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ASSESSMENT OF AIR POLLUTION USING PLANT MATERIAL

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ABSTRACT
Technological procedure of extracting metals is being constantly modernised so that polluting of the basic life resources is reduced. Emissions of waste gases and particulate matter are still present in larger mining-metallurgical complexes. Mining-metallurgical complex Bor (RTB) exploits sulphide copper ores, thus emitting acid sulphur gases and suspended particles with high content of Cu, Zn, Pb, Ni, Cd etc. into the atmosphere. Plants show a direct response to the state of the air. Contents of heavy metals and sulphur were analysed in leaves/needles of deciduous and evergreen trees, as well as in the vegetables and fruits. Topsoil around the examined woody plants present a sort of collectors of airborne pollutants.
Keywords: air pollution, copper smelter, heavy metals, sulphur

1. INTRODUCTION
The advantages of biomonitoring are the opportunity of long-term monitoring of pollution and easy sampling without the use of expensive equipment [1]. Biomaterials such as fungi, lichens, tree bark and leaves of higher plants have been used to detect the deposition, accumulation and distribution of heavy metals and sulphur in the environment. Lower plants, especially mosses and lichens, due to their higher capacity for metal accumulation, are probably the most frequently used in biomonitoring surveys [2]. Which plant species will be used as passive bioindicators also depends on their availability in the examined area. The most often used parts of higher plants are leaves/needles and bark of spruce, birch, pine and oak [3-6].
This paper presents biomonitoring of heavy metals and sulphur in woody plants, vegetables and fruits sampled in the area of Bor and its surroundings. Concentrations of heavy metals were also determined in soil of woody plants.

2. METHODOLOGY
The study area is the Bor town and its surroundings (60 000 inhabitants), which is located in Eastern Serbia. This region belongs to the Danube river basin. The climate of the study area is moderately continental. Concerning the distribution of the polluting substances from the source to other areas, wind is significant meteorological parameter [7].
The sampling sites were selected depending on the following factors: type of settlement (position and number of residential units), distribution of the main traffic flows, meteorological and topographic factors of the region, industrial zone, as well as the emission volume and type. The urban-industrial zone (UI) includes the sampling sites which are located from 0.5 km to 2 km from the dominant source of pollution (copper smelter), and the rural zone (R) includes sampling sites in the rural settlements from 2 km to 13 km [8].
The sampling of fresh plant material and soil in the quantity of 200 g is sampled at four outer sides of a plant. All the samples were dried at room temperature during a period of fifteen days. The samples

were then ground in a laboratory mill and griddled through 0.2-mm sieve. The dried samples were measured in the quantity of 0.25 g, and dissolved with acidic mixture HNO_3/30% H_2O_2/H_2O (3/2/5), using analytical grade reagents. Solutions were quantitatively transferred in 25 cm^3 calibrated flasks, diluted with double distilled water and analyzed by ICP-AES (model „Spektro Ciros Vision“) [9].

3. RESULTS AND DISCUSSION

The sampled vegetables were edible parts of potatoes, carrots, green beans, cucumber, tomato and cabbage. Fruits, which are grown in the Bor area used for the analysis of heavy metals, were apple, pear, apricot and peach. The mean values of the elements in fruits and tuber/roots, leguminous, leafy and tomato/cucumber fruit are shown in Fig.1.

a)

b)

