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PHYTOREMEDIATION POTENTIAL OF AQUATIC HERBS FROM STEEL FOUNDRY EFFLUENT

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Abstract - Discharge of industrial effluents in aquatic environments is a serious threat to life due to toxic heavy metals. Plants can be used as cheap phytoremedients in comparison to conventional technologies. The present study was conducted to check the phytoremediation capability of two free-floating plants, i.e., *Pistia stratiotes* and *Eichhornia crassipes,* for the removal of heavy metals from steel effluent by using Atomic Absorption Spectrophotometry. *P. stratiotes* was able to remove some of the heavy metals, showing the highest affinity for Pb and Cu with 70.7% and 66.5% efficiency, respectively, while *E. crassipes* proved to be the best phytoremediant for polluted water as its efficiency was greatest progressively for Cd, Cu, As, Al and Pb, i.e., 82.8%, 78.6%, 74%, 73% and 73%, respectively. In conclusion, aquatic plants can be a better candidate for phytoextraction from industrial effluents due to cost effectiveness.
Keywords: Phytoremediation; *Eichhornia crassipes*; *Pistia stratiotes*; Heavy metals; Steel effluent.

INTRODUCTION

Contamination of water and wastewater with heavy metals is emerging as a global environmental challenge. Increasing urbanization, industrialization and over population is leading to the degradation of the environment. The main hazardous contents of water pollution are heavy metals. Water bodies are the main target for disposing of pollutants directly or indirectly. The prevailing purification technologies used to remove the contaminants are too costly and sometimes non-ecofriendly also. Therefore, the research is oriented towards low cost and ecofriendly technology for water purification, which will be beneficial for community (Dhote and Dixit, 2009).

Phytoremediation is a cost-effective, environmentally-friendly, aesthetically-pleasing environmental pollutant removal approach and is most suitable for developing countries (Ghosh and Singh, 2005). The technologies based on the phytoremediation technique can be applied to both organic and inorganic pollutants present in soil (solid substrate), water (liquid substrate) or air (Raskin *et al*., 1994; Salt *et al*., 1998). Aquatic plants can be used as the natural catalysts to absorb and accumulate heavy metals in their tissues from wastewater (Vymazal and Kropfelova, 2008). The uptake of trace elements is often increased when plants are grown in effluent water containing a high level of macronutrients (Begum and HariKrishna, 2010). Pakistan, like other developing countries, also requires economical and cost-effective alternatives for wastewater treatment (Andleeb *et al.,* 2010).

E. crassipes is an aquatic invasive plant with natural tendency to absorb pollutants from the water, especially heavy metals (Schneider *et al*., 1995). This plant can tolerate heavy metals by having high ca-

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pacity for the uptake of heavy metals. Due to this potential, it is suitable for the biocleaning of industrial wastewater contaminated with Cd, Cr, Co, Ni, Pb and Hg (Upadhyay *et al*., 2007; Abou-Shanab *et al*., 2007; Maine *et al*., 2006; Skinner *et al*., 2007). *E. crassipes* also has the ability to remove toxins other than heavy metals, such as cyanide, and is helpful in gold mining areas (Ebel and Evangelou, 2007). Similarly *P. stratiotes* has also been extensively used for phytoremediation (Quian *et al*., 1999; Skinner *et al*., 2007). It was also used in lab experiments for the removal of heavy metals (Miretzky *et al*., 2010). The present study was designed to evaluate the efficiency of *E. crassipes* and *P. stratiotes* to remove heavy metals from the effluents of a Steel Foundry located in Hayatabad, Pakistan.

MATERIALS AND METHODS

Effluent Sample Collection

The effluent was collected from the outlet of the furnace of a Steel Foundry located in Hayatabad Industrial Estate, Peshawar, in clean plastic cans. The cans were properly washed with detergent and distilled water prior to water collection and were carefully rinsed with sample effluent, filled up to the brim and tightly closed to ensure bubble-free sample storage (Hussain, 1989).

