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EFFECT OF MACROPHYTIC PLANTS ON THE REMOVAL OF HEAVY METALS IN DOMESTIC WASTEWATER

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Abstract— In this research it was possible to identify the percentage of heavy metal removal and find the appropriate macrophyte plants. The following species Phragmites australis, Schoenoplectus colifornicus and Eichhornia crassipes were studied, three suitably impermeable wooden ponds were built, which had the following dimensions: 0.30 m wide x 0.40 m high and 1.60 m long, giving a volume of 0.192 m3, the experiment was carried out in the Province of Huaura, Lima, Peru. Three varieties of macrophyte plants were grown in each tank with domestic wastewater in each tank without disturbance, and after 120 days of macrophyte growth, the plants were analyzed by an INACAL-accredited laboratory. The results showed that the heavy metals considered were absorbed by the three types of macrophyte plants according to the following result: for Phragmites Australis it was 79.90% nickel, 60.23% lead and 29.11% cadmium, for Schoenoplectus Colifornicus, it was 83.00% for nickel, lead 61.23% and cadmium 51.90%, and for Eichhornia crassipes the results were 93.73% for nickel, 84.36% lead and 78.48% cadmium, it can be seen that Eichhornia crassipes turned out to be the most efficient and therefore this plant would be recommended for its better removal capacity to recover heavy metals from domestic wastewater.

Index Terms— Phragmites australis, Schoenoplectus colifornicus, Eichhornia crassipes, heavy metals, macrophytic plants, removal capacity

INTRODUCTION

Currently, water pollution is an alarming and global problem caused by the misuse of human beings. In this sense, the accelerated population growth and industrial activity have caused an increase in the global demand for water and, as a consequence, the generation of high volumes of wastewater. The population of Latin America is concentrated in its largest percentage in cities. Water pollution occurs at primary, secondary and tertiary levels of water sources. Substances that pollute water are organic and inorganic. In all cases, water contamination endangers Public Health, according to the World Health Organization (WHO). One concern is water contamination, which comes from the presence of high levels of inorganic arsenic, lead, and cadmium due to negative consequences such as cancer, diabetes mellitus, and cardiovascular diseases. The largest percentage of wastewater in the Latin American region is not treated. The water is extracted, used and returned completely contaminated to the rivers. Wastewater treatment is important to reuse water, avoid its contamination and that of the environment, especially due to its effects on agricultural production and public health. The WHO in 2010 published a list of the ten contaminants of greatest concern for public health, from which lead, mercury, cadmium and arsenic are found as the main heavy metals.

In Peru there is an overload of wastewater in treatment plants whose infrastructure is insufficient, which causes treated effluents to exceed the maximum permissible limits (LMP), and environmental quality standards (ECA) are not met. This generates environmental problems such as the contamination of bodies of water and the generation of bad odors that cause conflicts with the population. Domestic wastewater is that of residential and commercial origin that contains physiological waste, among others, from human activity, and must be properly disposed of. Domestic wastewater contains various organic and inorganic substances that must be treated with appropriate technology (Fauzul et al., 2023). Based on a general analysis of technologies for the treatment of contaminated water and taking the International Patent Classification as a reference, biological treatment using plants has been identified as one of the main technologies: Plants, when exposed to heavy metals, can present different physiological responses that can be classified as exclusive, the accumulation of metals in the plant is less than the concentration of the soil; indicator, where the accumulation of metals in the aerial tissue keeps a linear relationship with respect to the concentration of the soil; and, accumulators, where the accumulation of metals in its aerial part is much greater than the concentration of metals in the soil. Taking into account the above, it seeks to find efficient and viable alternatives in the treatment of domestic wastewater because it puts health and the environment at risk.

I. Method

The study was carried out in the Province of Huaura, Lima. Where three wooden tanks with dimensions of 0.40 m high x 0.30 m wide and 1.60 m long with a volume of 0.192 m3 capacity were installed; in pond number 1, Phragmites Australis was planted, in number 2 Schoenoplectus Colifornicus was cultivated and in number 3 Eichhornia crassipes was cultivated. The Phragmites australis and Schoenoplectus colifornicus were cultivated in the following way: calcareous aggregates were placed with an approximate thickness of 10 cm, then compost and black earth were placed equally with a thickness of about 10 cm, then the Phragmites australis and Schoenoplectus were planted. colifornicus collected from nearby places that grow naturally in the existing swamps, likewise 2" diameter plastic pipes were installed from a selected house and for distribution to each pond they were installed with controlled 1" diameter plastic pipes with their respective valves of the same diameter, and finally the domestic wastewater from family homes entered, as shown in Fig. 1.

Fig. 1. Pond with compost and Phragmites australis

For the cultivation of Eichhornia crassipes, the waterproofed pond was used, the residual water and the plant collected from areas near this town that grew naturally, the particularity of this plant is that it floats in the water and its roots are suspended in the water, as shown in Fig. 2.

Fig. 2. Pond with Eichhornia crassipes

Once the ponds and pipes were installed, protection was placed in place. Fig. 3 shows the installation of the three types of macrophyte plants planted on the sides of a temporary drain.

