PHYTOSORPTION POTENTIAL OF EICHHORNIA CRASSIPES AND PISTIA STRATIOTES FOR HEAVY METALS - COPPER, CADMIUM AND ZINC

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ABSTRACT

Environmental pollution affects the quality of pedosphere, hydrosphere, atmosphere, lithosphere and biosphere. Great efforts have been made in the last two decades to reduce pollution sources and remedy the polluted soil and water resources. Phytoremediation, being more cost-effective and fewer side effects than physical and chemical approaches, has gained increasing popularity in both academic and practical circles. Heavy metals contaminated both soil and water. It is one of the most serious environmental concerns. Number of plant species has been identified in the uptake of heavy metals. Hydrophytes showed great potential for the phytoremediation of water contaminated with heavy metals. Several researchers reported that the heavy metals are taken up by plant roots and trans-located to the shoots and other plant tissues, where they are concentrated. The objective of the present investigation is to examine the phytosorption capabilities of two aquatic plant species, E. crassipes and P. stratiotes by using three heavy metals (Copper, Cadmium and Zinc) at different concentrations based on their tolerance capacity with a view to suggest their use in the remediation of heavy metal pollution in aquatic systems.

Keywords: Phytosorption, Hydrophytes, Heavy Metals, Influencing Factors.

I. INTRODUCTION

One of the most serious environmental concerns is the widespread contamination of soil and water with heavy metals. Although a small portion of heavy metals in soils is derived from natural processes, a much higher amount originates from anthropogenic sources such as mining and smelting industry, use of mineral fertilizers, pesticides and sewage sludge application. Plants producing a high amount of biomass in a short time and accumulating heavy metals in their aerial parts are ideal candidates for phyto-remediation. Therefore tree species, besides supplying an important biomass, are promising plant materials to be used as phyto-remediators because little dispersal from the accumulated heavy metal is likely to occur from wood.

Csog et al. (2011) reported that the degradation of metals is not so easy and the clean-up usually requires their removal. Physicochemical approaches have been widely used for remedying polluted soil and water, especially at a small scale. However, they experience more difficulties for a large scale of remediation because of high costs and side effects. The use of plant species for cleaning polluted soils and waters named as phyto-remediation has gained increasing attention since last decade, as an emerging cheaper technology. Many studies have been conducted in this field in the last two decades. Numerous plant species have been identified and tested for their traits in the uptake and accumulation of different heavy metals. Mechanisms of metal uptake by whole plant and cellular levels have been investigated. Aquatic macrophytes have great potential for the phyto-remediation of water contaminated with heavy metals. Their characteristics to accumulate metals make them interesting research objects for testing and modeling ecological theories on evolution and plant succession, as well as on nutrient and metal cycling. They are easy to culture in laboratory and are thus a convenient plant material for eco-toxicological investigations. Elevated metal concentrations induce several defense strategies in plants.

The objective of the present investigation is to examine the phytosorption capabilities of two aquatic plant species, *E. crassipes* and *P. stratiotes* by using three heavy metals (Copper, Cadmium and Zinc) at different concentrations based on their tolerance capacity with a view to suggest their use in the remediation of heavy metal pollution in aquatic systems.

II. MATERIALS AND METHODS

Materials

The plant species used for the study included *Eichhornia crassipes* and *Pistia stratiotes,* both are aquatic weeds. They were collected from Coringa River (Atreya Godavari) near Tallarevu, East Godavari District and Andhra Pradesh for the study.

Reagents used

Magnesium Sulphide Reagent: Dissolved 10 gms of magnesium sulfate in 100 ml of distilled water placed in a conical flask. The conical flask was placed on a shaker or stirrer for proper mixing of magnesium sulfate in the water.

Precipitate Reagent: It is the reagent which is used for the formation of the precipitation. It is used in the sorption of the metals. Ten grams of magnesium sulphide was added to 100ml of distilled water placed in a conical flask. The sorption of metals was calculated based on the precipitate formed.

Copper sulphate solution: Dissolved 1gm of copper sulphate in 100 ml of distilled water placed in a conical flask. This solution was used for the formation of the precipitation in the phytosorption of heavy metals by using the aquatic plants *E. crassipes* and *P. stratiotes*.

