PHYTOREMEDIATION OF METALS (LEAD, COPPER, ZINC, CADMIUM & CHROMIUM) USING AQUATIC MACROPHYTE, WATER HYACINTH (*EICHHORNIA CRASSIPES*)

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Abstract

The phytoremediation potential of water hyacinth (*Eichhornia crassipes*) was investigated for several metals. The plants were cultivated for a period of 50 days in phytoremediation tanks containing solutions with concentrations of 10, 20, and 30 ppm for each of the following metals: Lead (Pb), Copper (Cu), Zinc (Zn), Cadmium (Cd), and Chromium (Cr). The percentage removal of these metals by the plants was determined using atomic absorption spectroscopy (AAS), and standard deviations were calculated using Microsoft Excel, 2016. The results indicated that the order of metal removal by *Eichhornia crassipes* (*E. crassipes*) was Cu > Zn > Pb > Cd > Cr. The efficiency of phytoremediation with *Eichhornia crassipes* depended on factors such as contact time, metal concentration, and the specific type of metal. These findings suggest that E. crassipes is an effective accumulator plant for the phytoremediation of these heavy metals.

Keywords: Phytoremediation, Heavy metals, Water hyacinth (*Eichhornia crassipes*)
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Introduction

All life forms on Earth depend on water for their existence in ecosystems, and water is the second most crucial element required by humans for survival. With increasing urbanization, industrialization, and population growth, the demand for water resources is expanding daily, leading to serious pollution of the aquatic environment (Isiuku & Enyoh, 2019). Pollution in the aquatic environment, characterized by high levels of heavy metals and exceeding water parameter limits, has become a major concern, particularly in countries like India, where the cost of remediation is often prohibitively high. HMs are apportioned into two categories viz. essential and in-essential. Metals (Co, Cu, Cr, Fe, Mg, Mn, Mo, Ni, Se, and Zn) have been recognized as essential elements for various physiological and biochemical activities. Other metals (Al, Sb, Ba, Cd, Au, In, Pb, Hg, Pt, Ag, Sr, Sn, Ti, V, and U) are non-essential since they have no known biological roles and are extremely lethal to living organisms. To avert the environmental effects caused by heavy metals and other pollutants, various conventional techniques, including reverse osmosis, ion exchange, chemical precipitation, electrochemical treatment, adsorption, electrodialysis, and advanced oxidation processes, have been reported (Volesky 2000 & Singh et, 2012).

Researchers are incessantly working to develop more advanced, efficient, and eco-friendly aspects of wastewater treatment, and phytoremediation has emerged as one of the most promising technologies for eliminating hazardous chemical species, including heavy metals, water parameters, and radioactive elements from contaminated water (Vinod *et al*., 2019). Moreover, India possesses a rich diversity of aquatic macrophytes with the potential to hyperaccumulate various water contaminants, offering an alternative method for remediating the aquatic metal burden (Suschismita *et al*., 2014). Phytoremediation relies on the ability of plants to absorb and accumulate metal contaminants in their tissues, effectively removing high amounts of metals and other contaminants from water.

Aquatic plants are well-known for their capacity to accumulate heavy metals and play a crucial role in the food chain as primary producers, oxygen level regulators, and maintainers of homeostasis (Anamika *et al*., 2000). Aquatic macrophytes absorb mineral salts and chemicals either from sediments via the root system, from the aquatic medium through their wide leaf surfaces, or from both sources (Zhou *et al*., 2013). Studies have shown that aquatic macrophytes can accumulate large amounts of nitrogen, phosphorus, and metals in their tissues, making them potentially useful in the remediation of contaminated aquatic ecosystems (Goswami, 2017; Zhou *et al*., 2017). In this regard, various aquatic plant species such as Lemna, *Wolfia, Azolla, Spirodela, Wolfialla, Hydrilla, Eichhornia, Typha, Pistia, Hyrocotyle ranocloide*and *Ceretophyllum demersum* have been tested for their ability to phytoremediate and hyperaccumulate metals, metalloids, and other contaminants (Al-rubaie*et a*l., 2015; Keskinkan*et al*., 2004; Vahdatiraad*et al*., 2012; Pandharipande*et al*., 2016). The metal accumulation ability of aquatic plants has been found to vary with plant species, different plant parts, and the type and concentration of the metal in the growth media (Preetha & Kaladevi, 2014).

E. crassipes, a perennial aquatic plant that freely floats, originates from tropical and sub-tropical South America, but has widely distributed in all tropic climates. Renowned for its remarkable biomass production, robust resistance to contamination, and ability to absorb heavy metals and nutrients, this plant is highly suitable for applications in wastewater treatment (Huynh*et al*., 2021; Jeevanathan*et al*., 2019; Ali*et al*., 2020).

Materials and methods

Plant collection

The experimental plant *E. crassipes* were collected from local pond located at chunkankadai, Kanyakumari District, Tamil Nadu. Separate healthy aquatic plants from the collected plant samples and washed with tab water followed by distilled water to remove periphyton and sediment particles. The selected plants were kept tap water for one week to adapt the new environment.

