BIOLOGICA NYSSANA

4 (1-2) • December 2013: 57-64

11th SFSES • 13-16 June 2013, Vlasina lake

Original Article

The bioconcentration of some metals in species *Potentilla visianii* Pančić

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***Abstract*:**
Branković, S., Glišić, R., Pavlović-Muratspahić, D., Topuzović, M., Đekić, V.: *The bioconcentration of some metals in species Potentilla visianii Pančić. Biologica Nyssana, 4 (1-2), December 2013: 57-64.*

The aims of this study were to determine content of eleven metals (Ca, Mg, Fe, Mn, Cu, Zn, Ni, Pb, Cd, Co, and Cr) in serpentine-obligate species *Potentilla visianii* Pančić and serpentine soil where it grows. The concentrations of all examined metals were higher in soil than in species *P. visianii* (excepting Ca). Our study exhibited different metal bioconcentration in species *P. visianii*, depending on kind of metals. In soil samples metal concentrations had the following order: Mg>Fe>Ca>Ni>Cr>Mn>Co>Zn>Pb>Cu>Cd, and in plant Ca>Mg>Fe>Ni>Mn>Cr>Zn>Co>Cu>Pb>Cd. The Ca:Mg ratio in soil was 0.02 and in plant 1.32. The Biological Absorption Coefficient was below one (except for Ca and Zn). The serpentine-obligate species *Potentilla visianii* have had different capacity in uptake and bioaccumulation of investigated metals. Selective absorption of certain ions, combined with it sedentary nature makes this plant suitable as biological monitors used in ecosystem quality studies to monitor heavy metals of serpentine soils.

Key words: bioconcentration, metals, *Potentilla visianii* Pančić

Introduction

Metals are considered to be one of the main sources of the environmental contamination, since they have a significant affect on its ecological quality. Soils are preferred monitoring tools, and they show less variation in time and space, allowing more consistent assessment of spatial and temporal contamination (Keshav et al., 2011). Therefore, the determination of metals in soils and plants are very important in monitoring environmental contamination.

Ultramafic soils cover substantial areas at many locations in Serbia, but there is little information about their flora and biogeochemistry in small serpentine localities. The extreme chemical nature of such as soils, with abnormally high concentrations of Ni, Cr and Co (in addition to Mg and Fe) and low concentrations of the important nutrients N, P and K, often leads to such areas having a characteristic flora consisting of many endemics (Brooks, 1987). In Balkan peninsula, serpentine endemics represent 19% of Balkan endemic plants (Stevanović et al., 1999). In this work we reported data obtained from a survey of soil and plant samples collected from serpentine locality near the village Kamenica (mountain Goč, Serbia). In spite of the fact that there are a lot of data connected with issue of heavy metals and plant, we have not found published data about serpentine-obligate species *Potentilla visianii* Pančić, which grows on the cliff and dry grassland, usually on serpentine in the North-West part of Balkan peninsula (Albania and former Yugoslavia). Therefore, the estimation of genetic variation between plants in the ability to accumulate metals is of both practical and theoretical importance. In addition, our results make contribution to comprehension of ecophysiology and ecological adaptations of species from genus *Potentilla* as well as to estimation the potential of species *Potentilla visianii* to uptake and bioaccumulate especially heavy metals from serpentine soils which they naturally contain.

The aims of this study were to determine content and bioaccumulation of eleven metals (Ca, Mg, Fe, Mn, Cu, Zn, Ni, Pb, Cd, Co, and Cr) in plant species *Potentilla visianii* Pančić and serpentine soil where it grows.

Material and methods

Study Area

Ultramafic (serpentine) soils are globally ubiquitous often distributed as small areas over a much larger geological province. The researched area was located in the village Kamenica (Central Serbia). Its site presents a part of a much larger part of serpentine substrate which located in Western and Central Serbia, and extends towards North, Central and South-Eastern parts of Albania.

Fig. 1. Location of investigated locality

The field work was conducted during March-August 2011. One serpentine locality in the village Kamenica (Fig. 1) was surveyed to collect *Potentilla visianii* Pančić (*Potentilla visianii* Pančić - POVIS) serpentine-obligate plant, together with their associated soils. The investigated site is at 359 m above sea level, and is centered on 74° 76' 284" N, 48° 29' 864" E (read by GPS Garmin-etrex, vista HCx).

Soil and plant sampling and analysis

Six soil replications near roots of researched plants were collected from 1 to 10 cm depth. This depth corresponds to the major rooting zone of the herbs and small shrubs (Reeves et al., 2007). Soil samples were initially air-dried and stone pieces were removed, sieved to 2 mm, and stored at 4 °C until analysis. Sub-samples of 10 g were ground to pass a 70-mesh sieve (< 215 μm) and then oven-dried at 105 °C for 24h.

