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Bioaccumulation of Cu, Zn and Ni from the wastewater by treated *Nasturtium officinale*

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Abstract

Aquatic plants are well known in accumulating and in concentrating heavy metals. In this study, several physiological responses of aquatic vascular plant, *Nasturtium officinale* (watercress), which were elevated concentrations of copper, zinc and nickel have been investigated. It was found that *Nasturtium officinale* were able to accumulate both copper and zinc at upper levels, but was able to accumulate to nickel at low levels. The final goal of this work was to examine the copper, zinc and nickel uptake using this aquatic plant from their solutions.

Key words: *Bioaccumulation, aquatic plants, physiological responses, removal, uptake.*

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Introduction

Aquatic plants are known in accumulating metals from their environment (Out ridge and Noller, 1991; Ali and Soltan, 1999) and affect metal fluxes rough those ecosystems (Jackson, *et al*., 1994, St- Cyr, *et al*., 1994). The ultimate disposal of wastewater can only be onto land or into water. But whenever water courses are used for ultimate disposal, the wastewater is treated to prevent any injury from aquatic life in the receiving water. Diverse industrial wastes have aggravated the problem of water pollution. This problem becomes complex because of the qualitative and quantitative differences in pollution according to the industries involved, and due to the non-degradability of inorganic pollutants like heavy metals which are hazardous when discharged into a water body (Srivastav, *et al*., 1994). Heavy metals produce undesirable effects, even if they are present in extremely minute quantities, on human and animal life. The toxic effects have been known for a very long time. However, water pollution by heavy metals has only become acute in recent years because metal ions from natural, domestic and industrial sources tend to concentrate in the organic residue at the sewage treatment works. Several studies have shown that constructed wetlands are very effective in removing heavy metals from polluted wastewaters (Qian, *et al*., 1999). Different wetland plant species differ, however, in their abilities to take up and accumulate various trace elements in their tissues (Rai, *et al*., 1995). Recently, wetland plant species with abnormally high capacities of trace element (Cu, Ni, Zn and so on) removal from water were identified (Zayed, *et al*., 1998a; Zhu, *et al*., 1999) duckweed (*Lemna minor* L.) and water hyacinth [*Eichornia crassipes* (Mart.) Solms-Laubach] were excellent accumulators Cd, Se and Cu. Laboratory studies of the water hyacinth have demonstrated the potential use of this species in removing metals from polluted water and have shown that metal concentrations of the plant and the water column are correlated (Soltan and Rashed, 2003).

Typically, submerged species have been found to accumulate relatively high heavy metal concentrations when compared with emergent species in the some area. Even so, this species (*Myriophyllum aquaticum*) overall contained the highest heavy metal concentrations found in any sample collected for this study with copper and zinc concentrations being over twice the concentrations of these metal concentrations may be a species (Gupta, *et al*., 1995).

Recently, there has been growing interest in the use of metal-accumulating roots and rhizomes of aquatic or semi aquatic vascular plants for the removal of heavy metals from contaminated aqueous streams. For example; water hyacinth (*Eichornia crassipes* Solms) (Kay, *et al*., 1984), watercress (*Nasturtium officinale*) (Kara, *et al*., 2003) duckweed (*Lemna minor* L.) (Kara, *et al*., 2004) take up Pb, Cu, Fe, Cd and Ni from contaminated solutions. In this article we studied the responses of *Nasturtium officinale* to excess copper, zinc and nickel with reference to accumulation of Cu, Zn and Ni (period and concentration). Several physiological responses of aquatic plant *Nasturtium officinale* to elevated concentrations of copper, zinc and nickel were investigated.

Materials and Methods

Nasturtium officinale (watercress) was collected from a natural pond in Burdur, Turkey (Figure 1). The plants were kept at a temperature of 25±2 °C and illuminated by cool daylight fluorescent tubes in 14 h light and 10 h dark cycle. In all the experiments 4.8 g. plant samples (fresh weight) were placed in 100 m/l of solution and kept under natural conditions. Before the start of the experiment the plants were cleaned properly using tap water to remove particles from their roots and leaves The aquatic plant was exposed separately to the individual metal ion solutions of copper ($CuSO_4$. $5H_2O$) zinc ($ZnSO_4$. H_2O) and nickel ($NiCl_2$. $6H_2O$) at nominal concentrations of 1.0, 3.0, 5.0 and 7.0 mg/l. The test plants exposed to heavy metals were harvested 24, 48 and 72 h after treatment and weighed. The harvested plant samples were dried at 80 °C. Both plants and water samples were digested in 99% HNO_3: $HClO_4$ (5:1) (AR, E. Merck, Germany). One control group was also used without the addition of any metal. The aquatic plants grown in the solutions were weighed after 4 days and analyzed for metal ion concentration in both plants. Copper, zinc and nickel were measured by an Atomic Absorption Spectrophotometer Shimadzu Model AA 640-F (Japan).

