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Performance Evaluation of *Eichhornia crassipes* and *Pista Stratiotes* for Treatment of Aquaculture Wastewater

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Abstract

The significance of wastewater management and disposal in aquaculture is growing steadily as a result of strict water regulations pertaining to the release of waste into natural water systems. The conventional methods are expensive to manage and thus, it is not sustainable especially in the developing countries. Therefore, the objective of this research is to utilize Eichhornia crassipes (Water hyacinth) and Pistia stratiotes (Water lettuce) in phytoremediation techniques as an environmentally friendly method, while also examining their effectiveness in decreasing the amount of aquatic waste pollutants before they are discharged. The plant samples were cultivated in plastic containers filled with 10 L of aquaculture effluent for different retention periods of 7, 14, 21, and 28 days. Each container received 100g of plant samples. Water samples were collected from each treatment and analyzed for various physicochemical parameters including temperature, pH, dissolved oxygen (DO), chemical oxygen demand (COD), electrical conductivity (EC), Ammonium-Nitrate (NH_4-N), Nitrate (NO_3), total dissolved solids (TDS) and Phosphate (PO_4) using standard methods. The two aquatic plants were discovered to have effectively decreased the concentration of aquatic waste pollution load. It is evident that these plants successfully treated the wastewater to comply with the effluent standards set by national and international regulatory agencies. It can be inferred that discharging untreated aquaculture wastewater could end in severe environmental problems for humans, aquatic life, and ecological diversity, as all pollution indicators exceed the tolerance limit.

Keywords Aquaculture effluent, bioremediation, physicochemical parameters, pollution, treatment, macrophytes

INTRODUCTION

Water is a vital necessity for every living organism, but when it becomes polluted, it poses a threat to the existence of ecosystems. The pollution of water resources has emerged as a major concern worldwide owing to various factors including industrialization, globalization, population expansion, urbanization, warfare, rising affluence, and extravagant lifestyles. Water resources face significant risks due to pollution caused by human activities and improper agricultural drainage from rivers. Proper management and disposal of wastewater in aquaculture is gaining significance as a result of strict water regulations concerning waste release into natural water bodies. The treatment of aquaculture wastewater poses a significant challenge for the aquaculture sector. Aquaculture involves the cultivation, breeding, and harvesting of aquatic organisms like fish, shellfish, prawns, and algae in both freshwater and seawater. Its primary

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objective is to provide sustenance for humanity while also safeguarding the environment. Aquaculture is a rapidly expanding sector within the global food economy. Over the past ten years, the value and volume of global aquaculture production have doubled, making it one of the fastest-growing industries. In fact, aquaculture now provides one-third of the seafood consumed worldwide. The majority of this production is concentrated in Asia, which accounted for 88.91% of the volume in 2014. Given the increasing global population, it is evident that aquaculture will play an even more significant role in meeting future food demands [1-3].

Aquaculture systems generate significant amounts of wastewater that contain various substances, such as suspended solids, total nitrogen, and total phosphorus. The accumulation of these substances can increase the vulnerability of fish to parasites and pathogens, and also poses a risk to the environment. With the growing demand for fish, aquaculture has become indispensable. However, the quantity of waste produced is directly proportional to fish production. Hence, it is vital to develop more advanced fish farming techniques that integrate efficient wastewater treatment systems. Conventional wastewater treatment methods, encompassing physical, chemical, and biological processes, have been effectively implemented in aquaculture systems.

Aquaculture effluent consists of waste materials from fish and nutrients that are not fully utilized by the fish. The discharge of waste from aquaculture into natural water sources affects both the quantity and quality of the waste thus, there is need for diverse strategies to address water quality concerns in the surrounding ecosystem. The primary cause of the deterioration in water quality is the accumulation of waste resulting from excessive feeding rates and the elevated nutrient content in the fish's diet, which are frequently observed in intensive aquaculture systems. Biological treatment techniques utilize plants, microorganisms, and other naturally occurring materials to remove nutrients and pollutants from discharged wastewater and it has proven to be a cost-effective and environmentally friendly. Some microalgae species, have been investigated and found to be efficient and promising in removing waste from industrial wastewater including Phormidium, Botryococcus, Chlamydomonas, and Spirulina Chlorella, Scenedesmus, *Cladophora glomerata*, *Oedogonium westii*, *Vaucheria debaryana* and *Zygnema insigne* for industrial waste water treatment [4-6].

