

Eichhornia crassipes and *Pistia stratiotes* as Biosorbents for Lead, Copper and Zinc in Wastewater Treatment

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In the world, a large part of the wastewater is not previously treated, resulting in the contamination of water resources. Thus, the present research aimed to evaluate *Eichhornia crassipes* and *Pistia stratiotes* as sorbents in the treatment of Pb, Cu and Zn in wastewater from the community of Cashaucro located in Oyón, Peru at 3600 masl. To evaluate the biosorption of the macrophytes, 6 glass cuvettes were used with concentrations of 750 mg/L of zinc, 25 mg/L of copper and 62.5 mg/L of lead. The treatment was carried out for 15 days and physicochemical parameters such as pH, electrical conductivity, dissolved oxygen and temperature were monitored every week. According to the results obtained, the best removals for copper, lead and zinc were achieved with the macrophyte *Eichhornia crassipes*, with values of 99.86, 99.89 and 29.45%, respectively. On the other hand, values higher than 90% were achieved in the improvement of physicochemical parameters. Finally, the study showed that floating macrophytes are good adsorbents of heavy metals and could be used as an alternative for improving water quality due to their low cost.

1. Introduction

In the world, more than 80% of wastewater is discharged directly into the river or the sea without giving it a previous treatment producing pollution of water resources (WWAP, 2017). This pollution is mainly caused by chemical substances that are dumped by mining industries, and is a debatable issue due to the effects it causes on human health, ecology and the environment (Latorre and Tovar, 2017; Canaza Choque, 2018).

Among the contaminants are heavy metals such as lead, cadmium, mercury and arsenic, among others. These metals, when in contact with living beings, generate disorders and alterations in the chemical reactions of metabolism, which are related to the time of exposure and their concentration. The absorption of lead in the blood affects intelligence quotient (IQ) and academic performance in children and cardiovascular diseases in adults (Osoreo Plenge, 2016). High concentrations of copper sulfate in sheep produce lethal hemolysis (Franco et al., 2016). High Zn intake for prolonged times can cause hypocupremia with anemia, neutropenia and leukopenia (Rubio et al., 2007). To counteract this, there are several technologies such as biological treatment using floating macrophytes. This treatment has received more attention because these species have the capacity to absorb toxic elements in their structure. In this regard, Caviedes Rubio et al. (2016) state that these plants are effective in the remediation of waters that have organic matter and heavy metals. In addition, they mention that *Eichhornia crassipes*, *Pistia stratiotes* and *Lemna minor* have been more researched species in wastewater treatment.

Heavy metal adsorption using natural plants has been studied by several authors, among them, Mwaniki et al. (2019) studied the adsorption of Pb and Zn using water hyacinth in wastewater and aqueous solutions. Similarly, Sarkar et al. (2017) employed water hyacinth powder to remove heavy metals.

Floating macrophytes are used in polluted waters using environmentally friendly technology. Among the floating macrophytes we have water hyacinth, which is highly resistant that can tolerate the toxicity of heavy metals, phenols, formaldehydes, formic acids, acetic acids, and oxalic acids, even in their high concentrations (Sanz et al., 2004). For the uptake of heavy metals and organic matter in phytoremediation systems, aquatic macrophytes such as *Lemna minor* and *Eichhornia crassipes* are very effective because they have the ability of resistance, bioaccumulation, mechanism, invasive and reproductive (Goswami and Das, 2018). The plant

Eichhornia crassipes contains in its roots biosurfactant characterized as a hydroxyl-containing unsaturated fatty acid that can remove petroleum derived contaminants (Selva et al., 2020).

Heavy metals in watersheds disrupt ecosystems and organisms causing short and long term problems in tissues and organs. These metals are considered to be one of the most toxic and polluting components in rivers. The toxicity of the metal will depend both on the chemical compound it is bound to and the route of administration (Jaramillo and Flores, 2012). Moreover, the danger lies not only in its toxicity but also in the exposure time, despite being present in low concentrations (Osoreo Plenge, 2016). Therefore, the research evaluated *Eichhornia crassipes* and *Pistia stratiotes* as sorbents in the treatment of Pb, Cu and Zn in the waters of the Quichas River, located at 3600 masl in the district of Oyón in Lima, Peru.