Results

The accumulation of metals in various parts of

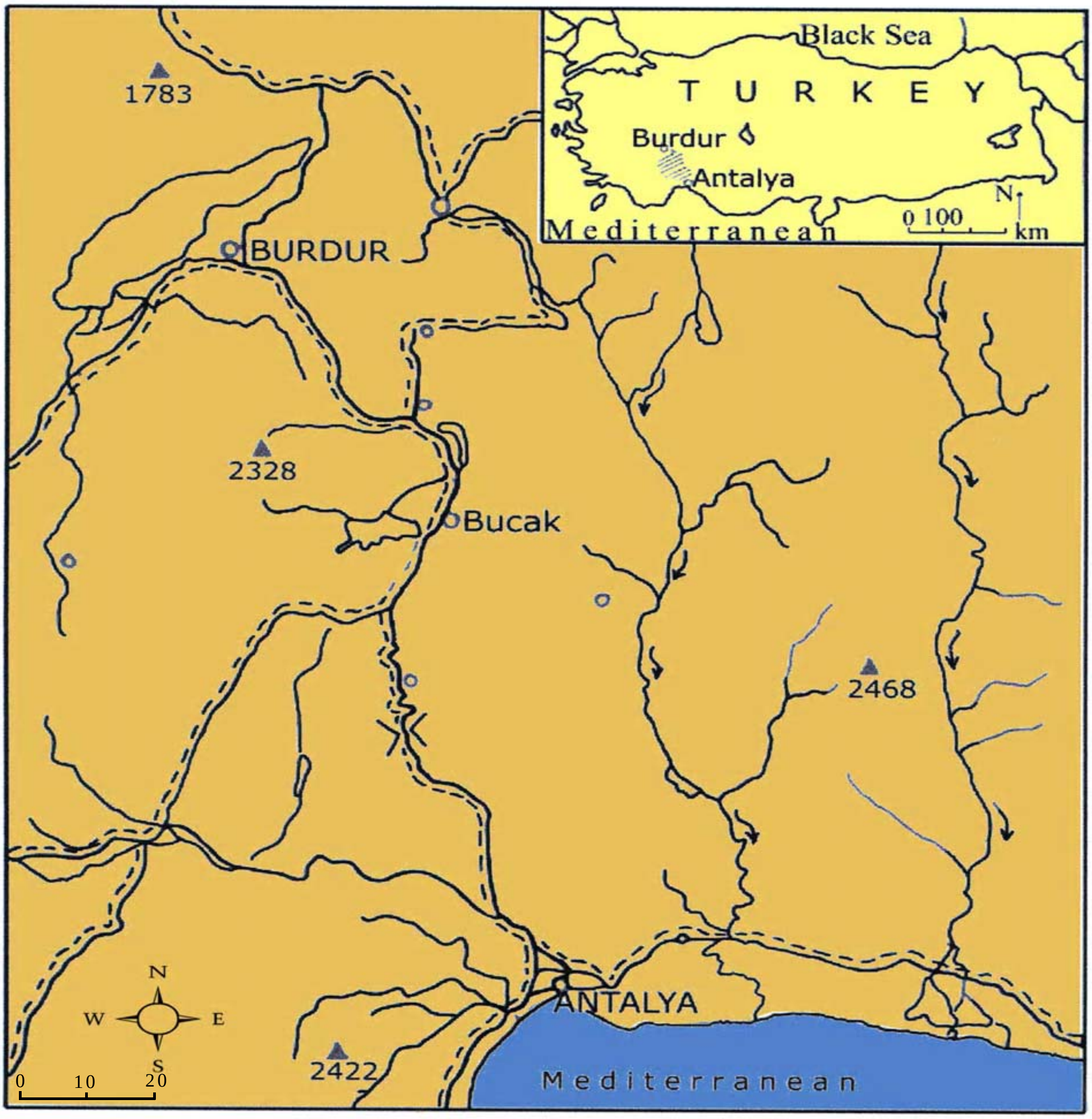

Figure 1: Map of the studied area

aquatic macrophytes is often accompanied by an induction of a variety of cellular changes, some of which directly contribute to metal tolerance capacity of the plants. In the present study, Cu, Zn and Ni accumulation in *N. officinale* resulted in considerable physiological changes. Copper uptake occurred rapidly during 24 h. but prolonged incubation depressed the slope of curve. After 48 h. further increase in Zinc level of test plant did not occur. Cu and Ni were also rapidly taken up in the beginning. The test plant apparently exhibited a high capability of concentrating heavy metals from the outer medium. This manner is depicted the kinetics of metal accumulation in *Nasturtium officinale* (Figure 2). The values are correlations means of three replicates. Zn and Ni in concentrations 5 and 7 mg/l promoted pigment degradation. *Nasturtium officinale* was found to have an apparently large capability of uptake and accumulation of heavy metals. In the present study negative correlations between concentrations of Cu in plants of the first group and Ni content in plant second group and Zn content in plant from their sampling sites and between concentrations of Ni in plant. Among the heavy metals tested Cu and Ni were more effective in lowering the levels of different elements; Zn had the least effect. *N. officinale* could tolerate elevated levels of Cu, i.e. up to 3 mg/l, without significant changes in photosynthetic pigments concentration. Metal availability and bioaccumulation is governed by several environmental factors, viz. chemical speciation of the metal, pH, organic chelators, humic substances, presence of other metals and anions, ionic strength, temperature, salinity, light intensity, oxygen level and other prevailing electrochemical functions. This result indicates that in the observed concentration range Cu is accumulated more effectively in comparison to Zn and Ni. Zinc uptake occurred rapidly during 48 h. After 48 h. further decrease in Zn level of test plant did not occur. Nickel was rapidly taken up in the beginning (Figure 2).

Discussion and Conclusion

The accumulation of metals in various parts of aquatic macrophysics is often accompanied by an induction of a variety of cellular changes, some of which directly contribute to metal tolerance capacity of the plants (Prasad, *et al*. 2001). The uptake of metals (Cu, Cr, Fe, Pb) by the test plants after 2, 7 and 15 days of treatment is important. It varied with