Determination of plant material was performed in the laboratory of the Institute of Biology and Ecology, Faculty of Science in Kragujevac, with the help of standard keys for determination: Javorka & Csapody (1979), Flora of the Republic of Serbia (Josifović, 1991) and Flora Europea (Tutin et al., 1964). Identified plant material was elutriated in distilled water and then dried at room temperature. Next it was dried in dryer (Binder/Ed15053), 24 hours at a temperature 105ºC and prepared for chemical analysis by standard procedures.

After drying on l05°C to constant mass, soil and plant materials (3 g of soil sample and 2 g of plant samples with accuracy of ± 0.01g) were measured on analytic scale. The measured samples were transferred in Kjeldahl balloon and perfused with 10 ml of concentrated HNO_3. Reaction mixture was heated carefully by flame, until the solution became dry. The treatment was repeated until clearing up of the solution, and stopping of releasing of nitric vapors. After that, samples were cooled, and content in the Kjeldahl's dish was perfused with 6 ml of concentrated $HClO_4$ and than heated. The heating was stopped at solution volume of approximately 3 ml in Kjedahl's balloon when solution became clear and achromatic. Also, the solution was cooled and distillate water was added. The content from Kjeldahl's dish was filtered through a moistened Whatman No. 40 filter paper into 50 ml volumetric flask. These solutions were used for determination of heavy metals in soil and plant materials.

Eleven metals were analyzed in soil and whole plants: calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), nickel (Ni), lead (Pb), cadmium (Cd), cobalt (Co) and chromium (Cr). Chemical analysis of soil and plant samples was done by standard methods, at the Institute of Public Health Division of Hygiene and Medical Ecology in Kragujevac. The metal concentrations in soil and plant samples were determined by inductively coupled plasma-mass atomic emission spectrometry (ICP-OES iCAP 6500, ICP-20100908), directly from the solution. The detection limits for Ca, Mg, Fe, Mn, Cu, Zn, Ni, Pb, Cd, Co and Cr in plant material were: 0.0087, 0.007, 0.0053, 0.0051, 0.0056, 0.0055, 0.006, 0.003, 0.0027, 0.0054 and 0.0053 mgkg^{-1}, respectively. The detection limits for Ca, Mg, Fe, Mn, Cu, Zn, Ni, Pb, Cd, Co and Cr in soil were: 0.009, 0.007, 0.0056, 0.0065, 0.0076, 0.0051, 0.0059, 0.0089, 0.003, 0.0079 and 0.0092 mgkg^{-1}, respectively. The six replications of one sample were prepared for soil and plant and than concentrations of mentioned metals were determined. Biological Absorption Coefficient (BAC) was calculated for each metal by dividing the total content of metal in plant by their total content in soil (Kabata-Pendias, 2001). The soil and plant metal data were subjected to analysis of variance and Pearson correlation coefficient analysis. The arithmetic mean and standard deviation were calculated. The statistical analysis of data was performed using the computing package called Statistical Package for Social Science (SPSS 10 for Windows). The concentrations of metals in soil and plant materials were expressed in mgkg^{-1} of dry matter (mgkg^{-1} d.m.).

Results and discussion

Under the term serpentinit is understood ultrabasical magmatic stones of different chemical compounds which changed under atmospheric influence. However, serpentine environments are typically inhospitable for many plants due to several factors of their soil chemistry, collectively called the "serpentine syndrome" (Kazakou et al., 2008; Kazakou et al., 2010): a) low availability of calcium relative to magnesium; b) deficiency of other essential macronutrients (P, N, K) and c) high levels of potentially phytotoxic elements (Ni, Cr, Co, and sometimes Mn and/or Cu). Plant species found on serpentine soils can be divided into two groups: (a) serpentine-tolerant or serpentine-facultative plants, which are able to survive on serpentine but grow better elsewhere; (b) serpentinicolous, serpentine-endemic or serpentine-obligate plants, which would grow exclusively on serpentine soils and are not found on other substrates (Reeves et al., 1996). However, the serpentine-tolerant plants must endure a variety of adverse physical and chemical conditions, especially high concentration of some heavy metals.

Generally, we found that the mean concentrations of investigated metals were higher in the soil samples than those calculated for same metals in plant samples (except for Ca) (Tab. 1). The results of this study are in accordance with previous the findings of some researches [Market, B. 1992; Shallari et al., 1998; Chaney et al., 2008].

