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Common water-hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*) used to treat leachate

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ABSTRACT

Objective: To evaluate the phytoremediation capacity of *Eichhornia crassipes* (common water-hyacinth) and *Pistia stratiotes* (water lettuce) exposed to water polluted with leachate from the El Guayabo landfill, located in Medellín, Veracruz, Mexico.

Design/Methodology/Approach: The phytoremediation experiment lasted 21 days. Diluted leachate (30%) and six plants were used, with 3:1 (TA) and 1:1 (TB) ratios for water lettuce and common water-hyacinth. Water turbidity, nitrite, and chemical oxygen demand (COD) were the response variables used to evaluate pollutant removal. A WGZ-200 turbidity meter was used to measure turbidity (NTU), following the NMX-AA-038-SCFI standard (2001). Nitrite was measured based on the NMX-AA-099-SCFI standard (2006), while COD was determined according to the NMX-AA-030/2-SCFI standard (2011).

Results: Compared with control, a high percentage of turbidity and nitrite removal (>90%) was observed. The reduction of COD fluctuated from 29.87±3.90 to 31.08±4.75%, while control recorded 18.80±4.65%.

Study Limitations/Implications: The biological material variables were difficult to control under *ex situ* conditions.

Findings/Conclusions: Common water-hyacinth and water lettuce can remove chemical pollutants from water polluted with leachate. Compared with TE, TB (T2) recorded significant differences regarding COD; consequently, the best treatment to reduce pollutants is TB (T2).

Keywords: physicochemical analysis, landfill, phytoremediation.

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INTRODUCTION

Mexico generates about 120,128 t of urban solid waste (USW) per day. An average of 84% of the total USW is collected; consequently, the domestic coverage reaches 100,751 t per day (1). The waste sent to landfills or final disposal sites generates leachate (liquid pollutants resulting from decomposition). Leachate is a combination of waste and elements dragged within the waste itself. The amount of leachate generated is directly related to several factors, including precipitation, evapotranspiration, surface runoffs, infiltration, and waste compaction degree (2).

Phytoremediation —a simple, economical, and environmentally-friendly method— has been implemented during the last years to treat leachate. It consists of using plants to remediate or mitigate water pollution (3).

Common water-hyacinth and water lettuce develop in nutrient-abundant waters (phosphorous, potassium, and nitrogen) and, as a result of their high growth rates, are considered as invasive aquatic weeds (4). However, they have important characteristics that can be used to restore water bodies, including the absorption of pollutants from their environment. Since macrophytes can assimilate water pollutants, they have been used to detect and remove pollutants from domestic and industrial sewages (5). According to several studies, water lettuce is a plant used for bioremediation, because it has a 15% potential of removing pollutants. For its part, the common water-hyacinth has similar morphological and pollutant-capture characteristics.

Therefore, the phytoremediation capacity of *E. crassipes* (common water-hyacinth) and *P. stratiotes* (common lettuce) exposed to water polluted with leachate was evaluated. The objective was to prove that the combined use of these plants can remove leachate from polluted water.

MATERIALS AND METHODS

The leachate was collected in 20 L demijohns from the leachate lagoon of the El Guayabo landfill, Medellín, Veracruz, Mexico. Subsequently, the demijohns were transported to the lab, where they were stored and kept at room temperature.

The common water-hyacinth and water lettuce were obtained from the artificial wetland located within the facilities of the Tecnológico de Boca del Río, Veracruz, Mexico. Once the healthy plants were collected, they were washed and distributed in the different treatments.

The plants were placed in 40 L plastic containers (55×38×33 cm). Three treatments were carried out with 30% leachate. Treatment A (TA) consisted of 75% water lettuce + 25% common water-hyacinth, while treatment B (TB) was made up of 50% water lettuce + 50% common water-hyacinth. Control (TE) consisted of 30% leachate, without plants.

The study lasted 21 days and water turbidity, nitrite, and COD were analyzed. A WGZ-200 turbidity meter was used to determine the nephelometric turbidity units (NTU), following the NMX-AA-038-SCFI standard (2001). Nitrite was measured based on the NMX-AA-099-SCFI standard (2006). Fifty mL of the filtered and diluted sample were poured into a flask; 1.0 mL of sulfonamide solution was added to the flask and the mixture was vigorously shaken. Subsequently, 1.0 mL of N-(1-Naphthy) ethylenediamine dihydrochloride dilution were added. The mixture was allowed to rest for 10 minutes and then absorbency was measured at 543 nm. Meanwhile, the COD was determined according to the NMX-AA-030/2-SCFI standard (2011): 2.0 mL of the leachate diluted (1:25) sample were poured into glass tubes with screw caps. Afterwards, 1.0 mL of digestion solution and 2.0 mL sulfuric acid solution were placed in a digestion bale, at 150 °C for 2 h. Subsequently, a spectrophotometric reading (620 nm length) was carried out at room temperature. A calibration curve, built with potassium biphthalate, was used for the calculation. Removal efficiency was calculated with the following equation:

$$R = (Ic - Fc) / Ic \times 100$$

Where *R* is the pollutant removal (%), *Ic* is the initial concentration of the pollutant, and *Fc* is the final concentration.

