



Accumulation of Heavy Metal Ions by *Eichhornia Crassipes* from Battery Industry Effluent under the Influence of Cattle Manure

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ABSTRACT

Phytoremediation, an emerging technology which uses plants to remove contaminants of concern (COC) such as organic and inorganic compounds especially heavy metals (HM). The present study focuses on assessing the toxicity of heavy metals available in effluents discharged from industries and the accumulation ability of an aquatic plant, *Eichhornia crassipes* (water hyacinth). Phytoremediation potential of *E. Crassipes* and HM interaction between soil and water were evaluated in the present study under the presence of cow dung manure as an enhancer. Heterogeneous accumulation of metal ions were found in the plant. Heavy metal concentration in plant parts were varied for roots and shoots. The concentration of HM ions in the plant parts were varied from root to shoot. Value of translocation factor (TF) was found to be in the region 0.5 – 0.8, with Fe has low (0.51) and Pb has high (0.77), bioconcentration factor (BCF) were in the order of $Ar > Ca > Zn > Fe > Pb$ at both roots and shoots. Transposition factor (TrF) of all HM ions were >1.5 except for Zn (1.21). *E. Crassipes* was found to accumulate a large amount of HM ions and could be used for efficient treatment of contaminated water.

Keywords

heavy metal; *Eichhornia crassipes*; battery effluent; transposition factor; Coimbatore

Academic Discipline And Sub-Disciplines

Environmental; waste water treatment; phytoremediation;

SUBJECT CLASSIFICATION

Remediation of heavy metals ion in effluent using plants

TYPE (METHOD/APPROACH)

Experimentation and analysis

INTRODUCTION

Heavy metal contamination from industrial discharges as effluent and sludge to environment is a key risk for human beings as it enters into food chains and causes a serious threat to living beings [1]. Essential heavy metals i.e., calcium, magnesium, zinc, cobalt, potassium etc. which are found to be toxic at excess level whereas non-essential elements i.e., chromium, lead, arsenic, cadmium etc. were toxic even at low concentrations [2]. Remediation and removal are the two important strategies used in the treatment of contaminants. Eliminating and remediating heavy metals from the environment is the toughest challenge faced by the researchers since the start of 21st century. Increasing ecological and health problems from conventional methods, it is important to turn out for effective and affordable method for the treatment of heavy metal pollution in environment [3]. In order to treat these pollutions, technologies such as precipitation, filtration, coagulation, adsorption, ion exchange and electrocoagulation have been developed and found to be expensive and produces sludge as waste product which affects the environment [4, 5]. In other hand phytoremediation is found to be more success with both economic and environmental wise. Phytoremediation is a method of using plant to uptake contaminants from water and soil [6-8]. Since it is more of biotechnology approach and low operational cost, it received a tremendous attention in recent years. Studies show that the ability of aquatic plant to remediate environment from heavy metal pollution at both living and dead conditions were higher than terrestrial plants [9, 10]. Plants which are seen in streams, coastal zones, drainage and everglades had high ability to remove heavy metal. Various species of aquatic plants such as *Myriophyllum spicatum*, *Potamogeton lucens*, *Salvinia herzogii*, *Cabomba* sp., *Ceratophyllum demersum*, *Lemna minor*, *Lemna gibba*, *Lemna aequinoctialis*, *Spirodela polyrhiza*, *Azolla filiculoides*, *Azolla caroliniana*, *Azolla pinnata* and *Pistia stratiotes* have been used in phytoremediation process [10, 11].

E. Crassipes, (water hyacinth) a free floating aquatic plant from Pontederiaceae family, which is very common in India and available largely in the lakes, irrigation ponds and drainage systems. Due to high growth rate and transpiration rate it is



considered as harmful plant [12, 13]. It has been studied on the removal of heavy metal ions presents in water and found to have the potential to accumulate large metal ions in its root [14]. Because of its high biomass, tolerance and heavy metal uptake capacity it could be used in the water treatment process. This study was conducted to determine the heavy metal concentration in plant parts (root and soil), soil, effluent and the detailed investigation on heavy metal removal by means of translocation, bioconcentration and transposition factor.

MATERIALS AND METHODS

Experimental set-up

Aquatic plant, Water hyacinth (*E. Crassipes*) was collected from the Singanallur Lake, (10°59'20.59"N 77°1'21.88"E) located in Coimbatore, Tamil Nadu, India which is available nearest to the experimental site. Collected plants were washed thoroughly with de-ionized water and transplanted to a plastic container which contains Hoagland solution to enrich the nutrient condition to the plant. Each three days Hoagland solution in the container were replaced with the new solution for 30days. Since *E. Crassipes* populates through the interconnected shoot parts, newly grown plants were collected and used for the removal of heavy metal ions from battery industry effluent.