Table 1. The mean concentrations of Ca, Mg, Fe, Mn, Cu, Zn, Ni, Pb, Cd, Co and Cr (mgkg^{-1} d.m.) in soil and species *Potentilla visianii* Pančić

	SOIL	**POVIS**
Ca	**1109.08±6.14**	**11104.58±36.59**
Mg	**59603.59±312.00**	**8443.75±45.65**
Fe	**35709.92±320.90**	**1912.29±25.55**
Mn	**288.86±6.38**	**69.53±0.46**
Cu	**6.11±0.30**	**3.21±0.03**
Zn	**23.12±0.15**	**23.10±0.02**
Ni	**931.49±23.77**	**84.38±0.17**
Pb	**13.20±0.08**	**2.13±0.05**
Cd	**1.41±0.01**	**0.19±0.00**
Co	**33.65±0.08**	**4.43±0.01**
Cr	**485.24±10.77**	**41.50±0.22**

[1] The mean value (n=6) ± standard deviation, POVIS – *Potentilla visianii* Pančić

The serpentine soil in the village Kamenica contained 1109.08 mg Ca kg^{-1} d.m., and Ca content in plant species was 11104.58 mg Ca kg^{-1} d.m. However, the mean concentrations of Mg and Fe in soil samples (59603.59 and 35709.92 mgkg^{-1} d.m., respectively) were significant higher than in the plant samples (8443.75 and 1912.29 mgkg^{-1} d.m., respectively). The serpentine-tolerant species survive on soils with depleted levels of Ca because they are still able to absorb quantities of Ca without taking up excessive quantities of Mg. The plant ability to maintain high leaf Ca:Mg by selective translocation of Ca and/or inhibited transport of Mg from roots is a key evolutionary change needed for survival on serpentine soils. Therefore, the concentration of Mg in plant tissue is inversely proportional to the concentration of other nutrients such as Fe, Co and Mn. These data suggest that the uptake of Mg comes at a cost to the plant so that the uptake of other element nutrients is forfeited. The heightened level of Mg in serpentine soils and its antagonistic behaviour toward other elements could be the most important factor in serpentine syndrome (Brooks & Yang, 1987). However, our results are in agreement with earlier findings that serpentine soils contain high amounts of iron and magnesium (Reeves et al., 2007; Bech et al., 2008). According to Market (1992), 5-200 mgkg^{-1} concentrations of Fe are considered as toxic to plants. However, in this study, the concentration of Fe in investigated plant (1912.29 mgkg^{-1} d.m.) was higher than previous cited data. The metal phytoavailability depends on the form of the element in soil and on the considered plant species. High content of Fe in species *Potentilla visianii* may be because of high iron content in soil. However, even in the case of testing the same species, the metal uptake does not necessarily correlate with metal content in the soil. This is probably due to diverse metal uptake mechanisms and to some disparities in their transport properties, resulting in differences in the metal concentrations in plants.

The Ca:Mg ratio in soil was 0.02 and in plant 1.32 (Figure 2). In soil samples metal concentrations had the following order: Mg>Fe>Ca>Ni>Cr>Mn>Co>Zn>Pb>Cu>Cd. The general trend of metal accumulation in plants was: Ca>Mg>Fe>Ni>Mn>Cr>Zn>Co>Cu>Pb>Cd. Among the limiting factors that make ultramafic soils unfavourable substrates for plant growth, the most attention has been given to low Ca:Mg quotients (due to low Ca and high Mg). Our results showed low Ca:Mg (0.013) ratio. Similar results were described by many authors (Robinson et al., 1997; Shallari et al., 1998).

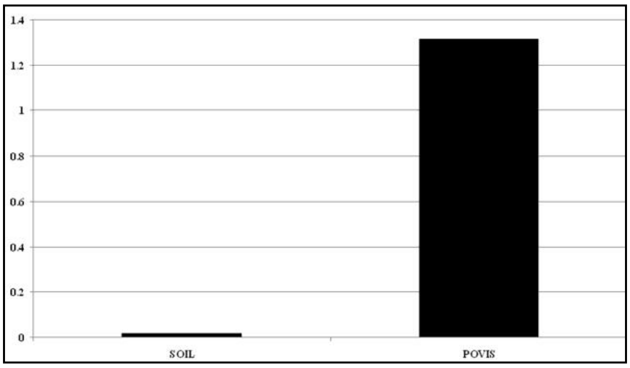

Fig. 2. The Ca:Mg ratio

Most serpentine soils contain high levels of Mn in the form of oxides. According to Adriano (Adriano, 2001), regular Mn content for most of soil types ranges from 500-1000 mgkg^{-1}. However, our results presented concentration of Mn (288.86 mgkg^{-1} d.m.) in soil samples. To fulfil its metabolic functions, Mn is only necessary at low concentration (20 mgkg^{-1} d.m.) (Živković et al., 2011). The manganese has a range between 20 and 300 mgkg^{-1} in most plants, while its level may be as high as 1500 mgkg^{-1}, without harm to some plant (Pais & Jones, 2000). Therefore, comparing our data with the previous cited, we could say that species *P. visianii* was contained lower concentration of Mn (69.53 mgkg^{-1} d.m.). This is probably due to antagonism in uptake between Fe and Mn, as well as very high negative correlation in content of Ca and Mn between plant and soil (Tab. 3).

