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ORIGINAL PAPER

Accumulation of heavy metal in *Platanus orientalis, Robinia pseudoacacia* and *Fraxinus rotundifolia*

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Abstract: Plants are capable of reducing environmental pollutions through uptaking contaminants in their tissues. In the study site, twenty one-year-old leaves and shoots as well as twenty soil samples were sampled and analyzed by Inductively Coupled Plasma (ICP). We investigated the uptaking ability of lead (Pb) and cadmium (Cd) by the leaves and shoots of *Platanus orientalis, Robinia pseudoacacia* and *Fraxinus rotundifolia* in Karaj city, the western Tehran, Iran. We also evaluated the total metal accumulation capacity by using metal accumulation index (MAI). Results indicated that there was no significant difference in uptaking contents of Cd and Pb in the leaves among the trees. However accumulation of Cd in shoots of *F. rotundifolia* and *R. pseudoacacia* was significantly higher than that of *P. orientalis*. The accumulation of Pb in shoots of *R. pseudoacacia* was significantly higher than the other species. The amount of Pb in the soil of the study area was significantly higher than Cd. Concentrations of Cd and Pb in leaves of the three species are in the ranges of 2.4–2.7 mg·Kg^{-1} and 7.1–14.4 mg·Kg^{-1}, respectively. *R. pseudoacacia* had the highest MAI value for leaves (2.21) and *F. rotundifolia* had the highest MAI value for shoots (2.4).

Key words: *Platanus orientalis; Robinia pseudoacacia*; *Fraxinus rotundifolia*; heavy metals; phytoremediation

Introduction

Air and soil in the neighborhood of metal mines and smelters have heavy metal concentrations of 100-fold higher than natural background (Pawlik-Skowrońska et al. 2008). Heavy metals create a critical concern to human health and the environment due to their common occurrence as a contaminant, low solubility in biota (Abou-Shanab et al. 2007). Plants can absorb contaminants from the environment in different ways (uptake, stabilization and translocation of materials (Ghosh and Singh 2005; Franca et al. 2010). Low concentrations of heavy metals in most organisms are harmless; some of them occurring in trace amounts are of vital importance as essential elements for organisms to function (Purchart and Kula 2007). During the last decades, phytoremediation has grabbed researcher's attentions because of being cheaper than other common methods and also being in harmony with environment (Khodakarami et al. 2009). The phytoremediation of metals is a cost-effective 'green' technology based on the use of metal-accumulating plants to remove toxic metals from soil, air and water (Raskin et al. 1997). These facts are the reason for monitoring heavy metal impact on affected plant communities and soil, as the metal uptake from the soil and by plants is an introductory pathway for heavy metals to enter the food chain (Zeidler 2005).

Some heavy metals such as lead (Pb) and cadmium (Cd) that are not essential nutrients in organisms and exposure to low concentrations of them would cause high toxicity for plant and animal, can be removed from environment by plants. As well Pb and Cd can concentrate in aerial organs, annual and perennial shoots of some plants (Dong et al. 2005; Tang et al. 2009).

Heavy metals are ubiquitous environmental contaminants in industrialized societies. Soil pollution by metals differs from air or water pollution, because heavy metals persist in soil much longer than in other compartments of the biosphere (Lasat 2002).

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Over recent decades, the annual worldwide release of heavy metals reached 22,000 t (metric ton) for cadmium, 939,000 t for copper, 783,000 t for lead and 1,350,000 t for zinc (Singh et al. 2003). Thus the researches which probe the ability of the plants for remedy of the Pb and Cd will help us to introduce more suitable plants for phytoremidation in contaminated regions (Amalia et al. 2011; Khodakarami et al. 2008).

The main objective of our study was to determine the ability of *Platanus orientalis, Robinia pseudoacacia* and *Fraxinus rotundifolia* in uptaking Cd and Pb from air and soil in 22-Bahman Park in Karaj city, Iran. The selected trees were extensively planted in Karaj and exposed to varying extents of Cd and Pb due to industrial and other activities.

Materials and methods

Study Site

This study was done in Karaj the center of the Alborz province in Iran. Since it is the nearest city to Tehran the capital of Iran, many people travels between Karaj and Tehran daily and most of them live in Karaj and work in Tehran. Therefore the traffic is a developing problem in Karaj and pollution is the most important negative effect. Based on the traffic condition and expected pollution, we chosed 22-Bahman park as highest traffic rate in Karaj with an area about 4,422 m^2 (35°51' N, 50°50' E and 1,300 m above sea level) (Fig. 1).