Plant Collection/Treatments

E. crassipes and *P. stratiotes* were collected from their natural habitat. Young plants were selected for the experiment. These plants were brought to the laboratory, carefully washed to remove dust and other organic matter. *E. crassipes* were arranged in sets of 3 plants each with 2 leaves / plant and with a total weight of 250 g. *P. stratiotes,* weighing about 40 g each set, was introduced in each replicate/ tub.

The test plants were introduced in their respective tubs of 34 × 30 cm size with ten liters of effluent to be treated. The effluent was used in raw form as collected from the sampling site. Three replicates for each treatment with a total 3 observations were performed. Test plants were harvested after 10, 20 and 30 days, respectively, from the day of commencement of the experiment. The plants were weighed after each observation to determine the increase in the weight of the plants. In *E. crassipes* the increase in the number of leaves was also recorded. There was a control set of treatment (tap water) for both the test plants.

The treated water from the replicates during each observation was stored in clean, dry glass bottles and was immediately carried to the laboratory for characterization of physical parameters, including pH, temperature, total dissolved solids, and electrical conductance. The pH was measured by using a glass electrode pH meter, while temperature, total dissolved solids, and electrical conductance of the control and steel effluent before and after treatment were measured by using a conductivity meter, model-145 (Thermonion). Chemical parameters, i.e., heavy metals such as Al, As, Cd, Co Cr, Cu, Fe, Mn, Pb and Zn, were measured by using Atomic Absorption Spectrometry as discussed by Khan (2003).

Analysis of Heavy Metals in Tested Plants

The heavy metals concentration in all the tested plants and control were detected with an Atomic Absorption Spectrometer. The plant samples were prepared by drying, grinding, dry ashing and wet ashing. Plants were dried in an oven at 65 °C for 72 hours. Grinding was done in a pestle and mortar. This powder material was preserved in plastic bags. The powdered sample was transferred to a muffle furnace at 400-450 °C for 2 hours for dry ashing. The ash produced was then packed in sealed plastic bags. Wet ashing was done by following the standard procedure adopted by Haynes (1980). The prepared solution was filtered and stored in clean, labeled plastic bottles until sent for analysis by the Central Resource Laboratory (University of Peshawar).

Statistical Analysis

All the results were the mean of three readings and the standard deviation was calculated for metal uptake by plants in their different parts like roots and shoots.

RESULTS AND DISCUSSION

Control and Steel Effluent

The initial values of the physical parameters of the control and steel effluent prior to and after treatment with test plants are presented in Table 1.

E. crassipes appeared to be more efficient than *P. stratiotes* as it minimized all the selected parameters after treatment of 30 days. The changes in initial weight (and also no. of leaves of *E. crassipes*) of the test plants were also noted in the control and steel industry effluent. The initial weight of *P. stratiotes* was found to increase in the control and steel industry effluent and a similar increase was also observed for *E. crassipes* (Table 2), indicating that both the test plants were capable of growing in the effluents and could be used for further experimentation. Odjegba and Fasidi (2004) also revealed the accumulation capacity and resistance of *P. stratiotes* against trace elements and concluded that it can tolerate heavy metals and growth responses of the plant varied inversely with the increase in metal concentration.

Phytoaccumulation of Heavy Metals in Test Plants

Results for the accumulation of metals in different plant parts and on the whole are summarized in Table 3, Figures 1 and 2.

Table 1: Effect of *Pistia stratiotes* and *Eichhornia crassipes* on some physical features of control and steel mill effluent.

	Temperature (°C)	pH	Total Dissolved Solids (mg/L)	Electrical Conductivity (µS)
Control (Initial value)	30.4	7.9	124	280
After treatment with *Pistia stratiotes*	29.8	7.6	121	254
After treatment with *Eichhornia crassipes*	29.7	7.4	118	243
Steel Effluent (Initial value)	30.3	9.1	430	900
After treatment with *Pistia stratiotes*	30.1	8.5	356	714
After treatment with *Eichhornia crassipes*	30.0	8.3	280	592

Table 2: Change in physical parameters (growth) of *Pistia stratiotes* and *Eichhornia crassipess* in control and steel effluent.

