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Toxicity and Accumulation of Chromium in *Ceratophyllum demersum* L.

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As a result of heavy metal pollution, significant degradation in water quality has occurred leading to acute scarcity of safe drinking water. Efforts have recently been made to develop simple but reliable biological systems to upgrade the water quality (Wolverton and Mc Donald 1979). In this process several aquatic plants effective in heavy metal uptake were identified (Wolverton and Mc Donald 1978; De et al. 1985; Sen and Mondal 1987; Charpentier 1987). Recently, a few aquatic species (Pistia, Lemna, Eichhornia, Hydrilla) have been reported to accumulate chromium (Sen et al. 1987; Mangi et al. 1978; Jana 1988). However, not much information is available on Cr uptake by the aquatic vascular plants. Chromium, which is one of the highly toxic metals is being released to the water bodies in high concentrations through the effluents from industries like leather, dye, paint, ink, electroplating and paper.

The interest on C. demersum a submerged aquatic plant was aroused because of its common occurrence and luxuriant growth in a polluted water body which contained 0.05 to 0.22 ppm Cr (Chandra, 1988; Rai and Chandra, 1989). Plants analysed from this site also showed high accumulation of Cr. In view of this it was considered worthwhile to evaluate chromium uptake ability of this plant under the laboratory conditions.

MATERIALS AND METHODS

Young shoots of Ceratophyllum demersum were cultured in 3% Hoagland solution for eight weeks under 14 hrs/day fluorescent tube light intensity 2500 lux at 35 ± 2°C temp. Stock solution of chromium was made using $K_2 Cr O_4$. Final concentrations, 0.005, 0.05, 0.1, 1 and 2 ppm were made in 3% Hoagland solution. 100 mg of oven-dried (at 80°C) plant material was digested in conc. HNO_3 and perchloric acid. Final volume 25 ml was made and analysed by using Perkin Elmer 2380, Atomic Absorption Spectrophotometer. Chlorophyll was estimated following Arnon (1949). Method suggested by Duxbury and Yentsch (1956) was followed for the determination of carotenoids. Statistical Analysis: Data were subjected to an analysis of variance using the factorial designs, method given by Schefler (1969) in order

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to determine the level of significance within concentration and exposure duration.

RESULTS AND DISCUSSION

Table 1 summarizes the effect of different Cr concentrations (0.005, 0.05, 0.1, 1 and 2 ppm) on biomass productivity. Plants were subjected to these concentrations for 48, 72 and 168 hrs. No significant change in biomass was observed in 0.005, 0.05 and 0.1 ppm Cr. However, decrease in biomass was observed at 1 and 2 ppm after 48 hrs.

Table 1. Biomass in relation to Cr concentration and duration in C. demersum

Conc. of Cr (ppm)	Biomass (% of control)		
	After 48 hrs	After 72 hrs	After 168 hrs
0.0	100.00	100.00	100.00
0.005	98.97 ± 0.80	99.87 ± 0.02	99.82 ± 0.11
0.05	97.55 ± 0.17	97.21 ± 0.24	97.34 ± 0.13
0.1	96.98 ± 0.07	96.98 ± 0.12	96.56 ± 0.13
1.0	94.14 ± 0.13	93.15 ± 0.02	91.76 ± 0.06
2.0	94.07 ± 0.16	89.62 ± 0.20	84.13 ± 0.26

± standard deviation, n=3
F value (concentration = 10.39^{*}
F value (exposure) = 1.82^{**}
* = P < 0.01
** = Not significant at P < 0.01.

Chromium uptake at each concentration was high within 48 hrs (Table 2, Fig 1). However, the uptake rate was comparatively low during the next 120 hrs in all the concentrations.

Table 2. Chromium uptake in relation to concentration and duration in C. demersum.

Conc. of Cr (ppm)	Chromium ug g1 dry wt.		
	After 48 hrs	After 72 hrs	After 168 hrs
0.0	0.0	0.0	0.0
0.005	75.22 ± 1.40	111.45 ± 0.42	156.91 ± 0.72
0.05	117.70 ± 1.20	133.04 ± 0.88	158.82 ± 1.00
0.1	160.87 ± 0.51	268.88 ± 0.52	270.97 ± 1.13
1.0	216.32 ± 0.91	324.10 ± 0.47	552.83 ± 1.00
2.0	576.98 ± 1.30	689.99 ± 0.66	867.80 ± 0.61

± standard deviation, n=3
F value (concentration) = 36.69^{*}
F value (exposure) = 5.927^{*}
*= P < 0.01

Chlorophyll content decreased in all the concentrations. The decrease may either be due to inhibition of chlorophyll synthesis or its destruction (Table 3).

