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Lab Scale Studies on Water Hyacinth (*Eichhornia crassipes* Marts Solms) for Biotreatment of Textile Wastewater

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ABSTRACT
Textile wastewater contains substantial pollution loads in terms of Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Suspended Solids (TSS), Total Dissolved Solids (TDS) and heavy metals. Phytoremediation used for removing heavy metals and other pollutants by aquatic macrophytes treatment systems (AMATS) is well established environmental protective technique. A lab scale study was conducted to test the feasibility of water hyacinth for treating textile wastewater. The pH was reduced from alkaline to nearly neutral in all cases studied with the introduction of water hyacinth. The maximum reduction in the conductivity was 55.71% while the BOD and COD reduction ranged from 40 to 70%. A great deal of reduction in the total solids was noted in all the waste samples with a maximum reduction of 50.64%. Water hyacinth has tremendous potential to absorb heavy metals from the textile wastewater as it resulted in 94.78% reduction of chromium, 96.88 % in zinc and 94.44 % reduction in copper. ANOVA showed a significant (p<0.05) reduction in all the pollutants with the passage of time. Thus water hyacinth can be an efficient biological agent in reducing the pollution loads in textile industry wastewater.

Key words: AMATS, Biological wastewater treatment, Biotreatment, textile wastewater, water hyacinth.

INTRODUCTION
Phytoremediation used for removing heavy metals and other pollutants by AMATS (aquatic macrophytes treatment systems) is a well established environmental protective technique (Hammer, 1992; Ali and Soltan, 1999). The most common aquatic macrophytes being employed in wastewater treatment are water hyacinth (*Eichhornia crassipes*), penny wort, water lettuce, water ferns and duck weeds. AMATS for waste-water treatment are the need of developing countries, because they are cheaper to construct and a little skill is required to operate them.

One of the major problems encountered in the textile industry is the production of large volumes of highly colored wastewater. It is often not possible to predict the characteris-tics of textile wastewaters by using reported values in the literature because every textile industry is unique with respect to the type of production, the technology and chemicals used. Furthermore, the concentrations of pollutants in textile wastewaters vary according to the wastewater management practices and their dilution after production. Textile processing employs a variety of chemicals depending on the nature of the raw materials and products. Some of these chemicals include different enzymes, detergents, dyes, acids, sodas and salts. Since industrial processes generate wastewater containing heavy metal contaminants, which are not biodegradable into non-toxic end products, their concentrations must be reduc-ed to acceptable levels before discharging them into environment. This could pose threats to public health and/or affect the aesthetic quality of potable water if not removed. According to WHO (1984) the metals of most immediate concern are chromium, zinc, iron, mercury and lead.

Textile wastewater also contains substantial pollution loads which increase the Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Suspended solids (TSS), Total Dissolved Solids (TDS) and heavy metals. The concentrations of these parameters have been found to be above the values in National Environment Quality Standards (NEQS) set by the government of Pakistan and other developed countries. Characteristics of textile wastewater are prerequisite for the investigation of treatment options. In Pakistan there is lack of facilities for effluent treatment due to lack of technical facilities and personnel. The current practice is that effluent is being discharged into streams or canals after some hours in stabilization pond without any secondary or tertiary treatment. This wastewater has serious negative impact not only on underground and surface water and land area in close proximity to the source of discharge but also on the aquatic ecological system. Due to usage of dyes and chemicals textile effluents are dark in colour, thus increasing the turbidity of the receiving water body. This in turn hampers the photosynthesis process, causing alteration in the habitat.

It has been shown that highly concentrated effluents as those from tanneries, distilleries, paper and pulp mills, fertilizer, and textile industries may not be suitable for hyacinth growth in undiluted conditions (Trivedy and Gudekar, 1985). So far little work has been done to treat concentrated textile wastewaters. The aim of this present study was to determine the potential of water hyacinth in reducing the pollution load of textile wastewater to meet international standards.

MATERIALS AND METHODS

Collection of Plants:

The water hyacinth used in research was collected from a natural pond near Jallo Park (10Km East of Lahore City, Pakistan). The plant is very common in Punjab Province especially in Gujranwala District, inhabiting vast marshy areas, propagating by stolons and multiplying very rapidly. The plants were stocked in a little pond located in the Botanical Garden at Forman Christian College Campus, Lahore. Young plants were collected for this purpose.

