University of Belgrade, Technical Faculty in Bor

29th International Conference Ecological Truth & Environmental Research

EcoTER'22

Proceedings

Editor

Prof. Dr Snežana Šerbula

21-24 June 2022, Hotel Sunce, Sokobanja, Serbia

University of Belgrade, Technical Faculty in Bor

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PREFACE

In today's world, the environment has been endangered by the use of outdated technology, fossil fuels and environmental law violations. Therefore, environmental and many other scientists all over the world have been concerned about finding sustainable technology in resolving these issues. That is why environmental research and ecological truth are at the focus of the 29th International Conference Ecological Truth & Environmental Research 2022 (EcoTER'22), which will be held in Sokobanja, Serbia, 21–24 June 2022. On behalf of the Organizing Committee, it is a great honor and pleasure to wish all the participants a warm welcome to the Conference.

We hope to convey the message of the conference, which is that a transformation of attitudes and behavior would bring the necessary changes. This is also an opportunity for the participants who are experts in this field to exchange their experiences, expertise and ideas, and also to consider the possibilities for their collaborative research.

The 29th International Conference Ecological Truth & Environmental Research 2022 is organized by the University of Belgrade, Technical Faculty in Bor, and co-organized by the University of Banja Luka, Faculty of Technology, the University of Montenegro, Faculty of Metallurgy and Technology – Podgorica, the University of Zagreb, Faculty of Metallurgy – Sisak, the University of Pristina, Faculty of Technical Sciences – Kosovska Mitrovica and the Association of Young Researchers, Bor.

These proceedings include 85 papers from the authors coming from the universities, research institutes and industries in 6 countries: Bulgaria, Italia, Albania, Bosnia and Herzegovina, Montenegro and Serbia.

As a part of this year's conference, the 4th Student section – EcoTERS'22 is being held. We appreciate the contribution of the students and their mentors who have also participated in the Conference.

Financial assistance provided by the Ministry of Education, Science and Technological Development of the Republic of Serbia is gratefully acknowledged by the Organizing Committee of the EcoTER'22 conference.

The support of the Platinum donor and their willingness and ability to cooperate have been of great importance for the success of EcoTER'22. The Organizing Committee would like to extend their appreciation and gratitude to the Platinum donor of the Conference for their donation and support.

We appreciate the effort of all the authors who have contributed to these Proceedings. We would also like to express our gratitude to the members of the scientific and organizing committees, reviewers, speakers, chairpersons and all the Conference participants for their support to EcoTER'22. Sincere thanks go to all the people who have contributed to the successful organization of EcoTER'22.

Prof. Snežana Šerbula,

President of the Organizing Committee

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TOXIC METALS BIOACCUMULATION IN *Plantago lanceolata* FROM ANTHROPOGENICALLY DISRUPTED AREA

Jelena Milosavljević[1*], Snežana Šerbula[1], Ana Radojević[1], Tanja Kalinović[1], Jelena Kalinović[1], Boban Spalović[1]

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Abstract

The study was carried out on Plantago lanceolata, sampled in the anthropogenically endangered area due to the long-term copper mining-metallurgical activities. The purpose of this paper was to analyze the concentrations of toxic metals (Al, Cu, Fe, Mn, Ni, Pb and Zn) in roots, leaves, stems and flowers of P. lanceolata. Toxic metals accumulation abilities in plant parts were assessed using the metal accumulation index (MAI). The MAI values ranged between 77.19 and 158.58 for roots, 63.64–101.24 for leaves, 60.17–146.57 for stalks and 52.86–118.96 for flowers. Relative deviations in toxic metal content from the corresponding values given for the "reference plant" were also calculated. The positive deviations were denoted for Cu, Ni and Pb in all parts at the site 1, which could indicate high bioavailability of these metals as well as good adaptation abilities to the extreeme environmental pollution. Positive deviations were denoted for all the analyzed toxic metals (except Mn) in the roots from all the sampling sites, which was particularly noticeable for Cu and Pb at the site 1 in the immediate vicinity of the copper smelter. The relative deviations for the aboveground parts were positive and negative depending on the sampling site.

