HEAVY METAL UPTAKE BY *Impatiens walleriana* GROWING IN URBAN SOILS

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Abstract
The objective of our research was to evaluate the heavy metal (Cd, Cr, Cu, Ni, Pb, and Zn) transfer from soil to different parts (root, stem, leaf, flower) of *Impatiens walleriana*. For this, we collected soil and plant samples from 5 different sites in the center of Budapest. Based on our analytical measurements, the accumulation and translocation of the studied heavy metals in plants clearly differ from each other. Cd concentration was relatively high in all plant parts, but Ni accumulated primarily in roots and leaves, Cr only in roots, while Pb in stem and flowers. In contrast, the plant accumulated a relatively low amount of Cu and Zn. According to our results, *Impatiens walleriana* is a potentially suitable plant for phytoremediation of Cd, Ni or Cr polluted urban soils.

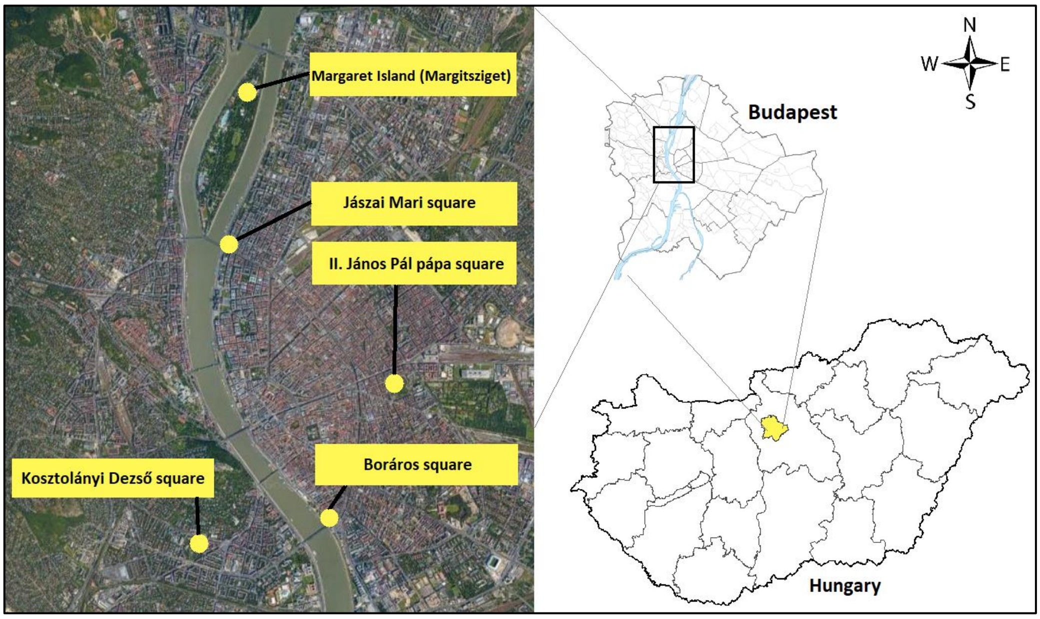
Introduction
I. walleriana (*Impatiens walleriana*, Hook. f.) is a species of the family *Balsaminaceae*, native to eastern Africa. Nowadays, it is one of the most widely grown ornamental herbaceous annual, found in many regions of the world [1]. It is often planted in urban parks and ornamental gardens, private backyard gardens, and along roadsides. According to previous studies, *I. walleriana* can accumulate large amounts of heavy metals, such as Cd [2,3], Ni [4], and Zn [5]. Therefore, this plant could be a good candidate to be used for phytoremediation purposes in heavy metal contaminated soils.

It is well-known, that heavy metals are one of the main pollutants in urban soils [6,7]. Although they are natural components of soil, most of them are mainly derived from anthropogenic sources (e.g. traffic, industrial, and domestic emissions) [8]. Since these emissions are not expected to decrease considerably in the near future, reducing heavy metals in the soil may become increasingly important in urban areas [6].

In our study, we investigated the heavy metal (Cd, Cr, Cu, Ni, Pb, and Zn) uptake of *I. walleriana* from the soil in Budapest, Hungary. Our objective was to evaluate the plant uptake, accumulation, and translocation of these metals, in order to learn about the suitability of *I. walleriana* for remediation of urban soils. In addition to this, we also investigated whether there is a correlation between the heavy metal concentrations of soil and plant.