Newly collected plants were placed in experimental container in presence of effluent and uncontaminated red soil which is found to improve plant growth. At initial condition, the ratio of effluent and soil in the experimental container was kept 1:1. Sample solutions were collected at an interval of 5 days' over a period of 25 days for the determination of metal concentrations in the container. Cow dung manure (CDM) was added to the experimental container during the interval period. Loss of effluent was observed due to plant uptake and evaporation. These obstacles were ignored in the experiment to maintain the condition of the setup. All the experimental sets were maintained in triplicate.

Heavy metal analysis in plants

Plants were harvested at an interval of 5 days after the exposure with effluent. Harvested plants were washed twice with tap water and by de-ionized water. After thorough wash, these plants were separated into roots and shoots. Separated plant parts were dried in an oven at 80 °C for 90 minutes to remove all the moisture content in plants. Dried samples were grounded to powder and digested with Con. HNO₃ and Con.HClO₄ in the ratio of 2:1. It is then diluted with 100 ml de-ionized water. The diluted solution was analyzed for heavy metals concentration with atomic absorption spectrophotometry (AAS, PerkinElmer) [15]. Initial heavy metal concentrations in effluent were analyzed and mentioned in the table 1.

Table 1. Initial heavy metal concentration in effluent

S. No	Heavy Metal	Concentration (ppm)
1.	Arsenic (Ar)	33.52
2.	Lead (Pb)	25.279
3.	Calcium (Ca)	26.562
4.	Iron (Fe)	177.333
5.	Zinc (Zn)	41.964

Parameters analyzed

Factors such as translocation (TF) and bioconcentration factor (BCF) in phytoremediation process were calculated. Apart from that contaminants settled into the soil from effluent were mentioned as transposition factor (TrF). It is a newly formed factor which enables us to get into the insight of heavy metal contaminants settled in soil.

Translocation Factor (TF)

It is common to understand that the plant translocates heavy metal ions into shoot via root parts of the system. The translocation of contaminants from root to shoot were calculated. In general, plants with >1 TF value is termed as phytoextractor. It is calculated by the given formula [16]:

$$TF = \frac{\text{Concentration in shoot (ppm)}}{\text{Concentration in root (ppm)}}$$

Bioconcentration Factor (BCF)

Concentration of heavy metal ions in plants parts and in effluent were used to calculate bioconcentration factor. When the plants possess a BCF value of >1, then the plant can be called as hyperaccumulator plant. Thus, it is calculated by the following formula [16]:

$$BCF = \frac{\text{Concentration in plant (ppm)}}{\text{Concentration in soil (ppm)}}$$

Transposition Factor (TrF)

Metal concentration in plant were excluded for the calculation of TrF, as it depends upon the contaminants transferred from effluent to soil. It can be calculated as follows:

$$TrF = \frac{\text{Concentration in soil (ppm)}}{\text{Concentration in effluent (ppm)}}$$

Quality Assurance

All the chemicals used in the experiment were analytical grade. pH of the effluent was maintained daily in the range of 6 – 6.5 using 1.0 M HCl and NaOH to yield a better removal of contaminants. Experimental setup and the datas obtained were triplicated to minimize the error for quality control.

RESULTS



Fig. 1. Effect of heavy metal ions on plants root at each interval.

Effect of heavy metal ions on the aquatic plant were indicated in the above figure 1. It explains that, due to toxicity of heavy metals, root parts of the plants were affected at initial stages but recovered after a period. The same phenomena was observed in the accumulation of heavy metal ions by the plant specified in the table 2.