Keywords: copper smelter, *Plantago lanceolata*, toxic metals, metal accumulation index

INTRODUCTION

Metal mining and smelting are regarded as one of the most environmentally destructive anthropogenic activities. Extremely high content of hazardous substances (i.e. toxic metals) originates from the metal production activities, as well as from the ore processing wastes, such as mine tailings. Toxic metals are extremely persistent and may be present in high concentrations for decades and even centuries in the environment. This poses a serious problem not only in the areas in the immediate vicinity of the pollution sources, but also in the adjacent areas to which toxic metals are subsequently transported [1–4].

Accumulation of different hazardous substances in the environment, and particularly their bioaccumulation, is a worldwide problem. Plants transfer toxic metals from abiotic to biotic environment, while avoiding their detrimental effects, thus posing a risk of metal transfer to higher food chain strata [1,5,6].

The areas impaired with anthropogenic activities could be observed as reservoirs of plants with different accumulation abilities. The analysis of biological material in the environmental quality monitoring is recognized as a distinctive approach to acquire information regarding toxic metal contamination [5]. *Plantago lanceolata* has been shown to have the abilities to accumulate toxic metals from different anthropogenically polluted environments [1,5,7].

The aim of this paper is to analyze toxic metals accumulation in the parts of *P. lanceolata* sampled in the area endangered by the long-term copper mining-metallurgical activities.

MATERIALS AND METHODS

Sampling and analysis of the plant material

Plant material was sampled at the most endangered sites in the Bor area in regard to the vicinity of the primary pollution source (i.e. copper smelter), secondary pollution sources (i.e. the city heating plant, flotation tailing ponds, traffic and individual home heating) and the prevailing wind directions. Sampling was performed at the following sites: site 1 (Town Park, 0.5 km SW from the copper smelter), site 2 (Brezonik, 2.5 km NW), site 3 (Oštrelj, 4.5 km ESE), site 4 (Slatina, 6.5 km SE) and site 5 (Gornjane, 17 km N, represented the control site).

Microwave digestion was performed by adding 7 mL 65% HNO_3 and 1 mL 30% H_2O_2 to 0.5 g of washed, air dried and grinded plant material (separated into roots, leaves, stalks and flowers). The concentrations of Al, Cu, Fe, Mn, Ni, Pb and Zn in plant parts were determined by the Inductively Coupled Plasma Optic Emission Spectroscopy (ICP–OES, Model Optima 8300).

Toxic metals analysis

Accumulation of toxic metals in the plant parts was assessed by calculating the metal accumulation index (MAI), according to the following expressions [8]:

$$MAI=\left(\frac{1}{N}\right)\sum_{j=1}^{N} Ij \quad (1)$$

where N represents the total number of toxic metals analyzed, and Ij is a sub-index for variable j which is defined as:

$$Ij=\frac{x}{\delta x} \quad (2)$$

where x represents toxic metal concentration, and δx represents its standard deviation.

Data visualization

Data visualization was performed in the R statistical environment (v 4.1.0) [9] with different packages [10,11].

RESULTS AND DISCUSSION

The MAI values for each individual plant part of *P. lanceolata* at selected sampling sites are given in Table 1. The highest MAI value was observed in the roots sampled at the control site 5, while the lowest was noted in the flowers sampled at the site 1. Taking into account different plant parts, the MAI values were in the following ranges: 77.19–158.58 (in the roots); 63.64–101.24 (leaves); 60.17–146.57 (stalks); 52.86–118.96 (flowers). In the study by Nadgórska-Socha *et al*. [7] the MAI values for Cd, Cu, Pb, Mn, Fe and Zn in *P. lanceolata* leaves sampled from the urban environment (i.e. around industrial plants, main roads, city parks and green areas) ranged between 4.71 and 23.1 and were far lower than for the samples from Bor and the surroundings.