Field sampling

We selected 20 trees of the nearly even-aged trees of Plain tree (*P. orientalis*), Black locust (*R. pseudoacacia*) and Persian Ash (*F. rotundifolia*). We also selected 20 even-aged trees of each mentioned species. The annual shoots and leaves from the lower part of crown were collected in four different directions in October, 2010. In total, 20 samples were taken from leaves and shoots of each species (60 leaves and 60 shoot samples). To determine the concentrations of Cd and Pb in the soil of mineral depth, we took 20 soil samples in the depth of 0–30 cm from surface to rooting layer.

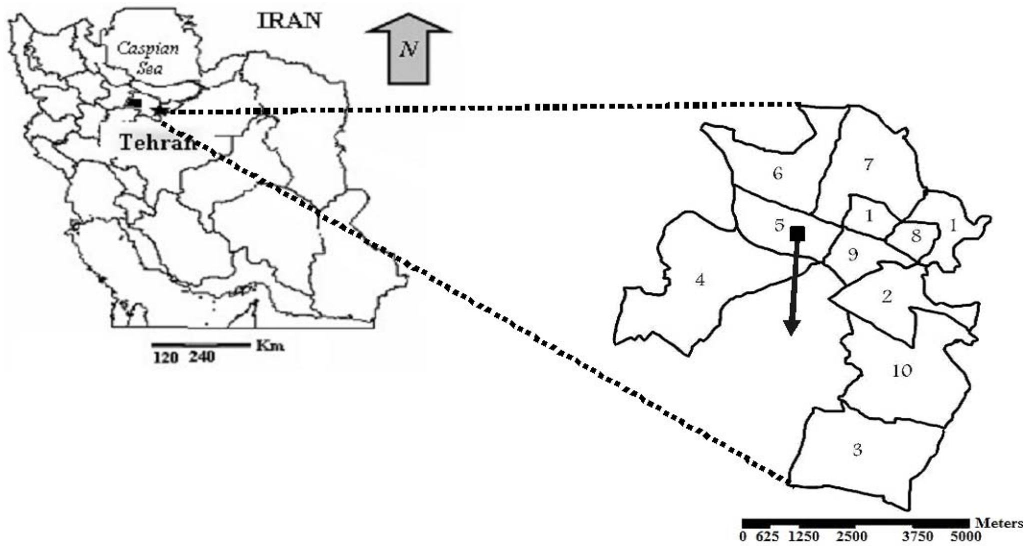

Fig. 1 Location of investigation area (22 bahman Park located in district 5 of Karaj city)

Laboratory measurements

Soil texture is clasy loam with pH of 8.1 and EC of 1.5 mS in the study area. For determining the concentrations of Cd and Pb in leaves and shoots, leaves samples were washed with a shaving brush and double-distilled water to eliminate surface contaminants. The samples were dried in oven 78°C for 48 h and pulverized with a chipper (Khodakarami et al. 2008). Then 4-mL sulphuric acid and 16-mL Hydrogen peroxide were added to 0.5-g sample for digestion process. The extracts were exposed at 480°C in the Digesdahl. After 5 min the digestion process were completed and metal accumulation of extracts were measured by ICP (OES) set. The calibration process was done by the 1,000 $mg \cdot Kg^{-1}$ solution for Lead and Cadmium (MERCK), respectively.

Data analysis

Finally, means of lead and cadmium in each organ were statistically compared using SPSS 16 software. At first, normality and homogeneity test were done and based on the results the Games-Howell test were chosen for mean comparisons. We used an accumulation index to assess the overall performance of the trees. Since this index is for metals, therefore it was termed as metal accumulation index (MAI) (Eq. 1) (Liu et al. 2007).

$$MAI = (1/N)\sum_{j=1}^{N} Ij \quad (1)$$

Where N is the total number of metals analyzed and $I_j = x/\delta x$ is the sub-index for variable j, obtained by dividing the mean value (x) of each metal by its standard deviation (δx).

