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Article

Comparison of *Canna indica*, *Pontederia sagittata* and *Heliconia rostrata* as phytoremediator species in the treatment of gray water in Úrsula Galván, Ver.

Comparación de *Canna indica*, *Pontederia sagittata* y *Heliconia rostrata* como especies fitorremediadoras en el tratamiento de aguas grises en Úrsulo Galván, Ver.

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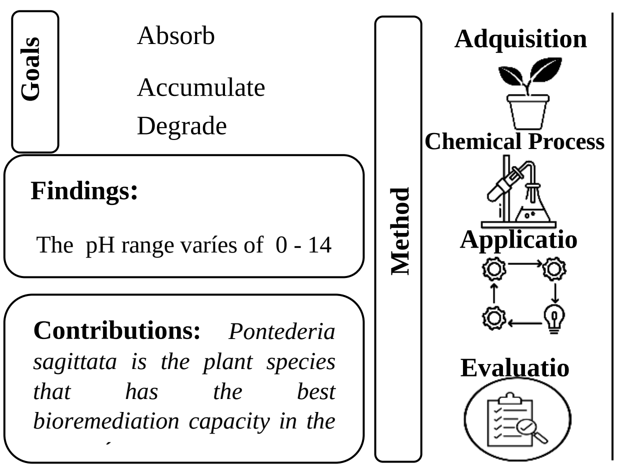
Abstract

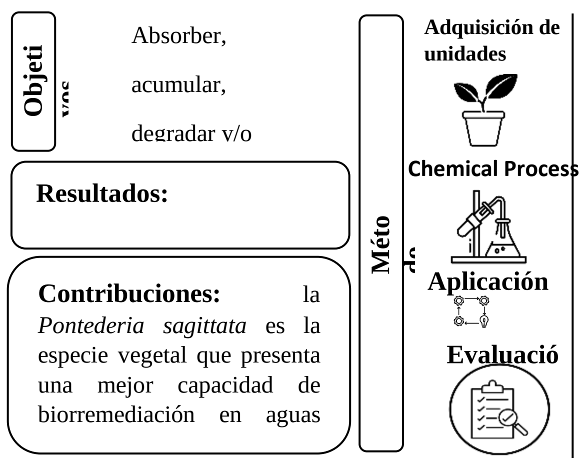
Artificial wetlands began to be used as tools for wastewater treatment. It was found that these could be built following the same operating principle as natural wetlands, which since they existed have fulfilled the function of storing and purifying wastewater. water. In some studies, the species: *Canna indica*, *Pontederia sagittata* and *Heliconia* spp. have shown potential for contaminant removal. Due to the high demand for these plants as phytoremediation species, several studies have evaluated the role of Heliconia in wastewater remediation, finding positive effects in bioremediation (Ascuntar and Toro 2007, Gómez and Segura 2008, Gutiérrez 2009, Sandoval 2009, Peña et al., 2011). Pontederia cordata has a root system, which has microorganisms associated with it that favors the purifying action of aquatic plants, retaining heavy metals (Cd, Hg, As) in their tissues. In addition, it removes some organic compounds, such as phenols, formic acid, dyes and pesticides, and reduces levels of BOD5, COD and suspended solids. (Celis et al., 2005). The species Canna indica is considered an effective plant for phytoremediation due to its physiological and morphological properties.



Humedales articiales, aguas grises, *Canna*

Resumen

Los humedales artificiales, empezaron a ser utilizados como herramientas para el tratamiento de aguas residuales, se encontró que estos podían ser construidos siguiendo el mismo principio de funcionamiento de los humedales naturales, los cuales desde que existen, han cumplido la función de almacenar y purificar el agua. En algunos estudios, las especies: *Canna indica*, *Pontederia sagittata y Heliconia* spp. han mostrado potencial para la remoción de contaminantes. Debido a la alta demanda existente alrededor de estas plantas como especies fitorremediadoras, Diversos estudios han evaluado el papel de la *Heliconia* en la remediación de aguas residuales encontrando efectos positivos en la biorremediación (Ascuntar y Toro 2007, Gómez y Segura 2008, Gutiérrez 2009, Sandoval 2009, Peña et al., 2011). *Pontederia cordata* posee un sistema de raíces, que tienen microorganismos asociados a ella que favorece la acción depuradora de las plantas acuáticas, retienen en sus tejidos metales pesados (Cd, Hg, As). Además, remueve algunos compuestos orgánicos, tales como fenoles, ácido fórmico, colorante y pesticidas, y disminuye niveles de DBO5, DQO y sólidos suspendidos. (Celis et al., 2005). La especie *Canna indica* es considerada una planta eficaz para la fitorremediación por sus propiedades fisiológicas y morfológicas.



