INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
1560–8530/2003/05–3–281–283
http://www.ijab.org

Bioaccumulation of Nickel by Aquatic Macrophyta *Lemna minor* (Duckweed)

YEŞIM KARA, DAVUT BAŞARAN†, İZZET KARA‡, ALI ZEYTUNLUOĞLU AND HASAN GENÇ∏
University of Pamukkale, Faculty of Science and Art Faculty, Department of Biology, 20017 Denizli, Turkey
†*University of Dicle, Faculty of Science and Art Faculty, Department of Biology, 21100 Diyarbakır, Turkey*
‡*University of Pamukkale, Faculty of Education, 20020 Denizli, Turkey*
∏*University of Süleyman Demirel, Department of Biology, Faculty of Education, 15100 Burdur, Turkey*

ABSTRACT

This investigation was undertaken to study nickel ($Ni^{++)}$ uptake by *Lemna minor* plant from wastewater polluted by contaminated with heavy metals. *Lemna minor* was collected from the spring water, Mediterranean region, Turkey. Metal contents were determined by Atomic Absorption Spectrophotometer (AAS Perkin Elmer Model 700) and statistically analyzed for differences between periods and concentrations. Our experiments showed that these plants accumulated high levels of Ni^{++} in the all periods.

Key Words: Accumulation; *Lemna minor;* Heavy metal; Bioabsorption; Aquatic plant

INTRODUCTION

Rapid urbanization, industrialization, fertilizer and pesticide use has resulted in heavy metal pollution of land and water resources. The increasing load of heavy metals has caused imbalance in aquatic ecosystems and the biota growing under such habitats accumulate high amounts of heavy metals (Cu, Zn, Cd, Cr and Ni etc.) which in turn, are being assimilated and transferred within food chains by the process of magnification (Pergent & Pergent-Martini, 1999). This paper presents a study of the uptake by the macrophytes plants *Lemna minor* and *Riccia fluitans* of the cations Fe, Cr, Cu, Zn and Pb from the alkaline sludge which results from leaching of uranium ores. This bioaccumulation decreases in the order: Fe > Cr > Cu > Zn > Pb >, for a given plant and is higher for *Lemna minor* than for *Riccia fluitans* (Cecal *et al*., 2002).

Bioaccumulation of essential and non-essential metals by aquatic macrophytes is well documented in the literature (Vesk & Allaway, 1997; Khan *et al*., 2000). This property of bioaccumulation was found useful in monitoring and ameliorating the water bodies (Wang & Williams, 1988; Dunhabin & Bowner, 1992; Whitton & Kelley, 1995; Vajpayee *et al*., 1995). From water, all plants have the ability to accumulate heavy metals which are essential for their growth and development. These metals include Fe, Mn, Zn, Cu and Ni (Langille & MacLean, 1976). Certain aquatic plants also have the ability to accumulate heavy metals which have no known biological function. However, excessive accumulation of these heavy metals can be toxic to most plants. The ability to both tolerate elevated levels of heavy metals and accumulate them in very high concentrations has evolved both independently and together in number of different plant species (Ernst *et al*., 1992). The emphasis of most studies gradually shifted toward the use of aquatic plants as monitors for heavy metal water pollution.

