Original Article

Accumulation and Soil-to-Plant Transfer Factor of Lead and Manganese in some Plant Species in Semnan Province, Central Iran

Mohamad Sakizadeh[1], Rouhollah Mirzaei [2], Hadi Ghorbani [3]*

Received: 06.10.2015 *Accepted: 25.11.2015*

ABSTRACT

Background: Heavy metals have detrimental effects on the health of human being. The values of manganese (Mn) and lead (Pb) in some plant species and soil samples in an arid area of Iran were evaluated in this study.

Methods: The values of Pb and Mn in 94 plant samples from 8 plant species and the related soil samples in 2010 were considered in Shahroud and Damghan, central Iran. Moreover, the soil-to-plant transfer factors of these two elements were investigated.

Results: Except for barley, the values of Pb in all of the considered plants were higher than the standard level of 0.3 mg/kg. The amounts of Mn in all of the plant species other than pistachio were higher than the standard level of 25 mg/kg. As a whole, the bio-concentration factor of Mn was higher than that of Pb in the study area.

Conclusion: None of the soil-to-plant transfer factors exceeded one. Grape recorded the highest amounts of Pb and Mn compared with that of other investigated plant species. However, since its respective bio concentration factor (BCF) was lower than one, it cannot be considered as a hyper accumulator of lead and manganese.

Keywords: Bio Concentration Factor, Heavy Metals, Plant, Soil.

IJT 2016 (3): 29-33

INTRODUCTION

If the levels of metals in soil exceed standard values, the toxicity for cultivated plants may occur, which pose a threat to the health of human if they accumulate in food crops [1].

According to WHO, the selective study of individual foodstuffs is an important step in the estimation of dietary intake of metals [2]. The dominant factor for the accumulation of heavy metals in plant species seems to be related to genotype of different biotic and non-biotic factors [3].In general, every plant species can act as a potential bio-indicator of environmental condition. In this field, some plants can accumulate high amounts of heavy metals in their living tissues especially their leaves [4].

Among different elements, manganese (Mn) and lead (Pb) have been known as heavy and trace elements in the environment. There are few environmental pollutants having detrimental effects on humans, animals and ecosystems like that of Pb. It has been recently phased out from the petrol used in most of the developing countries to reduce these detrimental effects. However, because of its persistence the long-term effects of this pollutant are still available in the environment [5]. In unpolluted natural soils, it stems mainly from parent materials and the overall mean value of this element for different soil is about 25 mg/kg [6].

On the contrary, despite the fact that Mn is an essential element for plants especially for the proper function of photosynthesis process through an enzyme antioxidant-cofactor, an excess of this micronutrient is toxic for plants [7]. The excess of this element in plant species can alter various processes, such as enzyme activity, absorption, translocation and utilization of other mineral elements (e.g.Ca, Mg, Fe and P), causing oxidative stress [8]. Several oxidation states are available for manganese in environment (II, III, IV, VI and VII). However, the predominant forms in biological systems are II, III and IV. In the soil system, on the other hand, divalent Mn (Mn II) is the most soluble form, while the solubility of other forms is very low [9].Considering the above-mentioned introductory comments, the main objectives of

1. Department of Environmental Sciences, Shahid Rajaee Teacher Training University, Tehran, Iran.
2. Department of Environmental Sciences, University of Kashan, Kashan, Iran.
3. Department of Water and Soil, University of Shahrood, Shahrood, Iran.
*Corresponding Author:E-mail:msakizadeh@gmail.com

the present study were: (i) to consider the values of lead and manganese in some plant species in Shahroud and Damghan, central Iran and (ii) to consider the soil-to-plant transfer factor of these elements. As some of the investigated plants have been using for edible purposes by local people in the area, consideration of heavy metals is of great importance regarding the health risk that these metals may pose for the consumers.