The MAI values obtained for *P. lanceolata* sampled in the Bor area were higher compared to the data for different tree and shrub species sampled in the anthropogenically polluted areas [6,12–14]. Various factors, such as local atmospheric conditions and meteorological parameters, sampling time and plant features, could influence the MAI value [14]. Hu *et al*. [12] denoted that low-growing plants were more exposed to soil splash compared to the high-growing plants (i.e. trees). Plants with high MAI values should be used as barriers between polluted and non-polluted areas [12].

Table 1 *Metal accumulation index (MAI) of P. lanceolata sampled at different sites in the Bor area*

Plant part	**Sampling sites**				
	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**
Roots	77.19	82.72	120.59	129.10	158.58
Leaves	101.24	64.70	71.31	93.89	63.64
Stems	109.67	65.91	146.57	60.17	94.27
Flowers	52.86	118.96	78.30	68.86	79.74

The expression “Reference plant”, proposed by Markert [15], includes typical content of toxic metals in plants, which are: 80 mg kg^{-1} (Al), 10 mg kg^{-1} (Cu), 150 mg kg^{-1} (Fe), 200 mg kg^{-1} (Mn), 1.5 mg kg^{-1} (Ni), 1 mg kg^{-1} (Pb) and 50 mg kg^{-1} (Zn). In respect to the values for the “reference plant”, toxic metals content in the plant parts of *P. lanceolata* sampled in the Bor area were 0.06–14.43 (for Al), 0.62–46.29 (Cu), 0.15–6.80 (Fe), 0.04–0.71 (Mn), 0.44–3.87 (Ni), 13.90–37.99 (Pb) and 0.48–6.11 (Zn) times higher.

The reference values given by Markert [15] could be used to establish the baseline of the “chemical fingerprint”. The illustration of this approach is presented as the relative deviations in toxic metal content in comparison to the contents defined for the “reference plant” [16]. Figure 1 represents “chemical fingerprints” of *P. lanceolata* sampled in the anthropogenically disrupted Bor area.

Toxic metal content in the plant samples varied from the “reference plant” with relative deviations between: -93.71 and +1343.13 for Al (Figure 1a), -37.69 and +4529.07 for Cu (Figure 1b), -85.06 and +580.18 for Fe (Figure 1c), -96.47 and -28.69 for Mn (Figure 1d), -55.71 and +286.66 for Ni (Figure 1e), +1289.61 and +3698.61 for Pb (Figure 1f), -51.57 and +510.90 for Zn (Figure 1g).

With respect to the “reference plant” the relative deviations were predominantly positive for the analyzed toxic metals (except for Mn) in the plant samples from the site 1. This was particularly denoted for Cu and Pb whose relative deviations in roots were 4529.07% and 3698.61%, respectively, in respect to the “reference plant”. According to Remon *et al*. [16], high positive relative deviation from the “reference plant” could be explained with higher metal bioavailability at the given sampling site.

The positive relative deviations for Al in the roots from all the sampling sites were noticed, while negative relative deviations were calculated for almost all the aboveground plant parts (except sites 1 and 4).

The positive values of the relative deviations for Cu in all the analyzed plant parts from the site 1 could be an indication of high metal bioavailability at the given sampling site [16], in the conditions of the extreme environmental pollution. Positive relative deviations for Cu in the roots from the all sampling sites were noticed. The relative deviations of Cu content in the aboveground plant parts were positive, except in the stalks (sites 2, 3, 4 and 5) and in the leaves (site 5). Such regularities pointed out the good adaptation abilities to the environmental pollution with Cu.

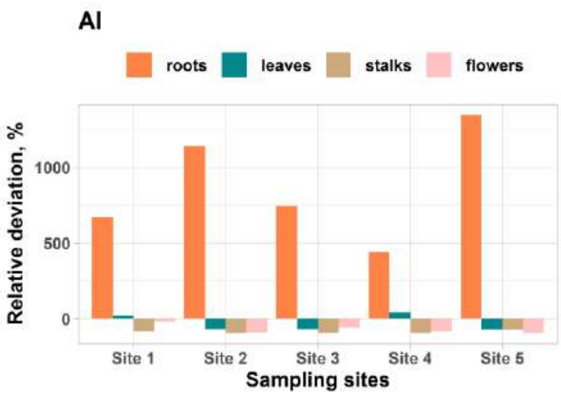
The relative deviations of Fe in the roots from all the sampling sites were positive, while negative deviations were calculated for Fe in the aboveground plant parts except in the leaves and flowers from the sites 1 and 4.

