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Bioremediation of Tannery Effluent by Aquatic Macrophytes

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Biological treatment system is potentially a simple, low-cost, self sustaining option for amelioration of wastewaters (Brix 1987; Brix and Scheirup 1989). Researches have demonstrated the ability of aquatic macrophytes in reducing the level of toxic metals in polluted waters (Wolverton and Mc Donald 1979;Wolverton 1981;Chigbo et al. 1982; Zirschky and Reed 1988 ;Munshi et al. 1989 ; Falbo and Weaks 1990 ; Selvapathi and Sreedhar 1991; Chandra et al. 1992). However, most of these were based on single plant culture and combination of two or three aquatic plant systems have been suggested (Everard and Denny 1985; Outridge 1992).

The anthropogenic discharge of chromium in the Indian environment is enormous due to indiscriminate use of chromate in leather industries (Khasim et al. 1989). As per a recent report (Thiagragan 1992), chromate salts release ca 2000 - 2300 tonnes of chromium as element in the environment annually in the country. Tannery effluent contains Cr (VI) which is soluble and highly toxic.However, on coming in contact with organic matter it gets converted in to insoluble Cr (III) at low pH and it may further get oxidised to Cr (VI) in presence of excessive oxygen and it is available to plants (Merian 1991).

The present study was undertaken to asses the ability of floating (Spirodela polyrrhiza (L.) Schleiden), submerged (Hydrilla verticillata(l.f.) Royle) and rooted emergent (Bacopa monnieri (L.) Pennell. and Nymphaea alba (L.) species individually and in combination of H.verticillata and S. polyrrhiza to reduce the chromium concentration in the tannery effulent.

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MATERIALS AND METHODS

Experiments were conducted with tannery effluent collected from Unnao, U.P. (India) containing high level of chromium (0.705 $\mu g\ ml^{-1}$). The effluent (0.912 $\mu g\ ml^{-1}$ Cr) was allowed to settle down for a week and filtered (0.705 $\mu g\ ml^{-1}$ Cr). The settled filtered effluent (100%) was diluted so as to be 75%, 50% and 25 % of original concentration using tap water. All the effluent grades (5 L) were treated with 100 g fresh weight of S. polyrrhiza, H. verticillata, B. monnieri and N. alba individually and by species mixed cultures (50 g each) of S. polyrrhiza and H. verticillata. Two sets of each experiment (three replicates each) were kept in large plastic containers of same size for each concentration and duration. These sets were harvested after 7 and 14 d. Harvested plants were washed thoroughly with distilled water, dried and digested with HNO_3: $HClO_4$ (3:1, v/v). Treated effluent (100 ml) was digested similarly and chromium concentration both in plant tissue and treated effluent was estimated using Perkin Elmer 2380 Atomic Absorption Spectrophotometer. Chromium was below detection limit in control samples. Water loss during period of experiments was compensated by regular addition of tap water as described earliar (Rai et al. 1994). The plants exihibited some weight changes during treatment studies but these were not significant. Physico-chemical analysis of tannery effluent was carried out following standard methods (APHA 1989). Validity of data and variability of results were checked employing simple linear regression and correlation analysis (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Physico-chemical analysis of effluent sample revealed alkaline nature of effluent having low dissolved oxygen (2.0 $\mu g\ ml^{-1}$). Effluent containing 0.705 $\mu g\ ml^{-1}$ chromium have high biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total dissolved solids (Table 1).

With the exception of S.polyrrhiza, all the test plants brought down the level of Cr more than 50% in filtered tannery effluent under monoculture system. Maximum reduction of chromium was observed with monoculture of N. alba followed by B.monnieri, H. verticillata and S. polyrrhiza irrespective of effluent dilution (Table 2). Plants exibited maximum chromium removing ability (97.72, 96.59, 81.93 and 64.55% by N.alba, B.monnieri,

Table 1. Physico - chemical characteristics of tannery effluent

Parameters	Values
Temperature	25°C
pH	8.67
Total dissolved solids	835
Dissolved oxygen	2.0
BOD	980
COD	2080
Chromium	0.705

Values are given in ug ml^{-1} otherwise stated

H. verticillata and S. polyrrhiza, respectively at lowest chromium concentration (25% effluent dilution having 0.176 µg ml^{-1} Cr). N.alba reduced nearly 88% of the Cr (0.705 to 0.081 µg ml^{-1}) from filtered tannery effluent while B. monnieri could remove ca. 68.26 % (0.705 to 0.218 µg ml^{-1}) chromium followed by H.verticillata (65.96%) and S. polyrrhiza (46.97%) after 14 d.