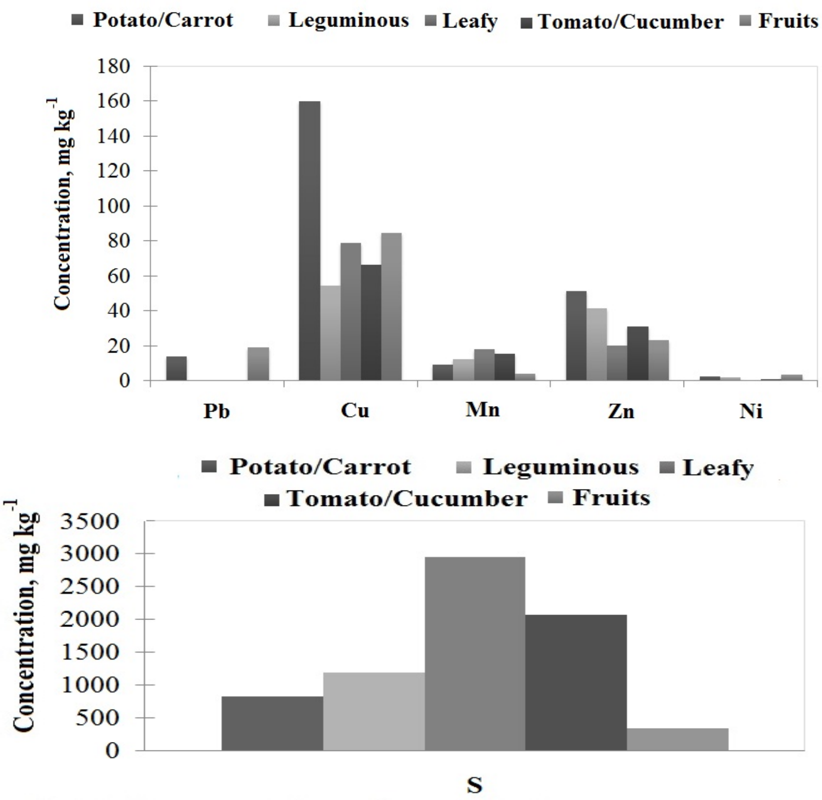

Figure 1. The mean concentrations of (a) Pb, Cu, Mn, Zn, Ni and (b) sulphur in tuber/roots, legumes, leafy and fruity vegetables and fruits

As can be seen in Fig.1a, the concentration of Pb was highest in fruits and tuber/root vegetables. Cu is mostly taken up by tuber/root vegetables, then by fruits and leafy vegetables. Mean values of Mn and Ni concentrations were lower compared to Cu and S in all the samples. Mn is mostly accumulated in leafy vegetables, whereas Ni is accumulated in fruits mostly. The content of Zn was highest in tuber/root vegetables and legumes, and the lowest in leafy vegetables (Fig.1a). Sulphur was most accumulated in leafy vegetables in the quantity of 2959.8 mg kg^{-1} and in fruity vegetables it was 2072.6 mg kg^{-1} of dry matter (Fig.1b).

The decreasing orders of the determined element concentrations in the examined vegetables and fruit samples are the following:

- ✓ Tuber/root S > Cu > Zn > Pb > Mn > Ni
- ✓ Legumes S > Cu > Zn > Mn > Pb > Ni
- ✓ Leafy S > Cu > Zn > Mn > Pb > Ni
- ✓ Tomato/cucumber fruit S > Cu > Zn > Mn > Pb > Ni
- ✓ Fruits S > Cu > Zn > Pb > Mn > Ni

From the orders, it can be concluded that in all the examined samples there is the highest quantity of S, Cu and Zn. Apart from industry all these elements in the surrounding area can appear from artificial fertilisers and pesticides, in whose structure they are included. However, such high concentrations of S are a consequence of the vicinity of the mining-metallurgical complex.

Compared to the results that were obtained by other authors, it can be concluded that fruits and vegetables from our region contain high concentrations of particular elements, especially Cu and S [10, 11].

Besides fruits and vegetables, bioaccumulation of heavy metals was examined in the leaves/needles of five woody plants which grow on the territory of Bor. Concentrations of Cu, Pb, Zn and Mn in the leaves/needles of birch, linden, acacia, pine and spruce in the urban-industrial and rural zone are shown in Fig.2.

In the UI zone, the highest concentrations of Cu and Pb were in the birch leaves, whereas the concentrations of these heavy metals in the R zone were highest in pine needles. In the UI zone, the highest content of Zn and Mn was in the linden leaves, and in the R zone it was in the birch leaves. The needles of spruce contained the minimum Zn and Mn in the UI zone. Concentrations of Mn in linden leaves in the UI zone were ten times higher than in the R zone. The birch leaves in the UI zone, contained about eight times more Mn than in the R zone. The leaves of acacia in the UI zone contained about five times more Cu than in the R zone. All the concentrations of Cu, Pb, Zn and Mn in the examined plant species were higher in the urban-industrial zone than in the rural, which indicates that the mining-metallurgical complex has influence on the heavy metal content in birch, linden, acacia, pine and spruce. By comparing the concentrations, it was determined that the foliar parts of five plant species in the two examined zones contained Cu, Zn and Pb more than other parts of the plants. Based on literature data it was determined that the leaves of acacia can be used as a bioaccumulator for Pb, Cu and Zn [12]. Birch, linden, acacia, pine and spruce are not hyperaccumulators of Cu, Pb, Zn, and Mn [2,13].