Artificial wetlands, grays water, *Canna*

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Introduction

Currently, we are facing a crisis due to water scarcity in different communities, as population growth in the area brings with it increased demand for drinking water and increases water pollution (Rhodes, 2019). Water pollution is an environmental challenge that affects the quality of life of all people. Among the various sources of contamination, we have graywater, which is generated by domestic activities, being very common represents a great concern due to the impact on human health and the aquatic ecosystem.

The main contaminants in graywater are nitrogen and phosphorus, organic compounds, fecal coliform bacteria, organic matter, among many others (Jiménez, et al., 2010). In Mexico in 2012, urban centers discharged approximately 7.3 km^3 (equivalent to 229.73 m^3/s) of wastewater. At the federal entity level, those that in 2012 generated the largest municipal water discharges were the state of Mexico (24.22 m^3/s), Federal District (21.96 m^3/s) and Veracruz (16.08 m^3/s), which together accounted for 27.1% of the national volume generated. For this reason, it is necessary to look for alternatives to help us solve this problem in a sustainable manner. Artificial wetlands began to be used as tools for wastewater treatment, it was found that they could be built following the same principle of operation of natural wetlands, which since they exist, have fulfilled the function of storing and purifying water. These wetlands consist of an intermediate ecosystem, between aquatic and terrestrial, in which three important elements interact: water, soil and macrophytic plants. During this interaction, several biological processes occur, which allow obtaining better quality water at the outlet of the system (Zarate, 2001). This is presented as a sustainable strategy for graywater treatment, using aquatic plants to absorb, accumulate, degrade and/or transform the pollutants present. In some studies, the species *Canna indica*, *Pontederia sagittata* and *Heliconia* spp. have shown potential for the removal of pollutants.

Pontederia spp. *as a phytoremediation plant*

Valdivia, G. 2019 in the work "Efficiency of *Eichhornia crassipes* (mart.) Solms laub - pontederiaceae and nasturtium officinale w.t. aiton - brassicaceae in the removal of dbo5 and dqo from the effluent of the wastewater treatment plant of celendín", mentions that Pontederia cordata has a root system, which has microorganisms associated with it that favors the purifying action of aquatic plants, retaining heavy metals (Cd, Hg, As) in their tissues. In addition, it removes some organic compounds, such as phenols, formic acid, dyes and pesticides, and decreases levels of BOD5, COD and suspended solids (Celis et al., 2005).

Studies of Canna indica as a phytoremediation plant

The same author mentions that the Canna indica species is considered an effective plant for phytoremediation due to its physiological and morphological properties. For Cheng et al. (2007) it is a species of the Cannaceae with high resistance to stress due to the presence of heavy metals, as well as a high potential for their degradation.

A study by Aguiar & Castillo (2019) points out the possibility of using the vegetative species Achira for the purification of water bodies and consequently improve water quality. In addition, achira according to (Caguana, 2018), presents other uses, in human food, animal feed and for the production of industrial starch and the preparation of noodles.

A study conducted by Quezada et al., (2012) called "Natural remediation to complete the purification of chromium (VI) in tannery effluents". He established the following results (*C. indica*) showed that, from the analysis of plant tissue, it was demonstrated that chromium, regardless of its oxidation state in solution, (III) or (VI), is stored in greater proportion in the root, reaching concentrations above 3,000 mg/kg (dry weight). Also (Wang LK, Shammas NK, Hung YT, 2010) mentions that C. indica has been used to treat the waters of the Yangtze River, China where the efficiency of this plant in the elimination of chromium in water is proven (Quezada, R et al., 2012) (Quezada, R et al, 2012). Likewise, contaminated water in the Zhujiang River (Guangzhou) was treated with a floating system of this species.

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Methodology

Plastic containers were lined with a black plastic bag to prevent water leakage, this ensures that it is possible a single water outlet that can be collected, then proceeded to cut 4 pieces of hose of 25 cm each, these hoses so that water can reach the receiving containers, A piece of hose was wrapped with an edge of insulating tape, this had the function of providing a relief in the hose, when introducing the hose through a hole in the container this relief allowed a pressure that prevented the exit of the hose and water.

Box 1

Figure 1
Installation of wetlands

The plastic containers were then filled with the substrate. Two different calibers were used for the first layer of gravel, one of 4-5 cm and the other of 2 cm. We placed 6 centimeters of fine gravel, 8 centimeters of sand after another 8 centimeters of gravel, the vegetal component was placed and then the last layer of soil was placed between 8 centimeters. The plastic containers were placed in a row and at the same level, and then the collection trays were placed.