Table 2. Chromium uptake (µg g^{-1} dw) from tannery effluent by individual species of aquatic macrophytes.

Effluent conc. (%)	d	Bacopa monnieri	Hydrilla verticillata	Nymphaea alba	Spirodela polyrrhiza
100	7	213.5± 2.5	157.5± 1.7	295.5± 2.8	129.0± 1.9
	14	240.6± 1.8	232.5± 2.9	310.8± 3.0	165.6± 1.5
75	7	174.5± 1.6	148.5± 1.8	238.5± 2.7	116.8± 1.9
	14	212.5± 1.7	190.0± 1.9	248.5± 2.5	150.2± 1.2
50	7	126.5± 0.9	107.0± 1.1	158.0± 1.4	84.0± 0.9
	14	153.0± 1.1	143.1± 1.2	167.8± 1.0	104.5± 1.3
25	7	71.0± 0.7	59.0± 0.7	83.0± 0.8	48.5± 0.6
	14	85.0± 0.8	72.1± 0.8	86.0± 0.8	56.8± 0.7

Values are presented as mean of triplicates ± SE. Initially settled filtered (100%), 75, 50 and 25 % diluted tannery effluent contained 0.705, 0.529, 0.353 and 0.176 µg ml^{-1} Cr, respectively.

Similar trend was evident with other dilutions (Fig 1). A strong positive correlation between Cr concentration in the effluent and accumulation in B. monnieri (r = 0.985), H. verticillata (r = 0.980), N. alba(r = 0.990)

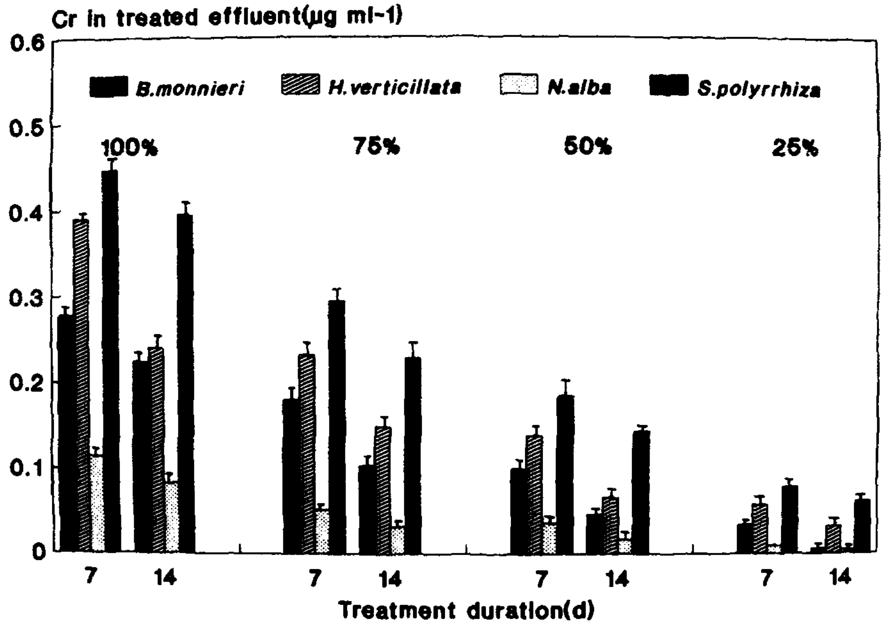

Figure 1 Chromium depletion by individual species of aquatic macrophytes from filtered (100%), 75 , 50 and 25% diluted effluent.

and S. polyrrhiza (r = 0.978) was observed (Table 3).

Table 3. Simple linear regression and correlation (r) analysis of chromium uptake data obtained during bioremediation of tannery effluent by individual species of aquatic macrophytes.

Aquatic macrophytes	d	Linear Regression	r
Bacopa	7	Y = 27.5 + 1.90 X	0.997*
monnieri	14	Y = 41.2 + 2.11 X	0.985*
Hydrilla	7	Y = 33.8 + 1.35 X	0.965*
verticillata	14	Y = 27.4 + 2.11 X	0.980*
Nymphaea	7	Y = 14.3 + 2.87 X	0.990*
alba	14	Y = 14.5 + 3.02 X	0.990*
Spirodela	7	Y = 26.0 + 1.10 X	0.980*
polyrrhiza	14	Y = 26.3 + 1.49 X	0.978*

Significant at df = 2, * = p <0.05

H. verticillata accumulated more chromium than *S. polyrrhiza* in species mixed culture treatment of tannery effluent (Table 4).

Table 4. Chromium (µg g^{-1} dw) uptake and removal by mixed species culture of *H. verticillata* and *S. polyrrhiza* during bioremediation of tannery effluent.

