Heavy and Toxic Metal Accumulation in Six Macrophythe Species from Fish Pond Ecka, Republic of Serbita

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Abstract

A phytoremediation study was carried out at the fish pond Ecka, Republic of Serbia. The bioaccumulation of Cd, Zn, Cu, Pb, Fe, Mn and Ni, and distribution between the organs of the macrophytes (Typha latifolia, Phragmites communis, Nuphar lutea, Ceratophyllum demersum, Salvinia natans and Hydrocharis morsus-ranae) grow in the Ecka fish pond was investigated. Heavy metal content was determined using AAS in dry samples of plants which were sampled at the time of their maximum growth. According to results of analysis there was no significant pollution of aquatic biotopes so the ecosystem and human risk were low. The presence of investigated metals in macrophytes indicates their good indicator and remedying properties, as well as the possible impact of pollution originating from the Tisza river or the air.

Key words: *phytoremediation, macrophytes, bioaccumulation, aquatic ecosystems*

Introduction

Basic topic that had been addressed in this research paper is related to problems and endangerment of fresh water ecosystems caused by heavy and toxic metals, whose pollution effects are developed both directly and indirectly.

It is known that metals are natural ingredients of fresh water ecosystems where they are found in relatively low concentrations. Main sources of microelements, i.e. heavy metals in natural waters, are related to natural processes and anthropogenic impact. Intensive industrial development and urbanization over the past several decades have led to the situation in which many fresh water ecosystems, both natural and constructed, are directly or indirectly exposed to the effects of various pollutants of various compositions and degree of harmfulness. Heavy metals are significant inorganic pollutants, which are, as a rule, a part of many industrial wastewaters and whose negative impact is reflected primarily in numerous changes at different levels of biological system organizations. Heavy metals have different chemical and physical intrinsic properties and physiological effects. Their common property is that even in relatively low concentrations their effects are toxic and therefore they fall under very dangerous environmental pollutants (Kastori *at al.*, 2006). Increased concentrations of heavy metals in water and sediments have harmful effects to plants and animals due to their toxic properties, and they also affect humans through food chain.

One of specific methods for removal of metals from these environmental segments is use of certain plant species which have the ability to accumulate heavy metals. In recent years, the ability of plants to accumulate pollutants has received significant of attention and given rise to a new technology called phytoremediation (Black, 1995). Most plants are able to accumulate heavy metals from water and soil, of which some are very important for their growth and development (Fe, Mn, Zn, Cu, Mo and NI); certain plants can accumulate metals which do not have high biological significance (Cd, Cr, Pb, Co, Se, Hg), but excessive concentration of heavy metals may be toxic for most plants (Rascio, 1977; Peterson, 1983,1993; Salt *et al.*,1995; Lasat, 1996).

Wetland vegetation species are primary candidates for use in phytoremediation because they play a major role in the removal of toxic trace elements from waters passing through the wetland (Wang *et al.*, 2003; Fritioff, Kautsky, and Greger, 2005). Wetland species differ, however, in their abilities to take up and accumulate various trace elements in their tissues and several studies have been conducted that have examined the abilities of some species to accumulate metals in their biomass (Rai *et al.*, 1995; Wang, Cui, and Dong, 2002; Kamal *et al.*, 2004). A high bioconcentration factor (BCF) for metal elements at low external concentrations is important for phytoremediation because the process is more cost efficient than other conventional techniques in treating large volumes of wastewater with low concentrations of pollutants (Wang *et al.*, 2002; Kamal *et al.*, 2004). If a plant has a high BCF and there is appreciable translocation (as determined by site requirements) of the target contaminants to the shoots, then harvesting the aboveground portion of the biomass can remove a large amount of the

target contaminants. Thus, phytoremediation is generally considered to be a relatively low-cost alternative for sites with low to moderate contamination (Fritioff and Greger, 2003; Weis and Weis, 2004).
This research addressed bioaccumulation of Cd, Zn, Cu, Pb, Fe, Mn and Ni and their distribution among macrophyte organs (*Typha latifolia, Phragmites communis*, *Nuphar lutea*, *Ceratophyllum demersum*, *Salvinia natans* and *Hydrocharis morsus-ranae),* autochthonic species which grow in fish pond Ecka in the Republic of Serbia. Fish pond selected for the purposes of this paper is a constructed ecosystem which contains all the components of natural fresh water ecosystems. Production of fish as primary business in such constructed ecosystem is possible only when all its components, water quality primarily, are established and maintained at a level which would encourage development of commercial species. Hence, it is necessary to bear in mind always that survival of such species does not require only large quantities of water, but it is also necessary that water quality ensures usefulness of the water resource (Nešić *et al*., 2006).
Fish pond Ecka is located in Banat, Republic of Serbia, near Zrenjanin (figure 1). It is situated in the area of alluvial plain near the Tisza river, while its borders are the Tisza from the west and the Begej from the east.