Box 2

Figure 2
Greywater treatment plants

Box 3

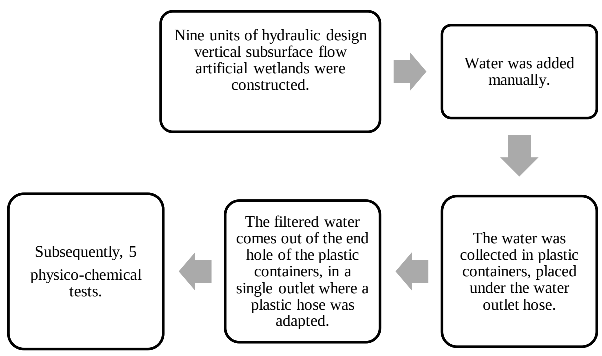

Figure 3
Graywater treatment process

Results

pH test

Hydrogen potential (pH) is used to determine whether water is acidic or alkaline. The pH range varies from 0 to 14 standard units (S.U.), where 7 is neutral. A pH below 7 indicates acidity, while a pH above 7 indicates a basic or alkaline condition. The pH is expressed in logarithmic units and each whole number represents a 10-fold change in the acidity or alkalinity of the water. Water with a pH of 5 is ten times more acidic than water that has a pH of 6. Because chemicals can affect pH, pH is an important indicator of water that changes from a chemical standpoint (Perez, R, 2017).

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Pollution can change the pH of water which, in turn, can harm the organisms living there. Table 1 shows the pH values obtained when entering through the wetland, as well as the values obtained when having been 24 hours inside the wetland.

Box 4

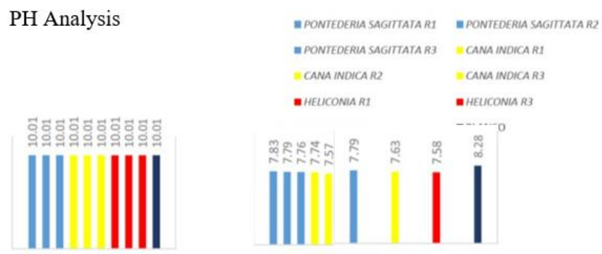

Figure 4
Hydrogen Potential

Considering the hydrogen potential readings obtained from the water samples, we can say that the heliconia is the one that manages to reduce the hydrogen potential of the treated graywater the best.

Hardness test

It is a chemical characteristic of water that is determined by the content of carbonates, bicarbonates, chlorides, sulfates and occasionally calcium and magnesium nitrates. Hardness is undesirable in some processes, such as domestic and industrial washing, causing more soap to be consumed, as insoluble salts are produced. In boilers and water-cooled systems, it causes scaling in pipes and a loss in heat transfer efficiency.

It also imparts an undesirable taste to drinking water. Large amounts of hardness are undesirable for the reasons stated above and must be removed before water is suitable for use in the beverage, laundry, metal finishing, dyeing, and textile industries (Romero J., 1999).

Hardness is measured in $CaCO_3$ and according to each limit is considered from soft to very hard water as shown in Table 1.

Box 5

Table 1
Classification of water according to its total hardness

Hardness	Definition
0 - 75	Soft Water
75 - 150	Little Hard Water
150 - 300	Hard Water
> 300	Very hard water

Five different physicochemical tests were performed on the treatment to compare the efficacy of each species. The results are shown in the table:

Box 6

Table 2

	Parameters				
Treatment	pH	D	CE	SD	SS
Pontederia S.	7.79	287	1.06	0.04835	1.30988
Canna I.	7.63	628	3.03	0.08320	0.84949
Heliconia R.	7.58	532	2.44	0.05869	0.67410
Target	8.28	520	1.19	0.05834	1.39291
Gray Water	10.0	0	33.3	1.71411	12.2377

Results of physical-chemical analysis (pH, hardness, electrical conductivity, suspended solids, dissolved solids).

Heliconia spp. reduced the pH of the water up to 24.26%, with 7.58, complying with the regulation of 6.5 to 8.5 according to Delgado, J. in 2021. It is also the most effective in reducing suspended solids, leaving them at 0.67%, the variations that occurred in the other species may be due to environmental factors and wetland conditions (Delgado, J. 2021).

Pontederia sagittata decreased water hardness to 287 mg $CaCO_3$/L and significantly reduced electrical conductivity to 1.06 µS/cm. Based on Morales et al., 2019, plant components tolerated and absorbed soluble salt ions by adhering them to their tissues without affecting growth.

As for dissolved solids resulted in 0.0483 mg/L. according to Buitrón, A., 2024, it is below the established norm, indicating that a considerable proportion of dissolved solids could be effectively controlled by the implemented treatments.

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Conclusions

According to the tests carried out, it can be concluded that the *Heliconia rostrata* species presented a better capacity to reduce the hydrogen potential in graywater. On the other hand, the *Pontederia sagittata* species decreased water hardness, which indicates a better performance of the plant, and also gave positive results in the conductivity analysis, i.e., it has great potential for the removal of salts present in gray water and finally it was the species that obtained the best performance in the removal of dissolved solids in water. Overall, *Pontederia sagittata* is the plant species with the best bioremediation capacity in graywater.

More research should be done on the physicochemical analysis of artificial wetlands. Consider the use of *Pontederia sagittata* and *Heliconia rostrata* for graywater treatment. It is proposed to continue monitoring and optimizing the system.

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