Experimental
Soil and plant samples were collected from 5 different sites, which are located in the center of Budapest (Figure 1.). All sample sites were close to the Grand Boulevard (Nagykörút), one of the busiest parts of the city. Within each site, three 1 × 1 m subplots were randomly established. Soil samples were taken from these subplots (from the upper 0-20 cm layer of soil), with a composite of 5 subsamples. 3 plants (along with their roots) were also collected from each subplot.

Figure 1. Location of the study sites



In the laboratory, soil samples were homogenized, air-dried, and manually sieved through a 2 mm sieve. The plants were separated into root, stem, leaf, and flower, then each part was washed, dried at 105 °C, and grounded separately. Heavy metal (Cd, Cr, Cu, Ni, Pb, Zn) concentration of soils and plant parts were measured after HNO_3+H_2O_2 digestion by AAS. Statistical analyses were performed using GraphPad Prism 8.0.1 software. During this, Tukey's or Games-Howell test ($p<0.05$) was carried out to test for any significant differences between the heavy metal concentrations in soil and different plant parts. Pearson's correlation analysis was also used, to detect if there was any connectivity between the metal concentration of soils and plants. For this, we calculated the average metal concentration of the whole plant, based on the known data (weight and metal concentration of the plant parts).

Results and discussion

The measured heavy metal concentrations are shown in Table 1. *I. walleriana* clearly accumulated Cd in its tissues, as in most cases the metal concentrations in the plant parts were significantly higher than in the soil. This is consistent with the results found in the literature [2,3]. Highest Cd concentrations were observed in plant roots and leaves.

At each site, significantly higher Cr concentrations were measured in plant roots than in soil. However, the concentration of Cr in the above-ground parts of the plant was not very high (except for the leaf samples from Jászai Mari square). This may be because the plant can limit the toxic effect of Cr by the secretion of it in the vacuole of the root cells [9].

In the case of Cu, the results were a little controversial. Relatively high Cu concentration was measured in soil samples from Jászai Mari square and Kosztolányi Dezső square. In contrast, Cu concentration was very low (below 1 mg kg^{-1}) in samples from Margaret Island and II. János Pál papa square. Despite this, the concentration of Cu in plant parts was more or less constant. This can be explained by the fact that Cu is an essential element for plants, so *I. walleriana* took up only the required amount of Cu from the soil [10].

I. walleriana accumulated Ni in its roots and leaves, as the Ni concentration of these plant parts were significantly higher than in soil at all sites. However, there was no remarkable Ni accumulation in stem and flower.

In contrast to Ni, Pb accumulated primarily in the stem and flower of the plant. Moreover, the Pb concentration in leaves was in many cases lower than in soil.