MATERIALS AND METHODS

Ninety-four sampling locations were selected in 2010 in Shahroud and Deamghan, Semnan Province central Iran, in which plant and the associated soil samples were taken randomly from the same location that the plant samples were prepared to estimate the soil-to-plant transfer factors of Pband Mn. The plant species, number of samples for each plant type and the respective sampling part have been given in Table1. For soil samples, the surface soil (0-5cm) was taken from each sampling station. In laboratory, the collected soil samples were air-dried and sieved through a 2-mm stainless steel mesh to remove stones and plant roots. Following digestion of soil samples with nitric acid (HNO_3) and hydrochloric acid (HCl) in a ratio of 3:1 (HNO_3:HCl), the total metal concentrations of Pb and Mn were analyzed by inductively coupled plasma (ICP) optical emission spectroscopy(ICP-OES). Plant species were threshed manually, with glumes and dust was removed whereas no washing of grains was performed. Dried samples were ground using a stainless steel grinder (<0.25 mm) and the total content of the above-mentioned heavy metal and trace elements were detected by ICP-OES.

Table1. The number of samples and the respective sampling part for each plant.

Plant type	Number of samples	Sampling part
Wheat	21	Stem,Leave,Grain
Apricot	12	Stem And Leave
Chives	4	Stem And Leave
Pistachio	19	Leave
White Mulberry	13	Fruit And Leave
Grape	4	Leave
Barley	12	Grain
Spindle Tree	9	Leave

RESULTS

The results of detection of Pb and Mn in the associated plant species in the study area have been illustrated in Figure1 and2.Considering the levels of Pb, the highest amounts were recorded in grape with the average value of 2.03 mg/kg. Whereas, the lowest amounts were found in barley, which has, mean value of 0.228 mg/kg. The order of lead levels in the plant species was as follows:

Grape>chives>mulberry>apricot>spindle tree>wheat>pistachio>barley

In this respect, except for barley, the values of lead in all of the considered plants were higher than the standard level of 0.3 mg/kg set by WHO for Pb in plant species. On the contrary, the highest values of Mn were also observed in grape with the average level of 115.75 mg/kg and the lowest amount was recorded in pistachio with the mean value of 23.89 mg/kg. In this field, the order of Mn in the respective plant species was as follows:

Grape> spindle tree> mulberry> wheat> chives> apricot> barley> pistachio

In this field, the values of Mn in all of the plant species other than pistachio were higher than the standard level of 25 mg/kg. On the other hand, a method for expressing the accumulation of metals from soil to above-ground tissues of plants is through bio-concentration factor (BCF), generally obtained by dividing the concentration of the element in plant tissues(grains, shoots, straw, etc) to the total concentration of the same element in the rooted soil. The bio-concentration factor of Pb and Mn for different plant species in the regionis given in Table2.Accordingly, the BCF of Mn is higher than that of Pb. The highest BCF of manganese was recorded for grape ranging from 0.116 to 0.319. While, the lowest observed value was for pistachio fluctuating from 0.019 to 0.048. On the contrary, Pb has most actively accumulated in chives as its bio-concentration factors fluctuate between 0.051 and 0.152.Whereas, the lowest amounts were for barley in which they varied from 0.006 to 0.026.

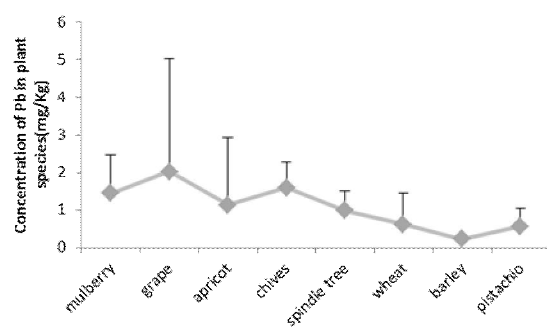

Figure1. Variation of lead among different plant species.

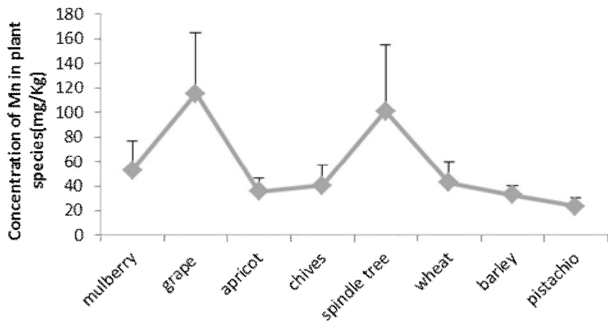

Figure2. Variation of manganese among different plant species.