Many scientists have explored the applications of different types of plants, including terrestrial and aquatic plants for phytoremediation of wastewater such as Pistia stratiotes, E. crassipes, azolla filiculoides and lemna minor, water cabbage, cattail, duckweed, water lettuce, giant salvinia, Desmodesmus armatus, and water lily for domestic wastewater. The efficiency of *Salvinia molesta* in the removal of heavy metals from municipal waste. Some hydrophytic species, including cattail, water hyacinth, duckweed, and water cabbage were studied for their potential in treating industrial waste. Hence, the objectives of this research were to analyze the identified pollutants in aquaculture effluent and assess the efficiency of water hyacinth and water lettuce in removing these pollutants from aquaculture effluent [7-9].

Study Area

The study area is Yenizue-gene, Yenagoa, Bayelsa state, Niger Delta, Nigeria. The plotted position is Latitude and Longitude coordinates are: N 4° 52' 3.9972", E 5° 53' 55.3704" Bayelsa State located in the South South region of Nigeria, with the total area exceeding 8,000 square miles [10-12].

Collection of Aquaculture Effluent

Effluent from the catfish was collected early morning at 6.30am from a semi-earthen pond measuring 4 m x 4 m x 6 m, which containing the catfish. To ensure the preservation of the sample and prevent it from getting mixed with other elements, the aquaculture effluent samples was collected specifically on non-rainy days. The grab technique was employed to collect the aquaculture effluent sample. Before introducing the aquatic plants into the aquaculture effluent, they were acclimatized in a plastic tank filled with distilled wate. For the experiment, wastewater samples of 10 liters each were collected in 15

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plastic containers. The selection of 10 liters of aquaculture effluent per cleaned and sterilized plastic container was done carefully to account for the volume of the aquaculture effluent samples that would be collected and utilized for the physicochemical analyses in the laboratory. The effluent and aquatic plants were collected between the 15^{th} and 26^{th} of August, 2022 [13-15].

Laboratory Analysis

The physicochemical parameters were assessed using the techniques outlined in the by APHA in 1998 and 2005. In the lab, seven physicochemical characteristics were examined. Phosphate, nitrite, Ammonia, Chemical Oxygen Demand (COD), Electrical Conductivity (EC), Total Dissolved Solid (TDS) and $p^{H.}$ [16-20].

Statistical Analysis

The results were subjected to statistical analyses for analysis of variance (ANOVA) and descriptive statistics. Probability significance was affirmed at p<0.01, p<0.05 and p<0-001.

RESULTS AND DISCUSSION

The Phosphate concentration in aquaculture wastewater showed a decrease as the water hyacinth retention time increased to 28 days. The values varied from 1.085±0.55 mg/L (Day 28) to 4.69±0.01 mg/L (Day 1) for water hyacinth, and 1.2275±0.078 mg/L (Day 28) to 4.69±0.01 mg/L (Day 1) for water lettuce (Figure 1). The percentage reduction of phosphate by water hyacinth and water lettuce were 76.87% and 73.83% respectively. Water hyacinth exhibited a higher purification performance in reducing phosphate content in aquaculture wastewater. The acceptable limit for Phosphate concentration ranged between 0.1-1.0. The obtained result for phosphate after 28 days was slightly above the recommended value. The reduction in phosphate levels observed in all treatments can be ascribed to the actions of microorganisms that employ phosphate for their metabolic activities. Both plants and microbes rely on dissolved inorganic phosphorus for essential processes such as photosynthesis, chemosynthesis, and decomposition [21-23].

The Nitrate concentration decreased throughout the 28-day retention periods. The average concentration of Nitrate ranged from 0.129±0.02 mg/l on Day 28 to 0.62±0.01 mg/l on Day 1 for water hyacinth, and from 0.15975±0.004 mg/l on Day 28 to 0.62±0.00 mg/l on Day 1 for water lettuce as shown in Figure 2. The Nitrate values obtained after 28 days of treatment fell within the acceptable limit set by 0.07-0.37 mg/l. The percentage reductions of Nitrate concentration in aquaculture wastewater were 79.19% for water hyacinth and 74.23% for water lettuce. Water hyacinth had a higher efficiency in reducing nitrate content in aquaculture wastewater. The observed decrease in Nitrate concentration could be adduced to the uptake of nitrogen by plants enhanced by microorganisms, a process known as denitrification or ammonia volatilization. The ammonium-nitrogen concentration decreased throughout the 28-day residency period. The mean ammonia concentration for water hyacinth varied from 0.3±0.05 mg/L on Day 28 to 2.74±0.01 mg/L on Day1, while for water lettuce differed from 0.3675±0.0675 mg/L on Day 28 to 2.74±0.02 mg/L on Day 1 (Figure 3). Water hyacinth and water lettuce effectively reduced the ammonia concentration to permissible level by EPA (2010) (0.01-2.0 mg/L). The percentage reduction efficiency in ammonium-nitrate using water hyacinth and water lettuce as phytoremediators were 89.05% and 86.59% respectively. The results indicated that water hyacinth was more efficient in reducing ammonia concentration in aquaculture effluent. The decrease in ammonia levels over time could be traced to ammonia volatilization [24-27].