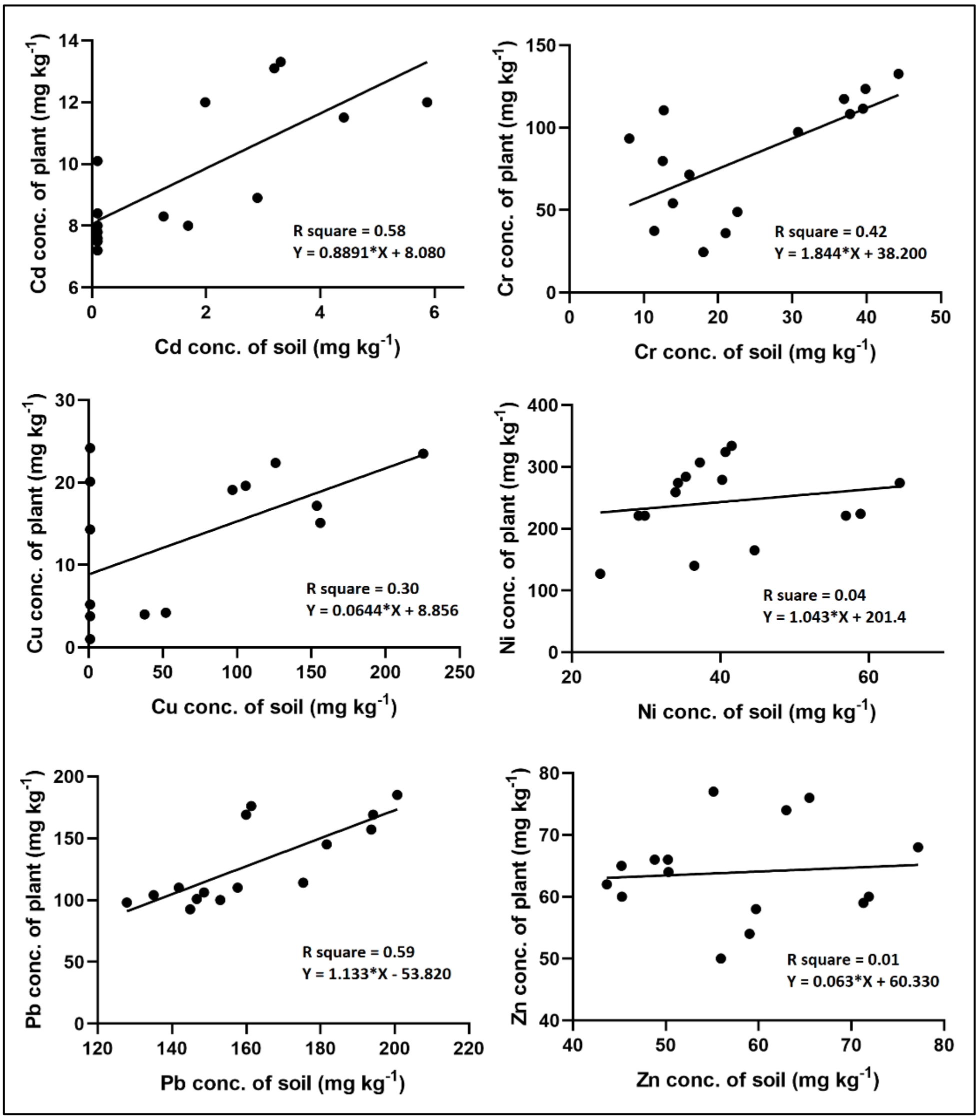
In most cases, there were no significant differences between the Zn concentration measured in plant parts and soil (except for samples from Kosztolányi Dezső square). The Zn concentration in plant parts was varied between a small range, which may be due to its essential role, similar to Cu [10].

Table 1. Mean concentration of heavy metals (mg kg^{-1}) in soil and different plant parts. Different letters mean statistically significant differences according to Tukey's or Games-Howell test (p<0.05).

Site	Soil/Plant part	Cd	Cr	Cu	Ni	Pb	Zn
Margaret Island	soil	1.03**a**	20.55**a**	<1.00**a**	34.42**a**	146.76**ac**	59.09**a**
	root	8.73**b**	98.60**c**	<1.00**a**	241.65**b**	125.59**ab**	61.33**a**
	stem	5.96**ab**	29.99**ab**	<1.00**a**	15.10**a**	214.64**ac**	68.73**a**
	leaf	10.97**b**	15.13**a**	10.00**b**	423.90**b**	81.48**b**	80.89**a**
	flower	4.56**a**	34.37**b**	<1.00**a**	30.69**a**	233.88**c**	53.80**a**
Jászai Mari square	soil	<0.1**a**	40.37**a**	178.34**a**	34.99**a**	174.01**a**	73.46**a**
	root	8.21**b**	212.49**c**	37.81**b**	95.21**b**	200.44**ab**	62.83**ab**
	stem	7.67**bc**	37.38**a**	1.95**c**	16.88**a**	255.86**b**	62.33**ab**
	leaf	10.81**c**	115.61**b**	9.69**c**	210.82**c**	138.56**a**	59.76**b**
	flower	6.28**b**	27.11**a**	1.00**c**	47.00**a**	230.25**ab**	65.28**ab**
II. János Pál pápa square	soil	1.01**a**	36.02**a**	<1.00**a**	60.01**ac**	189.86**a**	58.23**a**
	root	8.63**b**	226.30**c**	30.75**b**	121.94**c**	168.77**a**	58.45**a**
	stem	6.49**b**	42.38**a**	<1.00**a**	13.38**b**	223.55**b**	70.73**a**
	leaf	9.11**b**	62.36**a**	14.09**ab**	280.54**c**	131.64**a**	53.53**a**
	flower	7.79**b**	3.08**b**	<1.00**a**	45.23**a**	228.19**b**	50.72**a**
Boráros square	soil	2.83**a**	11.09**a**	30.25**a**	33.18**a**	134.94**a**	48.01**a**
	root	14.05**c**	175.75**c**	2.49**a**	288.78**b**	139.24**a**	72.37**ab**
	stem	13.58**bc**	15.87**a**	<1.00**a**	12.11**a**	333.16**b**	53.29**ab**
	leaf	10.64**bc**	35.12**ab**	6.67**a**	313.46**b**	75.81**a**	82.86**b**
	flower	7.77**b**	39.90**b**	<1.00**a**	26.81**a**	258.08**b**	66.79**ab**
Kosztolányi Dezső square	soil	3.46**a**	13.81**a**	109.54**a**	39.84**a**	162.03**a**	48.61**a**
	root	12.85**b**	99.70**b**	26.27**b**	247.71**d**	142.52**ab**	62.48**c**
	stem	7.44**a**	19.13**a**	1.01**c**	13.85**b**	228.17**ac**	37.42**b**
	leaf	11.00**ab**	37.13**a**	16.47**b**	415.35**d**	66.76**b**	79.29**d**
	flower	6.07**a**	33.74**a**	<1.00**c**	30.24**c**	219.01**c**	52.07**ac**