Collection of textile effluents and treatment with Water Hyacinth

Five effluent samples in triplicates were collected from five textile industries in Lahore District. Grab samples were collected from main outlet of factories at the peak hours of activity. i) M/S Asma Dyeing and printing Industries, Kot Lakhpat, Lahore. ii) Cebee Industries (Pvt) Ltd; 75 Ravi Road, Lahore. iii) Comfort Knit wears (Pvt) Ltd; Township, Lahore. iv) Al-Saeed Dyeing and Printing units, Kot Lakhpat, Lahore v) Kamran Textiles Kot Lakhpat, Lahore.

Each effluent was taken in tubs of 12 liter capacity in triplicates. Nearly equal weight of water hyacinths (300 g fresh weight) was transferred to tubs containing textile effluents labeled as experimental plants.

Equal weights of water hyacinths were transferred into another set of tubs containing natural water and these were labeled as control. The experimental and control tubs were kept in a green house for 96 hours after which samples were collected after every 24 hours for analysis.

Analytical procedures

The quality of the wastewater samples was determined before the treatment with water hyacinth plants. The results for all the parameters determined are presented in Table 1. Standard methods were used for all determinations (Eaton, 1995).

Statistical Analysis

The data were analyzed through SAS (Version 9.0) statistical package for two-way ANOVA. The means were compared by using the Turkey's HSD test.

RESULTS AND DISCUSSIONS

The feasibility of water hyacinth to treat the wastewater from five effluent samples of textile industry was carried out for 96 hours. The results are presented in Tables 2 and 3. The results for each parameter determined are presented in Fig 1 a-h. The results indicate that the water hyacinth is very efficient in reducing the pollution loads in textile industry wastewater.

Reduction in pH and conductivity

The results before and after the biological treatment with water hyacinth showed a considerable reduction in the conductivity and pH of the wastewater (Fig 1a and b). The pH was reduced to nearly neutral in all cases studied. The maximum reduction in the conductivity was obtained for wastes from CEBEE Textile Industries (55.71%). It can be interpreted that the reduction in pH and conductivity might be due to absorption of pollutants by plant. The reduction in pH favored microbial action to degrade BOD and COD in the wastewater.

Table 1. Characteristics of a typical textile wastewater

Sample No	Parameter	Range in textile wastewater (mg/L)
1	pH	5.5 - 10.5
2	COD	350-700
3	BOD	150-350
4	Total Dissolved Solids	1500-2200
5	Total Suspended Solids	200-1100
6	sulfides	5-20
7	Chlorides	200-500
8	Chromium (Cr)	2-5
9	Zinc (Zn)	3-6
10	Copper (Cu)	2-6
11	Oil and grease	10-50
12	sulfates	500-700
13	Sodium (Na)	400-600
14	Potassium (K)	30-50

Reduction in COD and BOD

In general, all the waste samples collected were devoid of dissolved oxygen (DO). There was increase in the DO after treatment as indicated by reduction of BOD and COD in the wastewater. According to Reddy (1981), the presence of plants in wastewater can deplete dissolved CO_2 during the period of high photosynthetic activity. This photosynthetic activity increases the dissolved oxygen of water, thus creating aerobic conditions in wastewater which favor the aerobic bacterial activity to reduce the BOD and COD. In present study the introduction of water hyacinth in textile wastewater has shown 40 to 70% reduction in BOD and COD. The maximum reduction in BOD was obtained for the samples obtained from CEBEE textiles. The BOD and COD reduction ranging from 40-70 % is very encouraging performance for any kind of industrial waste after only 96 hours of treatment (Fig 1 c and d). The maximum reduction (70%) was obtained for wastewater collected from CEBEE textiles along Ravi Road, Lahore. Tripathi and Shukla (1991) reported 96.9 % reduction in BOD using water hyacinth and algae for sewage wastewater. Water hyacinth has also been demonstrated in the treatment of raw wastewater and has provided 17% lower levels of BOD and TSS when compared to wastewater stabilization pond effluent (Kumar and Garde, 1989; Mandi, 1994). The reduction in COD and BOD can result to an increase in dissolved oxygen concentration of wastewater. The use of water hyacinth as the functional unit in wastewater treatment systems has been increasingly demonstrated and treatment regimens developed as a result of successful pilot projects (Brix and Schierup, 1989; Mandi, 1994). Wastewater treatment with water hyacinth has been successfully implemented by the city of San Diego, USA, to produce a treated effluent attaining quality standards that would be expected from advanced secondary treatment processes (Tchobanoglous *et al.*, 1989). Water hyacinth can be used in both secondary and tertiary treatment systems, for the removal of nutrients and in integrated secondary and tertiary treatment systems, where both BOD and nutrient removal is the goal (Brix and Schierup, 1989; Middlebrooks, 1995).