Figure 1. Location of the fish pond Ecka

In addition to fish production, a part of the area is used for food production, while uncultivated areas are used for hunting or tourism. It is important to state that part of the territory is protected by the state as special nature reserve “Stari Begej – Carska bara” and it covers an area of 1,676 ha.
Fish pond Ecka is as many other fish ponds supplied from surface waters, i.e. from the Tisza. The Tisza enters our country from Romania already quite polluted with various forms of pollution, unfortunately. Even major accidents have occasionally happened, and catastrophic pollution of this river, such as spillage of cyanide into the Tisza from Romania in spring 2000. According to water analyses, the Tisza can be classified into II category of water, but changes have been observed, unfortunately negative ones, which categorize this river into III, sometimes even into IV water quality category.
The aim of the present study was to determine the capacity of bioaccumulation of metals due to the selection of indigenous macrophyte species suitable for the process of phytoremediation. Since metals present basic factor of anthropogenic pollution, but they are at the same time a natural ingredient of water, knowing their composition, binding ways and degree of possible accumulation are very important factors for estimation of water quality and for understanding eco-physiological and eco-chemical processes which occur in aquatic systems.

Material and methods

Plant samples collected in the fish pond in middle summer were separated into rhizomes, stems and leaves (*Typha ltifolia*, *Pragmites communis* and *Nuphar luteum*) or kept as whole plants (*Ceratophyllum demersum*, *Salvinia natans* and *Hydrocorus morus-ranae*) and washed carefully with bi-distilled water. The plant material was separately dried to constant weight in an air-circulated oven (60 °C).

The dried samples of plants were homogenized and wet digested. (ISO 11460; ISO 11047, ISO 6636/2). The digested samples were filtered by 0.45 μm filter, diluted with bidistilled water and then analyzed for element concentrations.
Concentrations of Cd, Zn, Cu, Pb, Fe, Mn and Ni were determined by AAS (Pye Unicam 192).
Quality control measures including calibration with reference samples, blanks, and replicate analysis, were followed throughout the analysis in order to ensure reliable analytical data. Two blank samples were run with each set of samples to check the purity of the reagent and possibility of contamination. Precision and analytical accuracy of the methods were evaluated by analyzing a standardized reference certified Apple leaves, SRM-1515 (National Institute of Standard and Technology, USA). We used Certipur standards (MERCK) in element measurement.
Each analysis of the soil and plant material were performed with three replicates, in addition, each of the chemical analyses were run with two replicates. Arithmetic means are shown in the table. Standard deviations not exceed 5% for soil samples and 10% for plant material samples. Statistical evaluations were made using SPSS 10.0 for Windows.

Results and discussion

Table 1 contains results obtained in measurements of heavy and toxic metals concentrations in parts of *Typha latifolia, Phragmites communis* and *Nuphar lutea.* As for *Typha latifolia,* it has been found that highest bioaccumulation is seen with zinc, copper, iron and nickel, which are found in the plant rhizome. Furthermore, it has been found that concentration of cadmium is highest in the stalk, while lead and manganese are found mostly in leaves of *Typha latifolia*. It is characteristic that there is no nickel in leaves, and that accumulations of zinc, iron and manganese are lowest in plant stalk. When it is about *Phragmites communis,* it has been found that concentrations of cadmium, zinc, lead, iron and manganese are highest in rhizome. In case of copper and nickel, they accumulate mostly in the stalk. It is characteristic that quantity of iron in *Phragmites communis* is several times lower in comparison to other samples, which indicates that *P. communis* has more efficient defensive system against this element. It has been found that stalk of *Nuphar lutea* has highest concentrations of cadmium, zinc, copper, lead and nickel. Lowest concentrations of cadmium and nickel are found in rhizome, while lowest concentrations of zinc, copper, iron and manganese are found in leaves of *Nuphar lutea*. It is characteristic that rhizome of *Nuphar lutea* accumulates most of iron and manganese, while their concentrations in leaves are lowest. Also, concentrations of iron and manganese in rhizome of *Nuphar lutea* are significantly higher in comparison to *Typha latifolia* and *Phragmites communis*.
Table 2 shows that *Ceratophyllum demersum, Salvinia natans* and *Hydrocharis morsus-ranae* mostly accumulate iron in their tissues, and cadmium the least. Highest concentrations of zinc, copper and iron were found in tissues of *Ceratophyllum demersum.* Tissues of *Hydrocharis morsus-ranae* contain highest concentrations of cadmium and nickel. Contents of copper and lead are almost the same for all three plant species.
Different trends are noticed in accumulations of certain heavy metals in different organs and tissues. Bioaccumulation of Cd and Cu is uniformed in all researches related to *macrophytes* (4.66-22). In the stalk of *Nuphar lutea* Zn in concentrations of 349.82 ± 8.53 were found, which manifold exceeds concentrations of Zn in other macrophytas. In leaves of *Phragmites communis* significantly lower Pb was found than in rhizome. Most significant accumulation discrepancies are seen in Mn, from 12.22 in stalk of *Typha latifolia* to 4889.7 in *Salvinia natans*. All examined plants bio-accumulate iron the most. Among examined macrophytes, it has been found that *Typha latifolia* accumulates iron the most (12962.28± 479.80). Highest concentrations of this element are measured in rhizome. *Typha latifolia* shows lowest measured values for cadmium, while nickel was not found in the leaves, not even in traces. *Phragmites communis* also accumulates iron the most, but found concentration of iron is several times lower than with other examined macrophytes. In the rhisome of *P. communis* highest accumualtion of lead was found. Of all macrophytes, *Nuphar lutea* accumulates cadmium, zinc, copper and nickel the most. Highest concentrations of these elements are found in the stalk of *Nuphar lutea.* After *Typha latifolia,* highest bioaccumulation of iron was found in *Ceratophyllum demersum*. Highest concentration of manganese in examined macrophytes was found in *Salvinia natans*.
Obtained values of concentration of heavy and toxic metals in analysed macrophytas show accordance with literature data provided by authors (Stoltz and Greger, 2001).