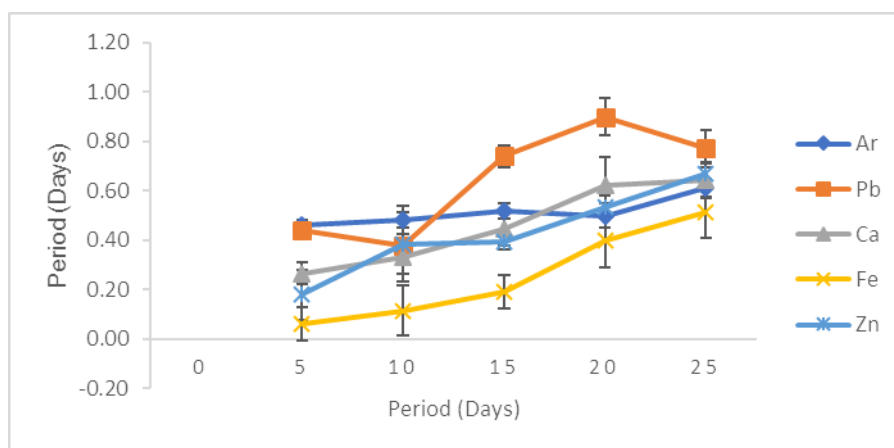


Fig. 2. Translocation factor of plant from root to shoot metal concentration

In general, contaminants accumulated in the shoots transferred through roots. Amount of contaminants translocated to the shoots is called as TF from the above figure 2 it is understood that Pb possess high TF value even though it is found to be decreased at later stages. All other metal ions show a gradual increase of TF value with the accumulation of heavy metal ions. TF of metal ions is ordered as follows Pb > Zn > Ca > Ar > Fe.



Days	Root					Shoot					Soil					Effluent				
	5	10	15	20	25	5	10	15	20	25	5	10	15	20	25	5	10	15	20	25
Ar	0.06 ±0.00	0.41 ±0.01	1.21 ±0.05	4.34 ±0.24	8.35 ±0.20	0.03 ±0.00	0.19 ±0.02	0.61 ±0.07	2.09 ±0.26	4.71 ±0.49	0.39 ±0.03	1.30 ±0.09	8.15 ±0.84	11.5 ±1.25	13.3 ±0.89	33.05 ±0.03	31.62 ±0.13	23.55 ±0.95	15.6 ±1.77	7.16 ±1.55
Pb	0.06 ±0.00	0.24 ±0.01	0.62 ±0.02	1.52 ±0.08	2.64 ±0.06	0.03 ±0.00	0.09 ±0.01	0.44 ±0.05	1.29 ±0.16	1.94 ±0.20	0.44 ±0.03	1.84 ±0.14	7.42 ±0.76	11.27 ±1.23	13.43 ±0.90	24.81 ±0.04	23.65 ±0.16	16.07 ±0.84	10.98 ±1.48	7.41 ±1.15
Ca	0.536 ±0.02	1.492 ±0.17	2.995 ±0.28	4.246 ±0.27	5.568 ±0.13	0.145 ±0.01	0.486 ±0.05	1.296 ±0.26	2.617 ±0.54	3.42 ±0.62	1.33 ±0.06	3.88 ±0.1	7.47 ±0.31	10.16 ±0.57	11.72 ±0.28	24.55 ±0.10	20.7 ±0.36	14.8 ±0.84	9.53 ±1.36	5.85 ±0.99
Fe	4.7 ±0.51	7.89 ±0.65	12.56 ±0.62	20.46 ±2.20	26.91 ±3.80	0.29 ±0.03	0.93 ±0.07	2.42 ±0.21	8.14 ±1.05	13.32 ±2.16	13.02 ±0.61	27.17 ±1.03	44.29 ±1.79	74.78 ±1.85	85.79 ±1.12	159.72 ±1.02	141.7 ±1.55	118.4 ±2.50	74.35 ±7.4	51.71 ±7.95
Zn	1.27 ±0.05	2.73 ±0.10	5.71 ±0.13	7.92 ±0.44	7.88 ±0.19	0.22 ±0.05	1.03 ±0.26	2.19 ±0.25	4.08 ±0.52	4.87 ±0.51	1.96 ±0.09	3.85 ±0.15	8.15 ±0.33	14.25 ±0.79	16.16 ±0.39	38.51 ±0.19	34.35 ±0.47	25.92 ±0.79	15.71 ±1.75	13.05 ±1.09

Table 2. Heavy metal concentration in plant (root and shoot), soil and effluent for the experimental period.
(Ar = Arsenic; Pb = Lead; Ca = Calcium; Fe = Iron; Zn = Zinc)