RESULTS AND DISCUSSION

The treatments were kept under the following average environmental conditions: 25.08 °C temperature, 53.73% relative humidity, 1,418 lux light intensity, and 2,758.34 mW/m^2 irradiance. In average, the plants selected had a 100-g fresh weight, 12-cm long leaves, and 20-cm long roots.

After 21 days, the plants of both treatments with 30% leachate (TA and TB) were able to adapt to the conditions between day 3 and 4 (Figure 1). These results match the findings of Carrion (6), who compared the *Pistia stratiotes* and the *Azolla filiculoides* species and determined that the treatment was efficient after 21 days.

Other authors have reported that *P. stratiotes* was the most efficient macrophyte, because it reduced the turbidity by 2.80 NTU, reaching a 98.92% removal. These results match the findings of this study. *P. stratiotes* can easily adapt and have the capacity to live in different nutrient-saturated water bodies. Coronel-Castro (7) compared *Eichhornia crassipes* and *Lemna minor* and recorded that the former removed turbidity by >75%, proving that it removes more pollutants than the latter, as a consequence of its root system, whose associated microorganisms enabled the removal of organic compounds and the reduction of levels of physical parameters.

In order to evaluate the effectivity of plants in water polluted with leachate, the initial sample (30% leachate) was subjected to a physicochemical analysis. The results obtained were 28.586 NTU, 913.2 mg/L, and 65.934 mg/L for turbidity, COD, and nitrite, respectively. These data were used to determine the pollutant removal percentage of the treatments.

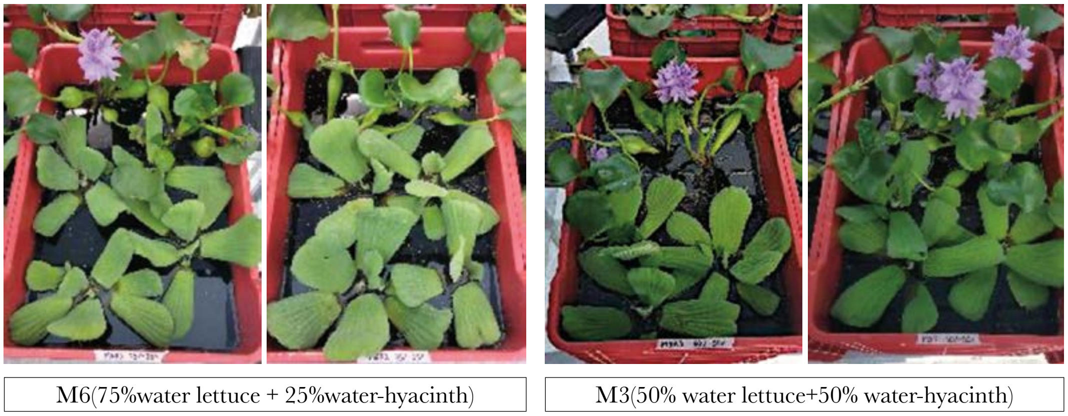

Figure 1. Common water-hyacinth and water lettuce treatments.

Table 1 shows the results after 21 days. Turbidity removal ranged from 91.90±1.82 to 95.02±3.34% in TA and TB, proving plant activity. Meanwhile, control recorded 71.45±0.58% turbidity removal. The same phenomenon happened with COD: the results fluctuated from 29.87±3.90 to 31.08±4.75%, proving the removal of chemical pollutants from water polluted with leachate; meanwhile, control recorded 18.80±4.65%. These findings match the reports of Vásquez (8) and Sayago (9). The former author experimented with wastewater from mines, while the latter used wastewater from tanneries. Both authors used combined or one-species treatments with *Pistia stratiotes* L. and *Eichhornia* in their evaluations. They pointed out that good results can be obtained for the removal of biological and chemical oxygen pollutants, even using artificial wetlands.

Abbas (10) proved the effective phytoremediation of leachate using water lettuce and common water-hyacinth for a 15-day period. The results of this study match Abbas and Camacho (11). The latter author carried out a similar experiment using *Eichhornia crassipes* to treat wastewater and recorded a significant reduction of COD in the evaluated treatments.

Finally, nitrite values ranged from 94.54±1.54 to 96.60±0.51% and recorded a higher reduction percentage than control (83.22±0.51%).

Nitrogen absorption was the result of the plant's biological pathway (ammonification, nitrification, denitrification, nitrogen capture, biomass assimilation and fixation, and nitrate de-assimilation reduction). Denitrification is the main nitrogen removal mechanism of the artificial wetlands (12).

The statistical analysis of the results —through the Student's t-test and the Tukey's Multiple Comparison Test— indicated that TA and TB did not record significant differences regarding turbidity, nitrite, and COD parameters (Figures 2a, 2b, and 2c); however, control recorded significant differences. Except in the case of COD (Figure 2b), TA did not record significant differences regarding TE. Nevertheless, TB was significantly different than TE. Consequently, TB was the best treatment for pollutant reduction.