Experimental set up

Tubs of 20 liters capacity were used for the study. In each tub, 5 liters of distilled water was poured. Three heavy metals were selected to evaluate the sorption rate by *E. crassipes* and *P. stratiotes*. Copper sorption at 0.50%, 0.20%, 0.05%, 0.02% and 0.01% by *E. crassipes* and *P. stratiotes;* Zinc at 0.50%, 0.20%, 0.05% and 0.02% and Cadmium at 0.50% and 0.20% by *E. crassipes* was evaluated. These concentrations of heavy metals were added to the tubs separately in which distilled water was poured. Then, the selected plant species after washing with distilled water to remove any dirt and mud was placed in the tubs and kept daily under sunlight for a minimum of six hours for the survival of the plants. After placing the plants, the sorption rate of these heavy metals at different concentrations was recorded each day for 8 days. For this, a sample of 20 ml was taken from the tub and injected into a test tube using measuring cylinder. Then, 10 ml each of the precipitate reagent solution and copper sulphate was added to the test tube, and left for an hour for the formation of precipitate at the bottom. The same test was done for each chosen concentration for each heavy metal. The precipitate was collected from the test tube, dried in a hot air oven and weighted in an electronic balance (W_f). The same procedure was done with the standard metal (1 mg/1ml) solution to get the initial weight of the metal (W_i). The percent sorption was calculated as (W_i-Wf) x 100/W_i, where W_i is initial weight of the metal before phytosorption and W_f is final weight of the metal after phytosorption.

III. RESULTS

The results indicated that *E. crassipes* survived at 0.01% concentration of copper, 0.05% and 0.02% concentration of zinc and 0.50% and 0.20% concentration of cadmium. *P. stratiotes* survived at 0.01% concentration of copper because they were resistant as leaves were normal without any changes. These two species perished at 0.50%, 0.20%, 0.05% and 0.02% concentration of copper because they were very sensitive due to which the leaves became wrinkled and dry subsequently. *E. crassipes* perished at 0.50% and 0.20% concentration of zinc while *P. stratiotes* perished in all tested concentrations of zinc and cadmium on the first day itself (Table 1).

E. crassipes and *P. stratiotes* showed gradual increase in sorption of copper at 0.01% concentration from day 1 to day 8. In case of *E. crassipes*, sorption percent increased from 15% on day 1 to 65% on day 8 while in case of *P. stratiotes*, it increased from 15% on day 1 to 58% on day 8 (Table 2). *E. crassipes* showed a gradual increase in sorption rate at both concentrations (0.5% and 0.2%) of cadmium from day 1 to day 8. The sorption percent was 18% on day 1 and 88% on day 8 at 0.5% concentration of cadmium; 15% on day 1 and 92% on day 8 at 0.2% concentration of cadmium (Table 3). Similarly, *E. crassipes* showed a gradual increase from day 1 to day 8 in sorption rate at 0.05% and 0.02% concentration of zinc. The sorption percent was 14% on day 1 at both concentrations of zinc but it was 76% on day 8 at 0.05% concentration and 78% on day 8 at 0.02% concentration (Table 4).

Table 1. The survival of selected aquatic plants at different concentrations of metal ions

Metal	Concentration (%)	Survival	Plant species
COPPER	0.50	Perished	*E. crassipes, P. stratiotes*
	0.20	Perished	*E. crassipes, P. stratiotes*
	0.05	Perished	*E. crassipes, P. stratiotes*

	0.02	Perished	*E. crassipes*, *P. stratiotes*
	0.01	Survived	*E. crassipes*, *P. stratiotes*
ZINC	0.50	Perished	*E. crassipes*, *P. stratiotes*
	0.20	Perished	*E. crassipes*, *P. stratiotes*
	0.05	Survived	*E. crassipes* (survived), *P. stratiotes* (perished)
	0.02	Survived	*E. crassipes*, *P. stratiotes* (perished)
CADMIUM	0.50	Survived	*E. crassipes* (survived), *P. stratiotes* (perished)
	0.20	Survived	*E. crassipes* (survived), *P. stratiotes* (perished)

Perished on the 1st day itself

Table 2. The percent sorption shown by *E. crassipes* for Copper at 0.01% concentration

Days	Percent sorption by *E. crassipes*	Percent sorption By *P. stratiotes*
1	15	15
2	28	28
3	35	36
4	42	42
5	50	50
6	58	53
7	60	53
8	65	58

Table 3. Percent sorption shown by *E. crassipes* for Cadmium at 0.5 and 0.2% concentration

Days	Percent sorption at 0.5% concentration	Percent sorption at 0.2% concentration
1	18	15
2	28	28
3	35	39
4	42	48
5	59	60
6	68	72

7	76	86
8	88	92

Table 4. Percent sorption shown by *E. crassipes* for Zinc at 0.05% and 0.02% concentration

Days	Percent sorption at 0.05% concentration	Percent sorption at 0.02% concentration
1	14	14
2	24	24
3	35	35
4	42	42
5	50	50
6	58	58
7	67	67
8	76	78