Effendi (2003) reported that COD is the quantity of oxygen necessary to oxidize organic matter, whether it can be biologically degraded (biodegradable) or is resistant to biological degradation into CO_2 and H_2O. The concentration of Chemical Oxygen Demand in fish wastewater decreased on average over the 28-day retention period. The COD concentration of the fish wastewater ranged from 23.5±0.06 mg/L on Day 28 to (40.3±0.01mg/L) on Day 1 for water hyacinth, and 27.125±0.58 mg/L on Day 28 to 40.3±0.00 mg/l on Day 1 for water lettuce (Figure 4). The treatment of catfish wastewater using water

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hyacinth and duckweed was effective in meeting the acceptable limit of 30.0 mg/L. In accordance with the regulations outlined by the Department of Environment (DoE), the Department of Public Health Engineering (DPHE), and the World Health Organization, the acceptable threshold of COD for drinking purposes stands at 4 mg/L. On other hand, USEPA (2012) has established an irrigation standard of 200 mg/L. Based on the analysis of the effluent samples, it can be concluded that they are not suitable for drinking, domestic, or agricultural use. The COD percentage reduction for water hyacinth and water lettuce were 41.69% and 32.69% respectively. Water hyacinth showed a higher capacity to reduce the concentration of COD in catfish wastewater. The values of Electrical Conductivity decreased over the 28-day period of the experiment. The EC of fish wastewater ranged from 3734±0.00µS/cm on Day 1 to 454.25±10.25 µS/cm on Day 28 for water hyacinth, and 744.5±23.5µS/cm on Day 28 to 3734±7.65 µS/cm on Day 1 (Figure 5). [28-32] The results obtained surpassed the acceptable thresholds set for drinking water (700 mS/cm) and irrigation water (1000 mS/cm), with the exception of the effluent sample at the 28th day retention time for both plants. Therefore, water samples taken before the 28th day retention time are not suitable for drinking, household use, recreational activities, or agricultural purposes. Both aquatic plants were unable to meet the acceptable limit recommended, which ranged from 340-700 µS/cm. The percentage reduction in Electrical Conductivity for water hyacinth and water lettuce were 87.83% and 80.06% respectively.

The Total Dissolved Solids decreased over the period of experiment. For water hyacinth, TDS ranged from 265.5±6.5mg/L on Day 28 to 1865±0.00mg/L on Day 1, while for water lettuce, it ranged from 440.25±8.25mg/L on Day 28 to 1865±0.00mg/L on Day 1 (Figure 6). Based on the guidelines provided by the World Health Organization in 2017, the United States Environmental Protection Agency in 2012, and the Department of Public Health and Environment in 2019, the acceptable levels of Total Dissolved Solids ranged between 500 and 600 mg/L. Therefore, all TDS measurements taken on the 28th day were found to be within the acceptable limits.

According to the Department of Environment (1997), the permissible TDS limit for irrigation is 2,000 mg/L. This indicates that the aquaculture effluent samples were deemed appropriate for irrigation purposes, but not suitable for domestic use like bathing and drinking [33-37].