2. Materials and methods

2.1 Study area

The study was conducted in the community of Cashaucro in the district of Oyón in Lima, Peru. This district is located at 3560.61 m.a.s.l., with UTM coordinates 306022.909 E, 8824560.639 N.

2.2 Characterization of macrophyte plants

Macrophytic species such as *Eichhornia crassipes* and *Pistia stratiotes* were physically characterized to determine the color, shape and size of the roots.

2.3 Application of macrophyte plants in wastewater treatment

For the experimentation, 6 glass cuvettes with a capacity of 30 liters were designed. The dimensions of the basin were 35 cm wide, 30 cm high and 45 cm long.

Before the experiment, the *Eichhornia crassipes* and *Pistia stratiotes* plants were in the adaptation phase for 2 days. Then, the plants were placed in the cuvettes for experimental development. For this, the best macrophytes of each species of similar size were selected. For wastewater treatment, 3 plants of each species were placed in each cuvette. The cuvettes contained zinc sulfate, copper sulfate and lead nitrate solutions at concentrations of 750 mg/L, 25 mg/L and 62.5 mg/L, respectively (Figure 1).

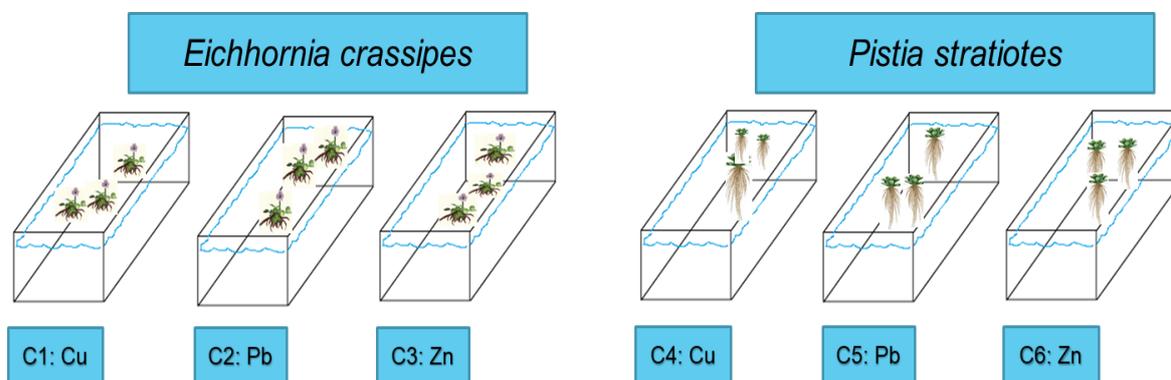


Figure 1: Wastewater treatment using macrophytes: water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*)

The treatment was monitored every week, measuring physical and chemical parameters such as pH, temperature, dissolved oxygen, electrical conductivity, copper, lead and zinc. This treatment was evaluated for 15 consecutive days.

The atomic absorption spectroscopy technique was used to determine the concentration of heavy metals. Subsequently, the percentage removal of each metal was determined using equation 1.

$$\%R = \frac{(\text{Initial metal concentration} - \text{Final metal concentration})}{\text{Initial metal concentration}} \times 100 \quad (1)$$

3. Results

3.1 Characteristics of macrophyte plants

Figure 2 shows the images of the macrophyte plants used in the study. *Eichhornia crassipes* presented abundant well-developed lateral roots, with sizes ranging from 2 to 3 cm, and its leaves were rounded and green in color. Meanwhile, *Pistia stratiotes* presented roots that varied in size from 1 to 2 cm, and its leaves were trapezoid-shaped and green in color.



Figure 2: Macrophyte plants: a) *Eichhornia crassipes* and b) *Pistia stratiotes*

3.2 Determination of physical and chemical parameters

Table 1 shows the results of the physicochemical parameters of the water before treatment with *Eichhornia crassipes* and *Pistia stratiotes*.