IV. DISCUSSION

Heavy metals are the most serious pollutants due to their toxicity, persistence and bioaccumulation behavior (Jamila and Fernandez 1995; MacFarlane and Burchett 2000). Contamination of aquatic environment by the heavy metals is a serious environmental problem, which threatens aquatic ecosystems, agriculture and human health (Sasmaz et al. 2008). The presence of heavy metals varies from site to site depending upon the source of individual pollutant. Excessive uptake of metals by plants may produce toxicity in human nutrition and cause acute and chronic diseases. High concentrations of heavy metals in soil can negatively affect crop growth, as these metals interfere with metabolic functions in plants, including physiological and biochemical processes, inhibition of photosynthesis, and respiration and degeneration of main cell organelles, even leading to death of plants (Garbisu and Alkorta 2001; Schmidt 2003; Schwartz et al. 2003). However, the ability to accumulate heavy metals varies significantly between species and there are different categories of phytoremediation, including phytoextraction, phytofiltration, phytostabilization, phytovolatization and phytodegradation, depending on the mechanisms of remediation. Phytoextraction involves the use of plants to remove contaminants from soil. The metal ions accumulated in the aerial parts can be removed to dispose or burnt to recover metals. Phytofiltration involves the plant roots or seedling for the removal of metals from aqueous wastes. In phytostabilization, the plant roots absorb the pollutants from the soil and keep them in the rhizosphere, rendering them harmless by preventing them from leaching. Phytovolatization involves the use of plants to volatilize pollutants from their foliage. Phytodegradation involves the use of plants and associated microorganisms to degrade organic pollutants. Some plants may have one function whereas others can involve two or more functions of phytoremediation (Garbisu and Alkorta 2001). The hyper-accumulation of metals in various plant species has been investigated and. It becomes clear that different mechanisms of metal accumulation, exclusion and compartmentation exist in various plant species (Frey et al. 2000). The ability of plant species which are resistant to heavy metals, or can accumulate great amounts of them would certainly facilitate reclamation of contaminated areas (Bizly et al 2000; Lasat 2002). It is in this context, the present study on the efficiency of *Eichhornia crassipes* and *P. stratiotes* for the sorption of certain heavy metals assumes importance.

In the present study, two aquatic plant species which are widespread weeds, *E. crassipes* and *P. stratiotes* have been used to evaluate their efficiency for the sorption of heavy metals, copper, zinc and cadmium in a lab set up. The results indicated that *E. crassipes* has the ability to absorb copper at 0.01% concentration, zinc at 0.05 and 0.02% concentration and cadmium at 0.50% and 0.20% concentration. This species continued to show an increase in sorption percentage of these heavy metals at these concentrations during the observation period that lasted for 8 consecutive days suggesting that the plant is healthy and survives well at these concentrations of heavy metals. The study also shows that the concentration of copper more than 0.01% and of zinc more than 0.05% are toxic to this species and in effect the plant dies without any initial survival. At these concentrations, the leaves wrinkle and become dry due to which all metabolic activities would be affected. Therefore, *E. crassipes* can be suggested as efficient in the sorption of heavy metals tested at the concentrations where it showed continued survival and hence is a potential candidate for treating aquatic systems polluted with heavy metals that come from industrial effluent waters. In case of *P. stratiotes*, the results showed that the plant is highly sensitive to heavy metals tested and it is capable of survival only at 0.01% concentration of copper and not at other concentrations of copper and also at the tested concentrations of zinc and cadmium. Of the two species studied, *E. crassipes* is the ideal species for the treatment of polluted aquatic systems. The additional advantage of this plant is that it has a well-developed fibrous root system and large biomass due to which it is capable of assimilating heavy metals and clean-up the aquatic bodies contaminated with heavy metals (Dos Santos and Lenzi 2000). Other workers have also reported that *E. crassipes* absorbs and translocates cadmium, lead, copper, zinc, and nickel (Zhu et al. 1999; Liao Wei-Shao et al. 2004; Zayed et al. 1998; Zaranyika and Ndapwadza 1995; Low et al. 1994). The ability of plants for the accumulation of heavy metals is an indication that such plants have the genetic potential to clean-up contaminated soil (Baumann et al. 1885). Therefore, *E. crassipes* as a candidate species for phytoremediation of heavy metals is effective and eco-friendly for the remediation of metal-contaminated waters (Chaney 1983; Baker et al. 1991; Baker et al. 1995; Keller et al. 2003).

V. CONCLUSIONS

The aquatic weeds, *E. crassipes* and *P. stratiotes* evaluated for their efficiency in the sorption of heavy metals, copper, zinc and cadmium in a lab set up showed that *E. crassipes* is efficient in the sorption of heavy metals tested at the concentrations where it showed continued survival and hence is a potential candidate for treating aquatic systems polluted with heavy metals that come from industrial effluent waters. In case of *P. stratiotes*, the results showed that the plant is highly sensitive to heavy metals tested except at one concentration in case of copper. *E. crassipes* with its well-developed fibrous root system and large biomass is capable of assimilating heavy metals as well as other pollutants to the extent possible and hence is a potential species for the clean-up of the aquatic bodies contaminated with heavy metals. Since *E. crassipes* is an obnoxious weed and a great menace in water bodies, it can be effective utilized for the remediation of heavy metals from water bodies and at the same time the plant can be removed and extracted heavy metals for subsequent use.

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