Experimental setup

For each experiment, twelve plastic tubs were utilized and filled with 20 liters of water, with the water having a pH ranging from 6.13 to 6.37. Stock solutions of 1000 mg/L for each metal, including Cd, Pb, Cu, Zn, and Cr, were prepared using analytical-grade CuSO4·5H2O, CdCl2·2H2O, Pb(NO3)2, ZnSO4·7H2O, and Cr2(SO4)·12H2O, respectively, and were subsequently diluted to the required concentrations. The selected plants were then placed in the water supplemented with Cu (0.35, 0.70 & 1.05 mg/L) for the Cu experiment, Pb (0.16, 0.32 & 0.48 mg/L) for the Pb experiment, Zn (0.44, 0.88 & 1.32 mg/L) for the Zn experiment, Cd (0.27, 0.54 & 0.81 mg/L) for the Cd experiment, and Cr (0.38, 0.76 & 1.52 mg/L) for the Cr experiment. All the tubs were exposed to sunlight. After each experiment, the tested plants were harvested, dried, and used for further heavy metal analysis. The duration of each experiment was 50 days, and this procedure was repeated for all metals.

Metal analysis

For metal analysis, 50 ml of water sample was collected from each tub after 10 days, 20 days, 30 days, 40 days and 50 days of the phytoremediation experiment. Water samples were filtered throughWhatman41 filter paper and preserved at pH < 2.0 by adding concentrated HNO_3 before analyzing the total dissolved metal concentration (Qin *et al*., 2011, Sani *et al*., 2020) using Atomic Absorption Spectroscopy (AAS), with the model name AA-6300.

Removal of efficiency

The removal percentage of metal ions by *E. crassipes* was determined by using the initial metal concentrations if the treatment solution and the final concentrations at the end of the experiment (Barker *et al*., 2013; Mandakini *et al*., 2016).

$$\%R = \frac{(Initialmetalconcentration - Finalmetalconcentration)}{Initialmetalconcentration} \text{ X } 100$$

Statistical analysis

The readings obtained from the experiment were recorded in triplicate and the average results are reported as mean ± standard deviation (SD) using Microsoft Excel, Office 2016.

Results

Metal concentration in water

The concentrations of dissolved metals Pb, Cu, Cd, Cr and Zn, remaining in the residual solution after the phytoremediation experiment were depicted in Tables 1, 3, 5, 7 and 9 while the removal efficiency of each metal by *E. crassipes* was presented in tables 2,4, 6, 8 and 10.

Table 1. Lead uptake by *E. crassipes* at different concentrations and duration.

Initial concentration of Pb (mg/L)	Residual concentration of Pb (mg/L)				
	day 10	day 20	day 30	day 40	Day 50
0.16	0.14+0.004	0.075±0.0015	0.031±0.002	BDL	BDL
0.32	0.25±0.003	0.198±0.003	0.18±0.0031	0.031±0.002	0.001±0.003
0.48	0.36±0.0037	0.27±0.002	0.21±0.002	0.1±0.001	0.01±0.032

BDL- below detection limit

Table 2. Lead removal (%) by *E. crassipes* at different concentrations and duration.

Initial concentration of Pb (mg/L)	Removal (%)				
	Day 10	Day 20	Day 30	Day 40	Day 50
0.16	12.5±2.5	52±0.93	83±1.25	100	100
0.32	21.87±0.93	37±0.9	42.78±0.96	89.68±0.6	96±0.2
0.48	24±0.7	43±0.4	55.8±0.4	78.75±0.4	95±0.03

Table 3. Zinc uptake by *E. crassipes* at different concentrations and duration.

Initial concentration of Zn(mg/L)	Residual concentration of Zn (mg/L)				
	Day 10	Day 20	Day 30	Day 40	Day 50

0.44	0.27±0.0022	0.093±0.001	0.025±0.023	BDL	BDL
0.88	0.61±0.0051	0.374±0.0031	0.011±0.004	BDL	BDL
1.32	0.92±0.005	0.78±0.002	0.64±0.003	0.21±0.001	BDL

Table 4. Zinc removal (%) by *E. crassipes* at different concentrations and duration.

Initial concentration of Zn(mg/L)	Removal (%)				
	Day 10	Day 20	Day 30	Day 40	Day 50
0.44	38±0.5	78±0.2	94±5	100±0	100
0.88	30±0.5	57±0.3	95±0.45	90.9±0.1	100
1.32	30±0.3	40±0.9	51±0.1	84±0.07	100

Table 5. Copper uptake by *E. crassipes* at different concentrations and duration.

Initial concentration of Cu (mg/L)	Residual concentration of Cu (mg/L)				
	day 10	day 20	day 30	day 40	Day 50
0.35	0.12±0.0014	0.03±0.0013	BDL	BDL	BDL
0.7	0.32±0.0021	0.11±0.002	0.073±0.005	BDL	BDL
1.05	0.58±0.0032	0.37±0.004	0.19±0.0017	0.095±0.0018	BDL

Table 6. Copper removal (%) by *E. crassipes* at different concentrations and duration.

