductively coupled plasma, iCAP 7000 Plus DUO). The lowest limits of definition of elements were: in the soil: As – 0,5 mg kg^{-1}, Cr and Cd – 0,2 mg kg^{-1}, Pb – 0,5 mg kg^{-1}, Cu – 0,1 mg kg^{-1}, Zn – 1,0 mg kg^{-1}; in the plants: As – 0,1 µg kg^{-1}, Cr - 4 µg kg^{-1}, Cd – 0,8 µg kg^{-1}, Pb – 4 µg kg^{-1}, Cu – 2 µg kg^{-1}, Zn – 10 µg kg^{-1}.

The plant up-taking index (PUI) for metals was calculated as follows:

$$PUI = \frac{Cp}{Cs} \qquad (1)$$

Where c_p – bioavailable concentration in plant, mg·kg^{-1} (dry weight);

c_s – concentration in soil, mg·kg^{-1}.

Results and discussion

Among all studied metals, copper and zinc were characterized by the highest concentrations in plants of *Ambrosia artemisiifolia L.* (Figure 2).

Arsenic had the lowest content in total plants as well as in the inflorescence part of *Ambrosia artemisiifolia L.* There are several reasons for it. Cu and Zn are obligatory elements for plant growth and usually, they are present in significant concentrations both in the soil and in the plant. However, at the same time, Zn also could be a pollutant because of possible

Figure 1: Sampling site: *yellow point -sample cite; **red point – enterprise location; ***the line is drawn at a distance of 716 meters from the source of pollution (enterprise for the production and processing of batteries in Dnipro city in Ukraine) to the sample site.