Table2. Bioconcentration factor of manganese and lead in the considered plant species.

Plant species	Manganese	Lead
White Mulberry	0.058-0.177	0.014-0.262
Grape Vine	0.116-0.319	0.013-0.433
Apricot	0.021-0.105	0.015-0.484
Chives	0.057-0.119	0.051-0.152
Spindle Tree	0.090-0.473	0.015-0.069
Wheat	0.026-0.121	0.007-0.804
Barley	0.035-0.093	0.006-0.026
Pistachio	0.019-0.048	0.010-0.108

DISCUSSION

Both soil and atmosphere contribute to the levels of Pb in plant species among them the lowest contents are found in cereals and grains (<1 mg/kg) while higher amounts are found in roots and tubers (>1 mg/kg). Elevated levels of lead have also been found in leafy vegetables (>2 mg/kg) [5].

Next to industrial activities and vehicles, mining activities are among the main contributing factors to the release of lead to the environment [5]. In mining areas, Pb may be dispersed due to the erosion and chemical weathering of tailings [10]. Mining activity is one of the main sources of heavy metal release and its subsequent soil pollution in the study area. Semnan is the largest province of Iran with known gold and base metal [11]. For instance, it hosts five gold and base metal deposits, i.e., Gandy (Au-Ag-Pb-Zn), Abolhassani (Pb-Zn-Ag-Au), Cheshmeh Hafez (Pb-Zn), Chalu (Cu), Chahmosa (Cu), pousideh (Cu), Baghu and Arghash (Au-Sb) deposit. The discharge of heavy metals due to the widespread mining area in the region has been reported [12,13]. In addition, deposition of Pbin the air on the plant's leave and its following uptake by the plant during photosynthesis is another path of entry for Pb to plant species [14].

The highest amounts of metals (Pb and Mn) were observed in grape. One of the possible reasons for this might be because this species can absorb metals from both soil and aerosols in the atmosphere simultaneously. For instance, the heavy metal levels (including Pband Mn) decreased about 3 times following water washing of leaves implying that the pollution mainly takes place via aerosols [15]. In this field, the amounts found in this study were lower than that recorded by Angelova et al. in the leaves of grape in Bulgaria [15]. The other plant which showed a high level of lead was chives which is a sought-after vegetable consumed by local people. The values of heavy metals including Pb were higher than normal in areas in which the vegetables are irrigated with waste water [16]. The findings of this study confirm resultsof Bigdeli and Seilsepour [17] on the investigation of heavy metals in vegetables irrigated with wastewater in Shahre-Rey, Iran. The amounts of Pb found in the current research are far lower than reported earluer [18] on some medicinal herbal products in Iranian market.

In general, Pbis mainly accumulated near the soil surface as it is absorbed by the soil's organic matter. However, some soil parameters such as soil's acidity may facilitate its mobility in the soil [5]. The mean concentration of Pbin wheat grain in 16 different studies conducted in various countries was mostly high ranging from 0.015 to 22.6mg/kg [19]. The amounts of Pb detected in wheat grains by Eriksson [20] ranged from 0.005 to 0.011mg/kg (mean 0.007), while, the levels for barley grains fluctuated between 0.007 and 0.028 mg/kg(mean 0.013) [20] in which both of them were lower than that of the current research. In Iran, the health risk of heavy metals via consumption of cereals and vegetables was studied in Isfahan, Iran, so total non-carcinogenic hazard of As and Pb was greater than 1 indicating that there was a high risk for the health of consumer through consumption of these food products [21].

The results of this study are comparable with those reported earlier in which the mean value of Mn in wheat grain samples was equal to 49.8 mg/kg. However, the concentration value of

Mn found in wheat grain [19] in Pakistan was 4.9mg/kg, which is significantly less than that of the current research.

In the previous studies, elevated levels of Mn has been found in the soils of the study area attributed to the presence of ultramafic rocks and weathering and leaching of elements from them [13]. In area with elevated levels of Mn active absorption of Mn is happening across the soil–root interface resulting in its accumulation in plants [22]. It might be one of the contributing factors for the higher than normal values of Mn in plant species in this study [22]. Mn is mainly accumulated in the root of wheat and its translocation in the mature plant is restricted due to the importance of xylem in the transport of this element [23]. In other words, Mn transport from roots to shoots was visualized in the xylem and was essentially immobile in the phloem [24].

