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Uptake of Lead from Aqueous Solution using *Eichhornia crassipes*: Effect on Chlorophyll Content and Photosynthetic Rate

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Abstract : Lead is the most significant toxin of the heavy metals posing serious effects on plants and animals. The remediation of this toxic pollutant using environment friendly materials is an urgent need. In the present study the effect of pH and concentrations on uptake capacity of lead by Eichhornia crassipes and their interplay have been studied. The rate of Pb uptake by Eichhornia crassipes is very rapid in the first 48 hrs for all the initial concentration and at various pH. The uptake efficiency of roots were more as compared to shoots. The accumulation of Pb in roots of *Eichhornia crassipes* was found to be very high at all pH and concentrations. The photosynthetic rate of *Eichhornia crassipes* sharply declined when grown in aquatic medium containing Pb. The chlorophyll content got reduced, with increasing concentration over the experimental duration, reflecting probable Pb toxicity. The results show that the plant *Eichhornia crassipes* does have the pH neutralizing capacity.

Keywords: Lead, *Eichhornia crassipes*, accumulation, photosynthetic rate, chlorophyll.

1. Introduction

Contamination of the aquatic environment by heavy metals is a worldwide environmental problem. Lead (Pb) is an extremely toxic heavy metal having serious threat to the plants and animals[1,2]. The main sources of Pb poisoning include lead paint and old gasoline spills resulting in dust and soil contamination of food and water[3]. Other areas with high Pb concentrations include Pb mines and smelters ($PbSO_4$, $PbO{\cdot}PbSO_4$, and PbS), shooting ranges, and disposal sites for old batteries[4]. Permissible limits for Pb in drinking water given by the U.S. Environmental Protection Agency (USEPA) is 0.015 mg/L and for wastewaters is 0.1 mg/L, given by both USEPA and Bureau of Indian Standards (BIS)[5]. Thus it becomes mandatory to remove lead from drinking and waste waters. Phytoremediation is a group of technologies that use plants to reduce, remove, degrade, or immobilize environmental toxins, primarily those of anthropogenic origin, with the aim of restoring area sites to a condition useable for private or public applications.[6]. Phytoremediation efforts have largely focused on the use of plants to accelerate degradation of organic contaminants, usually in concert with root rhizosphere microorganisms, or remove hazardous heavy metals from soils or water[7]. Although many plants may have a strategy of Pb exclusion, which hyperaccumulates Cd and Zn but excludes Pb [8,9] several plant species can hyperaccumulate soluble Pb in the soil. Recently there is a considerable interest in developing cost effective and environmentally friendly technologies for the remediation of soil and wastewater polluted with toxic trace elements[10,11]. Plants have the ability to accumulate nonessential metals and this ability could be harnessed to remove pollutant metals from the environment [12-15]. The report of Pb accumulation by *Eichhornia crassipes* at different pH or at various initial concentration are available in the literature[7], however, in the present research work, the effect of these two factors on

2. Experimental Methods

2.1 Plant Analysis

The Eichhornia crassipes, which were acclimatized in the laboratory condition, applied to a solution of Pb of concentration of 15.0, 20.0 and 30.0 mg/L in nine plastic tubs of five-liter capacity. pH of the solutions was maintained at ~3(low), ~5(medium) and ~ 7(neutral). The set up was examined for duration of ten days. Chlorophyll content was estimated after 5-day interval using UV-Visible spectrophotometer. Periodically, after every two days (48 hour) water samples were removed from each tub for ten days and

2.2 Bio Concentration Factor (BCF)

BCF is an index of the ability of a plant to accumulate metal ions with respect to the metal ion concentration in the growth environment. It is defined as the ratio of metal concentration in the dry biomass to the initial concentration of metal ion in feed solution.. BCF was calculated by using existing methods [17].

3. Results and Discussions

3.1 Uptake of Lead

The present trend of bioaccumulation of Pb by Eichhornia crassipes shows that the rate of uptake of Pb by Eichhornia crassipes is found to be very rapid just upto 48 hours of exposure for 15 mg/L, 20 mg/L and 30 mg/L concentration in low, medium and neutral pH (Fig1). This shows the plants have the maximum efficiency of accumulation up to 2^{nd} day of its application and in some cases it almost reaches the saturation. The efficiency of biosorption (or reduction of concentration of Pb in solution) of Pb up to 48 hrs was so high that it could uptake upto 85.05% at initial concentration of 20 mg/l with medium pH as compared to a total of 89.78% accumulation (or reduction of concentration of Pb in solution) pb after 240 hrs. This shows that the plants have the maximum efficiency of accumulation up to 2^{nd} day of its application. It was found that for 15 mg/L initial solution concentration, maximum biosorption of Pb i.e

uptake capacity and their interplay have been studied. Moreover, there is no report on the effect of Pb on the photosynthetic rate. The effect of Pb toxicity on *Eichhornia crassipes* is a new study in this direction.