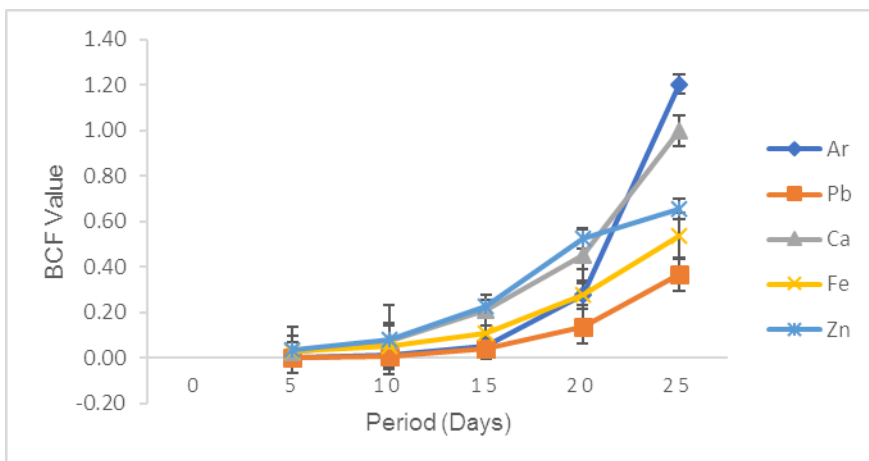


Fig. 3. BCF value of root from effluent to shoot metal concentration

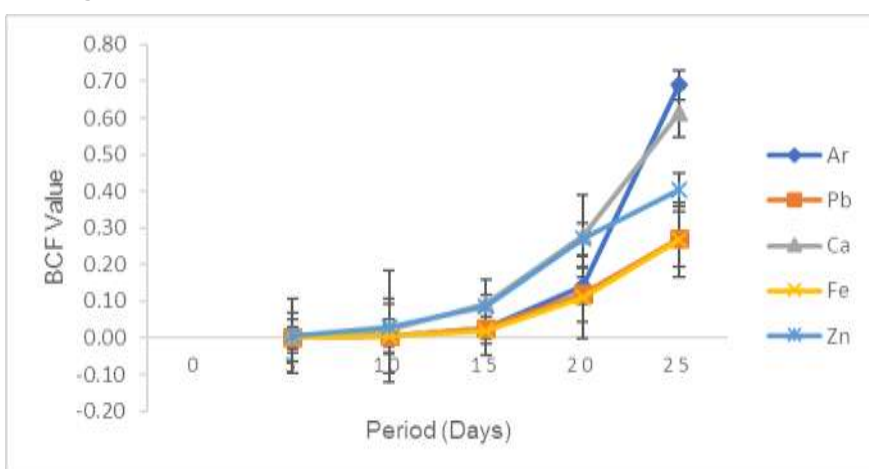


Fig. 4. BCF value of shoot from effluent to shoot metal concentration

BCF value of root and shoot were illustrated in the Fig. 3. and 4. In both cases Ar was found to have high BCF value with 1.21 and 0.69 for root and shoot respectively. Both the figure forms similar sketch only a small deviation between Fe and Pb. It also expresses that root parts of the plant translocates a small amount of HM ions from its accumulation. BCF value of HM's in root and shoot for heavy metal ions is ordered as follows: Ar > Ca > Zn > Fe > Pb.

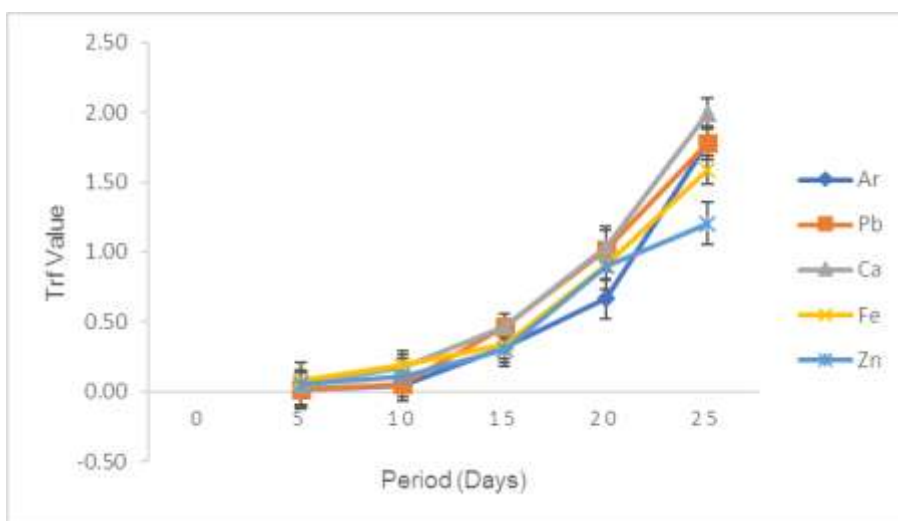


Fig. 5. Transposition factor of heavy metal ions from soil to effluent

It is commonly known that in any medium transferred from higher to lower concentration level and it is understood that heavy metal ions in the contaminated medium might transferred to uncontaminated medium. The contaminants in effluent transferred to soil is calculated by the newly framed factor, known as transposition factor (TrF). Fig. 5. obtains >1 value for



all the metal ions. It indicates that the metal ions were continuously settled into soil and the Fig. 5. indicates a gradual increase of TrF after the 10th day of experimental period.