Regarding Table2, all of the calculated bio-concentration factors (BCFs) found in this study was lower than one indicating the low amount of accumulation of heavy metals in the considered plants. Considering Table2, the BCFs of Mn were higher than that of Pb. One of the possible reasons for this higher value may be because Mn is an essential element for plant species so; it is more actively absorbed from the soil by the root system of the respective species compared. The bio-concentration factor of Mn [25] ranged between 0.005 and 0.167 in the consumed parts of different plants in Gabon, which waslower than that of the current study.

Among the 36plants [26], G. *pennelliana* showed the highest BCF for Pb (BCF=11). The BCF of Pb in this study was lower than that found by Kim et al. [27] in *P. thunbergii* (BCF=5–58), and in the same range of those reported by Stoltz and Greger [28] (BCF=0.004–0.45).

CONCLUSION

The values of manganese and lead in eight plant species were considered in this study. Grape recorded the highest amounts of Pb and Mn compared with that of other plant species in the area of study. However, since it's respective BCF was lower than one so, it cannot be considered as a hyper accumulator of Pb and Mn. The amount of these two elements was higher than standard values in most of the plant species indicating the high health risk for the consumers. However, their respective bio-concentration factor was low implying that this high accumulation is due to elevated levels of these two elements in the soil rather than their high accumulation capability.

ACKNOWLEDGEMENT

The authors are grateful to Geological Survey of Iran for assistance in analysis of heavy metals. The financial support of this project has been provided by the grant number100-2164 offered by Geological Survey of Iran. The authors declare that there is no conflict of interests.

REFERENCES

1. Terzano R, AlChamiZ, VekemansB, JanssensK, Miano T, RuggieroP. Zinc distribution and speciation within rocket plants (Erucavesicaria L. Cavalieri) grown on a polluted soil amended with compost as determined by XRF microtomography and micro-XANES. J Agric Food Chem 2008;56:3222–31.
2. WHO, Global Environmental Monitoring System. Guidelines for the Study of Dietary Intakes of Chemical Contaminants. WHO Offset Publication No. 87.World Health Organization, Geneva; 1985.
3.Nikolic N, Kojić D, Pilipović A, Pajević S, Krstić B, Borisev M, et al. Responses of hybrid poplar to cadmium stress: Photosynthetic characteristics, cadmium and proline accumulation and antioxidant enzyme activity.ActaBiologicaCracoviensia, Series Botanica 2008; 502, 95-103.
4. Baker AJM, Brooks R. Terrestrial higher plants which hyperaccumulate metallic elements-A review of their distribution, ecology and phytochemistry. Biorecovery 1989; 1: 81-126.
5. Kabata-Pendias A, Mukherjee AB. Trace elements from soil to human. Springer; 2007.
6. Kabata-Pendias A, Pendias H. Trace elements in soils and plants, 3rd ed., CRC Press, Boca Raton, FL;2001.
7. Millaleo R, Reyes-Díaz M, Ivanov AG, Mora ML, Alberdi M. Manganese as essential and toxic element for plants: Transport, accumulation and resistance mechanisms. J Soil Sci Plant Nutr 2010; 10 (4): 476 – 94.
8. Lei Y, Korpelainen H, Li C. Physiological and biochemical responses to high Mn concentrations in two contrasting Populuscathayana populations. Chemosphere 2007; 68, 686-94.
9. Guest C, Schulze D, Thompson I, Huber D. Correlating manganese X-rayabsorption near-

