Bull. Environ. Contam. Toxicol. (2004) 72:467–471

DOI: 10.1007/s00128-004-0269-4

Environmental Contamination and Toxicology

Bioaccumulation of Copper from Contaminated Wastewater by Using *Lemna minor*

Y. Kara

University of Pamukkale, Faculty of Art and Sciences, Department of Biology, 20017 Denizli, Turkey

Received: 8 March 2002/Accepted: 30 November 2003

The ability of aquatic plants to accumulate heavy metals from water is well documented (Sinha et al. 1996). Many-free floating, emergent and submerged species have been identified as potential accumulators of heavy metals (Nasu et al. 1984; Nor 1990; Sinha and Chandra 1990). Such plants could be utilized for the improvement of water quality and for reducing the pollution load in water bodies. Toxic metals also cause a high level of phytotoxicity in plants as a result of several physiological and biochemical changes which take place in the plant systems. These changes are due to the interaction of heavy metals with sulphydryl groups of the enzymes (Thapa et al. 1988). Aquatic plants growing in the polluted water absorb heavy metals which enter into the food chain, posing a serious threat to human health (NAS 1978). Copper is a necessary element for all living organisms on earth, in air and sea. There are some amounts of coppers in tissues of bodies. Copper exists in the structure of enzyme metal proteins and it is an enzyme activator that gets catalysis some amino acids transfer (Negri et al. 1996). Copper is trace metal which is necessary for plants to survive. The submerged macrophytes are particularly useful in the abatement and monitoring of heavy metals. They do not migrate and attain equilibrium with their surroundings within a short period, as these plants are used to bioabsorp the metals from waste water (Rai et al. 1995).

Other species with a phytoremediating abilities are; *Myriophylum brasiliense*, *Salix* sp. and *Populus* sp. (Brown 1994). *Lemna minor* is an aquatic plant, which absorbs heavy metals in water has been used as research material in our study. Heavy metal absorption of this plant is in maximum levels all certain conditions. The explosion of *Lemna minor* within water pollution has been increased by factors like advancing of technology in industrial actions. They conclude that duckweed shows promise for the removal of Cd, Se, and Cu from contaminated wastewater since it accumulates high concentrations of these elements (Zayed 1998). In the light of studies that are mentioned above, we have analyzed the Cu^{++} heavy metal absorption by using the *Lemna minor* aquatic plant under laboratory conditions.

MATERIALS AND METHODS

Lemna minor (duckweed), which absorbs heavy metals in wastewater has been used as research material. This aquatic plant has been picked up from the surface of the fifteenth km of Burdur-Antalya highway (Figure 1). Duckweed plants were collected from wetlands. The plants were washed very well and rinsed in distilled water 3 times for 5 min.

Aquatic plants were exposed to individual trace element at 1.0, 3.0, 5.0, and 7.0 mgL^{-1} concentrations. Plants without added trace elements served as controls. Plants were then oven dried at 60 °C for 48 hr before plant dry weight was determined. The dry plant materials were ground to powder and representative samples were taken for chemical analysis. Plant material was digested in duplicate with 65% HNO_3 and 60% HCl during which temperatures were raised to about 95 °C until evolution of nitrous gas stopped and the digest became clear (Kacar 1972). Quantitative determination of Cu^{++} was carried out by atomic absorption analysis, with a Shimadzu AAS F 640 spectrophotometry (Table 1.)

RESULTS AND DISCUSSION

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*), 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 and Camardese, 1993). Few laboratory studies have clearly demonstrated the 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 μgg^{-1} Cu^{++} in roots and 1-13 μgg^{-1} Cu^{++} in shoots, when the concentration of Cu^{++} in water was 4 μgL^{-1} (Lenka et al. 1992). For the growth of floating, *Lemna minor*, in 96 hr test, Ni was extremely toxic, thus I_{50}-value for Ni was 0.45 $mgdm^{-3}$ and Cr was much less toxic than NiI_{50} value for Cr was 35 $mgdm^{-3}$ indicating that nickel is more mobile than chromium (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 higher levels of elements supply.

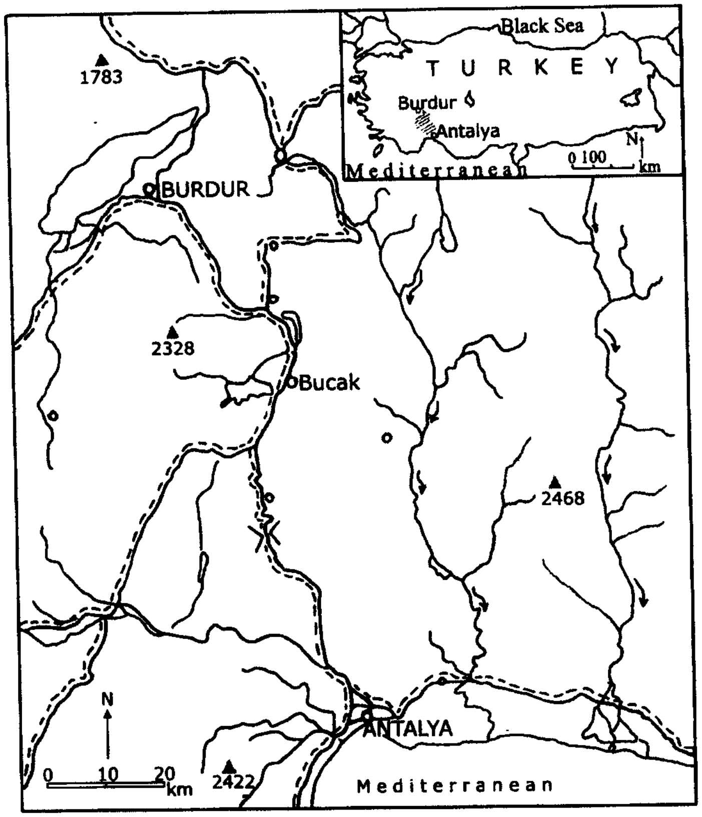

Figure 1. Map of the study area.