Pb present in different pH and solution concentration were determined in the inductively coupled plasma-optical emission spectrometer (ICP-OES, optima 2100 DV, Perkin Elmer). After five days and 10 days of the experiment, the Eichhornia crassipes plants were removed, washed thoroughly and cut into three segments: roots and shoots (petiole and leave). They were then dried at 103-105°C in a hot air oven. The dried samples were digested following the standard method [16] and were analyzed to determine tissue accumulation. The photosynthetic rate of E. crassipes was determined with the help of LI-6400 Portable Photosynthesis system.

71.31 % occurs at neutral pH while 53.45 % and, 64.23 % of Pb were removed at low and medium pH just after two days exposure. After 10^{th} day for 15 mg/L initial solution concentration, the removal rate is only 68.90 %, 69.09 %and 84.54 % at low, medium and neutral pH respectively (fig not shown here), which shows the efficiency of uptake by Eichhornia crassipes get reduced after 2^{nd} day.

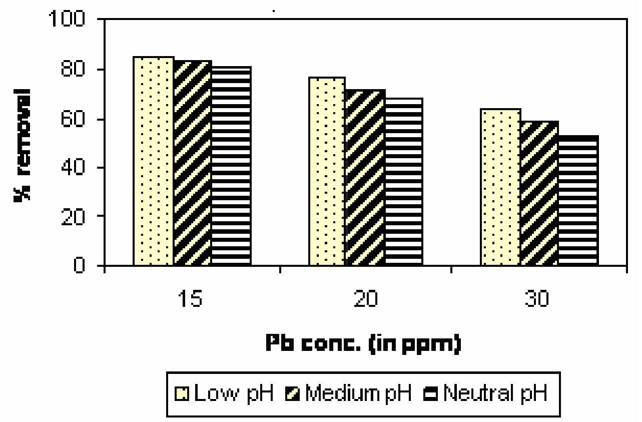

Fig1: Percentage absorption by Eichhornia crassipes at 15.0, 20.0 and 30.0 mg/L solution Pb concentration at 2^{nd} day.

Pb accumulation by the dry biomass of *Eichhornia crassipes* and BCF at different concentrations and at different pH are shown in (Table 1). The absorption of Pb by the root was found to be much higher at all initial concentration and pH. In the present study it was observed that the root absorb a high very amount of Pb as compared to shoot (Table1) at initial concentration 30 mg/l and at low P^H . This trend was noticed for all the concentrations and at different pH. This investigation showed that the efficiency of absorption of Pb by root was found to be quite high as compared to the shoot. The BCF increases with exposure time from 5th day to 10th day (fig2). It was found that BCF values for Eichhornia crassipes treated with Pb gradually decrease with increasing metal concentration in the feed solution. The highest BCF (533) was observed at lowest initial concentration and lowest pH. The experimental results shows that with the increase of initial concentration bioaccumulation of Pb decreases.

Table 1: Table showing Pb accumulation in root and shoot at the end of 5th and 10th day.

Initial Pb conc. (in ppm)	pH	Accumulation (mg/g)dry wt after						
		5th day		10th day				
		Roots	BCF	Petiole	BCF	Leaf	BCF	BCF (Mean)
	Low	7.995	533	0.158	38.42	0.1187	7.912	193.11
15	Medium	5.248	349.8	0.173	11.53	0.171	11.36	124.23
	Neutral	5.282	352.13	0.308	20.55	0.121	8.052	126.91
	Low	9.835	491.5	0.487	24.36	0.195	9.74	172.2
20	Medium	4.62	231	0.673	33.63	0.571	28.53	97.62
	Neutral	4.98	249.15	0.492	24.61	0.251	12.56	95.43
	Low	11.04	368	1.13	37.63	0.097	3.21	136.2
30	Medium	7.365	245.5	0.335	11.18	0.288	9.57	87.53
	Neutral	5.75	165.83	0.489	16.29	0.205	6.82	62.98
Control	Neutral	0.053	-	0.01	-	0.003	-	-

