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Removal of Cadmium from Water Using Duckweed (*Lemna trisulca* L.)

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ABSTRACT

This study examined the ability of duckweed (*Lemna trisulca* L.) to remove soluble cadmium from water. The duckweed was obtained from the Işikli Lake plant in Denizli. Cadmium tolerance in *L. trisulca* was investigated under hydroponics conditions. Within a span of 4 days, the plant was capable of removing about 75-85% Cd from 100 mL of both kinds of waste waters containing 3.0-7.0 mgL^{-1} of the metal at an optimum pH of 6.5. All measurements were done in triplicate and performed in accordance with standard methods. The aim of this study was to establish more knowledge about this species innate metal tolerance and its may rapidly to absorb heavy metals.

Key Words: Cadmium; *Lemna trisulca* (duckweed); Heavy metal; Aquatic plants

INTRODUCTION

Duckweed (*Lemna trisulca* L.) is an aquatic plant with an excellent potential for toxicological studies. Like other species of the family *Lemnaceae*, it is small in size, grows rapidly and, because it is unattached to the substrate, is relatively easy to culture. It differs from the species of duckweed normally used for toxicity assessment such as *L. minor* and *L. gibba*, since it grows entirely submerged. *Lemna trisulca* is a truly aquatic plant and working with it avoids complications, which may be associated with air/water interfaces (Huebert *et al*., 1993). Duckweeds (*Lemna*, *Spirodela*, *Wolffia* & *Wolfiella*) are worldwide distributed in freshwater to brackish estuaries. These are free-floating, easy to culture in laboratory and are a convenient plant material for ecotoxicological investigations (Prasad *et al*., 2001). In particular, species of *Lemna* are reported to accumulate toxic metals and therefore are being used as experimental model systems to investigate heavy metal induced responses. Bioavaibility and bioaccumulation of various heavy metals in aquatic and wetland ecosystems is gaining tremendous significance globally (Greger, 1999).

Aquatic macrophytes take up metals from the water, producing an internal concentration several fold greater than their surroundings. Many of the aquatic macrophytes found to be the potential scavengers of heavy metals from aquatic environment and are being used in wastewater renovation systems (Abbasi *et al*., 1999; Kadlec *et al*., 2000). Cadmium does not have any metabolic use for plants, it has several industrial applications, electroplating, pigments, (nickel-cadmium; silver-cadmium; mercury-cadmium) alloys etc.

Intrinsic growth rates of aquatic plants are not constant overtime. Hubert and Gorham (1993), and Landolt and Kandeler (1987) found that the doubling time of *L. minor* varied from 1-3 to 2-8 days over 18 month period. Data on the effect of a reference toxicant over time are scarcer reported no cyclic changes in the effect of relationship between intrinsic growth rate and the Cd reference toxicant (Thorsteinsson *et al*., 1987). The aim of the present work is to investigate the performance of (*Lemna trisulca* L.) to remove Cd from aquatic systems and to represent the rate of Cd removal.

MATERIALS AND METHODS

(*Lemna trisulca* L.) (duckweed) was used as research material. The plants used in the study were obtained from the Işikli Lake wastewater treatment plant located in Işikli Lake, Denizli Turkey (Fig. 1). The duckweed was acclimatized to laboratory conditions for one week before starting the experiments. Different concentrations (1.0, 3.0, 5.0 & 7.0 mg/L) of Cd was prepared using $Cd (NO_3)_2$ with stock solution (AR, E. Merck, Germany). Test plants were cultivated for one week in laboratory for the experiment. Control samples have been prepared selecting an equal number of plants kept under in the conditions in Cd solutions for 24, 48, 72 and 96 h. After the water samples have been taken analyzed at 228.8 nm by Atomic Absorption Spectrometry, with a Pelkin Elmer, USA AAS 700 (Table I).