Physical Parameter	***Pistia stratiotes***								***Eichhornia crassipes***							
	Control				**Steel effluents**				**Control**				**Steel effluents**			
	Initial	10 days	20 days	30 days	initial	10 days	20 days	30 days	Initial	10 days	20 days	30 days	Initial	10 days	20 days	30 days
Initial wt (g)	40	58	80	101	40	53	66	86	250	284	320	366	250	294	347	430
Total increase in wt (g)	61				46				116				179			
Initial no of leaves	-	-	-	-	-	-	-	-	6	9	17	23	6	10	19	25
Total increase in no of leaves	----------------				----------------				17				19			

Table 3: The initial and final concentration of heavy metals in control and steel effluent (mg/L) after the treatment with test plants.

Treatment	**Heavy Metal Concentration**								
	Al	**As**	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Pb**	**Zn**
Initial concentration in control	0.0489±0.022	0.6641±0.032	0.0091±0.015	0.0323±0.021	0.0028±0.031	0.8333±0.019	0.0806±0.012	0.0091±0.031	0.0019±0.006
After treatment with PS	0.0458±0.021	0.6269±0.012	0.0045±0.032	0.0142±0.002	0.0009±0.041	0.3277±0.006	0.0484±0.023	0.0030±0.011	0.0006±0.018
After treatment with EC	0.037± 0.062	0.5957±0.041	0.0328±0.032	0.0008±0.031	0.0007±0.017	0.3202± 0.045	0.0104± 0.013	0.0018±0.033	0.0004±0.030
Treatment	**Al**	**As**	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Pb**	**Zn**
Initial concentration in effluent	22.168±0.045	5.0342±0.019	0.0279±0.023	2.8378±0.052	0.16378±0.018	14.6984±0.008	20.3655±0.017	5.2479±0.043	2.0097±0.070
After treatment with PS	15.3326±0.025	4.2210±0.054	0.0140±0.043	1.6600±0.018	0.1090±0.041	10.1343±0.047	15.8014±0.012	1.5345±0.061	1.2941±0.028
After treatment with EC	6.0055±0.051	3.7218±0.006	0.0048±0.029	1.0552±0.003	0.0351±0.027	5.7113±0.031	10.6748±0.002	1.9676±0.065	0.4352±0.023

EC= *Eichhornia crassipes*
PS= *Pistia stratiote*

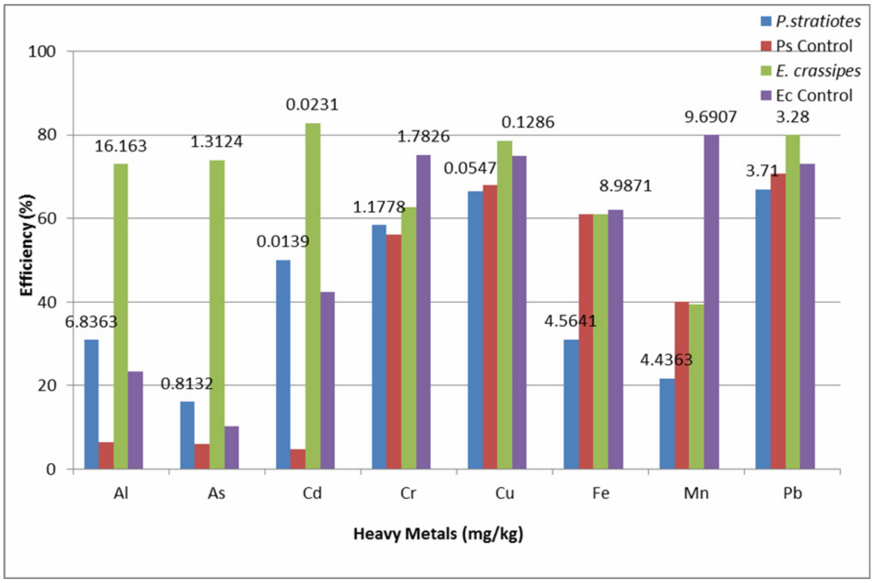

Figure 1: Heavy metal accumulation and % efficiency of test plants.