Effluent conc. (%)	d	*H. verticillata*	*S. polyrrhiza*	Cr in effulent (ug ml^{-1})	Cr Removal (%)
100	7	148.2± 1.1	90.2± 0.9	0.450± 0.023	33.8
	14	154.0± 1.7	98.8± 0.5	0.440± 0.017	35.8
75	7	120.5± 1.3	78.6± 0.7	0.310± 0.011	37.6
	14	128.0± 1.7	84.5± 0.6	0.200± 0.008	40.2
50	7	80.0± 0.8	55.2± 0.9	0.210± 0.005	38.3
	14	89.5± 0.8	62.5± 0.5	0.198± 0.003	43.0
25	7	45.3± 0.3	27.3± 0.4	0.098± 0.002	41.2
	14	49.2± 0.3	30.8± 0.4	0.089± 0.001	45.0

Values are presented as mean of triplicates ± SE. Initially filtered (100 %), 75, 50, 25% diluted tannery effluent have 0.705, 0.529,0.353 and 0.176 µg ml^{-1} Cr.

The removal of chromium from filtered tannery effluent by species mixed culture of *S. polyrrhiza* and *H. verticillata* was 35.80 % (0.705 to 0.440 µg ml^{-1}) after 14 d. Their mixed population could remove 40.2, 43.0, 45.0 % chromium from 75, 50 and 25 % diluted tannery effluent, respectively after 14 d. Like mono culture bioremediation of chromium rich tannery effluent, mixed population of floating (*S. polyrrhiza*) and submerged (*H. verticillata*) macrophytes have maximum (45 %) Cr removing ability at lowest effluent dilution (25% effluent containing 0.176 µg ml^{-1} Cr). But in absolute terms the most Cr was removed from undiluted effluent.

During species mixed culture bioremediation of tannery effluent, a strong positive correlation between ambient chromium concentration in effluent and chromium accumulation by *S. polyrrhiza* (r = 0.995) and *H. verticillata* (r = 0.985) was observed (Table 5).

The performance of aquatic macrophytes based bioremediation systems depend mainly on its design and nature of effluent treated with. Also the efficiency of the system may vary from individual to species mixed

Table 5. Simple linear regression correlation (r) analysis of chromium uptake data obtained during mixed species culture bioremediation of tannery effluent.

Plants	d	Linear regression	r
Hydrilla	7	Y = 11.20 ± 1.40 X	0.997*
verticillata	14	Y = 16.95 ± 1.41 X	0.995*
Spirodela	7	Y = 9.80 ± 0.85 X	0.984*
polyrrhiza	14	Y = 12.65 ± 0.90 X	0.985*

Significant at df 2, * = $p < 0.05$

cultures. During the present study, the emergent plants (N. alba and B. monnieri) accumulated more metal than submerged (H. verticillata) and floating (S.polyrrhiza) ones. The substantial accumulation of metals by the tufts of the fine roots of B. monnieri and well developed adventitious roots of N. alba confirms the earliar study showing maximum removal of metals by the fine roots followed by other roots (Sinicorpe et al. 1992).

The lower level of accumulation of chromium shown by S.polyrrhiza during present study is in agreement with Staves and Knaus (1985) and Mangi et al.(1978) who reported least accmulation of Cr by S. polyrrhiza Another possibility of quantitatively less removal of Cr could be pH of the test effluent (8.67), as inihibitory effect of pH 8.0 and onwards on Cr uptake by S. polyrrhiza has been reported (Tripathi and Chandra 1991).

The interaction in mixtures of floating species (Salvinia minima and S.punctata) for reducing toxicity has been reported earliar (Outridge 1992). An alga (Navicula) accumulated higher quantity of Pb in mixture with Lemna (Everard and Denny 1985). A contrast trend in Cr accumulation was found both in H. verticillata and S. polyrrhiza which allowed to grow together under mixed species culture, although, both the plants have shown substantial accumulation of Cr during individual species culture.Thus, performance of mixed species culture was not encouraging. However, during mixed species culture system H. verticillata accumulated more Cr than S. polyrrhiza (cf Table 4).The higher accumulation in H. verticillata may be attributed to the plants tactice to protect other species (S. polyrrhiza) from phytotoxic effect of chromium as suggested for other mixed species culture system (Hutchinson and Czyrska 1975).

Though, the results of present study are quite significant, a clearcut picture would emerge on completion of on going project related to bioremediation of chromium rich tannery effluent by species mixed cultures of many aquatic macrophytes combinations. However, safe disposal of Cr contaminated plants will have to be worked out for a practical solution to the chromium pollution.

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