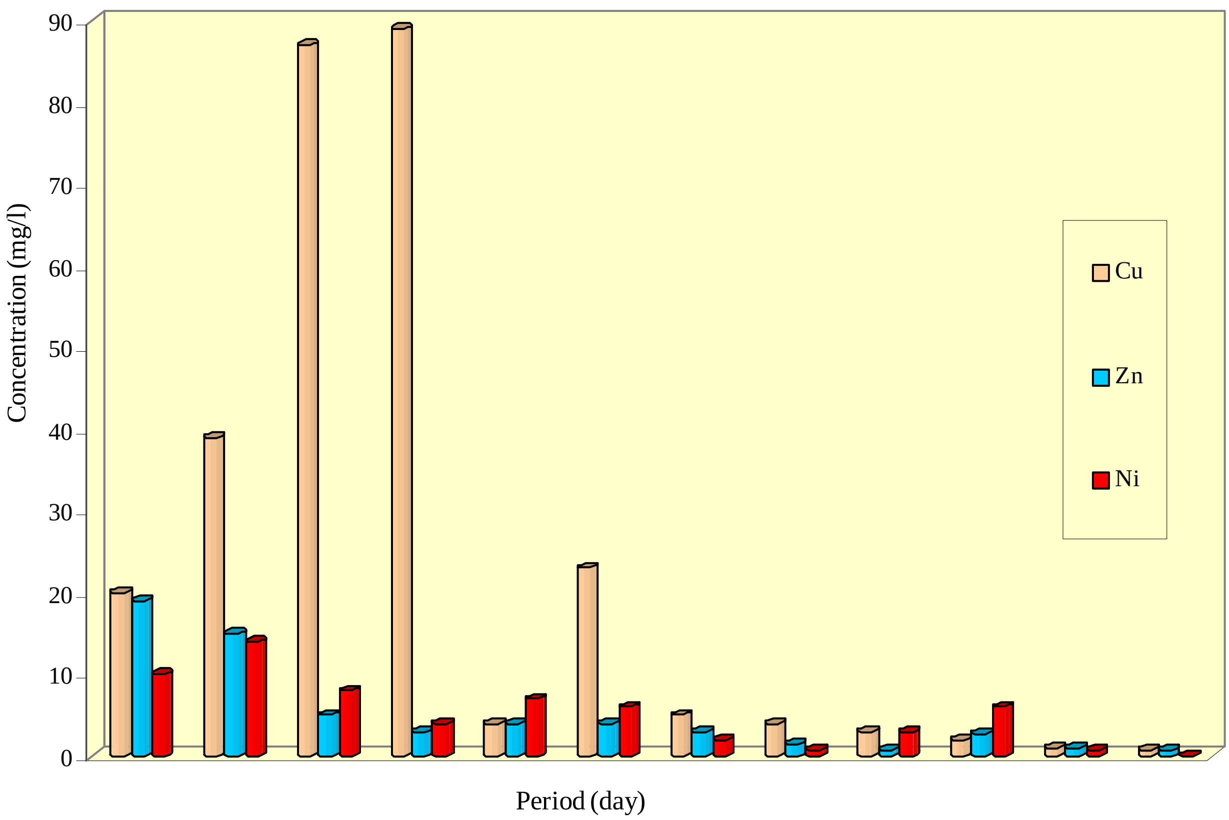

Figure 2: Bioaccumulation of heavy metals by *Nasturtium officinale* as a function of time

metal to metal and species to species (Rai, *et al.*, 1995). All the plants showed substantial accumulation of Fe. It was highest *Ceratophyllum demersum* (142 µm/lg DW).

Plants of *Ceratophyllum demersum L.* also accumulated high amounts of Cu and Pb (11.81, 2.51 and 12.06 µm/lg DW), respectively. The metal mobility within the plant was in the descending order of Zn>Ni>C>Pb.Zinc is an essential element for plant metabolism (Nora, *et al.*, 1997).A significant database exists describing the bioaccumulation of various contaminants by algae and macrophysics. These are used in ecological survey as in situ indicators of water quality due to their ability to accumulate chemicals, and to the fact that they comprise the largest biomass in wetlands and are immobile. The bioaccumulation ability of macrophysics has been studied in the field and laboratory for metals (Aulio, 1980; Tripathi and Chandra, 1991) and pesticides (Hinman and Klaine, 1992). It was summarized the enrichment rations for a variety of aquatic plants and metals (Kelly, 1988). These rations for several plant species ranged from 104 to 163750 for zinc, 189 to 1853125 for lead, 3 to 1070 for nickel and from 36 to 691250 for copper.