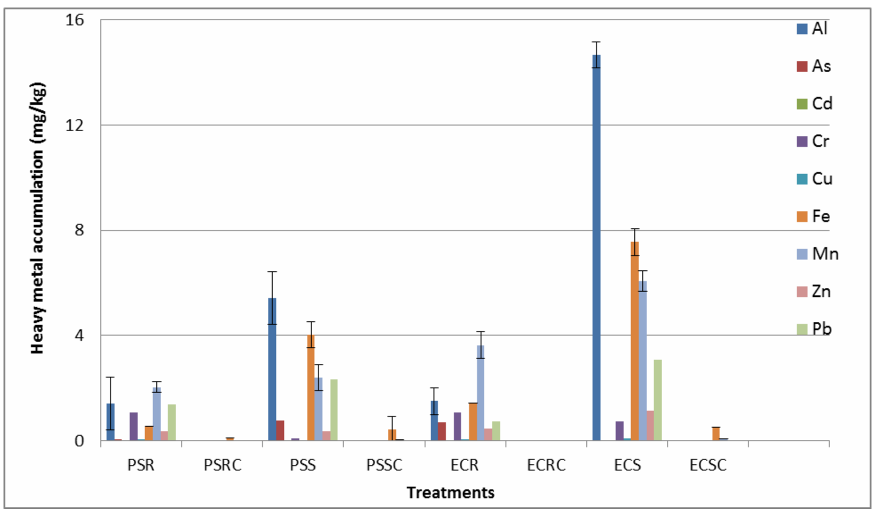

Figure 2: Heavy metal accumulation of different parts of test plants PSR= *Pistia stratioites* roots, PSRC= *Pistia stratiotes* roots control, PSS= *Pistia stratiotes* shoots, PSSC=*Pistia stratiotes* shoots control, ECR= *Eichhornia crassipes* roots, ECRC= *Eichhornia crassipes* roots control, ECS= *Eichhornia crassipes* shoots, ECSC= *Eichhornia crassipes* shoots control.

Al was accumulated in highest concentration, 16.1634 mg/kg in *E. crassipes* and in *P. stratiotes* 6.8363 mg/kg. The shoots of *E. crassipes* accumulated 14.6647 mg/kg while *P. stratiotes* shoots accumulated 5.4342 mg/kg; 1.4021 mg/kg and 1.4987 mg/kg of Al was absorbed by the roots of *P. stratiotes* and *E. crassipes*, respectively.

Deposition of As was in the range of 0.8132 mg/kg to 1.3124 mg/kg in *P. stratiotes* and *E. crassipes,* respectively; 0.7706 mg/kg and 0.6013 mg/kg As was absorbed in the shoots of *P. stratiotes* and *E. crassipes*, while the roots of *P. stratiotes* and *E. crassipes* accumulated 0.0426 mg/kg and 0.7111 mg/kg As, respectively.

P. stratiotes and *E. crassipes* deposited Cd in their tissues to the extent of 0.0139 mg/kg and 0.0231 mg/kg, respectively. The shoots of the test plants stored 0.0018 mg/kg Cd each. In the same way, these plants accumulated 0.0121 mg/kg and 0.0123 mg/kg in their roots, respectively. Cr was deposited in *P. stratiotes* and *E. crassipes* at concentrations of 1.1778 mg/kg and 1.7826 mg/kg, respectively; 0.0934 mg/kg and 0.7277 mg/kg of the total Cr was deposited in the shoots of *P. stratiotes* and *E. crassipes.* Similarly, 1.0844 mg/kg and 1.0549 mg/kg remained in the roots of the test plants, respectively. These results are in accordance with Prajapati et al. (2012) who investigated aquatic plants for Cr remediation. Retention of Cr was more in roots as compared with shoots, confirming the findings of Rehman and Haesgawa (2011) who found that arsenic translocation in *P. stratiotes* was slow and most of the arsenic remained adsorbed onto root surfaces from solution. Earlier findings have also revealed that arsenic compounds are less readily translocated through the root system of aquatic plants.