CONCLUSIONS

The *Pistia stratiotes* and *Eichhornia crassipes* phytoremediation treatments can tolerate a 30% landfill leachate. The treatment with a 50:50 ratio of *Pistia stratiotes* and *Eichhornia crassipes* (TB) increased the efficient removal of pollutants from a 30% diluted leachate. The efficiency of *Pistia stratiotes* and *Eichhornia crassipes* as phytoremediation plants reduced pollutants from the leachate of the El Guayabo landfill.

Table 1. Mean values of the turbidity, COD, and nitrite parameters and percentage of removal per treatment (±SD).

Traeatments	Turbidity (NTU)	Removal (%)	COD (mg/L)	Removal (%)	Nitrite (mg/L)	Removal (%)
TE	8.16±0.16	71.45±0.58	741.56±42.47	18.80±4.65	11.06±0.34	83.22±0.51
T1	2.32±0.52	91.90±1.82	640.44±35.64	29.87±3.90	3.60±1.02	94.54±1.54
T2	1.42±0.95	95.02±3.34	629.33±43.33	31.08±4.75	2.24±0.34	96.60±0.51

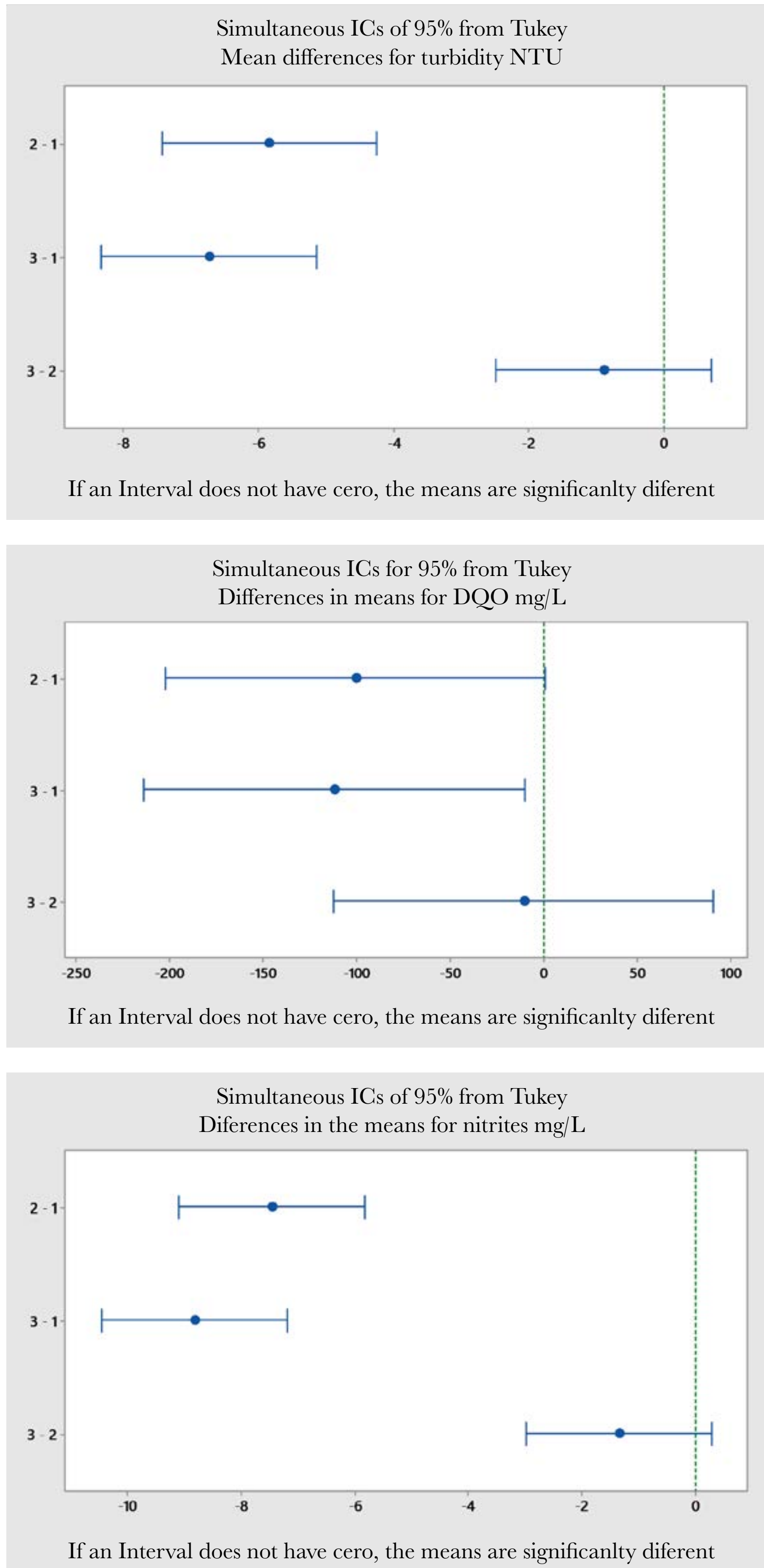

Figure 2. Comparative analysis of the parameters per treatment: a) turbidity; b) COD; and c) nitrite.

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