Table 1. Rate of total element accumulation of Cu^{++} element by *Lemna minor*.

Periods (hr)	Initial Concentration mgL^{-1}	Final Concentration mgL^{-1}	Removed Concentration (%) mgL^{-1}
24	1.0	0.67	66.67
	3.0	1.78	59.26
	5.0	2.56	51.11
	7.0	4.78	68.25
48	1.0	0.78	77.78
	3.0	1.89	62.96
	5.0	2.33	46.67
	7.0	4.67	66.67
72	1.0	0.11	11.11
	3.0	1.67	55.56
	5.0	2.44	48.89
	7.0	1.89	26.98
96	1.0	0.44	44.44
	3.0	1.22	40.74
	5.0	0.89	17.78
	7.0	1.78	25.40

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 of the other metals.

Our experiments showed that these plants accumulated at high levels of Cu^{++} in the first few days and then showed a decrease in the accumulation may be due to reaching its saturation level.

Acknowledgments. Thanks to Dr. Yakup Kaska (Pamukkale University, Zoology of Department) for analyses of the data and suggestions about the earlier version of this manuscript.

REFERENCES

Albers PH, Camardese MB (1993) Effects of acidification on metal accumulation by aquatic plants and invertebrates 1. constructed wetlands. Environ Toxicol Chem 12:959-976

Brown SL, Chaney RL, Angle JS, Baker AJM (1994) Phytoremediation potential of *Thlaps*i *caerulescens* and bladder campion for zinc and cadmium-contaminated soil. J Environ Qual 23:1151-1157

Dierberg FF, DeBusk TA, Goulet Jr. NA (1987) Removal of copper and lead using a thin film technique, In:Reddy KB, Smith WH (eds.). Aquatic plants for water treatment and resource recovery. Magnolia Publishing Inc, Florida

Dutta RN, Jha UN (1986) Relationship of biomass yield of Makhana (E.ferox) with soil proporties and water quality. Plant Soil 95:345-350

Jain SK, Vasuden P, Jha NK (1989) Removal of some heavy metals from polluted waters by aquatic plants studies on duckweed and water velvet. Biol Wastes 28:115-126

Kacar B (1972) The analyzer of plants. vol 155, Agriculture Pres. Ankara, p 644

Lytle CM, Farrel W (1998) Reduction of Cr (VI) to Cr(III) by wetlands plants. Potential for in situ heavy metal detoxification. Environ Sci Technol 32:3087-3093

NAS (1978) An assessment of mercury in the environment. National Academy of Sci Press, Washington, DC

Nasu Y, Kugimoto M, Tanaka O, Takimoto A (1984) *Lemna* sp. as an indicator of water pollution and the absorption of heavy metals by *Lemna* In: Pascae D, Edwards RW(Eds.). Fresh water biological monitoring conference proceedings. Pergamon Press, Oxford

Negri MC, Hinchman RR, Gatliff EG (1996) Using green plants to clean up contaminated soil, ground water and wastewater. In: proceedings. American Nuclear Society International topical meeting on nuclear and hazardous waste management, Spectrum 96 Seattle WA, August

Nor YM (1990) The absorption of metal ions by *Eichornia crassipes*. Chem Specia Bioavail 2:85-91

Rai UN, Sinha S, Tripathi RD, Chandra P (1995) Waste water treatability potential

of some aquatic macrophytes in wetlands. Ecol Eng 5:5-12
Salt DE, Blaylock M, Kumar PBAN, Dushenkov S, Ensley BD, Chet I, Raskin I (1995) Phytoremediation:A novel strategy for the removal of toxic metals from the environment using plants. Biotechnol 13:468-474
Sinha S, Chandra P (1990) Removal of copper and cadmium by *Bacopa monnieri* L. Water Air Soil Pollut 51:271-276
Sinha S, Gupta M, Chandra P (1996) Bioaccumulation and biochemical effects of mercury in the plant of *Bacopa monniferi* L. Environ Toxicol Water Qual 11: 105-112
Thapa D, Srivastava HS, Ormord DP (1988) Physiological and biochemical effects of lead in higher plants. Vegetos 1:107-119
Thomas PR, Glover P, K alaropan T (1995) An evaluation of pollutant removal from secondary treated sewage effluent using a constructed wetland system. Water Sci Technol 32:87-93
Wang Q, Cui Y, Dong Y (2002) Phytoremediation of polluted waters potentials and prospect of wetland plants. Acta Biol Technol 22:199-208
Zayed A, Gowthaman S, Terry N (1998) Phytoaccumulation of trace elements by wetland plants: I. Duckweed. J Environ Qual 27:715-721