edge structure spectra with extractable soil manganese. Soil SciSoc Am J 2002; 66: 1172-81.
10. Da Silva EF, Zhang C, Pinto LS, Patinha C, Reis P. Hazard assessment of arsenic and lead in soils of Castromil gold mining area, Portugal. Applied Geochem 2004; 19:887–98.
11. Shamanian GH,HedenquistJW, HattoriKH, HassanzadehJ. The Gandy and Abolhassani Epithermal Prospects in the Alborz Magmatic Arc, Semnan Province, Northern Iran. Econ Geol 2004; 99(4): 691-712.
12. Doulati Ardejani F, JodieriShokri B, Moradzadeh A, Shafaei SZ, Kakaei R. Geochemical characterisation of pyrite oxidation and environmental problems related to release and transport of metals from a coal washing low-grade waste dump, Shahrood, northeast Iran. Environ Monit Assess 2011; 183:41–55.
13. Hajizadeh Namaghi H, Karami GH, Saadat S. A study on chemical properties of groundwater and soil in ophiolitic rocks in Firuzabad, east of Shahrood, Iran: with emphasis to heavy metal contamination. Environ MonitAssess 2011;174:573–83.
14. Doumett S, Lamperi L, Checchini L, Azzarello E, Mugnai S, Mancuso S, et al. Heavy metal distribution between contaminated soil and Paulownia tomentosa, in a pilot-scale assisted phytoremediation study: influence of different complexing agents. Chemosphere 2008; 72:1481– 90.
15. AngelovaVR, IvanovAS, Braikov DM. Heavy metals (Pb, Cu, Zn and Cd) in the systemsoil - grapevine – grape.JSci Food Agric 1999;79:713-21.
16. KhanS, CaoQ, ZhengYM, HuangYZ, Zhu YG. Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China.Environ Pollut 2008; 152 : 686-92.
17. BigdeliM, Seilsepour M. Investigation of Metals Accumulation in Some Vegetables Irrigated with Waste Water in Shahre Rey-Iran and Toxicological Implications. Am-Eura J Agric Environ Sci 2008; 4 (1): 86-92.
18. MousaviZ, ZiaratiP, DehaghiME, Qomi M. Heavy Metals (Lead and Cadmium) in some Medicinal Herbal Products in Iranian Market. Iran J Toxic 2014;8(24):1004-10.
19. Hassan NU, MahmoodQ, WaseemA, IrshadM, PervezA. Assessment of heavy metals in wheat plants irrigated with contaminated wastewater. Polish J Environ Stu 2003;22 (1):115-23.
20. Eriksson JE. Concentrations of 61 trace elements in sewage sludge, farmyard manure, mineralfertilizers, precipitation and in oil and crops. Swedish EPA Rep 5159, Stockholm; 2001.
21. Salehipour M, Ghorbani H, Kheirabadi H, Afyuni M. Health Risks from Heavy Metals via Consumption of Cereals and Vegetables in Isfahan Province, Iran. Hum Ecol Risk Assess 2015; 21(7):1920-35.
22. Skinner WM, Martin RR, Naftel SJ, MacfieS, ChorchesneF, SeguinV. Multi-technique studies of the distribution of metals between the soil, rhizosphere and roots of Populustremuloides growing in forest soil. ICOBTE, 8 Int.Conf Book Abstr. 488–489, Adelaide; 2005.
23. Rengel Z. Xylem and phloem transport of micronutrients. In: W. J. Horst et al. (eds). Plantnutrition – Food security and sustainability of agro-ecosystems. Kluwer Academic Publishers, Netherlands, pp. 628-629;2001.
24. Page V, Feller U. Selective transport of zinc, manganese, nickel, cobalt and cadmium in the root system and transfer to the leaves in young wheat plants. Ann Bot 2005; 96: 25-434.
25. OndoJA, BiyogoRM,EbaF, PrudentP,Fotio D, Ollui-Mboulou M, et al. Accumulation of soil-borne aluminium, iron, manganese and zinc in plants cultivated in the region of Moanda (Gabon) and nutritional characteristics of the edible parts harvested. J Sci Food Agric 2013; DOI 10.1002/jsfa.6074.
26. YoonJ, CaoX, ZhouQ, Ma LQ. Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site.Sci Total Environ 2006; 368:456-64.
27. Kim IS, Kang HK, Johnson-Green P, Lee EJ. Investigation of heavy metal accumulation in Polygonumthunbergii for phytoextraction.EnvironPollut 2003; 126:235–43.
28. Stoltz E, Greger M. Accumulation properties of As, Cd, Cu, Pb and Zn by four wetland plant species growing on submerged mine tailings. EnvironExp Bot 2002;47:271–80.