Table 1: Results of physicochemical parameters and heavy metals before treatment

Parameters	C1 and C4 (Cu)	C2 and C5 (Pb)	C3 and C6 (Zn)	ECA-water/category 3	
				Irrigation of vegetables	Drinking of animals
pH	7.03	5.90	6.12	6.5-8.5	6.5-8.4
Temperature (°C)	14	14	14	14±3	14±3
Dissolved oxygen (mg/L)	4.72	5.18	4.50	≥4	≥5
Electrical conductivity (µS/cm)	890	888	895	2500	5000
Copper (mg/L)	0.2150	-	-	0.2	0.5
Lead (mg/L)	-	1.831	-	0.05	0.05
Zinc (mg/L)	-	-	6.3049	2	2.4

Where: C1, cuvette 1; C2, cuvette 2; C3, cuvette 3; C4, cuvette 4; C5, cuvette 5; C6, cuvette 6; and ECA, environmental quality standards

From Table 1, it was observed that the water temperature was 14 °C, which did not vary during the experimental period. Parameters such as pH, dissolved oxygen and electrical conductivity comply with the values established by Ministry of the Environment (MINAM) in the environmental quality standards (ECA) for water, both for the vegetable irrigation category and the animal drinking category (MINAM, 2017).

The initial concentration of copper (Cu), belonging to cuvette 1 and cuvette 4 is 0.21 mg/L, a value that is above the ECA category 3 for vegetable irrigation which is 0.2 mg/L. However, it does meet the ECA category 3 for animal drinking, which is 0.5 mg/L.

The initial concentration of lead (Pb), belonging to cuvette 2 and cuvette 5 is 1.83 mg/L, which is well above the ECA category 3 for both vegetable irrigation and animal drinking.

The initial zinc (Zn) concentration in cuvette 3 and cuvette 6 is 6.30 mg/L, which is above the ECA category 3 for vegetable irrigation (2 mg/L). However, it does meet the ECA category 3 for animal drinking, which is 24 mg/L.

Table 2 shows the results of the physicochemical parameters of the water after treatment with the macrophyte plants.

Table 2: Results of physicochemical parameters after treatment

Floating macrophytes	Metal	Temperature (°C)	pH	Dissolved oxygen (mg/L)	Electrical conductivity (µS/cm)
Water hyacinth (<i>Eichhornia crassipes</i>)	Cu (C1)	15	7.8	6.87	78.7
	Pb (C2)	15	8.5	7.32	38.3
	Zn (C3)	15	7.6	6.24	350
Water lettuce (<i>Pistia Stratiotes</i>)	Cu (C4)	15	8.4	7.10	185.5
	Pb (C5)	15	7.2	8.69	96.3
	Zn (C6)	15	7.3	5.42	130.0

From Table 2 it was observed that the temperature remained almost constant with respect to the initial value of 14°C. With respect to electrical conductivity, the concentration of salts presents in the wastewater sample treated with the floating macrophytes was reduced between 60.89 and 89.06% with respect to the initial values. As for pH, the values measured in the 6 cuvettes were found to be within the ECAs. The presence of dissolved oxygen increased between 1 and 2 mg/L with respect to the initial values, improving water quality. Table 3 shows the concentrations of heavy metals in the water and their percent removal in the water after treatment with *Eichhornia crassipes* and *Pistia Stratiotes*.

Table 3: Concentration of heavy metals in water and percent removal after treatment with floating macrophytes

Floating macrophytes	Metal	Concentration (mg/L)	Removal (%)
Water hyacinth (<i>Eichhornia crassipes</i>)	Cu (C1)	<0.0003	99.86
	Pb (C2)	<0.002	99.89
	Zn (C3)	4.448	29.45
Water lettuce (<i>Pistia Stratiotes</i>)	Cu (C4)	<0.0003	99.86
	Pb (C5)	<0.002	99.89
	Zn (C6)	5.751	14.63

From Table 3, it was observed that the metals are within the environmental quality standards established by MINAM. The concentration of copper in both treatments with water hyacinth and water lettuce was less than 0.0003mg/L. The concentration of lead for both treatments was less than 0.002 mg/L, and the concentration of zinc was 4.448 mg/L with water hyacinth and 5.751 mg/L using water lettuce. These results indicated that the metals copper and lead had reductions of 99% in both treatments; while the metal zinc achieved reductions of 29.45% and 14.63% for the water hyacinth and water lettuce treatments, respectively. This last metal did not comply with the values established in the ECAs, both for vegetable irrigation and animal drinking, showing low efficiency of the floating macrophytes.