The negative relative deviations of Mn in all the plant parts from all the sampling sites. These results could indicate low Mn bioavailability in the study area.

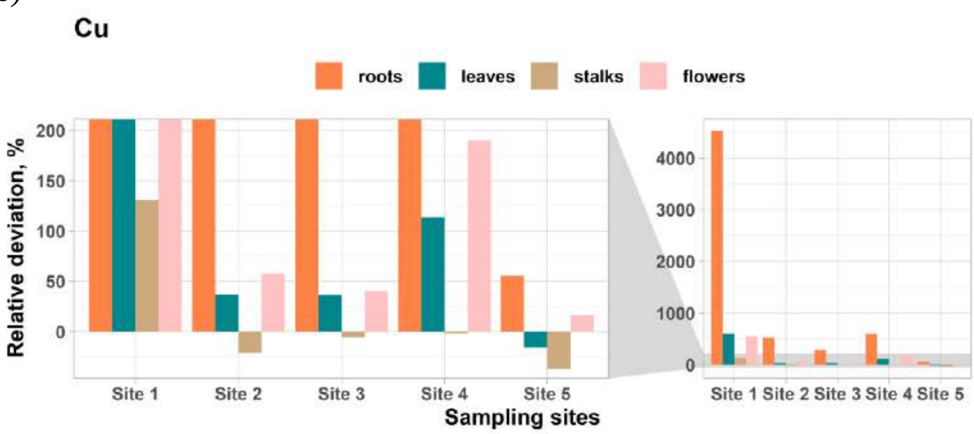
The relative deviations of Ni were positive in all plant parts from the analysed sampling sites except the sites 2 and 5, where deviations in the aboveground parts were negative depending on the part.

Unlike Mn, all relative deviations calculated for Pb were positive, which could indicate high bioavailability of this toxic metal [16], as well as good adaptation ability to Pb.

a)



b)