In any case, discrepancies which were found in contents of metal in examined plants are most probably caused by specific characteristics of plants with respect to ways and possibilities of accumulation, as well as degree of their tolerance to toxic effects of heavy metals.

Table 1. Distribution of heavy and toxic metals in macrophyte organs, $mgkg^{-1}$ [DM]

Sample	Part of the fraction	Cd	Zn	Cu	Pb	Fe	Mn	Ni
Typha latifolia	Leaf	7.90	36.64	12.5	53.77	982.80	676.24	0.00
	Stalk	9.08 ± 0.60	22.89 ± 0.61	12.57 ± 2.62	44.04 ± 5.83	205.02 ± 6.61	12.22 ± 3.29	27.88 ± 2.97
	Rhisome	5.88 ± 1.47	121.4 ± 6.85	15.84 ± 1.31	38.45 ± 3.52	12962.28 ± 479.80	425.14 ± 26.31	44.43 ± 7.37
Phragmites communis	Leaf	9.62	42.66	12.35	8.25	313.85	205.86	30.00
	Stalk	15 ± 1.67	39.74 ± 10.35	25.83 ± 8.95	38.1 ± 5.75	1094.54 ± 322.18	134.72 ± 28.96	51.59 ± 8.95
	Rhisome	22 ± 2.42	56.34 ± 8.94	20.04 ± 4.52	92.4 ± 13.56	6324.24 ± 542.88	346.82 ± 68.34	26.92 ± 8.54
Nuphar lutea	Leaf	9.16 ± 0.95	52.82 ± 1.19	18.37 ± 1.16	29.90 ± 5.72	2353.93 ± 124.93	67.39 ± 4.87	52.76 ± 5.21
	Stalk	14.94 ± 1.41	349.82 ± 8.53	40.47 ± 6.84	47.81 ± 10.22	8309.24 ± 1045.24	461.78 ± 25.65	103.24 ± 18.79
	Rhisome	6.85 ± 1.61	56.66 ± 4.90	18.57 ± 0.18	42.33 ± 5.71	8549.16 ± 1678.84	759.05 ± 53.57	16.11 ± 4.08

*The results present means of three biological measurements ± standard deviation

Table 2. Contents of heavy and toxic metals in macrophytes, $mgkg^{-1}$ [DM]

Sample	Cd	Zn	Cu	Pb	Fe	Mn	Ni
Ceratophyllum demersum	9.69 ± 0.33	106.47 ± 2.33	28.25 ± 0.54	33.67 ± 3.32	8919.94 ± 280.52	1864.52 ± 123.12	23.58 ± 5.87
Salvinia natans	4.66 ± 0.19	84.62 ± 11.31	25.41 ± 1.14	34.04 ± 12.90	5979.46 ± 198.53	4889.70 ± 344.49	44.22 ± 8.57
Hydrocharis morsus-ranae	10.15 ± 0.63	87.57 ± 3.70	23.50 ± 1.10	33.67 ± 3.57	3023.27 ± 335.94	816.78 ± 36.43	49.82 ± 20.70

Conclusion

Examined macrophytes spontaneously inhabit fish pond Ecka were tested to contents of heavy and toxic metals.
Obtained results indicate that heavy and toxic metals are present in the fish pond water, but their concentrations in macrophytes range within limits which do not endanger development of fish and further consumers in food chain.
In order to obtain precise indicators of this anthropogenic ecosystem it is necessary to apply parallel researches on contents of heavy metals in water and sediment as well.
In any case, heavy metals accumulated in macrophyte, especially in their floating organs, may be easily removed through collection. This should be done during highest bioaccumulation, as it was measured.
Obtained results indicate that importance of macrophytes in the processes of ecoremediation of aquatic ecosystems, both natural and constructed ones, and they provide recommendations for their growth and systematic removal in order to maintain water quality.

Acknowledgements

The present work was supported by project "Biorational usage and ecoremediation of land and water by growing plants for industrial processing", No. TR 20208, funded by Ministry of Science, Republic Serbia.

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