The results of the correlation analysis are shown in Figure 2. It can be concluded that with the increase of the heavy metal concentration in soil, the metal concentration in the plant also increased. However, this increase was not significant in the case of Ni and Zn. This was not unexpected, as the amount of heavy metal taken up by a plant also depends on a number of other factors besides metal concentration of soil, such as plant physiological factors, soil properties (texture, pH, etc.) or other environmental factors (temperature, precipitation, etc.) [11]. The strongest correlation between soil and plant metal concentrations were found for Cd (R^2 = 0.58) and Pb (R^2 = 0.59).

Figure 2. Correlation between heavy metal concentration of soil and plant according to Pearson's correlation analysis.



Conclusion

We investigated the heavy metal uptake and accumulation of *I. walleriana* growing in urban soils. It was revealed that the plant can accumulate relatively large amounts of Cd and Ni. In some cases, the concentration of these metals in the leaf was ten times higher than in the soil. Based on these results, *I. walleriana* could be a suitable plant for phytoremediation of Cd and Ni polluted urban soils. In most of the urban green areas, ornamental plants are harvested at the end of the growing season. The entire plant (including roots) is then removed from the area. Since Cr has accumulated in roots, *I. walleriana* can be also used to control the amount of Cr in the soil (besides Cd and Ni) in these areas.

I. walleriana is practically unsuitable for phytoremediation of the other three heavy metals. Although relatively high concentrations of Pb were observed in the stem and flower of the plant, these plant parts make up only a small part of the whole plant. Thus, only a small amount of Pb can be removed from the soil with this technique. Based on our measurements, *I. walleriana* has not accumulated Cu and Zn remarkably, therefore cannot be used for remediation of soils contaminated with these metals.

Acknowledgments

This research has been supported by the ÚNKP-19-3-I-SZIE-34. New National Excellence Program of the Ministry for Innovation and Technology, Hungary.

References

[1] C. Salgado-Salazar, N. LeBlanc, A. Ismaiel, Y. Rivera, C. Y. Warfield, J. A. Crouch, Plant Dis. 102 (2018) pp. 2411-2420.

[2] J. L. Wei, H. Y. Lai, Z. S. Chen, Ecotox. and Environ. Saf. 84 (2012) pp. 173-178.

[3] H. Y. Lai, Chemosphere, 138 (2008) pp. 370-376.

[4] F. Schenato, N. T. Schröder, F. B. Martins, International Conference on Energy, Environment, Ecosystems and Sustainable Development (2008) pp. 366-373.

[5] J. K. Torrecilha, G. P. Mariano, P. S. da Silva, International Nuclear Atlantic Conference (2013) p. 9.

[6] B. Wei, L. Yang, Microchem. J. 94 (2010) pp. 99-107.

[7] L. Madrid, E. Díaz-Barrientos, F. Madrid, Chemosphere 49 (2002) pp. 1301-1308.

[8] C. Su, Environ. Skeptics and Critics. 3 (2014) p. 24.

[9] M. Shahid, S. Shamshad, M. Rafiq, S. Khalid, I. Bibi, N. K. Niazi, M. I. Rashid, Chemosphere, 178 (2017) pp. 513-533.

[10] M. Adrees, S. Ali, M. Rizwan, M. Ibrahim, F. Abbas, M. Farid, S. A. Bharwana, Environ. Sci. Poll. Res. 22 (2015) pp. 8148-8162.

[11] J. R. Peralta-Videa, M. L. Lopez, M. Narayan, G. Saupe, J. Gardea-Torresdey, Int. J. Biochem. Cell Biol. 41 (2009) pp. 1665-1677.