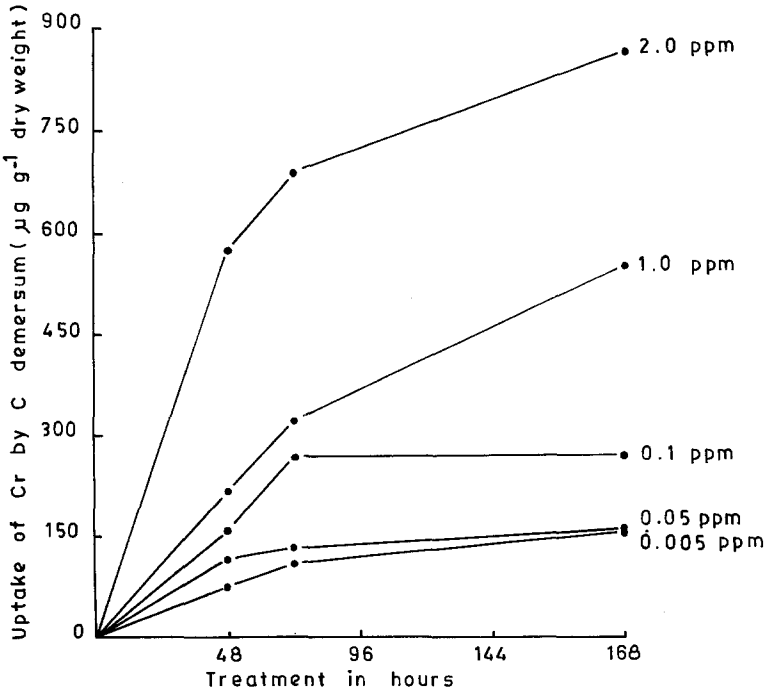

Figure 1. Cr uptake by C. demersum in relation to concentration and duration.

Carotenoids gradually decreased with the increase in Cr concentrations (Table 4).

Chromium is reported to be moderately toxic to other aquatic vascular plants, viz., Ipomoea and Duckweeds. Ipomoea can withstand Cr upto 5 ppm (Khalap 1986) whereas growth of Duckweeds was inhibited by 10 ppm Cr in natural waters (Mangi et al. 1978). In the case of C. demersum as observed presently, growth was not inhibited upto 0.1 ppm.

High accumulation of Cr is usually reported in the roots, both in the terrestrial (Lahouti and Peterson 1979) and aquatic plant like Eichhornia (Jana 1988). Ceratophyllum demersum, though being a rootless species has shown remarkable potential for Cr accumulation (158.52 ug/g dry wt.) at 0.05 ppm under the laboratory conditions. The plants have accumulated slightly less amount of Cr (136.62 ug/g dry wt.) while growing in the natural conditions at 0.05 ppm Cr. It is presumed that the other heavy metals (Pb, Fe, Cu, Mn) present in the pond did not interfere much in the uptake of Cr by C. demersum.

It is concluded that i) 0.1 ppm Cr is the safe limit for C. demersum ii) since the plants survive beyond 0.05 ppm Cr (highest desirable limit recommended by WHO 1985) and with its high uptake potential,

Table 3. Effect of chromium concentrations on chlorophyll contents in C. demersum.

Conc. of Cr (ppm)	Chlorophyll mg g^{-1} fresh wt.								
	After 48 hrs			After 72 hrs			After 168 hrs		
	Total chl	Chl a	Chl b	Total chl	Chl a	Chl b	Total chl	Chl a	Chl b
0.0	0.60 ±0.0	0.44 ±0.01	0.16 ±0.01	0.66 ±0.01	0.49 ±0.01	0.17 ±0.01	0.89 ±0.04	0.66 ±0.03	0.22 ±0.02
0.005	0.50 +0.04	0.39 ±0.03	0.11 ±0.05	0.63 ±0.01	0.46 ±0.01	0.17 ±0.01	0.75 ±0.07	0.57 ±0.04	0.18 ±0.03
0.05	0.47 ±0.03	0.33 ±0.01	0.13 ±0.02	0.60 ±0.06	0.44 ±0.04	0.16 ±0.02	0.65 ±0.09	0.46 ±0.07	0.19 ±0.03
0.1	0.43 ±0.02	0.32 ±0.01	0.11 ±0.01	0.59 ±0.01	0.44 ±0.01	0.15 ±0.01	0.58 ±0.01	0.43 ±0.01	0.15 ±0.0
1.0	0.37 ±0.01	0.28 ±0.01	0.11 ±0.0	0.37 ±0.02	0.28 ±0.01	0.11 ±0.01	0.32 ±0.08	0.23 ±0.07	0.09 ±0.02
2.0	0.24 ±0.02	0.24 ±0.01	0.10 ±0.01	0.28 ±0.02	0.19 ±0.02	0.09 ±0.01	0.11 ±0.04	0.10 ±0.06	0.05 ±0.01

± standard deviation, n=3

F value for total chlorophyll (concentration)= 12.35^{*}

(exposure) = 2.52^{**}

*= $P < 0.01$

**= Not significant at $P < 0.01$.

Table 4. Effect of chromium concentration on carotenoid contents in C. demersum.

Conc. of Cr (ppm)	Carotenoid mg g^{-1} fresh wt.		
	After 48 hrs	After 72 hrs	After 168 hrs
0.0	0.20 ± 0.02	0.24 ± 0.0	0.28 ± 0.02
0.005	0.19 ± 0.04	0.24 ± 0.01	0.27 ± 0.01
0.05	0.17 ± 0.03	0.23 ± 0.04	0.23 ± 0.04
0.1	0.17 ± 0.01	0.23 ± 0.01	0.23 ± 0.0
1.0	0.16 ± 0.01	0.21 ± 0.02	0.14 ± 0.02
2.0	0.16 ± 0.01	0.15 ± 0.02	0.09 ± 0.02

± standard deviation, n=3
F value (concentration) = 4.9^{***}
F value (exposure) = 2.5^{**}
** = Not significant at $P < 0.05$
***= $P < 0.05$

C. demersum could be an effective material for the abatement of Cr pollution in the aquatic environment.

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