Initial concentration of Cu (mg/L)	Removal (%)				
	day 10	day 20	day 30	day 40	Day 50
0.35	65±0.4	91±0.3	100	100	100
0.7	52±1	84±0.2	89±0.7	100	100
1.05	44±3	64±0.3	81±0.6	90±0.17	100

Table 7. Cadmium uptake by *E. crassipes* at different concentrations and duration.

Initial concentration of Cd (mg/L)	Residual concentration of Cd (mg/L)				
	day 10	day 20	day 30	day 40	day 50
0.27	0.10±0.003	0.07±0.0014	0.01±0.001	BDL	BDL
0.54	0.33±0.005	0.15±0.0023	0.071±0.0011	0.024±0.0031	0.001±0.0021
0.81	0.61±0.0037	0.56±0.0022	0.39±0.0041	0.074±0.0018	0.0031±0.0014

Table 8. Cadmium removal (%) by *E. crassipes* at different concentrations and duration.

Initial concentration of Cd (mg/L)	Removal (%)				
	day 10	day 20	day 30	day 40	day 50
0.27	62±1	73±0.5	96±0.2	100	100
0.54	38±0.9	72±0.4	86±0.2	95±2	97±0.1
0.81	24±0.4	30±0.2	51±0.5	90±0.2	91±0.4

Table 9. Chromium uptake by *E. crassipes* at different concentrations and duration.

Initial concentration of Cr	Residual concentration of Cr (mg/L)				
	day 10	day 20	day 30	day 40	day 50

(mg/L)					
0.38	0.21±0.002	0.199±0.0013	0.07±0.003	0.013±0.001	BDL
0.76	0.59±0.0041	0.36±0.0014	0.18±0.0051	0.11±0.002	0.052±0.0023
1.52	1.17±0.0072	0.99±0.002	0.57±0.0032	0.132±0.0015	0.041±0.003

Table 10. Chromium removal (%) by *E. crassipes* at different concentrations and duration.

Initial concentration of Cr (mg/L)	Removal (%)				
	day 10	day20	day 30	day 40	day 50
0.38	44±0.5	47±0.3	81±0.7	96±0.2	100
0.76	22±0.5	52±0.1	76±0.6	85±0.2	95±0.3
1.54	22±0.4	34±0.8	62±0.2	75±0.09	97±0.2

Discussion

The results demonstrate that *E. crassipes* removed (0.35, 0.70 & 1.05) mg/L of Cu, (0.16, 0.32 & 0.48) mg/L of Pb, (0.44, 0.88 & 1.32) mg/L of Zn, (0.27, 0.54 & 0.81) mg/L of Cd, and (0.38, 0.76 & 1.52) mg/L of Cr in the desired amounts from the solution, respectively. The aquatic macrophyte *E. crassipes* exhibits phytoremediation potential for metals such as Cd, Cr, Zn, Pb, and Cu. Previous studies have reported that *E. crassipes* can bioaccumulate some of these metals (Priyanka *et al*., 2017; Huynh *et al*., 2021; Swain *et al*., 2014; Taiwo *et al*., 2015; Okunowo & Ogunkanmi, 2010).

The metal uptake capacity of water hyacinth was highest for Cu and lowest for Cd. (Lio and Cheng, 2004) ranked the heavy metal removal rate based on the ability of *E. crassipes* to remove (Cu > Zn > Ni > Cd) and showed that higher and lower efficiency belonged to Cu and Cd. However, this may be attributed to the concentration of metals and the essential metal factor in the medium. In lower concentrations, the metal removal efficiency was higher, but in higher concentrations, the removal efficiency was lower for all metals (Li *et al*., 2015; Preetha & Kaladevi, 2014; Venkateswarlu *et al*., 2019; Taiwo *et al*., 2015).

The results indicate that *E. crassipes* has the capacity to effectively remove heavy metals such as Pb, Cd, Cr, Cu, and Zn within 50 days of the phytoremediation experiment, reducing their concentrations below the detection limit (BDL) almost all metals. Various exposure durations of aquatic plants to metal concentrations in the culture medium resulted in different metal uptake performances (Lu et al., 2011). This study also proved that *E. crassipes* would remove the metals at various time durations, with the highest removal efficiency observed at 40 days for each metal. Moreover, the contact time increased the metal uptake capacity of the plants, indicating that the removal efficiency is directly proportional to the contact time. The removal of metals progressively increased as the retention time and sampling period increased (Hauwa et al., 2021). Although Cu Cr and Zn are essential metals for plant metabolism, *E. crassipes* also removed heavy metals (Pband Cd) to levels close to WHO standards for permissible limits of heavy metals in water.

Conclusion

The present study concluded that *E. crassipes* can effectively phytoremediate metals such as Cd, Cr, Zn, Pb and Cu, thus; reducing the environmental hazard that could arise from untreated wastewater ecosystem. The phytoremediation efficiency of *E. crassipes*depends on the contact time, metal concentration and type of metal. The possibilities of using E. crassipes to improve the quality of wastewater to an acceptable level, because of its ubiquity, rapid growth rate, ease of harvest, wide range of temperature tolerance and removing various contaminants.

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