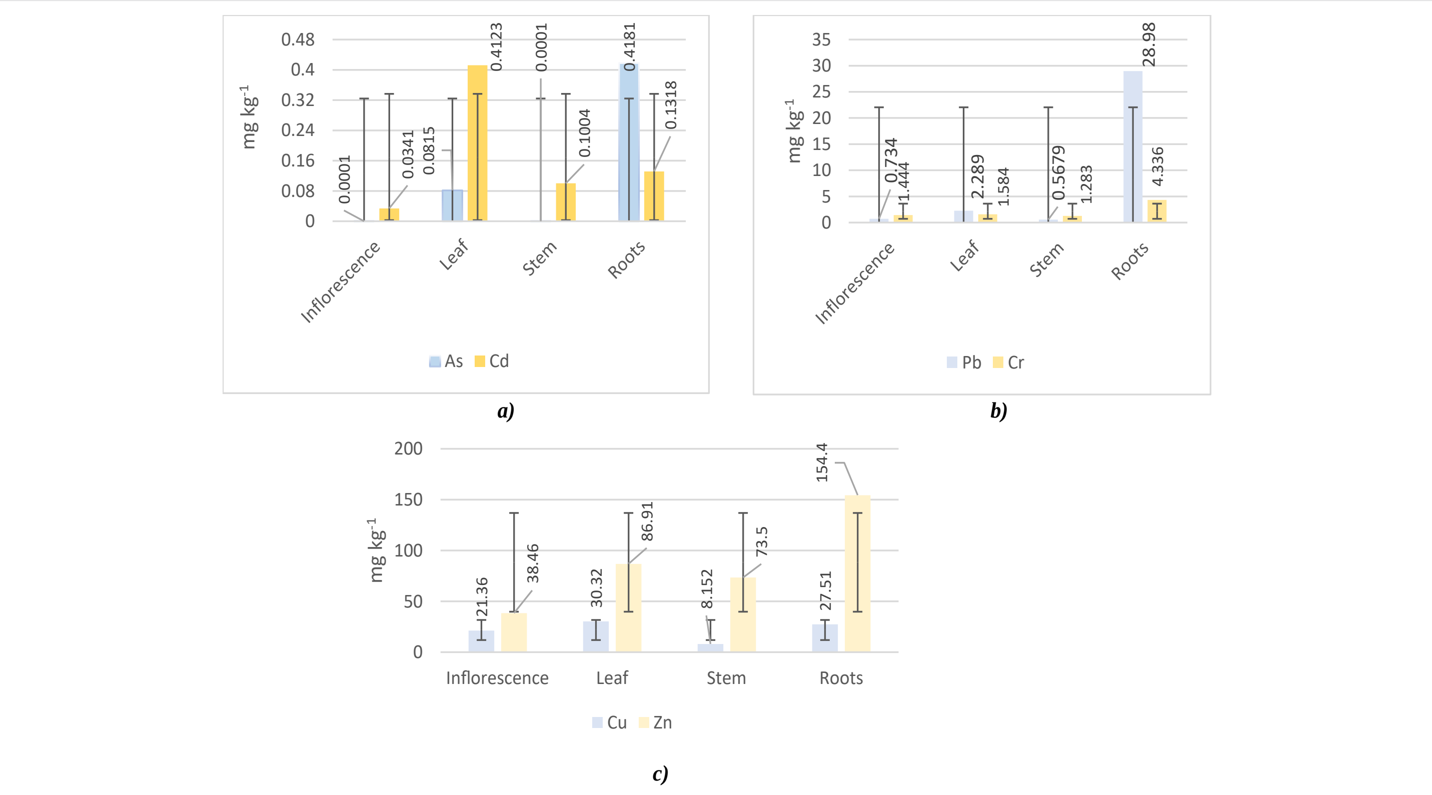

Figure 2: Metals average concentration (mg kg^{-1}, dry mass) in a different part of *Ambrosia artemisiifolia L*. phytomass: a): As and Cd; b) Pb and Cr; c) Cu and Zn.

emissions by the enterprise for the production and processing of batteries. Lead was characterized also as a rather high concentration in plants, mostly in roots. Lead is one of the main pollutants in the production and processing of batteries [13]. Similar to lead, arsenic, chromium, and zinc also had the main concentration in their roots. It may be explained by the soil pollution of these elements. Cadmium was characterized by a high concentration in steam. In general, for all studied metals, the concentration in roots was scientifically higher than in the inflorescence part ($F_{theor} < F_{exper}$, P_{05}).

According to the coefficient variation of metals concentration in different parts of plants, Pb and As were characterized by the greatest variability (Table 1). It means, that the distribution of these metals in different parts of the plant was very uneven (V > 100%). Zinc and copper were most evenly distributed in different parts of the plant. This may be due to the low underground plant part bioavailability of these elements for the *Ambrosia artemisiifolia L*. In obedience to the coefficient of variation of metals concentration in different parts of the plant (V, %), studied metals can be ranked in the following descending order: Pb > As > Cd > Cr > Zn > Cu.

Cooper and zinc had the highest PUI for different parts of plants. Pb had the lowest PUI. Among numerous trace metals, lead is famous for its poor bioavailability even in polluted soils, in particular, in the aboveground part of plants [14-17]. This probably explains the main concentration of lead in the roots.

Lead was distinguished by the highest values of the content in the soil, and cadmium was the lowest (Table 2). However, Zn and Cu had the highest concentration in phytomass which is probably related to their obligatory functions in the plant [18]. According to plant-up-taking indexes studied elements can be ranked in the following descending order: Cu > Zn > Cr > Cd > Pb. The variability between bioaccumulation coefficients for different metals is significant, meaning that each metal

Table 1: Coefficient of variation of metals concentration in different parts of the plant (V, %) and plant-up taking indexes (*PUI*) for a different part of *Ambrosia artemisiifolia* L

Metals	V, %	Plant-up taking indexes (PUI)			
		Inflorescence	Leaf	Steam	Roots
As	138,04	-	-	-	-
Cd	85,15	0,09	1,03	0,23	0,33
Cr	58,28	0,88	0,96	0,78	2,63
Cu	39,11	11,89	16,88	4,54	15,3
Pb	147,97	0,015	0,05	0,01	0,59
Zn	47,62	1,86	4,2	3,56	7,47

Table 2: As, Cd, Cr, Cu, Pb, Zn bioavailable concentrations in soil and *Ambrosia artemisiifolia* L. phytomass and bioaccumulation.

Metals	Soil (acetate-ammonium buffer pH 4.8), mg kg^{-1}, $x_{average}$	Total plant mg kg^{-1}, dry matter, $x_{average}$	Plant-up taking indexes (PUI)
As	-*	0,499 ± 0,125	-
Cd	0,402 ± 0,010	0,679 ± 0,136	1,69
Cr	1,647 ± 0,241	8,647 ± 0,956	5,25
Cu	1,796 ± 0,189	87,342 ± 5,320	48,63
Pb	48,96 ± 4,123	32,571 ± 3,874	0,67
Zn	20,67 ± 1,875	353,270 ± 11,123	17,09
s^2	*437,68*	*18936,37*	*403,09*
(v), %;			*122,44*

*below the limit of definition

has its range of bioavailability. *Ambrosia artemisiifolia L*. could be proposed for phytoremediation in Zn, Cu, Cd, and Cr polluted soils. At the same time, this species is resistant to lead pollution in soil. Many herbaceous plant species are known that can be offered as phytoremediators. For example, *Urtica dioica L*. is known for its high bioaccumulative ability of Cd as well as polychlorinated biphenyls [19-21]. *Cichorium intybus L*. and *Plantago media L*. were suggested as possible biomonitors of toxic metals (Pb, Cd, Cu, and Zn) pollution, particularly in urban areas [22-24]. In our previous paper, *Impatiens parviflora* DC was considered as a plant with high plant up-taking indexes for Cd and Pb (7 and 1, respectively) [20].