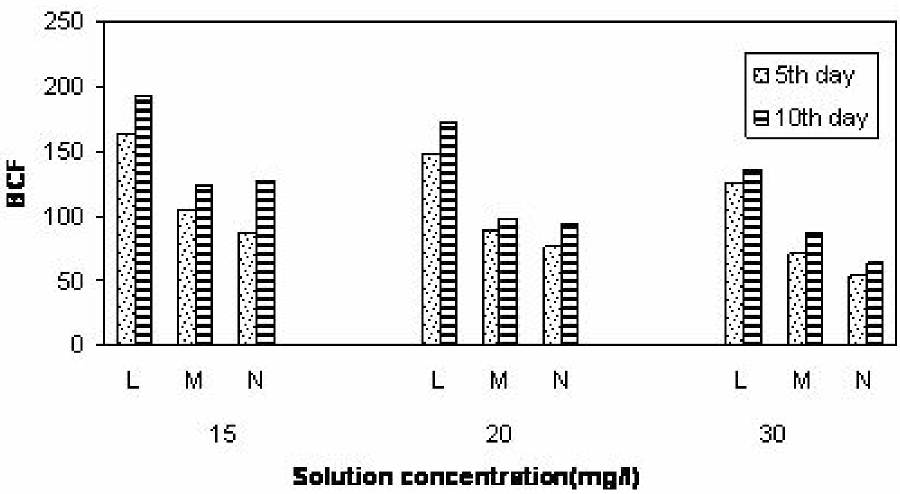

Fig 2: Graph showing Bioconcentration Factor for different concentration and pH after 5th and 10th days of exposure; L- low pH, M-medium pH, N- neutral pH.

3.3 Chlorophyll Content and Photosynthetic Rate

Both chlorophyll concentration and photosynthetic rate decreased with time and with lead concentration. Photosynthetic rate, which is a kind of biosynthesis, depends on biochemical content in leaf and environmental condition, such as temperature, water and light condition[17]. The photosynthetic rate was measured in the 2nd, 4th, 6th, 8th and 10th days (fig3). From fig3 it is shown that the photosynthetic rate decreases with time and initial lead concentration in the external solution The total chlorophyll content of Eichhornia crassipes significantly decreased when the exposure time and Pb concentration were increased. The reduction was highest at 30.0 mg/L concentration with only 0.353 mg/g fresh wt. at low pH on 10th day (Fig4). Maximum decrease in chlorophyll content occurred at low pH and highest solution concentration (30.0mgl/L). The higher reduction of chlorophyll content at higher initial conccentration of the solution and low pH is obvious because of higher accumulation of Pb that takes place under these two factors. Chlorophyll content is affected by Pb toxicity which ultimately leads to reduction in photosynthetic rate[18]. High concentration of Pb inhibits chlorophyll synthesis by impaired uptake of other essential ions by plants like Mg and Fe or due to increased chlorophyllase activity[19]. It has been shown that plants exposed to Pb ions showed a decline in the photosynthetic rate as a result of distorted chloroplast , restrained synthesis of chlorophyll, as well as deficiency of CO_2 as a result of stomatal closing [20].

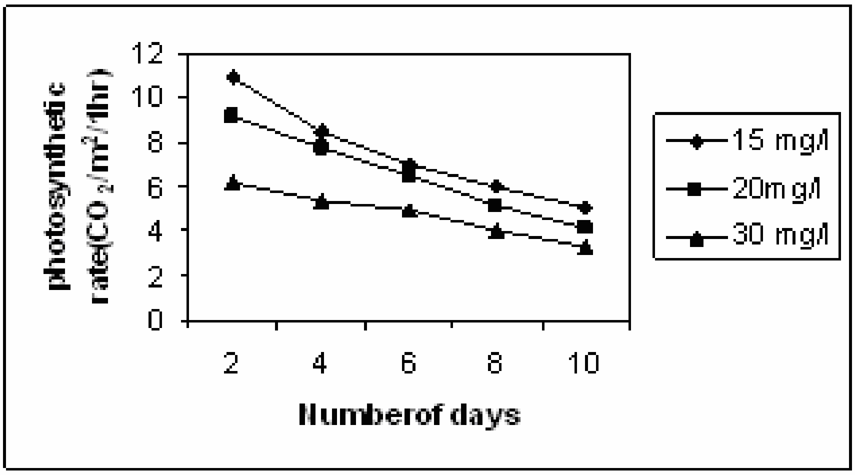

Fig3: Photosynthetic rate in E. crassipes at different initial concentration and days of exposure.

