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Treatment of laundry wastewater by constructed wetlands with *Eichhornia crassipes*

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ABSTRACT

Rapid urbanization and the increase in world population have led to the generation of substantial volumes of laundry wastewater. In the present research work, the efficiency of *Eichhornia crassipes* for the treatment of wastewater from domestic laundries was studied. It was created in a system of artificial floating islands and placed in polyethylene cells with a useful volume of 20 L of capacity, a hydraulic retention time of 21 d was established. During the treatment, the parameters of pH, electrical conductivity (EC), total dissolved solids (TDS), chemical oxygen demand (COD), and phosphate–phosphorus ions (PO_4–P) were determined. All parameters decreased significantly. The pH decreased from 9.33 to 8.29, the EC from 3,999 to 1,745 mS/cm, TDS from 2,000 to 847 mg/L, as well as the COD from 945 to 71 mg/L, and finally the PO_4^{3-} ions of 202.5 to 5.7 mg/L. According to the results obtained, the system of artificial floating islands with *E. crassipes* is considered efficient and adequate for the removal of contaminants present in laundry wastewater.

Keywords: Grey waters; Floating macrophytes; Phytoremediation; Constructed wetlands, Ecotechnology

1. Introduction

With the growth of the world population and urbanization in recent years, the generation of wastewater is increasing [1–3]. Most of this wastewater is usually spilled into bodies of water without pretreatment or monitoring [4–6], causing serious ecological problems, such as the deterioration of water quality and biodiversity loss [7–9]. Grey water is defined as wastewater generated from showers, cooking, dishwashers, and washing machines, but is separated from toilet wastewater. This type of water includes between 50% and 80% of domestic wastewater [10]. Grey water from the laundry is characterized by a diverse content of organic and inorganic compounds and surfactants (anionic and cationic), which causes these waters to be considered complex and difficult to treat [11–13].

Developing countries are paying attention to low-cost, ecological, and sustainable water treatments [14,15]. Artificial floating islands are a type of artificial wetland,

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designed to contain aquatic plants and float on the surface of the water [16]. The implementation of these systems has been highlighted for its easy operation, economic profitability, and environmental friendliness [17–19]. The water hyacinth (*Eichhornia crassipes*) is a floating macrophyte, which stands out for its ability and efficiency to capture chlorides, sulfates, nitrates, phosphates, carbonates, and heavy metals [20–23], which is why they have been used for the phytoremediation of agricultural, domestic, and industrial wastewater [24–27]. However, there is little information regarding the treatment of grey water with water hyacinth. The objective of this study is to evaluate the phytoremediation potential of *E. crassipes* in artificial floating island systems for the treatment of grey water from domestic laundries, by investigating its performance in the elimination of contaminants and evaluating the quality of the treated water, we seek to contribute to understanding its efficiency and effectiveness as a natural treatment option.

2. Materials and methods

2.1. Description of the study area and sample collection

The study was carried out at the Tecnológico Nacional de México, Zongolica Campus, in the experimental ranch "La Luisa", located in the municipality of Tezonapa, Veracruz, Mexico. The average temperature during the months of investigation was 34°C (±3.5). The water was collected from domestic laundry wastewater extracted from a house (18° 30′26.956″ N 96° 34′20.3″ W). 20 L of wastewater were collected and placed in polyethylene containers, in said containers the experiments were carried out.

2.2. Selection and adaptation of plants

Juvenile plants of *E. crassipes* extracted from a body of water located in the municipality of Tezonapa, Veracruz, Mexico, were collected, transported, and placed in culture cells to adapt them to the new environment for one week. The systems were arranged in a sheltered area, allowing adequate exposure to air and sunlight.

2.3. Assembly of artificial floating islands

Structures composed of a 0.5-inch PVC tube frame were designed, on which a plastic mesh, a jute fiber mesh, and recycled plastic bottles were placed (Fig. 1). The basal part of the plant's rests between the plastic mesh and the jute mesh, the first mesh serves as a support for the plants and the second maintains the humidity of the roots and gives a better appearance to the floating structures. Plastic bottles guarantee that the structure remains floating and are located under the PVC structure [28]. The aerial part of the plants protrudes above the plant fiber and the roots extend below the floating structure towards the bottom of the water body. 180 g (±32.3 g) of *E. crassipes* were placed on the artificial floating islands.

2.4. Sampling and chemical analysis

The experiments were carried out in discontinuous mode having a hydraulic retention time of 21 d. The treated water samples were taken in triplicate, and these samples were collected on days 7, 15, and 21. For the collection, preservation, and analysis of the samples, they were taken following the procedures established in the Standard Method [29]. Control parameters were pH, electrical conductivity (EC), and total dissolved solid (TDS) using a Hanna brand potentiometer (HI 98130, IN). The performance parameters were chemical oxygen demand (COD) using the Standard 5220 method and phosphate–phosphorus (PO_4–P) using a HANNA Brand Colorimeter (HI717).