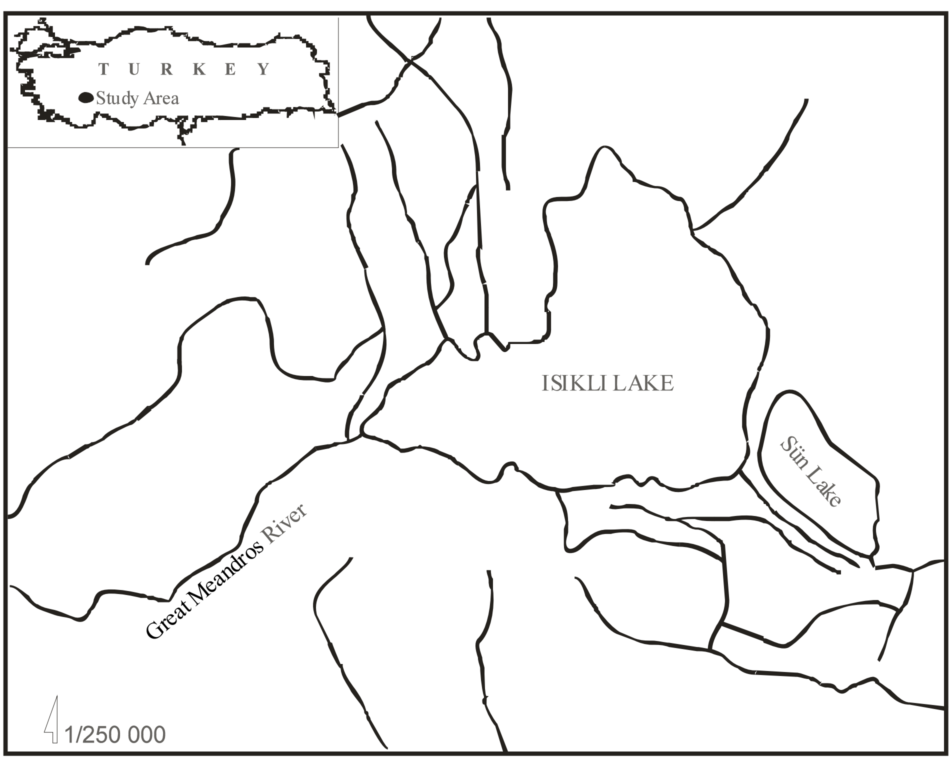
Trace element removal by wetland vegetation can be greatly enhanced by the judicious selection of appropriate wetland plant species. Selection is based on the type of elements to be remediation, the geographical location, environmental conditions, and the known accumulation capacities of the species. For this reason, it is important to develop knowledge about the abilities of different wetland plant species to absorb and transport trace elements under different conditions. The goal of the present research program is to quantify the capacity of various wetland plant species at removing trace elements from contaminated wastewater. This will be done by carrying out laboratory studies in combination with wetland field studies. In our laboratory study, we obtained trace element uptake curves under carefully controlled environmental conditions to eliminate the effects of all environmental factors. This procedure can then be used to test other plant species and effectively compare among them because all plant species are grown under constant environmental conditions. This study is the first of a series of investigations in which we determine the efficiency of different wetland plant species at removing trace element (Ni^{++}) from spring waters. In this first study we chose duckweed.

Duckweed is commonly found in wetlands, is fast-growing, adapts easily to various aquatic conditions, and plays an important role in the extraction and accumulation of metals from waters. Several studies have shown that duckweed can accumulate high concentrations of various heavy metals and trace elements. This has been shown for Ni, Cu, Mn (Jain *et al*., 1988). We compared the bioaccumulation of the element that is of great environmental concern due to these known toxicities to animals and humans and because of their widespread occurrence in the environment.

MATERIALS AND METHODS

The plants used in this study were obtained from the Işıklı Lake wastewater treatment plant, located in Işıklı Lake, Denizli, Turkey (Fig. 1). To investigate the extent of heavy metals uptake by aquatic plants in the southern, the Mediterranean domains were collected from spring water and transported to the laboratory in clean plastic bags. Plants were carefully washed using tap water and then distilled water, to remove visible debris (Sadler & Rynja, 1992; O'Halloran *et al*., 1997). The washed samples were carefully dried of adherent water using absorbent paper. Wet weights of the plants were registered with a digital balance a (sensitivity of 0.01). Standarts were prepared from 1000 mg/mL stock $NiCl_2$. *Lemna minor* plants were exposed to nickel solutions at 1.0, 3.0, 5.0 and 7.0 mg L^{-1}. The sampling period was 24, 48 and 72 h after the start of heavy metal application. The concentrations of heavy metals in water samples were determined using standard (reference materials E-Merck, Germany) of Ni^{++} to provide calibration and quality assurance for each analytical batch. *Lemna minor* have been kept in Ni^{++} containing solutions for 24, 48 and 72 h in laboratory conditions. After 24, 48 and 72 h samples were taken and analyzed by AAS (Perkin Elmer Model 700, USA). Quantitative determination of nickel was showed in Table I.