Table 2. Effect of time period on the absorption of various pollutants from textile wastewater by water hyacinth

Time (Hrs)	pH	COD	Chromium	Zinc	Copper	BOD	Total Solids	Conductivity
0	8.259 a	361.17 a	4.705 a	4.675 a	4.568 a	243.444 a	1713.17 a	1884.00 a
24	8.033 b	313.83 b	3.558 b	3.243 b	3.515 b	214.667 b	1500.50 b	1709.00 b
48	7.767 c	272.72 c	2.486 c	2.385 c	2.597 c	178.500 c	1285.00 c	1551.33 c
72	7.439 d	233.83 d	1.600 d	1.386 d	1.720 d	150.333 d	1107.83 d	1379.67 d
96	7.105 e	191.50 e	0.612 e	0.553 e	0.747 e	107.333 e	955.00 e	1161.83 e

Note: Means in each column followed by different letters are significantly different at ($P<0.05$).

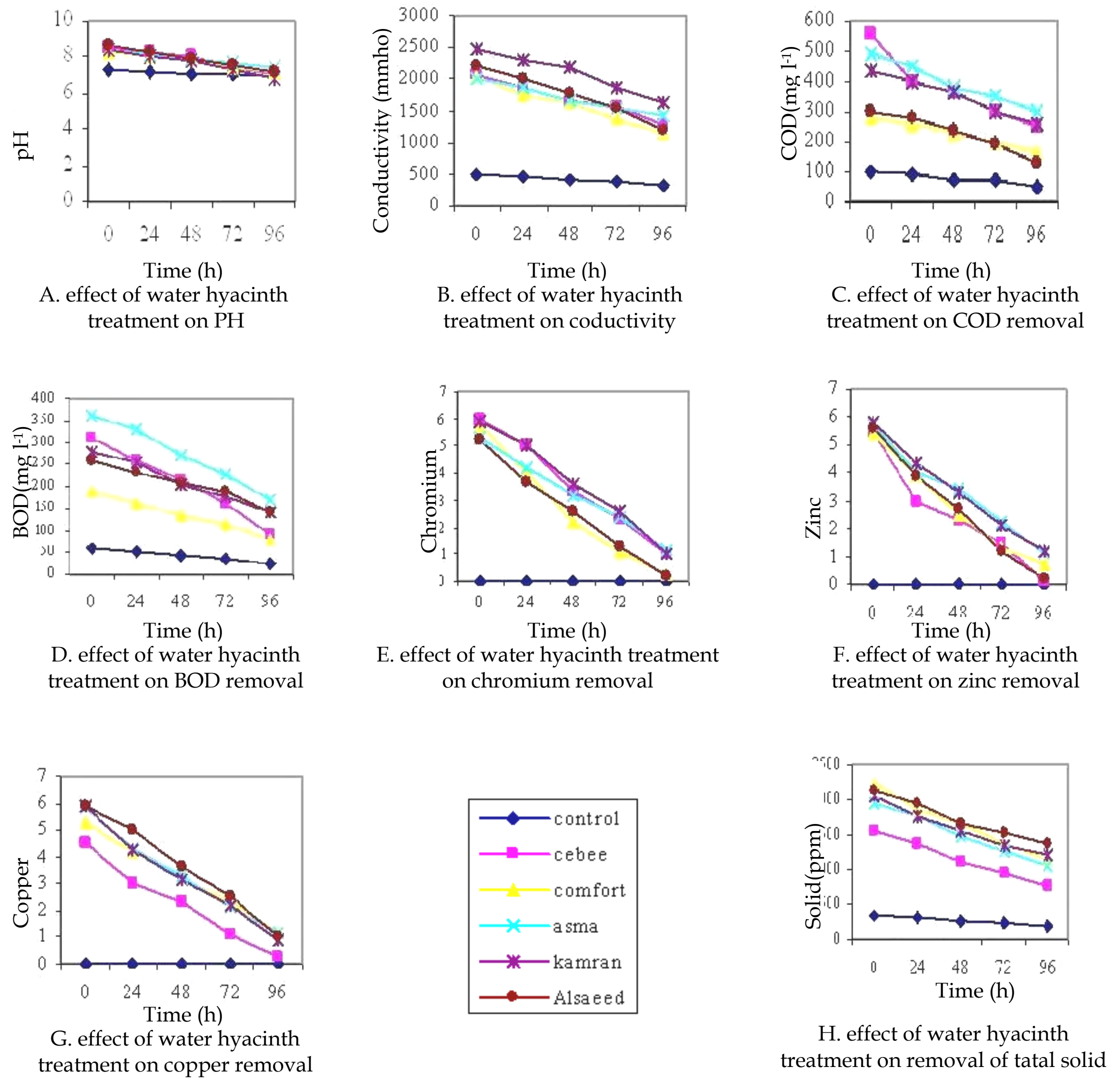

Fig 1. The effects of water hyacinth on the biotreatment of textile wastewaters

Effects on Plant Growth

The plant growth was not affected to any great extent but some yellowish and necrotic spots appeared on the leaves. The anatomy of plants showed some significant ($p < 0.05$) reduction in different cell sizes in various parts of plant (Mahmood *et al.*, 2005). While studying the uptake of some heavy metals by water hyacinth, Ingole and Bhole (2003) indicated that at lower concentrations (5 mg/l) of heavy metals, the plant growth was normal and removal efficiency was greater. At higher concentrations, greater than 10 mg/l, the plant started wilting and removal efficiency was reduced.

Statistical Significance of time period on the biotreatment of textile wastewater

The effect of time period on the absorption of various pollutants by water hyacinth has been presented in Table 2. It shows that there was a significant ($p<0.05$) reduction in all the pollutants with the passage of time.

Absorption of Heavy Metals

Water hyacinth has tremendous potential to remove heavy metals from a growth medium. As shown in results (Fig 1 e-g), treatment of textile wastes with water hyacinth resulted 78.30-94.78% reduction in chromium, 79.34-96.88 % in zinc and 78.30-94.44 % reduction in copper. The maximum reduction of chromium and zinc occurred from Al-Saeed Textiles while the maximum reduction for copper was noted in the wastewater from Cebee Textiles. Initially the absorption was greater but it decreased with the passage of time. Studies concerning freshwater resources decontamination are extensive and some freshwater plants have been found to be efficient in accumulation of heavy metals, among which water hyacinth is the most efficient in its prolific growth in the polluted environments (Yahya, 1990; Vesk *et al*., 1999; Ali and Soltan, 1999; Soltan and Rashed, 2003). It has not been long since water hyacinth was used commercially as a wastewater cleaning source. It has been recognized as very useful in domestic wastewater treatment also (Dinges, 1976; Wolverton and McDonald, 1979).