The behavior of arsenic in soil and *Ambrosia artemisiifolia L*. plants arouses interest. The bioavailable content of this element in the soil is below the detection limit, but its amount in the phytomass is quite significant. This can be explained by the foliar absorption of this element by the studied species or other sources of their content in the plant. In As hyperaccumulating species, such as *Pteris vittata L*, As is not immobilized in the roots, but is instead rapidly transported through the xylem to the leaves [25-27].

Conclusion

Among all studied metals, copper and zinc were characterized by the highest concentrations in plants of *Ambrosia artemisiifolia L*. although lead was characterized by the highest content of available to plants forms in the soil. The distribution of Pb and As in different parts of the plant was very uneven (V > 100%) in contradistinction to Zn and Cu (V < 50%). The metals' concentration in the roots was scientifically higher than in the inflorescence part ($F_{theor} < F_{exper}$, P_{05}). The content of As in the soil was below the detection limit, but its amount in the phytomass is quite significant. This can be explained by the potential foliar absorption of this element by the *Ambrosia artemisiifolia L*. According to plant-up-taking indexes studied elements can be ranked in the following descending order: Cu > Zn > Cr > Cd > Pb. *Ambrosia artemisiifolia L*. could be proposed for phytoremediation in Zn, Cu, Cd, and Cr polluted soils. At the same time, this species is resistant to lead pollution in soil.

References

1. Kabata-Pendias A, Mukherjee A. Trace Elements from Soil to Human, Springer-Verlag, Berlin-Heidelber. 2007; 550.
2. Alloway B. Heavy metals in soils. Trace elements and Metalloids in Soils and their Bioavailability, Third edition. Springer, UK. 2010; 235.
3. Hazrat A, Ezzat K, Ikram I. Environmental Chemistry and Ecotoxicology of Hazardous Heavy Metals: Environmental Persistence, Toxicity, and Bioaccumulation. Journal of Chemistry. 2019: 1-14. https://doi.org/10.1155/2019/6730305.
4. Tangahu B, Abdullah S, Basri H. A Review on Heavy Metals (As, Pb, and Hg) Uptake by Plants through Phytoremediation. International Journal of Chemical Engineering. 2011: 1-32. https://doi.org/10.1155/2011/939161.
5. Tchounwou P, Yedjou C, Patlolla A, Sutton D. Heavy Metals Toxicity and the Environment. Molecular, Clinical and Environmental Toxicology. 2012; 2012: 133-164. doi: 10.1007/978-3-7643-8340-4_6.
6. Jiang X, Lu W, Zhao H, Yag Q, Yang Z. Potential ecological risk assessment and prediction of soil heavy metal pollution around coal gangue dump. Natural Hazards and Earth System Sciences. 2014; 14: 1599-1610. https://doi.org/10.5194/nhess-14-1599-2014.
7. Bondar O, Ryzhenko N, Laptiev V, Makhniuk V. Bioaccumulation of Hg, Cr, Zn, As, Cd, Pb, Cu in the "soil-plant" system in the rea of influence of enterprises for the production and processing of batteries. Ecological science. 2022; 1(40):11-16. doi https://doi.org/10.32846/2306-9716/2022.eco.1-40.2ю
8. Ambrosia artemisiifolia (common ragweed). 2021. CABI. https://www.cabi.org/isc/datasheet/4691
9. Smith M, Cecchi L, Skjøth CA, Karrer G, Šikoparija B. Common ragweed: A threat to environmental health in Europe. Environment International. 2013; 61: 115-126. doi: 10.1016/j.envint.2013.08.005.
10. Bae J, Byun C, Watson AK, et Benoît DL. Ground cover species selection to manage common ragweed (*Ambrosia artemisiifolia L*.) in roadside edge of highway. Plant Ecology. 2014; 216(2): 263-271. doi : 10.1007/s11258-014-0433-9
11. Cloutier-Hurteau B, Gauthier S, Turmel MC, Comtois P, Courchesne F. Trace elements in the pollen of Ambrosia artemisiifolia: what is the effect of soil concentrations? Chemosphere. 2014 Jan;95:541-9. doi: 10.1016/j.chemosphere.2013.09.113. Epub 2013 Oct 30. Erratum in: Chemosphere. 2014 Jun;104:271-2. PMID: 24183625.
12. Hoa KB, In SS, Gak LS, Ho KK, Chung Ill Min. 1998. Evaluation of Ambrosia artemisiifolia var. elatior, Ambrosia trifida, Rumex crispus for phytoremediation of Cu and Cd contaminated soil. Korean Journal of Weed Science. 18(3): 262-267.
13. Zhang J, Chen C, Zhang X, Liu S. Study on the Environmental Risk Assessment of Lead-Acid Batteries,Procedia Environmental Sciences. 2016; 31: 873-879. https://doi.org/10.1016/j.proenv.2016.02.103
14. Amin H, Arain B, Jahangir T, Abbasi M, Amin F. Accumulation and distribution of lead (Pb) in plant tissues of guar (Cyamopsis tetragonoloba L.) and sesame (Sesamum indicum L.): profitable phytoremediation with biofuel crops. Geology, Ecology and Landscapes. 2018; 2: 51-60.
15. Pourrut B, Shahid M, Dumat C, Winterton P, Pinelli E. Lead uptake, toxicity, and detoxification in plants. Rev Environ Contam Toxicol. 2011;213:113-36. doi: 10.1007/978-1-4419-9860-6_4. PMID: 21541849.
16. Pourrut B, Shahid M, Dumat C, Winterton P, Pinelli E. Lead uptake, toxicity, and detoxification in plants. Rev Environ Contam Toxicol. 2011;213:113-36. doi: 10.1007/978-1-4419-9860-6_4. PMID: 21541849.
17. Yan K, Zhaomin D, Wijayawardena MAA, Liu Y, Naidu R, Semple K. Measurement of soil lead bioavailability and influence of soil types and properties: A review. Chemosphere. 2017; 184: 27-42.
18. Seeda A, El-Motaleb Aly Abou El-Nour EA, Mervat G, Zaghloul SM. Interaction of Copper, Zinc, and their importance in plant physiology: Review, Acquisition and Transport. Middle East Journal of Applied Sciences. 2020; 10: 07-434. DOI: 10.36632/mejas/2020.10.3.37
19. Viktorova J, Jandova Z, Madlenakova M, Prouzova P, Bartunek V, Vrchotova B, Lovecka P, Musilova L, Macek T. Native Phytoremediation Potential of Urtica dioica for Removal of PCBs and Heavy Metals Can Be Improved by Genetic Manipulations Using Constitutive CaMV 35S Promoter. PLoS One. 2016 Dec 8;11(12):e0167927. doi: 10.1371/journal.pone.0167927. Erratum in: PLoS One. 2017 Oct 19;12 (10):e0187053. PMID: 27930707; PMCID: PMC5145202.
20. Ryzhenko N, Yastrebtsova N, Ryzhenko D. Cd and Pb in the "soil-plant" system of Holosiyiv green park area in Kyiv. Polish journal of soil science. 2020; 53(2): 199-210. doi: 10.17951/pjss/2020.53.2.199
21. Dimitrijevic V, Krstić N, Stanković M, Arsić I, Nikolić R. Biometal and heavy metal content in the soil-nettle (Urtica dioica L.) system from different localities in Serbia. Advanced Technologies. 2016; 5(1): 17–22