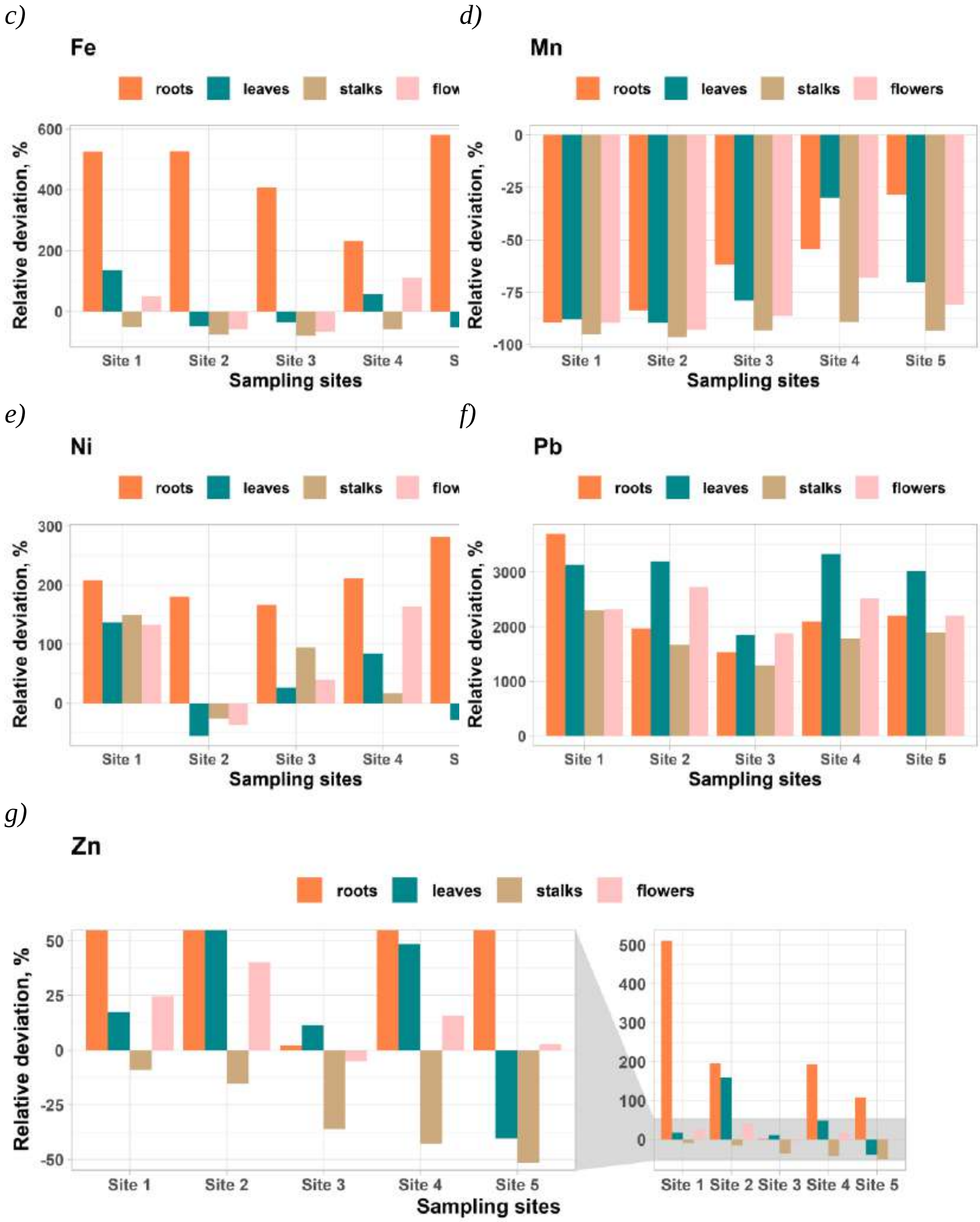


Figure 1 *Chemical fingerprints of toxic metal content in parts of P. lanceolata, sampled from the anthropogenically disrupted Bor area, expressed as relative deviations from the "reference plant"*

It was characteristic that relative deviations for Zn were positive in the roots at all the sampling sites, while for stalks they were negative. The relative deviations for the leaves were negative only for samples from the control site 5, which was probably because of the low Zn environmental concentration at this unpolluted site. Taking into account Zn concentrations in the flowers, regularities concerning relative deviations calculated for the samples from the study area were not observed.

CONCLUSION

The content of toxic metals (Al, Cu, Fe, Mn, Ni, Pb and Zn) was determined in the plant parts (roots, leaves, stalks and flowers) of *P. lanceolata* sampled in the Bor area endangered by the mining-metallurgical activities. Sampling of the plant material was performed at the most imperilled sites due to their location in the vicinity of the copper smelter, as well as the other pollution sources (i.e. the city heating plant, flotation tailing ponds, traffic and individual home heating) and in the prevailing wind directions. The analyzes of the toxic metal concentrations in the plant samples were performed using metal accumulation index (MAI). Taking into account the investigated plant parts, the roots were characterized with the highest MAI values, which indicated higher accumulation efficiencies in roots, compared to the other parts. Moreover, comparisons of toxic metals content obtained in the investigated plant parts to the corresponding contents given for the “reference plant” allowed establishing chemical fingerprints. The results indicated positive deviations for Cu, Ni and Pb in all plant parts at the site 1, which could be an indication of the good adaptation abilities of *P. lanceolata* to the environmental pollution with these toxic metals. The relative deviations for all the studied toxic metals in the roots (except Mn) were positive. The highest positive deviations were denoted for Cu and Pb in the roots samples from the site 1, which was the most anthropogenically endangered. The obtained negative relative deviations of Mn in the plant material from all the sampling sites, and positive deviations of Pb in the plant material from all the sampling sites could indicate the environmental load with these elements.

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