Figure 1. Map of the study area



RESULTS AND DISCUSSION

Ideally, all plant species should be at the same size and growth stage when exposed to trace element treatments in order to compare among them for their ability to remove various trace elements under study. Wetland plant species, however, differ substantially in their growth rate, morphology, physiology, and size. 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 hyacinths (*Eichornia crassipes*) (Kay *et al*., 1984), pennywort (*Hydrocotyle umbellata* L.) (Dierberg *et al*., 1987), duckweed (*Lemna minor*) and water velvet (*Azolla pinnata*) (Jain *et al*. 1989) take up Pb, Cu, Cd, Fe and Hg from contaminated solutions. Free-floating macrophytes are those that float on the surface of the water and are not attached to the substrate. Emergent macrophytes have leaves and/or stems which rise above the water surface and generally anchored to the substrate. Submerged macrophytes are those residing below the surface which may have emergent flowering bodies (Thomas *et al*., 1995). The extent of metal accumulation within aquatic macrophyte is known to vary significantly between species. For example, the emergent aquatic plants are usually accumulates lower amount of metals than submerged aquatic vegetation (Albers & Camardese**,** 1993). Few laboratory studies have clearly demonstrated importance of aquatic plants in accumulation of copper (Salt *et al*., 1995). Emergent macrophytes like *Baccopa monnieri*, *Cyperus rotundus*, *Eichornia crassipes* and *Marsilea* spp. growing near a chloralkali plant at Ganjam and Orissa were reported to accumulate 9-25 μg g^{-1} Cu^{++} in roots and 1-13 μg g^{-1} Cu^{++} in shoots, when the concentration of Cu^{++} in water was 4 μg L^{-1} (Lenka *et al*., 1992). For the growth of floating, *Lemna minor*, in 96 h test, Ni was extremely toxic, thus I_{50}-value for Ni was 0.45 mg dm^{-3} and Cr was much less toxic than Ni I_{50} value for Cr was 35 mg dm^{-1} indicating that nickel is more mobile than chromium[3] (Wang *et al*., 1986). The results show that under experimental conditions, duckweed proved to be a good accumulator of Cu^{++}. Duckweed exhibited some symptoms of toxicity at

Table 1. Bioaccumulation of made by *Lemna minor* from synthetic wastewater

Periods (h)	Initial Concentration (mg L^{-1})	Standard Concentration (mg L^{-1})	Sample Concentration (mg L^{-1})	Final Concentration (mg L^{-1})
24	1.0	0.018	0.006	41.65
24	3.0	0.037	0.017	52.49
24	5.0	0.056	0.025	105.76
24	7.0	0.076	0.070	150.32
48	1.0	0.018	0.003	51.27
48	3.0	0.037	0.012	64.70
48	5.0	0.056	0.010	153.80
48	7.0	0.076	0.055	160.34
72	1.0	0.018	0.001	57.68
72	3.0	0.037	0.008	74.49
72	5.0	0.056	0.022	172.03
72	7.0	0.076	0.035	180.22

higher levels of elements supply. The toxicity effect of each trace element on plant growth was, in descending order of damage. Further, the growth rates and harvest potential make duckweed a good species for phytoaccumulation activities. *Lemna minor* (duckweed) is a hyperaccumulator plant. This plant can also be used for the accumulation the other metals. Our experiments showed that these plants accumulated high levels of Ni^{++} in the first few days and then showed a decrease in the accumulation may be due to reaching its saturation level. Finally, show the highest concentrations of various rare and toxic heavy metals. Even though the accumulation of certain elements is highest in the plant, it is extraordinarily high when compared to other aquatic plants. Therefore, the plant is considered as accumulators of those elements. We conclude that duckweed shows promise for the removal of Ni^{++} from contaminated wastewater since it accumulates high concentrations of this element.

REFERENCES

Albers, P.H. and M.B. Camardese, 1993. Effects of acidification on metal accumulation by aquatic plants and invertebrates 1.constructed wetlands Environ. *Toxicol. Chem.,* 12: 959–76

Cecal, A., K. Popa, I. Craciun, V. Poptoraca and A. Iordon, 2002. Bioaccumulation in hydrophytaae plnts of some microelements from alkaline sludge resulting in uranium ores processing. *Kevista De Chimie.,* 53: 290–3

Dierberg, F.F., T.A. DeBusk, and Jr. Goulet, 1987. Removal of copper and lead using a thin film technique. *In:* Reddy, K.B. and W.H. Smith (eds.). *Aquatic Plants for Water Treatment and Resource Recovery.* Magnolia Pub. Inst., Florida