Most species under study accumulated Cu to more or less the same degree in their roots (300-650 mg/kg) expect water lettuce (1038 mg/kg). Floating wetland plants seem to be an exception because they accumulate Cu to higher levels of 300 to 15000 mg/kg in duckweed (Jain, *et al.*, 1989), 6000 to 7000 mg/kg in water hyacinth (Low, *et al.*, 1994), 2500 to 3000 mg/kg in bacopa (Gupta, *et al.*, 1994) and 10000 to 19000 mg/kg in watercress (Kara, 1994). Highest Ni concentrations in roots (1077 mg/kg DW) and shoots (80 mg/kg DW) were attained by parrot's feather and water zinnia, respectively. The greatest Ni accumulation by a wetland plant species of 9000 mg/kg DW was found in the water fern (*Azolla filiculoides* Lam.) followed by *Salvinia natans* L. 6295 mg/kg DW. Most emergent wetland plant species, however, showed lower Ni accumulation than floating species: for example cattail had low root Ni concentrations of 1000 mg/kg DW and shoot concentrations of 400 mg/kg DW (Qian, *et al.*, 1999) and watercress had an all of the plant Ni concentration of 350 mg/kg DW. In the pots receiving the highest level of zinc in the nutrient solution (600 µg/g Zn), the roots contained a mean concentration of about 10 000 µg/g Zn in the dry root tissue, while the tops contained about 1000 µg/g Zn. The small amount of zinc in the controls is from the zinc present in the nutrient solution as an essential nutrient.

In summary, the results presented in this study demonstrate that the common macrophysics alga, *Nasturtium officinale* is very enduring to low dose, long term exposure to certain heavy metals.

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