Bull. Environ. Contam. Toxicol. (1997) 59:777-782


Bulletin of Environmental Contamination and Toxicology

# Observation on the Utility of Integrated Aquatic Macrophyte Base System for Mercury Toxicity Removal

S. Shrivastava, K. S. Rao

School of Studies in Zoology, Vikram University, UJJAIN (M. P.), India 456010

Received: 1 March 1997/Accepted: 29 July 1997

Heavy metals originating from domestic, industrial wastewaters, acid mine drainage etc. are increasingly contaminating the aquatic ecosystem, causing several pollution problems. The removal of heavy metals by chemical processes like precipitation and membrane segregation techniques cannot always give satisfactory removal (Tare et.al. 1988) whereas advanced technologies may not be economically and commercially viable. The aquatic weed plants absorb and incorporate the dissolved toxicant material in their own body tissues so rapidly and effectively that they are now considered for use in treatment of heavy metal from contaminated effluents. Biosorbents may be a viable approach for recovery of heavy metals from wastewater contaminated with toxic metals (Reddy and Smith 1987 and Oke and Juwarkar 1996). The present study evaluated the relative efficiencies of five selected weeds and proposed an integrated macrophyte base system for mercury detoxification suggesting possible method of mercury removal from contaminated aquatic environment.

## MATERIALS AND METHODS

The fish Oreochromis mossambicus was selected as test animal. The fish were collected from Government Fisheries Department Ujjain India. They were brought to the laboratory and kept in several glass aquaria containing 10 litres of stored tap water under aeration.

The weeds, used in the present study viz. Eichhornia, Salvinia, Hydrilla, Chara, Vallisneria are basically selected on the basis of floating, submerged and emergent types. Mercuric chloride was used as toxicant material. The selected weeds were allowed to remain in the experimental water with toxicant for a period of 48 hrs., as this would facilitate the absorption of toxicant by the weed. The fish were then introduced. The LC 100 values and other acute toxicological data were obtained with the earlier experiment. Lethal concentration 1.0 ppm of mercuric chloride was selected as toxicant concentration for the present study.

*Correspondence to:* S. Shrivastava

To study the experimental detoxification nine experimental groups were set up. The details of which were as per details given under:

Experimental Sets :
1. Normal Control-Tap water+Fishes (NC)
2. Weed Control Group - Equal weight of five weeds+Tap water+Fishes (WC)
3. Lethal Concentration Group -LC100 concentration of Mercuric Chloride in Tap water + Fishes (LC)
4. Combined Weed Group-Equal Weight of 5 weeds+LC100 concentration of Mercuric Chloride in Tap water+Fishes (CW)
5. Eichhornia Group - Eichhornia + LC100 concentration of Mercuric Chloride in Tap water + Fishes (E)
6. Salvinia Group - Salvinia + LC100 concentration of Mercuric Chloride in Tap water + Fishes (S)
7. Hydrilla Group - Hydrilla + LC100 concentration of Mercuric Chloride in Tap water + Fishes (H)
8. Chara Group - Chara + LC100 concentration of Mercuric Chloride in Tap water + Fishes (C)
9. Vallisneria Group - Vallisneria + LC100 concentration of Mercuric Chloride in Tap water + Fishes (V)

The mercury detoxification study reported in the present study was based on relative fish mortality rate, accumulation of mercury in fish and weed and mercury recovery from water. Fish mortality rate was observed at eight-hour intervals up to 96 hours of experimentation. Mercury concentration in fish muscles, weed, and water were determined by atomic absorption spectrophotometer (Perkin Elmer 3100) followed by digestion in acid.

## RESULTS AND DISCUSSION

Oreochromis mossambicus was subjected to 1 ppm concentration of $HgCl_2$ which represents the LC100 concentration as mentioned earlier. The same concentration was used in all experimental setups (Table 1). 100% fish mortality was recorded in the lethal concentration group at 96 hrs. of experimentation. Experimental group No.4 contained all the five experimental weeds (100gm) which have shown no mortality. Experimentation with individual weed plants (No. 5,6,7,8,9) yielded low mortality rates. 20% fish mortality was recorded in lethal concentration containing Eichhornia; 40 to 80% mortality was recorded with Salvinia, Chara, Hydrilla and Vallisneria experimental group (Table 1). Eichhornia was established in this experiment as an individual weed having highest capacity of mercury removal from the media. Next in order were Salvinia, Chara. Hydrilla and Vallisneria.

