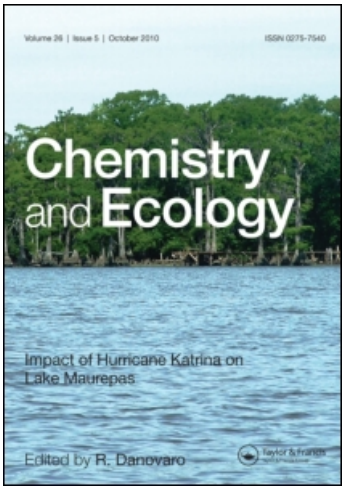

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REMOVAL OF MERCURY FROM POLLUTED WATERS BY THE WATER HYACINTH (*Eichhornia crassipes*)

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The uptake of mercury by water hyacinth (*Eichhornia crassipes*) was studied in an outdoor experiment for 25 days at different metal concentrations. The removal of mercury from the water and uptake by plants was very effective during the first hours and decreased rapidly thereafter. The uptake of mercury was directly proportional to the initial concentration in the water. The highest concentrations were found in plant roots. According to the results, water hyacinth could be used for treatment of mercurial waste waters.

KEY WORDS: mercury, water hyacinth, waste water treatment

INTRODUCTION

Certain aquatic plants accumulate heavy metals from water. The water hyacinth (*Eichhornia crassipes*), which is very common in tropical areas, has been used successfully as a bioindicator for pollution of mercury and other metals (González *et al.*, 1989, González, 1991). The purpose of this study was to evaluate the possibilities of using water hyacinth for the removal of mercury from mercury-containing waste waters in the climatic conditions of Cuba. The final goal is to develop a simple and cheap biological purification system for chlor-alkali plants. This purification system could be used as a final step, after chemical treatment.

Table I Conditions used in water hyacinth bioassays.

Range µg/l	*Duration days*	*Plants/ container*	*Vol l/plant*	*Reference*
875	1	1	0.8	Wolverton & McDonald 1975
10 000	2			Chigbo *et al.* 1982
500–2000	16	1	<2	Muramoto & Oki 1983
1000	28			Jana 1988
3–130	4	8–10	≤1	Lenka *et al.* 1990
7.5–893	25	15	10	This study

The growth of water hyacinth is optimal at temperatures between 25 and 36°C, while there is almost no growth below 10°C (Balasooriya *et al.*, 1984, Sato, 1988). This species may take up considerable amounts of mercury and other heavy metals within a short period of time (Chigbo *et al.*, 1982). Many factors affect the uptake of metals by the water hyacinth: concentration of the metal, pH, complexing agents, competing metals (Hardy & Raber, 1985, Heaton *et al.*, 1986). The uptake of mercury by the water hyacinth under various conditions has been studied in some bioassay experiments. Taking into account these results, we selected our test conditions in order to cover a wider range of environmental conditions (Table I).

MATERIALS AND METHODS

The plants used in the bioassay were obtained from the National Botanical Garden, Havana, Cuba without any known exposure to mercury. Four rectangular plastic jars with a volume of 250 l were used with 15 plants in each. Mercuric chloride ($HgCl_2$) was diluted in 150 l of tap water resulting in four concentrations: 0 (control), 7.5, 91 and 893 μg/l.

The plants were kept in test solutions for up to 25 days. During the first two days the sampling frequency was higher than at the end of the experiment. Approximately 60 ml was sampled from the middle layer of the water in glass flasks and preserved with conc. HNO_3 (pH < 2).

Twenty two hours after the beginning and thereafter, water samples were collected also from the top and the bottom layers in order to find possible depth-related gradients of dissolved mercury. For a better understanding of the factors affecting the removal efficiency, we measured water and air temperature, precipitation and evaporation rates. After the experiment, the plants were left to drip for 24 hours. We sampled five plants from each jar and prepared composite samples from roots, stems and leaves. The samples were freeze-dried, homogenized and digested in conc. HNO_3 at room temperature overnight and at 60°C for five hours. Mercury concentrations were measured using cold vapour atomic absorption (Saturn II spectrophotometer with electrodeless Hg lamp). The precision and accuracy of this method was checked periodically with good results (González, 1991). For each collecting time we calculated a) the percentage of mercury dissolved, and b) the mass of mercury removed:

$$\%D = \frac{[Hg]_t}{[Hg]_{t0}} * 100 \qquad MR_t = MD_{t0} - MD_t$$

a) D = Hg dissolved
t = concn at time of collection
t_0 = concn at time 0

b) MR = mass of Hg removed
MD = mass of Hg dissolved

RESULTS AND DISCUSSION

The mean daily air temperature ranged from 21.6 to 25.7°C and the water temperature varied between 22.0 and 28.3°C, temperatures suitable for the water hyacinth. Precipitation was only 21.4 mm, occurring during seven of the 25 days. The total