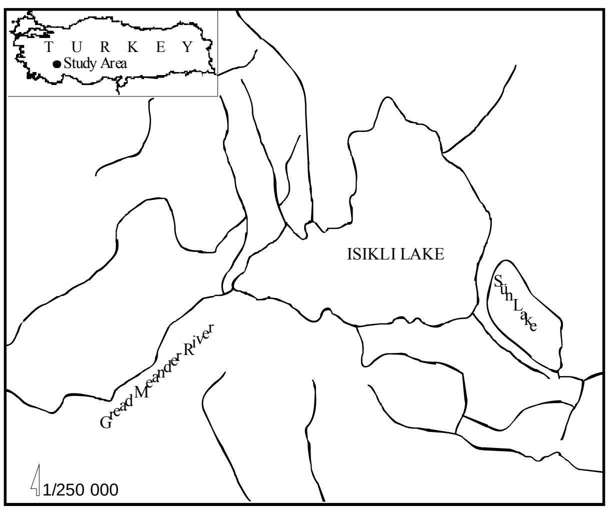
RESULTS AND DISCUSSION

Ideally, all aquatic plant species should be at the same size and growth stage when exposed to trace elements in order to compare their ability to remove various trace elements under study. The goal of the present study is to identify wetland plant species that are most efficient to

Table I. Bioremoval of cadmium by *L. trisulca*

Period (day)	Init. Con. (Cd in solution) (mg/L)	Cd^{++} Final Con. (mg/L)	Cd^{++} Removed Con. (mg/L) %
1	1	0.16	83.9
	3	0.56	81.4
	5	1.12	77.6
	7	1.58	77.4
2	1	0.23	77.1
	3	0.55	81.6
	5	1.06	78.9
	7	1.78	74.5
3	1	0.22	77.6
	3	0.63	79.2
	5	0.99	80.2
	7	1.33	80.9
4	1	0.23	76.7
	3	0.46	84.7
	5	0.81	83.7
	7	1.44	79.5

Fig. 1. Map of the study location



remove trace elements from wastewaters. There is little agreement regarding the optimum length of time for toxicity tests using duckweed. According to Wang (1991) duckweed should be grown for 4 weeks under constant conditions before any growth rate measurements are taken, but toxicity tests that use duckweeds are only of 1 to 4 days duration (Hughes *et al*., 1988; Taraldsen *et al*., 1990; Kwan & Smith, 1991; ASTM, 1991; Wang, 1990; Muramoto & Oki, 1983), using (*Lemna minor* L.) showed that the Cd content reached steady state conditions after 12 days when the plant was exposed to 1.5 µM Cd. This suggests that perhaps 4 weeks is too long, but that 4 to 7 days is not long enough to assess to toxicity adequately. However, some other wetland plant species have been shown to exhibit higher accumulation of Cd and, therefore, are considered excellent Cd accumulators. Muramoto *et al*. (1989), in two separate studies, showed that water hyacinth accumulated 36 and 10.6 g Cd, respectively while *Lemna trisulca* was even better accumulators of Cd than *Lemna minor*. Researchers have found high levels of Cd accumulation in inflated duckweed (*L. gibba*) and ivy duckweed (*L. trisulca*).

Within a span of 4 days treatment period, at an optimum pH of, test plant could remove more than 70% of Cd from a cadmium-based synthetic solution. We conclude that duckweed shows promise for the removal Cd from contained wastewater since it accumulates high concentrates of this element. Further, the growth rates and harvest potential make *L. trisulca* a good species for phytoremediation activities.

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 umbellate*) and water velvet (*Azolla pinnata*) (Jain *et al*., 1989) take up Pb, Cu, Cd, Fe and Hg, from contaminated solutions. A few laboratory studies have clearly demonstrated the importance of aquatic plants in accumulation of cadmium (Salt *et al*., 1995). (Qutridge *et al*., 1991; Qutridge & Hutchinson, 1991), in a similar experiment examined the effect of 15 or 25 ppb Cd on *Salvinia minima* plants that had been pretreated with 0, 10, 25 or 50 ppb Cd while there was clear evidence that exposure to 25 ppb Cd increased PC in the plants (Qutridge *et al*., 1991), there was no statistical evidence to indicate that pretreatment altered the amount of PC produced when the plants were exposed to 25 ppb Cd. There were also few consistent effects of pretreatment on Cd toxicity as tested by biomass, chlorophylla, metal binding proteins or trios. Our results and those of Qutridge *et al*. (1991) and Qutridge and Hutchinson (1991) suggest that more work needs to be done to characterize the long term response of aquatic plants to Cd.

It is believed that this system could be employed to remediate either wastewater effluent streams or water bodies contaminated with Cd.

CONCLUSION

This study demonstrates the use of *Lemna minor* (duckweed) to remove Cd from solution. Duckweed appears to be especially advantageous in such systems. Duckweed appears to be especially advantageous in such systems. It exhibits high potential for wastewater treatment because of its ubiquity, rapid growth rate, ease of harvest, wide range of temperature tolerance and extended growing and harvesting periods. The results from this study show that duckweed is effective in removal of Cd from water and that this Cd can then be removed from the water by simply harvesting the plant.