Limited data are available regarding toxicity removal by aquatic weed plants from polluted environments. Wolverton et al., (1983) suggested the use of vascular aquatic plants for inorganic and organic pollution removal. The aquatic plants absorb and accumulate Cadmium, Nickel, Mercury, Silver and Cobalt which may become 4000-20,000 times more concentrated in plant than in the water through the process of biomagnification (Moore, 1990) . Das (1984) indicated that water hyacinth (*Eichhornia crassipes*) was capable of absorbing mercury from mercury bearing effluents. Dhanekar et al (1984) and Shrivastava and Rao (1989) reported highest capability of mercury removal by *Eichhornia* in laboratory conditions. De et al., (1985) reported that the uptake of mercury by aquatic weed plant *Pistia stratiotes* gradually increases in the culture media and that the accumulation depends mainly on initial concentration of nutrients in water, exposure period, growth and the plant parts.

Mercury accumulation studies in test fish in different experimental groups show variable incorporation levels due to pollution reducing activity of weed (Lucia et al., 1996). The maximum incorporation level 2.41 ppm in fish was

Table 1. Mercury concentration and fish mortality response in different experimental groups at 96 hrs.

| Experimental group | Mercury concentration | | | % Fish mortality |
|---|---|---|---|---|
| | Fish mg/kg | Weed mg/kg | Water mg/l | |
| 1.Normal control group | - | - | - | - |
| 2. Weed control group | - | 0.22+0.09 | - | - |
| 3. Lethal concentration group | 2.41+0.09 | - | 0.77+0.05 | 100% |
| 4. Combined Weed | 0.072+0.01 | 6.79+0.85 | 0.2+0.044 | - |
| 5. Eichhornia group | 0.700+0.80 | 4.85+0.30 | 0.3+0.040 | 20% |
| 6. Salvinia group | 1.090+0.05 | 2.84+0.06 | 0.49+0.09 | 40% |
| 7. Hydrilla group | 1.820+0.05 | 1.54+0.08 | 0.71+0.06 | 80% |
| 8. Chara group | 1.600+0.13 | 1.50+0.07 | 0.63+0.06 | 80% |
| 9. Vallisnaria group | 1.800+0.16 | 1.72+0.08 | 0.60+0.11 | 80% |

recorded in lethal concentration group. Other experimental groups with selected weed plants yielded lower incorporation levels (Table 1). 92% 72%, 54%, 33%, 24% and 24% recovery in fish were observed in combined weed group, Eichhornia group, Salvinia group, Chara group, Hydrilla group and Vallisneria group respectively. Weed in the control group also has shown mercury incorporation level of 0.22 ppm which may be due to natural contamination, representing background concentration level in the present study. The concentration of mercury in water was observed to decrease in different experimental groups. The maximum decrease 80% was observed in combined weed group. Next in order were Eichhornia 60%, Salvinia 51% Chara 40%, Hydrilla 30% and Vallisneria 27%. These results indicate that combined weed group was having highest metal recovery capacity. Eichhornia weed was established as individual weed having highest metal recovery in the present study. Kaiser (1993) observed that Eichhornia is an adequate weed having a great capacity of removing heavy metal through roots. Oke and Juwarkar (1996) reveals that nearly 60% of heavy metal is retained in the root bed and 40% gets accumulated in plant biomass. In the present study the combined weed group contains different types of weeds like floating, emergent and submerged types forming an Integrated Macrophyte based system. This method was proposed for the first time and encouraging results were recorded showing this as a better system when compared to using individual weed plants. Nevertheless it may be noted that amongst the weeds selected for the present study, the floating weeds had extensive root system and were more efficient in toxicant removal when compared to submerged weeds.

However, the heavy metal load in natural conditions is concentrated more in the hypolimnic layers where the floating weeds have less access. Hence the authors feel that an integrated macrophyte based system shall remove the toxicant from all the layers of the aquatic body, providing an additional advantage of oxygenation, more area of absorption and location where the toxicant concentration was the most.

The results show that this integrated macrophyte base system provides efficient mechanism of metal absorption by two floating weeds. Eichhornia and Salvinia in the surface water layer, Chara and Hydrilla in the column layer and Vallisneria in the bottom layers through their roots. The present authors agree with Reddy and Smith (1981), Shrivastava and Rao (1989) Cooper and Findlate (1990), Brix (1991), Lucia (1996) regarding the utility of macrophytes in efficient toxicity removal. But the present authors suggest an integrated macrophyte base system. Which is more effective offering a low cost treatment system with less environmental damage. The present study also indicates that maximum quantity of toxicant was removed with greatest rapidity up to 72 hrs. of exposure, even though 50% of toxicity ab-