Kabata-Pendias (2001) reported that Cu levels of various soils ranged 1-200 mgkg^{-1}. In our study the concentration of Cu in soil samples was 6.11 mgkg^{-1} d.m. The Cu mobility seemed to be dependent on mineral fractions, since carbonates contents were positively correlated with Cu total fraction and negatively correlated with Cu mobilizable fraction. In our study the content of Cu in plant samples was 3.21 mgkg^{-1} d.m. Kabata-Pendias (2001) also reported that Cu levels of various plants from unpolluted regions in different countries changed between 2.1 and 8.4 mgkg^{-1}. According to results of our study, a concentration of Cu in species P. visianii was within limits of mentioned concentrations. The literature data were shown that copper availability to plants might be reduced due to high iron content in soil solution. In well-aerated soil Fe occurs mostly in the form of Fe^{3+} oxides or hydroxides, which are known as efficient sorbents for inorganic cations such as Cu.

The zinc is distributed evenly in the Earth's crust. According to Kabata-Pendias (2001), regular Zn content for most of soil types ranges from 1-800 mgkg^{-1}. Therefore, comparing our data with the findings of some researches (Shallari et al., 1998; Obratov-Petković et al., 2006; Bech et al., 2008) we could say that zinc content in analyzed soils (23.12 mgkg^{-1} d.m.) is in accordance with previous the findings. The Zn contents in plant samples were 23.10 9.503 mgkg^{-1} d.m. According to Bruneetti et al. (2009), the normal Zn contents in plants (15-150 mgkg^{-1}) and the maximum value (300 mgkg^{-1}) of Zn limits in foodstuff were not exceeded.

Most Ni in soil is expected to be either NiO (from emission sources), Ni chelated by organic matter, Ni in spinel and other Mg silicate minerals, Ni adsorbed or occluded in Fe and Mn oxides, Ni-Al layered double hydroxide and soluble chelated and ionic Ni^{2+}. According to our results, the concentration of Ni in soil samples was 931.49 mgkg^{-1} d.m. However, Obratov et al. (1997) were shown that the serpentine soils of mountain Goč contented 1.52-3.12 mg Ni kg^{-1} d.m. Therefore, our data are in accordance with previous the findings of some researches (Shaellari et al., 1998; Reeves et al., 2007). Some authors have described that the normal plants and crop species generally contain 1-5 mg Ni kg^{-1} (Berooks, R.R., 1987; Chaney et al., 2008), and suffer from significant phytotoxicity below 100 mg Ni kg^{-1}. In our study the Ni content in species *P. visianii* was higher than normal values in plants (84.38 mgkg^{-1}). These observations agree with those obtained by other authors (Zayed & Terry, 2003) who found that Ca:Mg quotient is a relatively important factor in Ni uptake. Interactions between Ca, Mg and Ni in plants have also been reported. In plants, Ni^{2+} may competitively inhibit the uptake of divalent cations such as Ca^{2+}, Mg^{2+}, Fe^{2+} and Zn^{2+} thereby inducing deficiencies that can result in characteristic plant chlorosis symptom and reduced efficiency of photosynthesis (Tappero et al., 2007).

On average, the Earth's crust is estimated to contain about 15 ppm of Pb, with parent rocks contributing to the natural content (Bech et al., 2008). The mean concentration of Pb in soil samples in our study was 13.20 mgkg^{-1} d.m. Kabata-Pendias (2001), reported that Pb levels of various soils ranged 2-200 mgkg^{-1}. According to Obratov-Petković et al. (2006), serpentine soils of mountain Goč contained 38.58 Pb (mgkg^{-1} d.m.) However, our results are in accordance with previous cited data (Bech et al., 2008; Reeves et al., 2007; Robinson et al., 1997). e (2001), reported that Pb contents in plants grown in uncontaminated areas varied in between 0.05 and 3.0 mgkg^{-1}. Carranza-Ălvarez et al. (2008), also reported that Pb concentration in plants ranged from 10 to 25 mgkg^{-1}. The mean concentration of Pb in plant samples in our study was 2.13 mgkg^{-1} d.m. The mobility of Pb seemed to be less influenced (compare with Zn and Ni) by soil properties and perhaps more related to the availability of metals like Ca, Cd or Zn, maybe due to competition processes between metallic cations (Adriano, 2001; Kabata-Pendias, 2001). The toxicity of Pb is strongly dependent on the Pb:Ca ratio of the cation exchange complex of the soil and dominant role for Ca in Pb toxicity (Ca effectively counteracts Pb toxity, most probably through inhibiting the uptake and the accumulation of Pb in the root).