22. Bursztyn Fuentes AL, José C, de Los Ríos A, do Carmo LI, de Iorio AF, Rendina AE. Phytoextraction of heavy metals from a multiply contaminated dredged sediment by chicory (Cichorium intybus L.) and castor bean (Ricinus communis L.) enhanced with EDTA, NTA, and citric acid application. Int J Phytoremediation. 2018;20(13):1354-1361. doi: 10.1080/15226514.2018.1524826. PMID: 30666892.

23. Aksoy A. Chicory (Cichorium intybus L.): A possible biomonitor of metal pollution Pakistan Journal of Botany. 2008; 40(2): 791–797.

24. Popova E. Impact of heavy metals on vegetation communities with Plantago Major L. and Plantago Media L. Journal of Chemical and Pharmaceutical Research. 2018; 10(1): 1-5.

25. Zhao FJ, Ma JF, Meharg AA, McGrath SP. Arsenic uptake and metabolism in plants. New Phytol. 2009 Mar;181(4):777-794. doi: 10.1111/j.1469-8137.2008.02716.x. PMID: 19207683.

26. Lombi E, Zhao FJ, Fuhrmann M, Ma LQ, McGrath SP. Arsenic distribution and speciation in the fronds of the hyperaccumulator Pteris vittata. New Phytol. 2002 Nov;156(2):195-203. doi: 10.1046/j.1469-8137.2002.00512.x. PMID: 33873285.

27. Finnegan PM, Chen W. Arsenic toxicity: the effects on plant metabolism. Front Physiol. 2012 Jun 6;3:182. doi: 10.3389/fphys.2012.00182. PMID: 22685440; PMCID: PMC3368394.