Dunhabin, J.S. and K.H. Bowner, 1992. Potential use of constructed wetlands for treatment of industrial waste waters containing metals. *Sci. Total Environ.,* 111: 151–68

Ernst, W.H.O., J.A.C. Verkleji and H. Schat, 1992. Metal tolerance in plants. *Acta. Bot. Neerl.,* 41: 229–48

Jain, S.K., P. Vasudevan and N.K. Jha, 1989. Removal of some heavy metals from polluted waters by aquatic plants: Studies on duckweed and water velvet. *Biol. Wastes,* 28: 115–26

Jain, S.K., G.S. Gujral, N.K. Jha and P. Vasudevan, 1988. Heavy metal uptake by Pleurotus sajor-caju from metal enriched duckweed substrate. *Biol.Wastes,* 24: 275–82

Kay, S.H., W.T. Hailer and L.A. Garrard, 1984. Effects of heavy metals on water hyacinths (*Eichornia crassipes*) (Mart). Solms). *Aquat toxicol.,* 5: 117–28

Khan, A.G., C. Kuek, T.M. Chaudhary and C.S. Khoo, 2000. Role of *mycorrhizae* and phytochelators in heavy metal contaminated land remediation. *Chemosphere*, 41: 197–207

Langille, W.M. and K.S. MacLean, 1976. Some essential nutrient elements in forest plants as related to species, plant part, season and location. *Plant Soil,* 45: 17–26

Lenka, W., K.K. Panda and B.B. Panda, 1992. Monitoring and assessment of mercury in the vicinity of a chrolalkali plant IV. Bioconcentration of mercury in situ aquatic and terrestial plant at ganjam, India. *Arch. Environ. Contam. Toxicol.,* 22: 195–202

O'Halloran, J., A.R. Walsh and P.J. Fitzpatrick, 1997. The determination of trace elements in biolojical and environmental samples using atomic absorption spectroscopy. *In:* Sheehan, D. (ed.). *Methods in Biotechnology, Bioremediation Protocols,* Vol.2; Humana Pres: New Jersey

Pergent, C. and C. Pergent-Martini, 1999. Mercury levels and fluxes in *Podosonia oceanica* meadows. *Environ. Pollut.,* 106: 33–7

Sadler, R. and G. Rynja, 1992. *Preservation, Storage, Trasport, Analysis and Reporting of Water Samples,* Queensland Goverment Chemical Laboratory Report Series No.12 Queensland Goverment Publishers, Brisbane, Australia

Salt, D.E., M. Blaylock, P.B.A.N. Kumar, S. Dushenkov, B.D. Ensley, I. Chet and I. Raskin, 1995. Phytoremediation: A novel strategy for the removal of toxic metals from the environment using plants. *BioTechnol.,* 13: 468–74

Thomas, P.R., P. Glover, T. Kalaropan, 1995. An evaluation of pollutant removal from secondary treated sewage effluent using a constructed wetland system. *Water. Sci. Technol.,* 32: 87–93

Vajpayee, P., U.N. Rai, S. Sinha, R.D. Tripathi and P. Chandra, 1995. Bioremediation of tannery effluent by aquatic macrophytes. *Bull. Environ. Contam. Toxicol.,* 55: 546–553

Vesk, P.A. and W.G. Allaway, 1997. Spatial variation of copper and lead concentrations of water hyacinth plants in a wetland receiving urban run-off. *Aquat. Bot.,* 59: 33–44

Wang, T.D., J.C. Weissman, G. Ramesh, R. Varadarajan and J.R. Benemann, 1986. Parameters for removal of toxic heavy metals by Water Milfoir (*Myriophyllum spicatum*). *Bull. Environ. Contam. Toxicol.,* 3: 779–786

Wang, W. and J. Williams, 1988. Screening and biomonitoring of industrial effluents using phytotoxicity tests. *Environ. Toxicol. Chem.,* 7: 645–-2

Whitton, B.A. and M.G. Kelley, 1995. Use of algae and other plants for monitoring rivers. *Australian J. Ecol.,* 20: 45–56

(Received 16 May 2003; Accepted 26 June 2003)