Results and discussion

The concentrations (mg·Kg^{-1}) of Cd and Pb in the leaves and shoots of the studied species as well as the soil of study area are shown in Table 1. The total amounts of Cd and Pb in the soil are low and the pollution rate could not be announced as a problem as reported by Purohit and Agrrawal (2006) and Liu et al. (2007) within their studied habitats. Concentrations of Cd and Pb in the *P. orientalis, R. pseudoacacia* and *F. rotundifolia* leaves, were shown in Figs. 2 and 3. The results showed that there were no significant differences in concentration of Cd and Pb among leaves of the species. However accumulation of Cd in shoots of *F. rotundifolia* (2.7 mg·Kg^{-1}) and *R. pseudoacacia* (2.7 mg·Kg^{-1}) was significantly higher than concentrations of Cd in shoots of *P. orientalis* (2.6 mg·Kg^{-1}) (Fig. 2). Also accumulation of Pb in shoots of *R. pseudoacacia* was significantly higher than concentrations of Pb in shoots of the other species (Fig. 3). The significant difference between species in shoots opposite of leaves introduce a transporting process from leaves to shoot in all of the species by the end of October. Also the results indicated that there was a significant difference between absorption amounts of Cd and Pb in leaves and shoots of the tree species. The concentration of Pb in aerial organs of the species was higher than Cd (Figs. 4 and 5). This could be due to the fact that the concentration of the Pb in the soil (9.2 mg·Kg^{-1}) was higher than Cd (3.7 mg·Kg^{-1}) (Table 1) (Prasad 2004). There was no significant difference in absorption for both heavy metals between leaves and shoots in all of the species (Figs. 6 and 7).

Table 1. The concentrations of Cd and Pb (mg·Kg^{-1}) in the leaves and shoots of the *Platanus orientalis*, *Robinia pseudoacacia* and *Fraxinus rotundifolia*.

Species		The average of concentration (mg·Kg^{-1})	
		Cd	Pb
Platanus orientalis	Leaf	2.4 ± 0.2	14.4 ± 2
	Shoot	2.6 ± 0.1	10.5 ± 1.8
Robinia pseudoacacia	Leaf	2.5 ± 0.1	11.4 ± 2.1
	Shoot	2.7 ± 0.2	13.9 ± 2.3
Fraxinus rotundifolia	Leaf	2.4 ± 0.2	9 ± 1.4
	Shoot	2.7 ± 0.1	7.1 ± 1.4
Soil		3.7 ± 0.3	9.2 ± 2.2

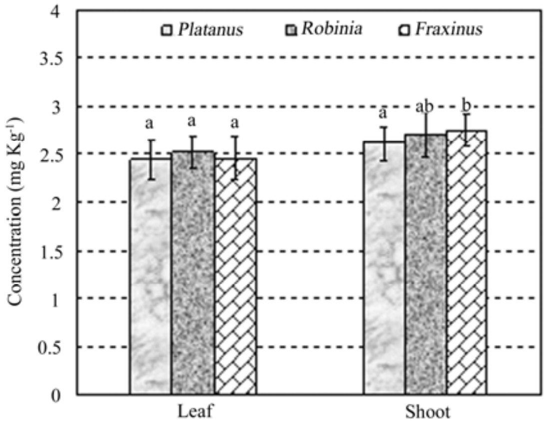

Fig. 2 Comparison of Cd uptake by the leaves and shoots of the studied species (Error bars show the Standard Error of Mean (SE); means with similar letters do not differ from each other ($p \le 0.05$)).

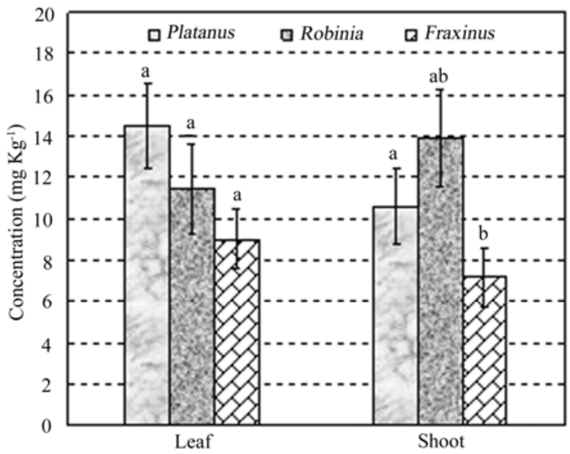

Fig. 3 Comparison of Pb uptake by the leaves and shoots in the studied species (Error bars show the Standard Error of Mean (SE); means with similar letters do not differ from each other ($p \le 0.05$)).