In particular, cadmium is considered one of the most widespread pollutant having toxic effects on plants and animals. According to Kabata-Pendias (2001) Cd levels of various soils ranged 0.001-2.5 mgkg^{-1}. According to Obratov-Petković et al. (2006), serpentine soils of mountain Goč contained 0.18 mg Cd kg^{-1} d.m. However, our results were shown higher concentration of Cd in soil (1.41 mg Cd kg^{-1} d.m.). The cadmium is considered to be toxic in the environment at low levels. The low concentration of Cd (0.19 mgkg^{-1} d.m) in species *P. visianii* is probably due to antagonism in uptake among metals, as well as in the existence very high positive correlation between soil and plant species in uptake of Cd and other metals (except Ca) (Table 3). Aditionally, the Cd mobility was negatively correlated with the clay content, which means that the competitive adsorption may be the predominant process in Cd bonding in these soils (Kabata-Pendias, 2001).

The results obtained in our study showed 33.65 mg Co kg^{-1} d.m. in soil, and 4.43 mg Co kg^{-1} d.m. in plant. Cobalt frequently interacts antagonistically with Ni, Fe and Mn in plants (Kabata-Pendias, 2001). Similar results were described by some authors (Kastori et al., 1997; Reeves et al., 2007; Robinson et al., 1997).

The results obtained in our study showed 485.24 mg Cr kg^{-1} d.m. in soil. According to Bruenetti et al. (2009), Cr concentrations in the investigated soil samples ranged 36.18-115.15 mgkg^{-1}. The chromium is the contaminant with highest total contents in soils, but it showed only average extractability of 0.008%, and some authors (Zayed & Terry, 2003) have found that nearly all the soil Cr was in a more resistant fraction (less soluble forms). Not all metals provide the same bioavailability and metal bioavailability depend on the mineralogy of the soil. For example, the high-Cr concentrations in the serpentine soils often are in the form of chromite, an unalterable mineral, and so Cr remains not bioavailable. This is just one factor that affects the uptake of Cr. Regular Cr content in plants usually ranges 0.006-18 mgkg^{-1} (Živković

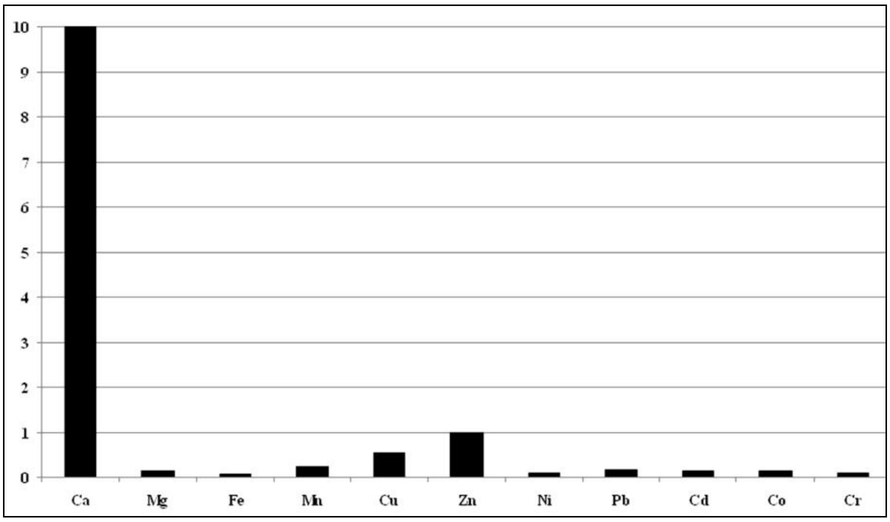

Fig. 3. The Biological Absorption Coefficient (BCA)

et al., 2011). According to Reeves and Baker (2000), the normal values of 0.2-5 mgkg^{-1} for Cr in plants. However, our findings were shown Cr content of 41.50 mg Cr kg^{-1} d.m in the investigated plant. and it was higher than some published data (Reeves & Baker, 2000; Živković et al., 2011). The metal bioavailability of plants is influenced by various factors, such as pH, temperature, redox potential, chemical speciation, seasonal changes, sediment type, salinity, and organic matter.

The Biological Absorption Coefficient (BAC), also known as the plant uptake factor, was calculated as the ratio of an element in plants to its concentration in soil. In our study, the value of BCA varied 0.09 - 10.01 (Fig. 3). Generally, the BCA were below one (except for Ca and Zn).