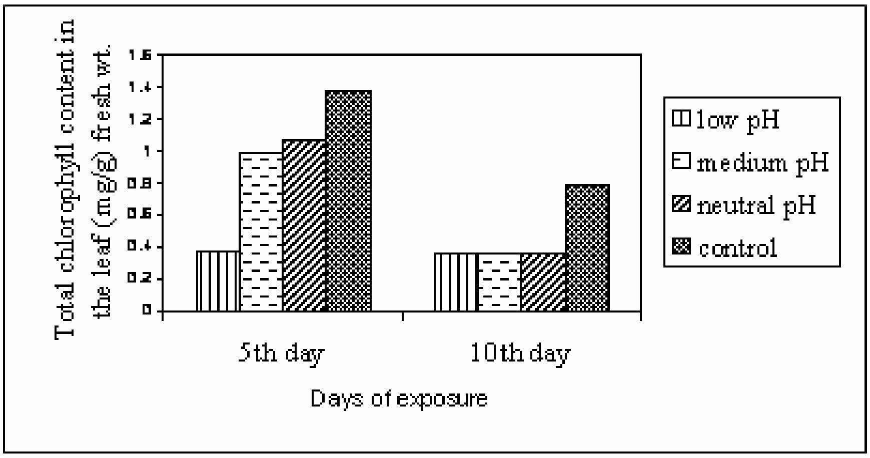

Fig4: Graphical representation of total chlorophyll content per plant of the different treatments at neutral pH at 30.0 mg/L as observed after 5th and 10th day of exposure

3.4 Effect on P^H

It was interesting to note that there was fluctuation of pH in solution of Pb after application of Eichhornia crassipes. Both low and medium pH of the solution shifted slightly towards neutral pH with increase in the number of days. It was also found that there was slight shift in the neutral pH towards lower side (acidic) at the end of the experiment (fig5). This change in pH may be due to release of some root exudates in response to the stress so as to adapt itself to the existing environment. Thus, the results of present study show that the plant Eichhornia crassipes does have the pH neutralizing capacity.

4. Conclusion

The present study shows the Eichhornia crassipes have the maximum efficiency of accumulation up to 2nd day of its application for all initial concentration and pH. After 2nd day the rate of Uptake was slowed down and in some cases increment was only 3-4%. The accumulation of Pb in Eichhornia crassipes does not follow any specific trend with respect to pH. The roots of Eichhornia crassipes have the maximum efficiency of absorption of Pb as compared to shoots and it was found to be 90% or more after 5th day and10th day of exposure for various initial concentration and pH. Chlorophyll content is affected by Pb toxicity. Eichhornia crassipes (E. crassipes Solms.) can be used as low cost treatment material for the removal of Pb.

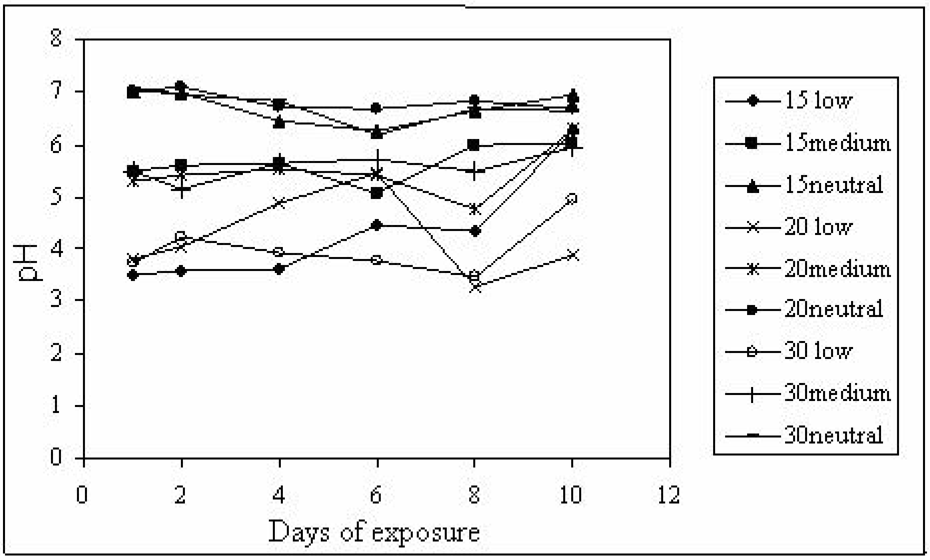

Fig 5: Graph showing fluctuation in the original pH during different days of exposure.

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