P. stratiotes and *E. crassipes* had total Cu concentrations of 0.0547 mg/kg and 0.1286 mg/kg, respectively. Of the total concentration, 0.0163 mg/kg and 0.0851 mg/kg were stored in the shoots of *P. stratiotes* and *E. crassipes,* respectively, while 0.0384 mg/kg and 0.0435 mg/kg were retained by the roots of *P. stratiotes* and *E. crassipes* when harvested from steel effluent.

The concentration of Fe in *P. stratiotes* was found to be 4.5641 mg/kg and in *E. crassipes* 8.987 mg/kg. The shoots of the test plants showed 4.0305 mg/kg and 7.5503 mg/kg deposition, respectively. The roots of *P. stratiotes* and *E. crassipes* accumulated 0.5335 mg/kg and 1.4368 mg/kg Fe, respectively.

The phytoaccumulation capacities of *P. stratiotes* and *E. crassipes* to absorb Mn were 4.4363 mg/kg and 9.6907 mg/kg, respectively. The shoots of *P. stratiotes* and *E. crassipes* concentrated 2.3996 mg/kg and 6.0546 mg/kg, respectively, while 2.0361 mg/kg and 3.6361 mg/kg Mn were deposited in the roots of the test plants.

The concentration of Pb in *P. stratiotes* was 3.7134 mg/kg and 3.2803 mg/kg in *E. crassipes*. The shoots of *P. stratiotes* retained 2.3386 mg/kg and of *E. crassipes* 3.0861 mg/kg Pb, whereas the roots of *P. stratiotes* and *E. crassipes* gathered 1.3748 mg/kg and 0.7342 mg/kg, respectively.

P. stratiotes and *E. crassipes* absorbed Zn from steel effluent and its concentrations in their tissues were 0.7156 mg/kg and 1.5745 mg/kg, respectively, while the shoots of the test plants deposited 0.3441 mg/kg and 1.1224 mg/kg. The roots of *P. stratiotes* and *E. crassipes* retained 0.3715 mg/kg and 0.4521 mg/kg Zn, respectively, when grown in steel effluent.

The results for percentage efficiency indicated that *E. crassipess* is a better candidate for phytoremediation. It was found to be progressively better for Cd, Cu, As, Al, Pb removal (82.8%, 78.6%, 74%, 73%, and 73%, respectively) and was moderately efficient for Zn, Cr and Fe (65.2%, 62.8% and 61%, respectively), but was a poor remedient of Mn (39.5%). These results are in accordance with Zhu *et al.* (1999), who concluded that *E. crassipes* accumulated trace elements such as Ag, Pb, Cd, etc. and is efficient for phytoremediation of wastewater polluted with Cd, Cr and Cu. The present results are also in accordance with other workers (Chua 1998; Maine *et al*., 2001; Mangabeira *et al.*, 2004) who indicated that *E. crassipes* has a huge potential for removal of a vast range of pollutants from wastewater. This may be due to its well-developed fibrous root system and large biomass that has been successfully used in wastewater treatment systems to improve water quality by reducing the levels of organic and inorganic nutrients.

Pistia stratiotes was helpful in the removal of some heavy metals from the industrial effluent and was found to be the best phytoremedient for Pb, Cu as it was successful in removing 70.7% and 66.5% of these metals (Lone *et al*., 2008). Similar findings were also reported by Lu (2011) while working on lettuce that was a hyper accumulator of Fe, Pb and Cu.The same kind of findings were also reported by Mokhtar *et al*. (2011) and Mishra and Tripath (2008).

CONCLUSION

Results of the present study supported the previous findings that aquatic plants can be used efficiently in phytoremediation technology. Tested plants were found to be efficient phytoremediators and can be used to treat industrial effluents, although *E. crassipess* proved to be the best candidate for phytoremediation of water contaminated mainly with heavy metals.

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