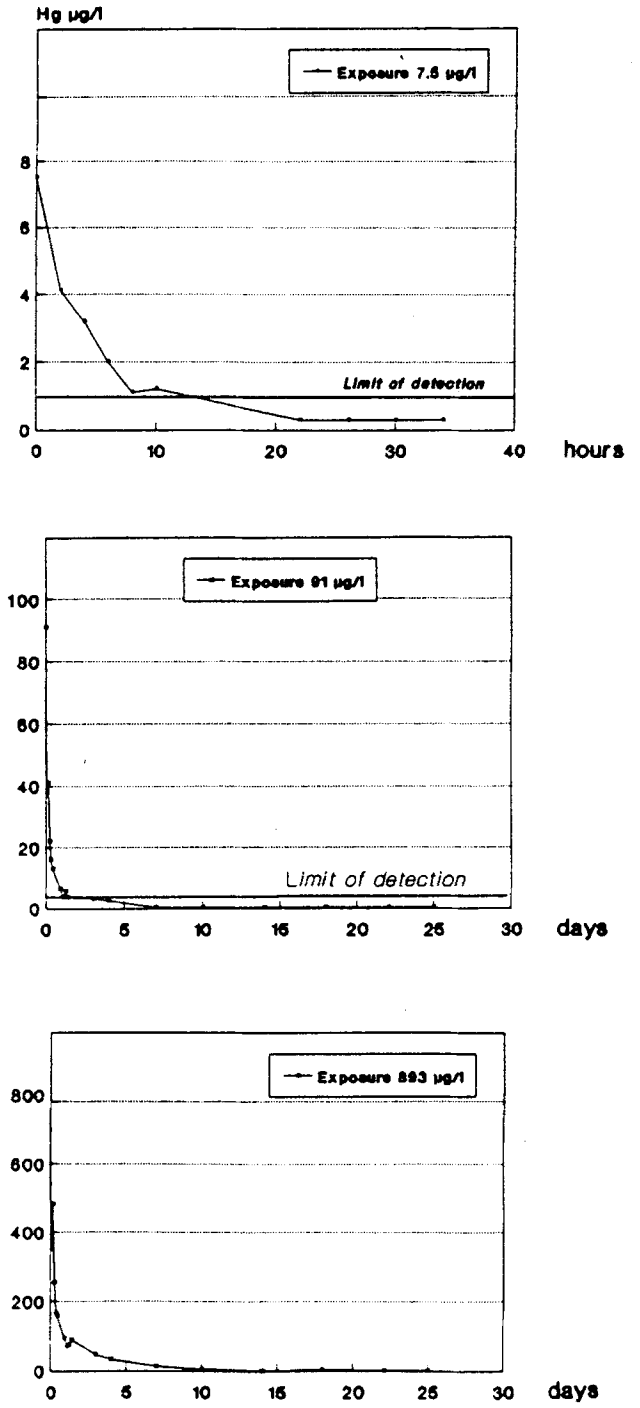

Figure 1 Reduction of mercury concentrations in water at the three concentrations used (Lowest concentration: initial phase only). Limit of detection = 0.5 µg/l. Note changes of scale in Y axis.

evaporation during the experimental period was 189.2 mm, a daily mean 7.6 mm (range 3.9–12.1 mm; coefficient of variation 26%). The mean evapotranspiration rate was calculated to be 56 ml per plant and day.

In all three exposures, where mercury was added, there was a remarkable decrease with time in the mercury concentration of the water (Figure 1). This decrease was most rapid during the first hours: after eight hours more than 80% of the mercury was removed (Table II). This behaviour is in accordance with results obtained for zinc (Hardy and Raber, 1985), lead (Heaton *et al.*, 1986) and cadmium (O'Keefe *et al.*, 1984, Nir *et al.*, 1990). The mass of mercury removed (Table III) was proportional to the concentration of mercury in solution.

At all three levels of mercury concentration the depth-relation was similar: bottom > surface ≥ mid-depth layer (Figure 2).

The lower concentrations in the mid-depth and surface layers might be explained by root uptake. After four days these differences tended to diminish. In a treatment

Table II Percentage of mercury removed from the solutions.

Time	*Exposure concentration*		
	893 µg/l	*91 µg/l*	*7.5 µg/l*
2 hours	61	58	46
4	46	54	58
6	72	76	74
8	82	82	85
10	82	85	84
22	90	94	>93
26	92	96	>93
30	93	94	>93
34	90	96	>93
48	96	97	>93

Table III Mass of mercury removed from the solutions (mg/container).