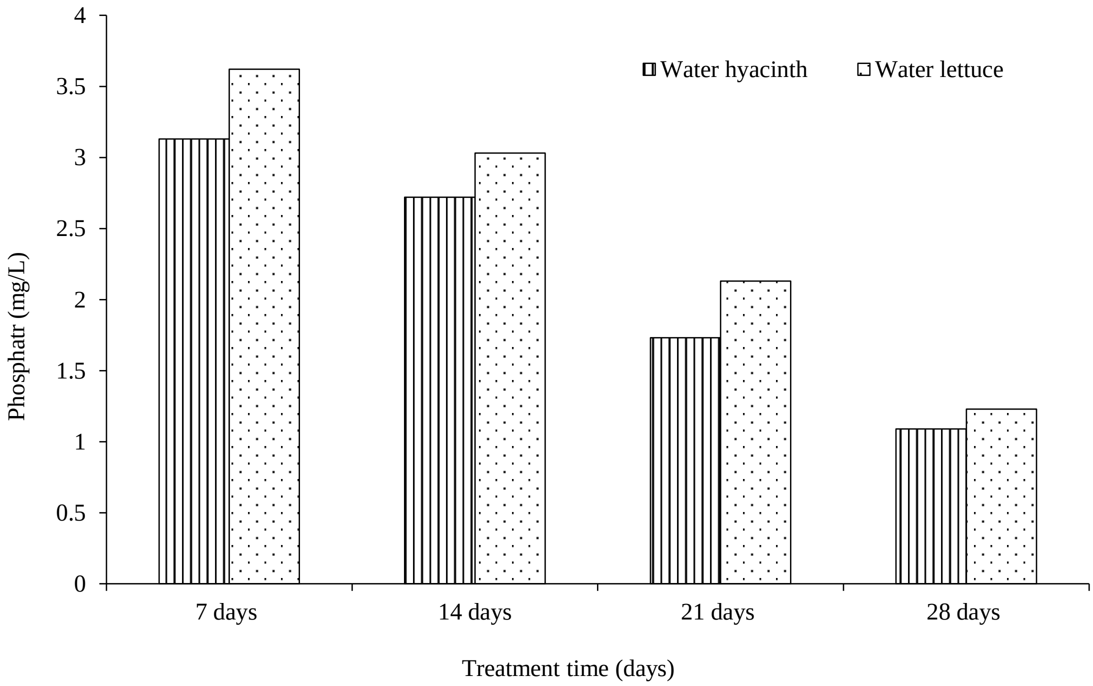

Figure 1. Phosphate concentration of aquaculture effluent.

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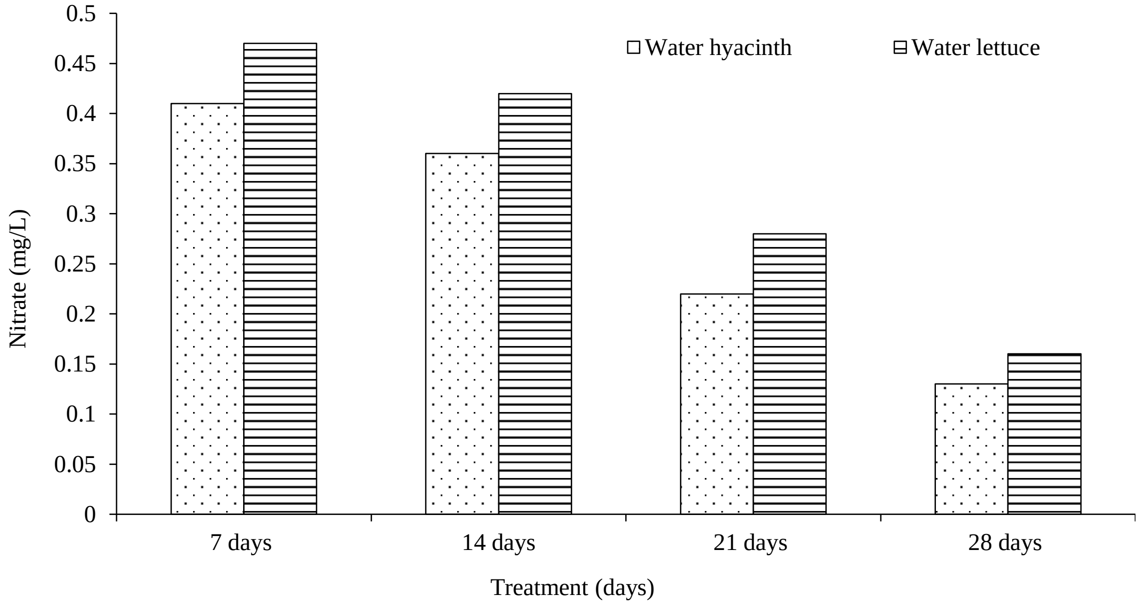

Figure 2. Nitrate concentration of aquaculture effluent.