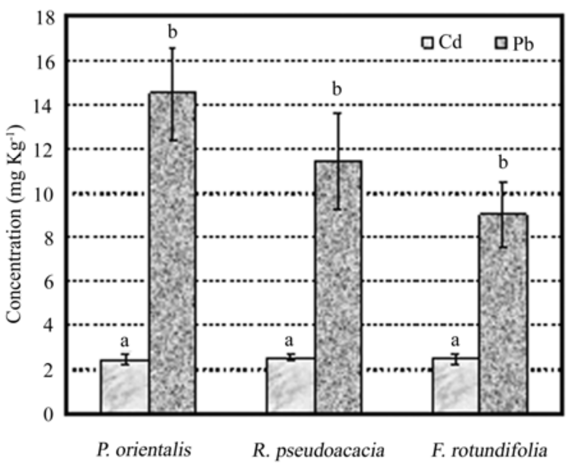

Fig. 4 Comparison of Cd and Pb uptake by the leaves in the studied spieces (Error bars show the Standard Error of Mean (SE); means with similar letters do not differ from each other ($p \le 0.05$)).

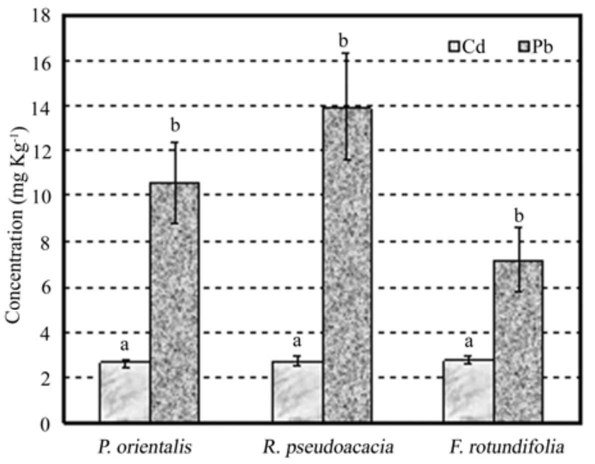

Fig. 5 Comparison of the amunts of Cd and Pb uptake by the shoots in the studied species (Error bars show the Standard Error of Mean (SE); means with similar letters do not differ from each other ($p \le 0.05$)).

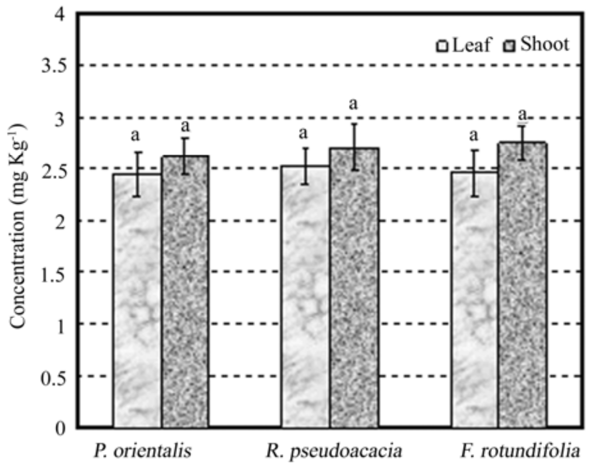

Fig. 6 Comparison of the leaves and the shoots uptak of Cd in the studied species (Error bars show the Standard Error of Mean (SE); means with similar letters do not differ from each other ($p \le 0.05$)).

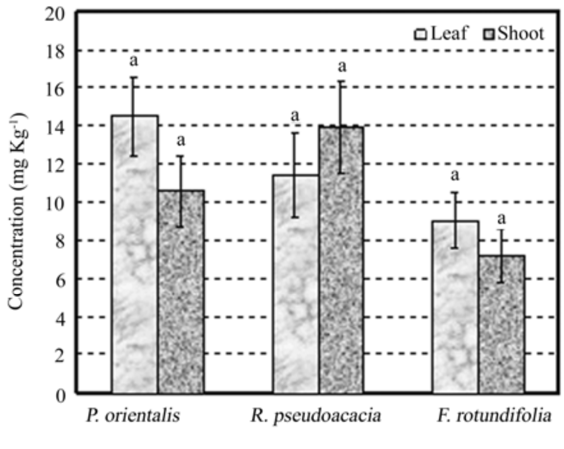

Fig. 7 Comparison of the shoots and leaves uptak of Pb in the studied species (Error bars show the Standard Error of Mean (SE); means with similar letters do not differ from each other ($p \le 0.05$)).