The results obtained from the ANOVA analysis (Tab. 2) were presented that very high statistically significant differences (p<0.001) exists in the content of metals between soil and investigated species (except for Zn).

Table 2. The analysis of variance between metal concentrations in soil and plant

metal	F-value	p-level
Ca	435581.70	***
Mg	157941.80	***
Fe	66136.50	***
Mn	7058.20	***
Cu	570.10	***
Zn	0.20	0.67
Ni	7618.00	***
Pb	76527.50	***
Cd	192422.70	***
Co	703192.20	***
Cr	10180.60	***

statistically significance: >0.05 - not statistically significant; 0.01-0.05 – statistically significant (*); 0.01-0.001 – highly statistically significant (**); <0.001 – very high statistically significant (***)

Table 3. The Pearson correlation coefficient analysis of metal concentrations between soil and species *Potentilla visianii* Pančić

	Ca	Mg	Fe	Mn	Cu	Zn	Ni	Pb	Cd	Co	Cr
	r	r	r	r	r	r	r	r	r	r	r
SOIL*POVIS	1.00	-1.00	-1.00	-1.00	-0.99	-0.14	-1.00	-1.00	-1.00	-1.00	-1.00

r - correlation coefficient; 0-0.3: no correlation; 0.3-0.5: low correlation; 0.5-0.7: medium correlation; 0.7-0.9: high correlation; 0.9-1.0: very high correlation; POVIS - *Potentilla visianii* Pančić

Table 4. The Pearson correlation coefficient analysis between metal concentrations in soil and species *Potentilla visianii* Pančić

metals	Ca	Mg	Fe	Mn	Cu	Zn	Ni	Pb	Cd	Co	Cr
Ca	1.00	-1.00	-1.00	-1.00	-0.99	-0.14	-1.00	-1.00	-1.00	-1.00	-1.00
Mg	-1.00	1.00	1.00	1.00	0.99	0.14	1.00	1.00	1.00	1.00	1.00
Fe	-1.00	1.00	1.00	1.00	0.99	0.14	1.00	1.00	1.00	1.00	1.00
Mn	-1.00	1.00	1.00	1.00	0.99	0.15	1.00	1.00	1.00	1.00	1.00
Cu	-1.00	1.00	1.00	0.99	1.00	0.24	0.99	1.00	1.00	1.00	0.99
Zn	-0.10	0.10	0.10	0.15	0.24	1.00	0.14	0.10	0.10	0.10	0.12
Ni	-1.00	1.00	1.00	1.00	0.99	0.14	1.00	1.00	1.00	1.00	1.00
Pb	-1.00	1.00	1.00	1.00	0.99	0.14	1.00	1.00	1.00	1.00	1.00
Cd	-1.00	1.00	1.00	1.00	0.99	0.13	1.00	1.00	1.00	1.00	1.00
Co	-1.00	1.00	1.00	1.00	0.99	0.14	1.00	1.00	1.00	1.00	1.00
Cr	-1.00	1.00	1.00	1.00	0.99	0.12	1.00	1.00	1.00	1.00	1.00

0-0.3: no correlation; 0.3-0.5: low correlation; 0.5-0.7: medium correlation; 0.7-0.9: high correlation; 0.9-1.0: very high correlation.

Correlation analysis was used to establish different relationships: between soil and tested plant in content of metals (Tab. 3) as well as between pair-metal concentrations in soil and tested plant (Table 4). The results obtained from the Pearson correlation coefficient analysis were indicated that very high negative correlation exists between concentration of Mg, Fe, Mn, Cu, Ni, Pb, Cd, Co and Cr in soil and species *P. visianii*. In addition, very high positive correlation exists between soil and species *P. visianii* in content of Ca, as well as there was not noted correlation in content of Zn between mentioned species and soil.

As means as correlation analysis between pair-metal concentrations in soil and tested plant, our results were indicated that exists very high negative correlation between following metal pairs: Ca*Mg, Ca*Fe, Ca*Mn, Ca*Cu, Ca*Ni, Ca*Cd, Ca*Co and Ca*Cr. In spite of the fact that very high positive correlation exists among other metal pairs, the soil and species *P. visianii* were not showed correlation in content of Zn.

The contents of heavy metals in the soil depend on numerous factors, such as: specific ability of some plants to over-accumulate various toxic heavy metals, chemical and physical characteristics of soil, metal and soil-metal interactions (Sústriková & Hecl, 2004). It is generally regarded that the bioavailability of heavy metals is closely related to their chemical speciation, rather than total concentration in soils. Heavy metals in soils occur in different geochemical forms (various binding phases of metals and structural properties), which have distinct mobility, biological toxicity and chemical behaviours. The concentration of heavy metals will show an increase with time, because there is no activity to funnel out the soils and dilute the effects of pollution.