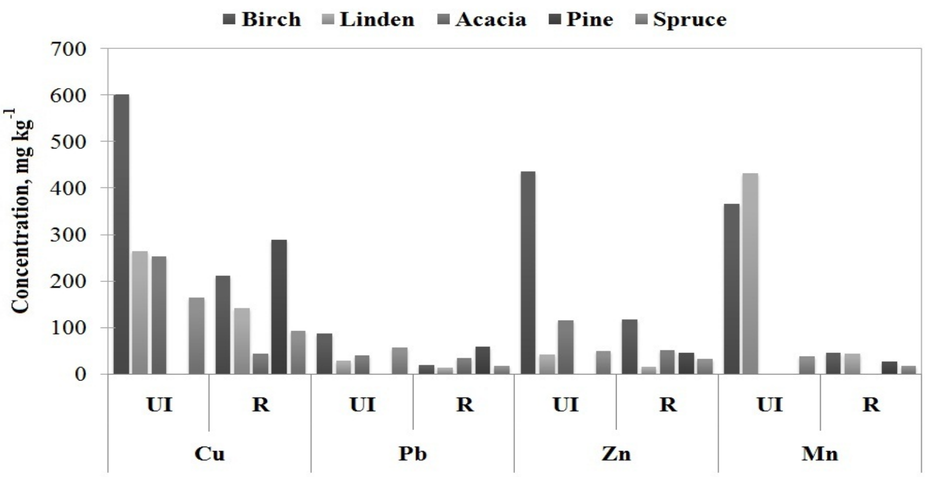

Figure 2. Concentrations of Cu, Pb, Zn and Mn in leaves/needles of birch, linden, acacia, pine and spruce in the urban-industrial (UI) and rural (R) zone

Concentrations of heavy metals in soil of birch, linden, acacia, pine and spruce sampled in urban-industrial and rural zone are given in Table 1.

Table 1. Concentrations of Cu, Pb, Zn and Mn in soil samples (μg g^{-1})

	Cu		Pb		Zn		Mn	
	UI	R	UI	R	UI	R	UI	R
Birch	1760.1	371.2	370.5	95.3	244.4	124.1	851.5	766.8
Linden	877.7	267.5	158.4	68.5	121.9	111.5	876.6	719.4
Acacia	605.3	265.1	70.2	50.1	248.2	195.7	/	/
Pine	/	489.9	/	87.5	/	137.5	/	842.6
Spruce	1035.8	730.3	229.8	162.5	144.7	250.2	889.4	646.5
MAC[a]	100		100		300		not defined	

[a] „The Official Gazette of Republic Serbia", No. 23/94

"/" not sampled or determined

It can be seen that all the concentrations of the studied metals were higher in the UI compared to the R zone, except for Zn in spruce soil. Concentrations of Cu in soil (for all plant species) were not within the maximum allowable concentration (MAC) [14] in both zones. Pb concentrations were not within the MAC in UI zone (except in soil of acacia), while in R zone only the concentration in spruce soil was above the MAC. All the Zn concentrations were within the MAC. The highest Cu concentrations in soil samples of birch, linden, acacia and spruce in UI zone, might be a consequence of long-term atmospheric deposition from mining-metallurgical complex.

4. CONCLUSION

The concentrations of Cu, Zn and S in vegetables and fruits, sampled at the sites in the rural zone, were the highest, compared to Mn, Pb and Ni. The concentrations of heavy metals in leaves, needles and soil of woody plants are higher at the sampling sites in the urban-industrial zone than in the rural zone. Cu concentrations were the highest in soil and woody plants compared to other elements. Presented results indicate that processing of sulphide copper ores has significant influence on plants growing in the study area, and that mining and metallurgy present a big risk for the environment.

5. ACKNOWLEDGMENTS

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