Proposed Mechanism for Water hyacinth based bioremediation

Many proposals have been put forward to explain the possible mechanism involved in the water hyacinth-based treatment systems (Reddy, 1981, 1983; Mandi, 1994; Zhenbim *et al*., 1993). The presence of aquatic macrophytes in water body alters the physiochemical environment of the water body (Reddy, 1983). The presence of other aquatic photosynthetic autotrophs can deplete dissolved CO_2 in water during the period of high photosynthetic activity. This increases dissolved oxygen in the wastewater thus resulting in increased water pH (Reddy, 1981). Although water hyacinth has been shown to be very effective in nitrogen and phosphorus removal (Sooknah and Wilkie, 2004), but its direct involvement in COD and BOD removal is doubtful. In terms of bacterial reduction by water hyacinth-based systems, two theories exist. First, bacteria are trapped in the rhizosphere of the macrophytes with TSS, and second, water hyacinth may secrete chemical substances having bacteriostatic effects (Mandi, 1994). Experiments have shown that bacteria and microorganisms are abundant in the subsurface root zone (rhizosphere) of the macrophytes and that reductions occur as the water passes through the rhizosphere complex of the floating macrophytes (Zhenbim *et al*., 1993). These experiments demonstrate that BOD, COD, TSS, N, P can be greatly reduced and that the resulting water used for in irrigation and aquaculture. The extensive removal of heavy metals by water hyacinth may be due to extensive adventitious root system, which absorbs these toxic substances from wastewaters.

The feasibility of water hyacinth to treat wastewater from five textile effluent samples was investigated for a period of 96 hours and the following conclusions can be drawn, (1) The water hyacinth was found to be efficient in reducing the concentrations of total solids, pH, conductivity, heavy metals etc within 96 hours of treatment. (2) Water hyacinth was found to be effective in reduction of BOD and COD. (3) At this time of water, energy and environmental purity crisis, water hyacinth can be a very effective tool in polishing the wastewater after primary and secondary treatments. It is hoped that in future more attention will be paid to water hyacinth for treatment of textile wastewater and the other kinds of wastewaters.

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