As explained before, we used metal accumulation index to assess the overall performance of the trees in terms of metal accumulation (Liu et al. 2007). By applying this index to individual species, we found that *R. pseudoacacia* had the highest MAI value for leaves (2.21) and *F. rotundifolia* had the highest MAI value for shoots (2.4) further than the *P. orientalis* and *R. pseudoacacia* (Table 2). In spite of high traffic, it is clear that the total amount of contaminants in this region is apparently very low and the pollution rate could not be announced as a threshold of sensitivity. This may be due to the wind effect that moves the pollution strongly.

Table 2. The values of metal accumulation index (MAI) for studied species

Species	Metal accumulation index	
	Leaf	Shoot
Platanus orientalis	2.09	2.3
Robinia pseudoacacia	2.21	1.94
Fraxinus rotundifolia	1.9	2.4

Serbula et al. (2012) demonstrated that in the lower concentration of Cd in air, we cannot conclude whether *R. pseudoacacia* behave as a good bioindicator of Cd pollution. Whereas based on the Celik et al. (2005) study, the leaves of *R. pseudo-acacia* reflect the environmental changes accurately, and they seem as an effective biomonitor of environmental quality in areas subjected to industrial and traffic pollutions. It seems that Black locust can be used as a suitable species for pollution monitoring at all, but in the lower concentration have low rate of heavy metal absorption.

Concentration of Cd and Pb in leaves of the species had no significant difference between different species, whereas Aftabtalab (2008) demonstrated the higher amount of *P. orientalis* leave absorption in Cd and Pb versus *Cupressus arizonica*. The lead concentration in leaves of *P. orientalis* are similar to lead concentration amounts of leaves in belgrade as the polluted region based on the Sawidis et al. (2011) studies.

Our study suggested that the uptake ability of *R. pseudoacacia* shoots in Cd and Pb was higher than that of *P. orientalis* and *F. rotundifolia*. The MAI index of *R. pseudoacacia* was lightly higher than the other species both for leaves and *F. rotundifolia* for shoots. Furthermore, *R. pseudoacacia* had the highest MAI value for leaves (2.21) and *F. rotundifolia* had the highest MAI value for shoots (2.4).

Conclusion

In conclusion, it seems that the little amount of pollutants in soil of the study area is the most important reason for lower absorption of Cd and Pb in the leaves and shoots of the trees. In addition, the significant difference between species in shoots versus leaves suggested a transporting process from leaves to shoots in all of the species by the end of October. Although results included that cadmium content in *F. rotundifolia* is significantly higher than the *P. orinetalis* and equal to *R. pseudoacacia*, therefore Persian Ash is more valuable for Cd accumulation in this habitat, whereas the accumulation of Pb in the shoots of *P. orientalis* is significantly higher than the *F. rotundifolia* and equal with *R. pseudoacacia*. Therefore it could be demonstrated that Plane tree is more valuable for Pb accumulation in compare with others. Moreover, it includes higher amounts of biomass and can remove higher amounts of pollutants from habitat as Zeynep and Atmaca (2011) announced similar condition for *P. orientalis*. Finally based on the Black locust results it seems that whenever we have a complex of both pollutants, it could be applied to the accumulation of these contaminants for Phytoremediation.

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References

Abou-Shanab R, Ghanem N, Ghanem K, Al-Kolaibe A. 2007. Phytoremediation potential of crop and wild plants for multi-metal contaminated soils. *Research Journal of Agriculture and Biological Sciences*, **3**: 370–376.

Aftabtalab N. 2008. Ability of phytoremediation of lead and cadmium by *Platanus orientalis* and *Cupressus arizonica*. M.Sc. Thesis Tehran University, Karaj, Iran (in Persian with English extended abstract). 140pp.

Amalia M, Favela-Torres E, Rivera-Cabrera F, Volke-Sepulveda T. 2011. Lead bioaccumulation in *Acacia farnesiana* and its effect on lipid peroxidation and glutathione production. *Plant and Soil*, **339**: 377–389.