3. Results and discussion

3.1. Characterization of the water

Table 1 shows the physicochemical characterization of domestic laundry residual water. The pH of the residual water has an average value of 9.94 (Table 1), a very alkaline value, which is considered typical of water from laundries. Melián et al. [30] report that the waters from industrial laundries have an average pH value of 11.07, SST 2,900 mg/L, and turbidity of 1,290 NTU. The COD of domestic laundry wastewater has an average value of 945 mg/L, a value below that reported by Melián et al. [30] characterized water from industrial laundries as having an average COD value of 1,920 mg/L. Phosphate concentrations are high concentrations since values of 200.2 mg/L are reached. The characterization carried out by Siswoyo et al. [31] obtained values ranging from 1 to 2 mg/L.

3.2. Sampling and chemical analysis

The pH monitoring is shown in Fig. 2A. After day 7, the pH value was observed to increase from 9.94 to 10.13.

Fig. 1. Artificial floating islands with *Eichhornia crassipes*.

Table 1
Characterization of laundry wastewater

Parameters	Average	σ
pH	9.94	0.03
Electrical conductivity, mS/cm	3,999	3.06
Total dissolved solids, mg/L	2,000	4.1
Chemical oxygen demand, mg/L	945	106.2
PO_4–P, mg/L	202.5	5.00

σ: Standard deviation.

On the other hand, from day 8 to 21, the pH value decreased from 10.13 to 8.28 (Table 2). This phenomenon may be due to the consumption of dissolved CO_2 in laundry water, CO_2 decreases due to the photosynthetic activity of *E. crassipes* reflected in the increase and subsequent decrease in pH [32]. Parwin and Paul [33] use *E. crassipes* for the treatment of grey water from raw kitchens where an increase in pH from 6.25 to 6.63 is shown. Rezania et al. [34] observed an increase in the pH value (13%) during domestic wastewater treatment using *E. crassipes*.

The monitoring of the EC (Fig. 2B) at the beginning was 3,999 mS/cm and after 21 d the wastewater reached the average value of EC of 1,714.5 mS/cm (Table 2), for which it decreased by 57.12%, this decrease is promotional to the behavior of STD. Parwin and Paul [33] observed a reduction of 69.97% using *E. crassipes* in the treatment of grey water. Rasool et al. [35] evaluated the potential of *E. crassipes* for 21 d, with three different waters; fresh, industrial, and urban waters, finding that the EC tends to increase. The TDS results are shown in Fig. 2C, which showed a significant reduction of 54.65% reaching an average value of 847 mg/L (Table 2) after 21 d. Prasad et al. [36] treated grey water using *E. crassipes* and after 30 d only 9.21% ± 2.65% were removed. In the study proposed by Parwin and Paul [33] a decrease of 72%–80% was achieved after 21 d of working with *E. crassipes*.

3.3. Removal efficiency

Fig. 3A shows the removal of COD, the decrease is more significant during the first 15 d, and after 21 d an average removal of 92.37% of COD is reached (Table 3), one of the

Table 2
Monitoring of input and output control parameters

Parameters	Influent		Effluent	
	Average	σ	Average	σ
pH	9.94	0.03	8.28	0.07
Electrical conductivity, mS/cm	3,999	0.8	1,714.50	3.54
Total dissolved solids, mg/L	2,000	0.01	847	8.49

σ: Standard deviation.

Table 3
Monitoring of contaminant removal

Parameters	Influent		Effluent		% Removal
	Average	σ	Average	σ	
Chemical oxygen demand, mg/L	945	35.35	71	4.24	92.37
PO_4–P, mg/L	202.5	1.9	5.77	0.56	99.06