Time	*Exposure concentration*		
	893 µg/l	*91 µg/l*	*7.5 µg/l*
2 hours	81	7.9	0.51
4	61	7.4	0.65
6	96	10	0.82
8	109	11	0.95
10	110	12	0.83
22	120	13	>1.0
26	123	13	>1.0
30	123	13	>1.0
34	121	13	>1.0
3 days	127	13	>1.0
4	129	13	>1.0
7	132	>14	>1.0
10	133	–	>1.0
14	134	–	>1.0
18	134	–	>1.0
22	134	–	>1.0
25	134	–	>1.0

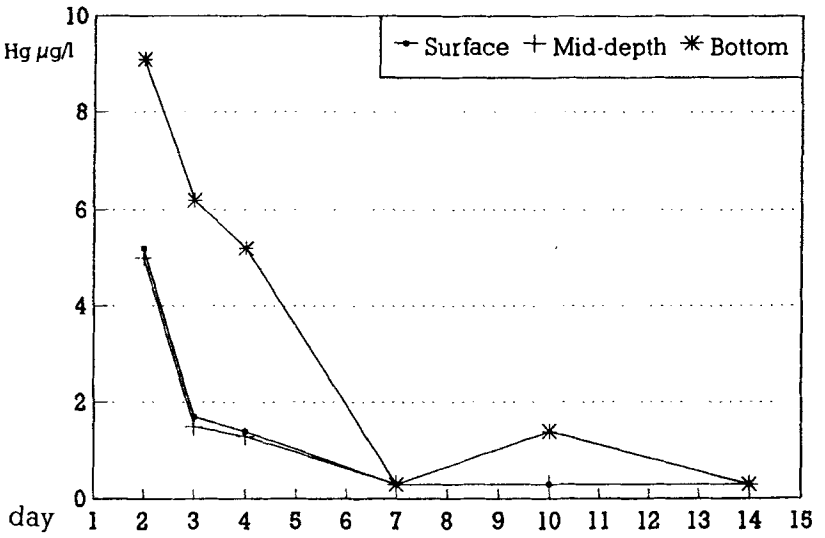

Figure 2 Mercury concentrations in bottom, surface and mid-depth layer layers at the concentration 91 µg/l.

system there should be a direct contact between roots and the largest volumes of water or a circulation pump.

Mercury concentrations on non-exposed plants (Table IV) were similar to those reported earlier from unpolluted sites in Cuba (González, 1991). The mercury contents of water hyacinth for all treatments and for all parts of the plant were higher at higher exposure. The uptake of mercury was directly proportional to the concentration in the water. At all concentrations the mercury level was higher in the roots than in the leaves and stems. Mercury is absorbed from the water through the roots and the roots are also the principal site for accumulation of the metal. Translocation to upper parts seems to be of minor importance. This result is in agreement with earlier findings for mercury (Muramoto and Oki, 1983, Jana, 1988), while other distribution patterns have been found for other metals (Pb, Cd and Cu) in stems and leaves (Lenka *et al.*, 1990, Kay *et al.*, 1984).

The enrichment factors (Hg in exposed plants/Hg in control plants) were 3067, 800 and 40, respectively, for roots; 483, 6.7 and 2.3 respectively, for leaves and 531, 22 and 4.6, respectively, for stems at the three concentrations. No physiological damage was observed in the water hyacinths nor were there any obvious differences between treated and control plants.

Table IV Mercury concentrations of different parts of the water hyacinth (µg g^{-1} dry wt).

Part	*Exposure Concentration*			
	893 µg/l	*91 µg/l*	*7.5 µg/l*	*Non-exposed*
Roots	184	48	2.4	0.06
Stems	6.9	0.29	0.06	0.013
Leaves	29	0.40	0.14	0.06

At an initial mercury concentration of 875 μg/l, similar to our highest concentration, Wolverton and McDonald (1975) obtained a removal of 150 μg Hg per g of dry plant material during 24 hours When we calculate the removal from our maximum concentration (893 μg/l) for 24 hours (mean of 22 and 26 hours; Table IV), we get a removal of 210 μg Hg/g of dry plant material. Our result is 40% higher and can possibly be explained by more favourable climatic conditions. For one hectare of water hyacinth we could remove potentially 126 μg of mercury daily. If the mercury concentration in the plant material is high, there could be difficulties in disposing of the plant material. It is, however, better to remove mercury from aquatic ecosystems, where the bioaccumulation is much more efficient than in terrestrial ecosystems.

CONCLUSIONS

On the basis of these results we can conclude that:
- in Cuban climatic conditions the water hyacinth accumulates mercury effectively from the water,
- the uptake is directly proportional to the concentration in the water within a wide range of water mercury concentrations,
- the greatest uptake occurs from the water layer in direct contact with the roots,
- the mercury taken up is distributed in all parts of the plant in the order: roots > leaves > stem,
- these results confirm the possibility of using water hyacinth in treatment of mercurial waste waters.

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