Casado M, Anawar HM, Garcia-Sanchez A, Santa Regina I. 2008. Cadmium and zinc in polluted mining soils and uptake by plants (El Losar mine, Spain). *International Journal of Environment and Pollution*, **33**: 146–159.

Celik A, Kartal A, Akdog˘an A, Kaska, Y. 2005. Determining the heavy metal pollution in Denizli (Turkey) by using Robinia pseudo-acacia L. *Environment International*, **31:** 105–112.

Dong J, Wu FB, Zhang GP. 2005. Effect of cadmium on growth and photosynthesis of tomato seedlings. *Journal of Zhejiang University Science*, **6**: 974–980.

Franca, EJ, Femandes, EADN. Bacchi, MA, Rodrigues, RR, Bode, P and Saiki, M. 2010. Native plant bioaccumulation strategies: a baseline study for biomonitoring the Atlantic Forest. *International Journal of Environment and Health*, **4**:181–200.

Ghosh M, Singh SP. 2005. A review on phytoremediation of heavy metals and utilization of its byproducts. *Applied Ecology and Environmental Research*, **3**: 1–18.

Khodakarami Y, Shirvany A, Zahedi G, Matinizadeh M, Safari M. 2009. Evaluation of soil bioremediation in *Pistacia atlantica* and *Quercus brantii*. *Iranian Journal of Forest*, **1**: 313–320 (in Persian with English abstract).

Lasat MM. 2002. Phytoextraction of toxic metals – A review of biological mechanisms. *Journal of Environmental Quality*, **31**: 109–120.

Liu YJ, Zhu YG, Ding H. 2007. Lead and cadmium in leaves of deciduous trees in Beijing, China: Development of a metal accumulation index (MAI). *Environmental Pollution*, **145**: 387–390.

Pawlik-Skowronska B, Wojciak H, Skowronski T. 2008. Heavy metals accumulation, resistance and physiological status of some epigeic and epiphytic lichens inhabiting Zn and Pb polluted areas. *Polish Journal of Ecology*, **56**: 195–207.

Prasad MNV. 2004. *Heavy metal stress in plants. From Biomolecules to Ecosystems*. Heidelberg: Springer Verlag,, p. 462.

Purchart L, Kula E. 2007. Content of heavy metals in bodies of ground beetles (Coleoptera, Carabidae) with respect to selected ecological factors. *Polish Journal of Ecology*, **55**: 305–314.

Purohit SS, Agrrawal AK. 2006. *Environmental pollution Causes, Effects and Control*. India: Agrobios Publication, 624pp.

Raskin I, Smith RD, Salt DE. 1997. Phytoremediation of metals: using plants to remove pollutants from the environment. *Current Opinion in Biotechnology*, **8**: 221–226.

Salt DE, Smith RD, Raskin I. 1998. Phytoremediation. *Plant Physiology and Plant Molecular Biology*, **49**: 643–668.

Sawidis T, Breuste J, Mitrovic M, Pavlovic P, Tsigaridas K. 2011. Trees as bioindicator of heavy metal pollution in three European cities. *Environmental Pollution*, **159:** 3560–3570.

Serbula S, Miljkovic D, Kovacevic R, Ilic A. 2012. Assessment of airborne heavy metal pollution using plant parts and topsoil. *Ecotoxicology and Environmental Safety*, **76**: 209–214.

Singh OV, Labana S, Pandey G, Budhiraja R, Jain RK. 2003. Phytoremediation: an overview of metallic ion decontamination from soil. *Applied Microbiology and Biotechnology*, **61**: 405–412.

Tang Y, Qiu R, Zeng X, Fang X, Yu F, Zhou X, Wu Y. 2009. Zn and Cd hyperaccumulating characteristics of *Picris divaricata*. *International Journal of Environment and Pollution*, **38**: 26–38.

Zeidler M. 2005. Heavy metals two herb species (*River Morava*, *Czech Republic*). *Polish Journal of Ecology*, **53**: 185–195.

Zeynep D, Atmaca M. 2011. Influence of airborne pollution on Cd, Zn, Pb, Cu, and Al accumulation and physiological parameters of plant leaves in Antakya (Turkey). *Water, Air, and Soil Pollution*, **214**: 509–523.