An organism is expected to reflect environmental pollution if it has the ability to take up elements proportionally to their concentration in the environment. This is more likely to occur in organisms with little capacity for discriminating between different elements, which are therefore accumulated independently from the organism’s physiological needs. Therefore, such metal uptake by plants does not follow their physical levels, but it is regulated by plant organism via physiological mechanism. Some of plant species can accumulate very high concentrations of toxic metals to levels which exceed far the soil levels. Our study exhibited different heavy metal bioconcentration in species *P. visianii*, depending on kinds of metal as well as differences in content of investigated metals in soil and mentioned plant. Metal uptake by plants depends on the bioavailability of the metal in soils, which in turn depends on the retention time of the metal, as well as the interaction with other elements and substances. Also, metal accumulation by plants is affected by many factors. In general, variations in plant species, the growth stage of the plants and element characteristics control absorption, accumulation and translocation of metals.

Under normal growing conditions, plants can potentially accumulate certain metal ions in order magnitude greater than the surrounding medium. Tolerance to heavy metals in plants may be defined as the ability to survive in soil that is toxic to other plants. Plant tolerance strategies are typically metal specific and they manifested by an interaction between a genotype and its environment. The genetic analysis has shown that metal hyperaccumulation and tolerance are genetically fully independent and controlled by different genes. However, comparison of metal content in plant is often difficult because of the difference in the age of plants and presence of different pollution sources during the time

Conclusion

The results our study showed that the concentrations of all examined metals were higher in soil than in species *P. visianii* (excepting Ca). Our study exhibited different heavy metal bioconcentration in species *P. visianii*, depending on kinds of metal as well as differences in content of investigated metals in soil and mentioned plant. The metal uptake and metal bioaccumulation does not necessarily correlate with metal content in the soil. Metal uptake by plants depends on the bioavailability of the metal in soils, which in turn depends on the retention time of the metal, as well as the interaction with other elements and substances. It is generally regarded that the bioavailability of heavy metals is closely related to their chemical speciation, rather than total concentration in soils.

Acknowledgements. The authors are thankful to colleagues from the Institute of Public Health Division of Hygiene and Medical Ecology in Kragujevac for help in chemical analysis of soil and plant samples as well as to colleagues from Geological Institute of Serbia.

References

Adriano, D.C., 2001: Trace element in terrestrial environments: biogeochemistry, bioavailability and risks of metals. Springer. New York. 248p.

Bech, J., Tume, P., Longan L., Reverter, F., Bech, J., Tume, L., Tempio, M., 2008: Concentration of Cd, Cu, Pb, Zn, Al, and Fe in soils of Manresa, NE Spain. *Environment Monitoring. Assessment*, 145: 257-266.

Brooks, R.R., 1987: Serpentine and its Vegetation: A Multidisciplinary Approach. Dioscorides Press. Portland, Oregon. 454p.

Brooks, R.R., Yang, X.H., 1987: Elemental levels and relationships in the endemic serpentine flora of the Great Dyke, Zimbabwe and their significance as controlling factors for this flora. *Taxon*, 33: 392-399.

Brunetti, G., Soler-Rovira, P., Farrag, K., Senesi, N., 2009: Tolerance and accumulation of heavy metals by wild plant species grown in contaminated soils in Apulia region, Southern Italy. *Plant Soil*, 318: 285-298.

Carranza-Ǎlvarez, C., Alonso-Castro, A.J., Alfaro-De La Torre, M.C., Garciá De La Cruz, R.F., 2008: Accumulation and Distribution of Heavy Metals in *Scirpus americanus* and *Typha latifolia* from an Artificial Lagoon in San Luis Potosĭ, Mexico. *Water Air Soil Pollution.*, 188: 297-309.

Chaney, R.L., Chen, K.Y., Li, Y.M., Angle, J.S., Baker, A.J.M., 2008: Effects of calcium on nickel tolerance and accumulation in Alyssum species and cabbage grown in nutrient solution. *Plant Soil,* 311: 131-140.

Kabata-Pendias, A., 2001: Trace Elements in Soil and Plants (2nd ed.). Boca Raton. CRC press. Washington, D.C. 489p.

Kastori, R., Vukmirović, Z., Polić, P., Blagojević, S., Bogdanović, D., Ubavić, M., Hadžić, V., Govedarica, M., Milosević, N., Jarak, M., Petrović, N., Arsenijević-Maksimović, I., Vapa, M., Vapa, Lj., 1997: Heavy metals in the environment. Institute of field and vegetable crop. Novi Sad, Serbia, 301 p.