DISCUSSIONS

Root pressure and leaf transpiration are the two-important process controls the translocation of metal ions from root to shoot [16, 17]. Due to physiological resistances, plants might not be able to accumulate large amount of metal ions [18]. In the present study, metal ions such as Ar, Pb, Ca, Fe and Zn concentration in root were 1.5 times more than shoot. Similar results were obtained for *E. Crassipes* with 3 to 15 time more concentration in roots [13, 18]. Due to industrial effluent, accumulation of various metal ions and external disturbance might affect the accumulation capacity of the plant [10, 12, 19].

Many researchers have mentioned that the higher concentration of metal ions were accumulated in root than in shoots [18]. Also it is found out that non-essential metal ions had higher TF value than the essential metal ions [20]. And the same has been obtained for the study with non-essential elements (Ar and Pb) had higher TF value than Ca, Fe and Zn. Even though the TF value were <1 for metal ions, plant possess >0.5 value for all metal ions and acts as a hyperaccumulator. Although the concentration of Fe ions was higher at initial but had low TF value than other metals. Due to the less availability and low concentration of metal ions such as Pb, Ca, Ar and Zn were distributed into shoot parts over a large biomass. Zn and Ca were found to be more portable but the presence of non-essential metal ions resist their nature. Metal ions were usually accumulated highly in fibrous root plant and the accumulation was justified by *E. Crassipes* after the experimental period [14].

Attraction of aquatic plants towards heavy metal ions were expressed by the bioconcentration factor (BCF), the ratio between plant-metal concentration [21]. Presence of metal ions in effluent and as tailings influences the accumulation ability of the aquatic plant [16]. It is commonly known that metal ion in effluent and BCF value were inverse to each other. Good accumulator plants were documented by two conditions (a) ability to uptake more metal ions in it than in effluent and (b) ability to bioconcentrate the metal ions in its tissues [11]. Various studies by researchers stated that the BCF value of root is always higher than that of shoot [7]. The result obtained from the experiment also justifies with the previous studies [22]. BCF values of root and shoot were high in Ca followed by Zn and Fe, whereas the value of non-essential element Ar was the highest and Pb at the least [23]. The sudden increase in BCF value at later stages indicates that the reduction of contaminant in effluent. It can be understood from the TF and BCF Fig. 2, 3, 4.

Researchers also suggest that the aquatic plant *E. Crassipes* had the ability to remove metal ions from fresh water under low concentrations [23]. But the experiment was not conducted on synthetic effluent and the result obtained by various researchers were not obtained. It indicated that the BCF value increases at low concentration and vice versa. In present study Ar and Ca had high BCF value in roots and shoots than Zn followed by Fe and Pb. Maximum BCF values for Ar, Pb, Ca, Fe and Zn in *E. Crassipes* roots were 1.21, 0.37, 1.00, 0.54 and 0.65 respectively; while their maximum BCF values in shoots were 0.69, 0.27, 0.61, 0.27 and 0.40 respectively. In this experiment, aquatic plant had the ability to concentrate various metal ions to its tissues and acts as very good accumulator [23-26].

Since TrF is a newly formulated one, it is must to understand the relation between contaminated and uncontaminated medium. TrF has a direct effect of metal ions in the contaminated medium and the metal ions accumulated by the plant. It is due to competitive nature of heavy metal ions ready to enter into plants system [27-29]. As most of the metal ions are already accumulated by the plant and the TrF value only increases for a specific period. In general, plant accumulates nutrients in soil through root [30-32]. It is understood that contact of plants root parts and soil was an important factor in the phytoremediation process. Based on the TF, BCF and TrF values of five metal ions from battery industrial effluent, *E. Crassipes* could be used as a phytoremediator.

CONCLUSIONS

The present study demonstrated that *E. Crassipes* was a very good accumulator for various elements and can be applicable to treat wastewater from different sources. It is found to be capable of uptake a large amount of HM ions under CDM. Moderate TF and BCF values indicates that the plants were potential phytoextractor. Accumulated HM ions were translocated into shoots but the HM toxicities were balanced in both root and shoots. As TrF value increases at later stage indirectly enhances the BCF value. It is understood that the aquatic plants uptake HM ions more from soil than the water and thus prevents BCF value of HM ions at initial stage. Since *E. Crassipes* can be used for biogas production, provides a positive result for phytoremedial treatment and CDM is an organic substance, it can be utilized in future for its accumulative capacity of contaminants in water and soils.

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