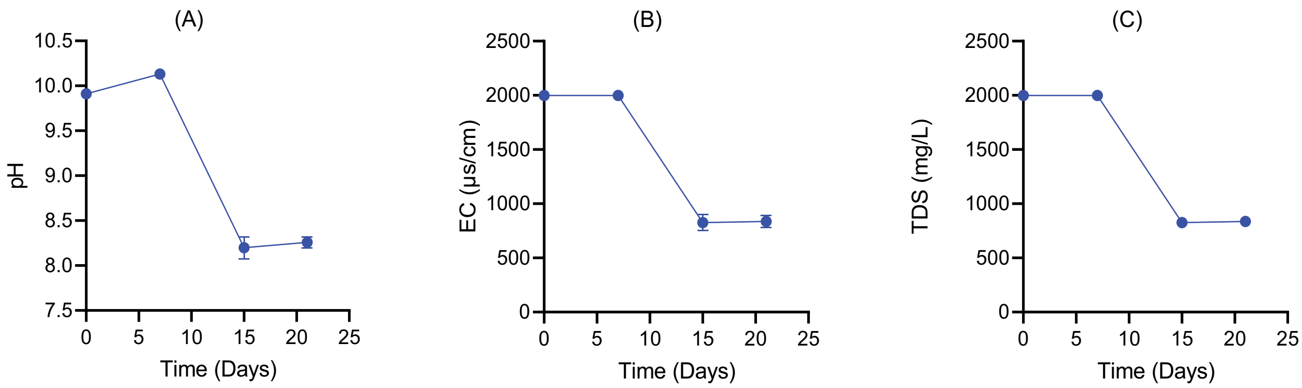

Fig. 2. Monitoring of control parameters, (A) pH, (B) electrical conductivity, and (C) total dissolved solids.

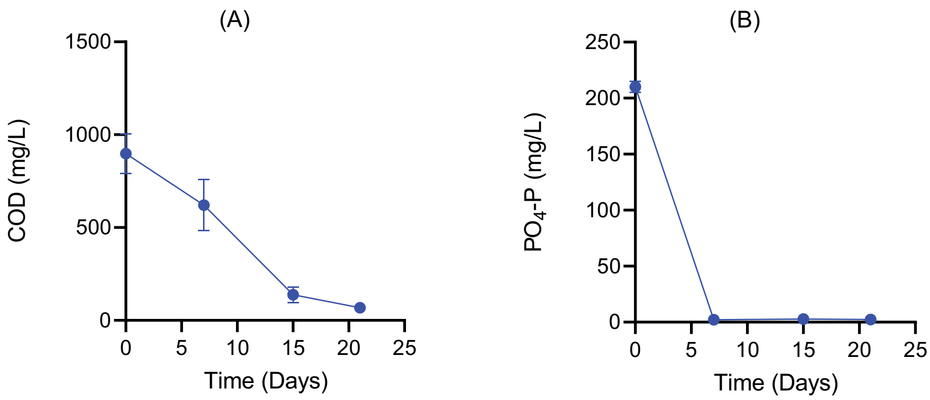

Fig. 3. Removal of contaminants (A) chemical oxygen demand and (B) PO_4–P.

factors that benefit a correct removal of COD. COD can be attributed to the ambient temperature of 34°C. Aquatic plants are very sensitive to atmospheric temperature which controls overall growth and nutrient removal. 20°C–38°C are considered appropriate ranges for *E. crassipes* phytoremediation processes [37]. Siswoyo et al. [31] evaluated the decontamination of laundry wastewater using *E. crassipes*, in combination with residual sludge, the treated water had an initial COD of 975 mg/L of COD and after 15 d up to 77.5% were removed. Similarly, Stefhany et al. [38] treated wastewater from laundresses that had a COD of 1,083 mg/L, after treating them for 20 d with *E. crassipes*, it reached a removal of 29.68.

Phosphorus is an important nutrient for plant vegetative reproduction and growth. Phosphorus removal can be determined by phosphates [36]. The removal of PO_4–P can be seen in Fig. 3B, the removal is more significant in the first 7 d, later a constant decrease can be seen until it reaches 99.06% (Table 3). One of the factors to which we can attribute the correct removal of phosphorus growth of the biomass [39], which after the evaluation period has an increase of 15%. Prasad et al. [36] Evaluated the removal of phosphorus in gray water with a content of 1.2 mg/L of phosphates, after 30 d of using it with *E. crassipes*, it managed to remove 58.13%, having an increase in biomass of 75%. Siswoyo et al. [31] treat laundry wastewater with a concentration of 2 mg/L of phosphates after 15 d, reaching a removal of 90%, but it is not mentioned if there is an increase in biomass.

4. Conclusions

E. crassipes (water hyacinth) is one of the most relevant macrophytes, studied for its ability to remove various contaminants under various physical and climatic conditions. In the present study, the efficacy of *E. crassipes* as a treatment agent for gray water from domestic laundries was shown with a significant reduction in COD (92.37% ± 4.24%) and phosphate–phosphorus (99.06% ± 0.56%). The physicochemical properties were found in descending order, the pH was from 9.94 to 8.28, the EC was reduced by 57.12% ± 3.54% and the TDS reduction was 57.65% ± 8.49%. So that the water treated by this system has a lower content of contaminants. The proposed treatment system is simple to operate, consumes little energy, and requires minimal maintenance. Furthermore, the process provides additional benefits in terms of the regular production of biomass.

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