REFERENCES

Abbasi, A.S. and E. Ramasami, 1999. *Biotechnological Methods of Pollution Control*. p. 168. Universities Press, Hyderabad.

ASTM, 1991. Standard guide for conducting static toxicity with Lemna gibba. G3. E 14115-91. Annual Book of AST M standarts, vol.1104, *American Soc. for Testing and Materials,* p. 1334. Philadelphia.

Dieberg, F.F., T.A. Debusk and Jr.N.A. Gouret, 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., Inc, Florida.

Greger, M., 1999. Metal availability and bioconcentration in plants. *In:* Prasad, M.N.V. and J. Hagemeyer, (eds.), *Heavy Metal Stress in Plants from Molecules to Ecosystems,* pp. 1–27. Springer, Berlin.

Huebert, D.B. and J.M. Shay, 1993. The response of (*Lemna trisulca* L.) to cadmium. *Environ. Pollut*., 80: 247–53

Huebert, D.B. and P.R. Gorham, 1993. Biohasic mineral nutrition of the subemered aquatic macrophyte *Potamogeton pectinatus* L. *Aqual. Bota.,* 16: 269–84

Hughes, J.S., M.M. Alexander and K. Balu, 1988. Anevoluation of appropriate expresssions of toxicity in aquatic plant bioassays as demonstrated by the effect of atrozine on algae and duckweeds. *In:* Adams, W.J. Chapman and W.G. Landis, (eds.) *Aquatic Toxicology and Hazard Assessment ASTM STP* (1971), pp. 531–47. American Society for testing and Materials, Philadelphia.

Jain, S.K., P. Vasudan 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

Kadlec, R.H., R.L. Knight, J. Vymazol, H. Brix, R. Cooper and R. Habert, 2000. *Constructed Wetlands for Pollution Control.* p. 164. Control Processes, Performance, Design and operation, IWA pub. London.

Kwan, K.H.M. and S. Smith, 1991. Some aspects of the kinetics of cadmium and thallium uptake by fronds of *Lemna minor* L., *New Phytol.,* 117: 91–117

Landolt, E. and R. Kandeler, 1987. Biosystematic investigations in the family of duckweeds (*Lemnaceae*). vol.4. The family of *Lemnaceae*-a monographic study, vol. 2. Veröffentlichungen des Geobatananischen Institutes der ETH, Stiftung Rubel, Zurich

Muramoto, S., Y. Oki, H. Mishizaki and S. Aoyama, 1989. Variation in some element contents of water hyacinth due to cadmium or nickel teatment with without anionic surface active agents. *J. Environ. Sci. Healt.,* A24: 925–34

Muramoto, S. and Y. Oki, 1983. Removal of some heavy metals from polluted water by waterhyacinth (*E. crassipes*). *Bull. Environ. Contam. Toxicol.,* 30: 170–7

Outridge, P.M. and T.C. Hutchinson, 1991. Induction of cadmium tolerance by acclimation transferred between gametes of the donal fern *S. minima* Baker. *New Phytol*., 117: 597–605

Outridge, P.M., W.E. Rauser and T.C. Hutchinson, 1991. Changes in metal-binding peptides due to acclimatation to cadmium transferred between ramets of *S. minima*. *Oecologia*, 117: 109–15

Prasad, M.V., P. Malec, M. Bojko and K. Stralka, 2001. Physiological responses of (*Lemna trisulca* L.) to cadmium and copper bioaccumulation. *Plant Sci*., 161: 881–9

Taraldsen, J.E. and T.J. Norberg-King, 1990. New method for determining effluent toxicity using duckweed (*Lemna minor*). *Environ. Toxicol. Chem*., 9: 761–7

Thorsteinsson, B., J. Tilberg and E. Tilberg, 1987. Carbonhydrate portitioning, photosynthesis and growth in *Lemna gibba* G3.I. Effect of nitrogen limitation. *Physiol Plant.,* 71: 264–70

Wang, W., 1991. Literature review on higher plants for toxicity testing. *Water Air Soil Pollut.,* 59: 381–400

Wang, W., 1990. Literature review on duckweed toxicity testing. *Environ Res.,* 52: 7–22

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