4. Discussion

In the present investigation, *Eichhornia crassipes* achieved copper and zinc removals of 99.86 and 29.45%, respectively. These results agree with the study conducted by Li et al. (2016), who used *Eichhornia crassipes* root powder for adsorption of heavy metals in aqueous solutions, achieving removals of 87, 70.23 and 35.62% for lead, zinc and copper, respectively. On the other hand, Mwaniki et al. (2019) used water hyacinth powder for adsorption of Pb and Zn in wastewater, obtaining an efficiency of 81.1% for lead and 78.7% for zinc. While,

Sarkar et al. (2017) demonstrated that *Eichhornia crassipes* powder is a locally available and economically viable adsorbent that can remove 98.83% Cr and 99, 59% Cu in tannery effluents.

The results showed that floating macrophytes decreased the electrical conductivity (EC) values from 895 to 350 $\mu\text{S}/\text{cm}$. Similarly, in the research of Leon and Lucero (2009), macrophytes decreased the electrical conductivity from 800 to 500 $\mu\text{S}/\text{cm}$. Maisa'a and Zakaria (2015) state that the reduction in EC is due to nutrient absorbance by floating macrophytes. The removal of physicochemical parameters shows that *Eichhornia crassipes* and *Pistia stratiotes* increased the pH of the wastewater to values between 7.2 and 8.5. To this, Qin et al. (2016) and Sekarjannah et al. (2019) mention that *Eichhornia crassipes* is good pH stabilizer and contributes to produce values close to water neutrality.

For lead and copper, removal efficiencies averaged 99% with *Eichhornia crassipes* and *Pistia stratiotes*. This result is corroborated by Baldeón et al. (2017) who removed Pb by 87 % using *Eichhornia crassipes*. On the other hand, zinc removal was low (29.45%), which could be influenced by the site temperature (14°C). Other authors such as Najila and Anila (2022) indicated that the macrophytes *Salvinia minima*, *Hydrilla verticillata* and *Eichhornia crassipes* could be used for phytoremediation of metals such as zinc, copper, lead, iron, cadmium and chromium. The macrophyte *Salvinia minima* had a higher affinity to zinc compared to the other plants, with a cumulative concentration of 129.5 mg/kg. In the research of Rena et al. (2022) used *Brassica juncea*, *Chrysopogon zizanioides* and *Pistia stratiotes* to remediate the toxicity of potentially toxic elements (PTEs) such as Cd, Al, Pb, Cu, Mn, Co and Zn in bio-medical wastes.

The use of floating macrophytes has proven to be efficient in the remediation of waters containing nutrients, organic matter and toxic substances such as arsenic, zinc, cadmium, copper, lead, chromium and mercury (Martelo and Borrero, 2012). To this, Li et al. (2016) indicated that *Eichhornia crassipes* powder can be taken to industry for wastewater treatment.

5. Conclusions

The study showed that *Eichhornia crassipes* and *Pistia stratiotes* species improved the physicochemical parameters of the wastewater and are good adsorbents of Pb, Cu and Zn in locations at 3600 masl. *Eichhornia crassipes* obtained a removal of 99.86, 99.89 and 29.45% for copper, lead and zinc, respectively. While, *Pistia stratiotes* obtained removals of 99.86, 99.89 and 14.63% for copper, lead and zinc, respectively. All these indicated that the floating macrophytes had higher removal efficiency for copper and lead metal than zinc metal. In addition, the treated water could be used for agricultural irrigation in the Cashaucro population of the Oyón district in Lima, Peru.

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