Fig. 3. Ponds with macrophyte

Se tomaron las muestras respectivas de las tres especies cultivadas, también se tomaron muestras de otras tres especies de la misma familia los que se desarrollaron de manera silvestre en los bofedales cercanos a la zona de estudio, para hacer una comparación en retención de metales pesados con los vegetales cultivados en los estanques preparados versus los vegetales que crecen de manera silvestre y con ello se medió la capacidad de retención de cada especie, y lógicamente los cultivados de manera controlada con las aguas residuales domésticas demostraron que contienen buen porcentaje de metales en sus raíces y tallos analizados.

II. Results

After 120 days of having been planted the macrophytes, Phragmites australis, Schoenoplectus colifornicus and Eichhornia crassipes, five water samples were taken at the entrance and exit of each pond, at different times and dates, this sampling was carried out by the laboratory. accredited by INACAL, in the same way, samples of the plant tissue of those cultivated in the prepared ponds and three other stems of the same variety that grow in the natural wetlands near the study area were taken.

Table I: Heavy Metal Removal with Phragmites australis

Metal mg/kg	Average wastewater input	Average wastewater output	Subtraction	% de % retention
Ni (tot)	0.0102	0.0021	0.0082	79.9
Pb (tot)	0.0120	0.0048	0.0072	60.23
Cd (tot)	0.0016	0.0011	0.0005	29.11

The results in Table I illustrate a decrease in the content of nickel, lead and cadmium. With greater detail of the averages, the percentage of removal is shown. This effectiveness of macrophytes coincides with that reported by (Mohsin et al., 2023) who indicated in their research with P. australis and I. pseudacorus were not exposed to metal toxicity, for example, necrosis, chlorosis or wilting in a multimetal environment based on visual observations, also indicated that the studied plant demonstrated productive responses to For all growth parameters, the overall fluctuations in Cd removal were approximately 76-86% for P. australis and 56-69% for I. pseudacorus. For this reason it can be indicated that this research can be sustainable as reported by (Moulisová et al., 2023) who studied the biomass and structural characteristics of rhizomes and roots of Phragmites australis in the entrance and exit parts of a recently established artificial wetland with horizontal underground flow, increasing the biomass of P. australis rhizome up to the 6th year.

Table II: Heavy Metal Removal with Schoenoplectus colifornicus

Metal mg/kg	Average wastewater input	Average wastewater output	Subtraction	% de % retention
Ni (tot)	0.01024	0.0017	0.0085	83.0
Pb (tot)	0.01202	0.0047	0.0074	61.23
Cd (tot)	0.00158	0.0008	0.0008	51.90

The results in Table I illustrate a decrease in the content of nickel, lead and cadmium. With greater detail of the averages, the percentage of removal is shown. The use of Schoenoplectus colifornicus is a great alternative for the decontamination of wastewater, as reported by (Puma-Sarmiento et al., 2022) who reported that the best efficiency in removal of contaminants in effluents was Schoenoplectus californicus with 78.88%.

Table III: Heavy Metal Removal with Eichhornia crassipes

Metal mg/kg	Average wastewater input	Average wastewater output	Subtraction	% de % retention
Ni (tot)	0.0102	0.0005	0.0097	94.73%
Pb (tot)	0.0120	0.0019	0.0101	84.36%
Cd (tot)	0.0016	0.0003	0.0012	78.48%

The results in Table I illustrate a decrease in the content of nickel, lead and cadmium. With greater detail of the averages, the percentage of removal is shown. In order to know and make a comparison of the three types of macrophytic plants, samples were taken from three vegetable stems that were cultivated in the prepared ponds that grew with the entry of domestic wastewater discharged from the houses in Huaura, Lima. These results are similar to those developed in irrigation canals, as reported by (Eid et al., 2021) who indicated that the samples of E. crassipes absorb heavy metals in its four plant organs (blades, petioles, roots and stolons). This study considered the absorption of Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn. The results highlight the efficacy of Eichhornia crassipes, as well as what was reported by (Zimmels & Malkovskaja, 2006) who highlight the effectiveness of the purification of wastewater by aquatic plants, such as the water hyacinth (Eichhornia crassipes), tested at laboratory scale and cascade and semi-continuous pilot verified that the plants are capable of reducing all the proven indicators of quality of water to levels that allow the use of purified water for the irrigation of tree crops. For this reason, the use of macrophytes in the treatment of domestic wastewater is recommended, as well as that reported by (Heisi et al., 2023) who recommend the use of hyperaccumulator macrophytes such as E. crassipes that accumulated significant amounts of heavy metals with higher concentrations in the root for the natural recovery of these heavy metals.

III. Conclusion

For Nickel and Lead heavy metals, the effect of Phragmites australis, Schoenoplectus colifornicus, and Eichhornia crassipes is insignificant, however, for cadmium retention is important for the three macrophyte plants, resulting in 29% for Phragmites australis, 51% in Schoenoplectus colifornicus and 78% for Eichhornia crassipes.

The findings indicate that this methodology could be used for the remediation of water bodies with high concentrations of Ni, Pb and Cd. The experimental period was remarkably short.

Conflict of Interest

Los autores declaran no tener conflicto de intereses

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