Kazakou, E., Dimitrakopoulos, P.G., Baker, A.J.M., Reeves, R.D., Troumbis, A.Y., 2008: Hypotheses, mechanisms and trade-offs of tolerance and adaptation to serpentine soils: from species to ecosystem level. *Biological Review.,* 83: 495-508.

Kazakou, E., Adamidis, G.C., Baker, A.J.M., Reeves, R.D., Godino, M., Dimitrakopoulos, P.G., 2010: Species adaptation in serpentine soils in Lesbos Island (Greece): metal hyperaccumulation and tolerance. *Plant Soil,* 332: 369-385.

Keshav, A.K., Mohan, K.R., Murthy, N.N. 2011: The effect of fertilizer additions on the solubility and plant-availability of Cd, Ni and Zn in soil. *Research Journal Environment Earth Science*, 3(2): 103-113.

Market, B. 1992: Presence and significance of naturally occurring chemical elements of the periodic system in the plant organism and consequences for future investigations on inorganic environmental chemistry in ecosystems. Vegetatio, 103, 1-30.

Javorka, S., Csapody, V., 1979: Iconographia Florae parties Austro-Orientalis Europae Centralis. Academia kido. Budapest.

Josifović, M., 1991: Flora of Serbia, vol. I. SAAS. Beograd. 325 p.

Obratov, D., Kadović, R., Mihajlović, N., 1997: *Alyssum markgrafii* Shulz (Brassicaeae, Capparales) as nickel hyper-accumulator on Goč and Kopaonik serpentinites. *Proceeding Development Forest Wood Science Technology* II, 24-27.

Obratov-Petković, D., Popović, I., Belanović, S., Kadović, R., 2006: Ecobiological study of medicinal plants in some regions of Serbia. *Plant Soil Environment,* 52(10): 459-467.

Pais, I., Jones, J.B., 2000: The Handbook of Trace Elements. St. Luice Press. Florida. 420p.

Reeves, R.D., Baker, A.J.M., Borhidi, A., Berazain, R., 1996: Nickel hyper-accumulation in the serpentine flora of Cuba. *Ann. Bot.,* 83: 29-38.

Reeves, R.D., Baker, A.J.M., 2000: Phytoremediation of toxic metals. In: Raskin, I. & Ensley, B.D. (eds.),Using plants to clean up the environment. Wiley and Sons Inc, New York.

Reeves, R.D., Baker, A.J.M., Becquer, T., Echevarria, G., Miranda, Z.J.G., 2007: The flora and biogeochemistry of the ultramafic soils of Goiás state, Brazil. *Plant Soil,* 293: 107-119.

Robinson, B.H., Chiarucci, A., Brooks, R.R., Petit, D., Kirkman, J.H., Gregg, P.E.H., De Dominicis, V., 1997: The nickel hyperaccumulator plant *Alyssum bertolonii* as a potential agent for phytoremediation and phytomining of nickel. *Journal of Geochemical Exploration*, 59: 75-86.

Shallari, S., Schwartz, C., Hasko, A., Morel, J.L., 1998: Heavy metals in soils and plants of serpentine and industrial sites of Albania. *The Science of Tototal Environment*, 209: 133-142.

Stevanović, V., Tatić, B., Janković, M., Diklić, N., Jovanović, B., Vasić, O., Jovanović, S., Niketić, M., Butorac, B., Boža, P., 1999: The red data book of flora of Serbia I. Ministry of environment of the Republic of Serbia. Belgrade, Serbia. 580 p.

Sústriková, A., Hecl, J., 2004: Influence of the environmental factors on the heavy metals content in some medicinal plants. 3rd Conf. Medicinal and aromatic plants of southeast European countries, Nitra, Book of abstracts., 107.

Tappero, R., Peltier, E., Gräfe, M., Heidel, K., Ginder-Vogel, M., Livi, K.J.T., Rivers, M.L., Marcus, M.A., Chaney, R.L., Sparks, D.L., 2007: Hyperaccumulator *Alyssum murale* relies on a different metal storage mechanism for cobalt than for nickel. *New Phytologist,* 175: 641-654.

Tutin, T.G., V.H. Heywood, N.A. Burges, D.H. Valentine, S.M Walters & D.A. Webb, (eds.), 1964: Flora Europea, II. Cambridge University Press. Cambridge.

Zayed, A., Terry, N., 2003: Chromium in the environment: factors affecting biological remediation. *Plant Soil,* 249: 139-156.

Živković, J., Ražić, S., Arsenijević, J., Maksimović, Z., 2011: Heavy metal contents in Veronica species and soil from mountain areas in Serbia. *Journal Serbian Chememical Societi.,* 76(0): 1-16.