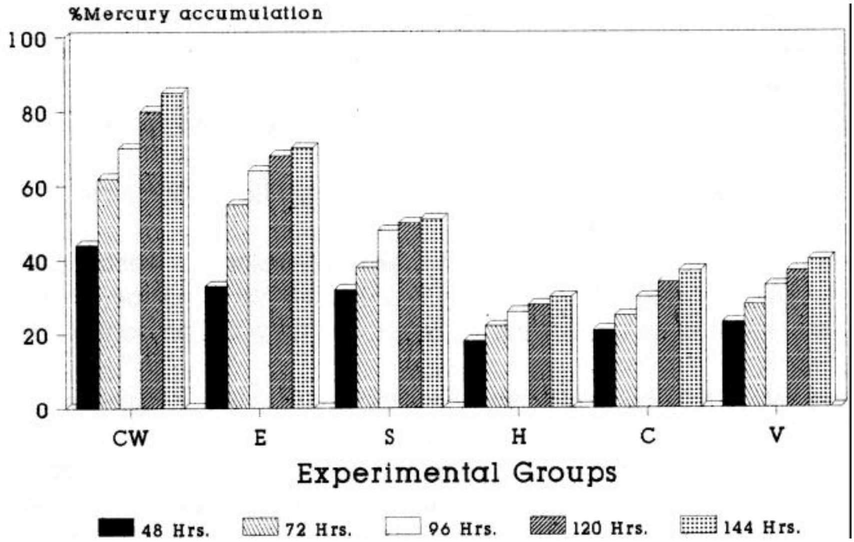


Fig.1 . Mercury accumulation in experimental weeds in different time intervals. CW - Combined weed group, E - Eichhornia group, S - Salvinia group, H - Hydrilla group, C - Chara group and V - Vallisneria group

sorption takes place in the first 48 hours of exposure (Fig. 1). After the critical period of 72 hrs exposure period the rate of toxicant absorption gradually recedes and becomes negligible. It is therefore suggested that resultant plant growth can be harvested regularly, each time leaving some plant to regrow a new crop, so that the water purification becomes a continuous process. Thus permanent treatment pond can be maintained in industrial area on a continuous basis. Studies with regard to aquatic macrophyte combinations to be used in treatment ponds and the period of macrophyte replacement should be seriously undertaken for developing a more efficient, natural and cheap integrated macrophyte based system, which will be most advantageous for toxicant removal.

## References


Brix H (1991) The use of macrophytes in water treatment : Biological features. In Proc of the Int symposium on Biological approach to sewage Treatment process : Current status and Perspectives, Madoni, P. (ed) Perugia Italy, 15-17 Oct, 1990, 321-328,

Cooper PF, Findlater BC (1990). Constructed wetland in water pollution control. Proc. Internat. Conf. on the use of constructed wetland in pollution control: Cambridge (UK) Pergamon press PP. 539-542.

Das H (1984) Mercury absorption capacity of water hyacinth, Eichhornia Crassipes. Environ Eco 2(4) 338-340.

De A K, Sen K A Modak P D Jana S (1985) Studies on toxic effect of Hg on Pistia stratiotes. Water Air soil pollut 24(4) 351-360.

Dhanekar S Rao KS Shrivastava S Pandya SS (1984). Effect of aquatic weed on mercury toxicity removal in relation to some fishes. IAWPC. Tech Annual Xl, 21-24.

Kaiser J (1993) The role of macrophytes in aquatic ecosystems. J. Fresh water Biol 5(2) 141-145.

Lucia C Roquetle P Jose R P (1996). New technology of waste treatment with biotechnological process utilizing aquatic plant. In Proc. 5th International conference on wetland system for water pollution control. Vieana VIII/1-7.

Moore J W (1990) Inorganic contaminants of surface water. Spinger - Verlag. New York Berlin Heideberg London.

Oke B H Juwarkar AS (1996) Removal of heavy metals from domestic wastewater using constructed wetland system. In Proc. 5th International conference on Wetland system for water pollution control Vieana. I/17-1-6.

Reddy K R Smith W H (1987). Aquatic plants for water treatment and resource recovery. Manglia Publishing Inc. Orlando. 1032 P.

Shrivastava S Rao K S (1989) Studies on activity recovery in some mercury exposed freshwater fish by using selected aquatic weeds. Bull. Environ. Contam. Toxico 42 : 840-846.

Tare V Mohammad J Jyenagar L (1988). Application of xanthates in heavy metal removal. IAWPC Tech Ann (15) 88-94.

Wolverton B C McDonald, Duffer W R (1983) Microorganism and higher plants for waste water treatment. J. Environ Qual. 12, 336-242.