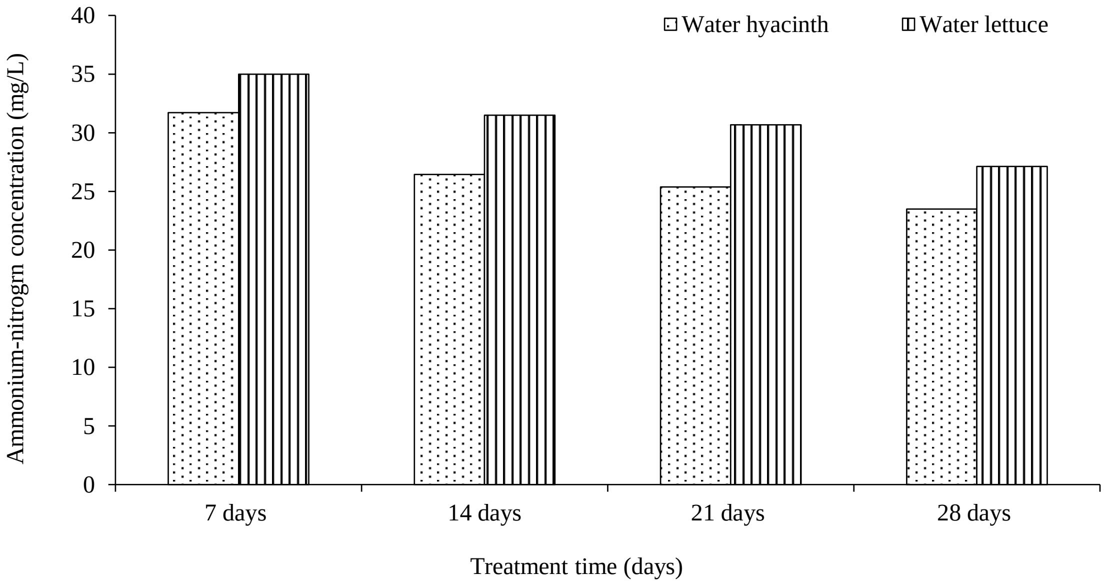

Figure 3. Amonium-mitrogen concentration in aquaculture effluent.

The p^H is a significant factor when assessing the quality of water. The water's p^H level is a measure of its acidity or alkalinity. Moreover, it gives an approximation of the amount of free hydrogen and hydroxyl ions in the water. The p^H of aquaculture wastewater increased throughout the 28-day experiment. The average p^H value varied from 6.2±0.11 on Day 1 to (7.475±0.08) on Day 28 for water hyacinth, and from 7.25±0.05 on Day 28 to 6.2±0.14 on Day 1 for water lettuce (Figure 7). The p^H of the wastewater was slightly acidic to alkaline. Water hyacinth and water lettuce were able to enhance p^H to meet the recommended p^H limits of 6.5-8.5. The acceptable p^H range is 6.5-8.5, while the ideal limit for irrigation and aquaculture falls within 6.5 and 8.0. Remediation process is facilitated by microorganisms that break down organic matter in wastewater, influenced by photosynthetic activity that absorbs dissolved CO_2 as H_2CO_3, resulting in a pH increase. Thus, maintaining a stable p^H during phytoremediation creates a pliable environment for microorganisms and selected plants to efficiently degrade and absorb pollutants [38-42].

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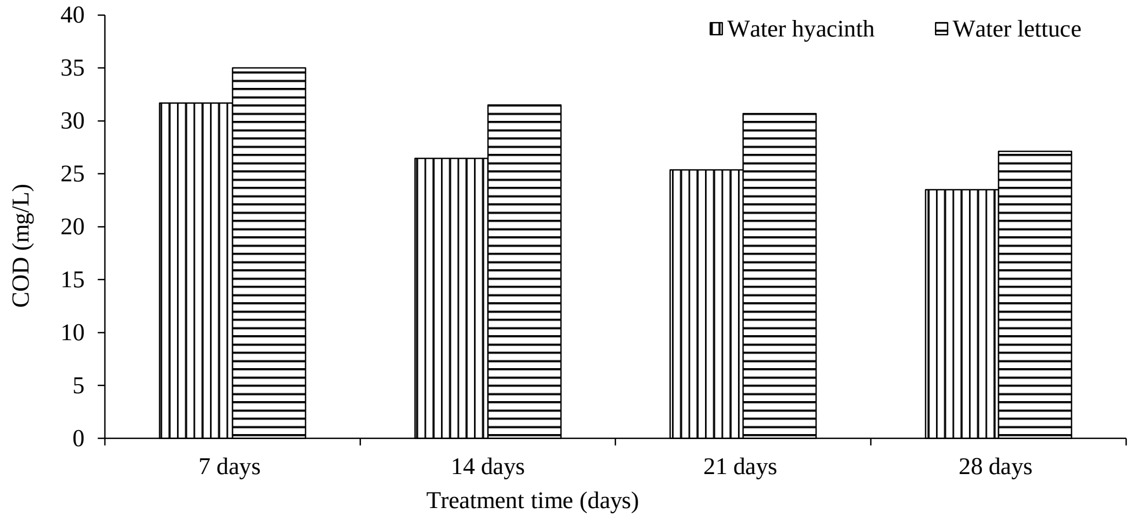

Figure 4. Chemical Oxygen demand of aquaculture effluent.

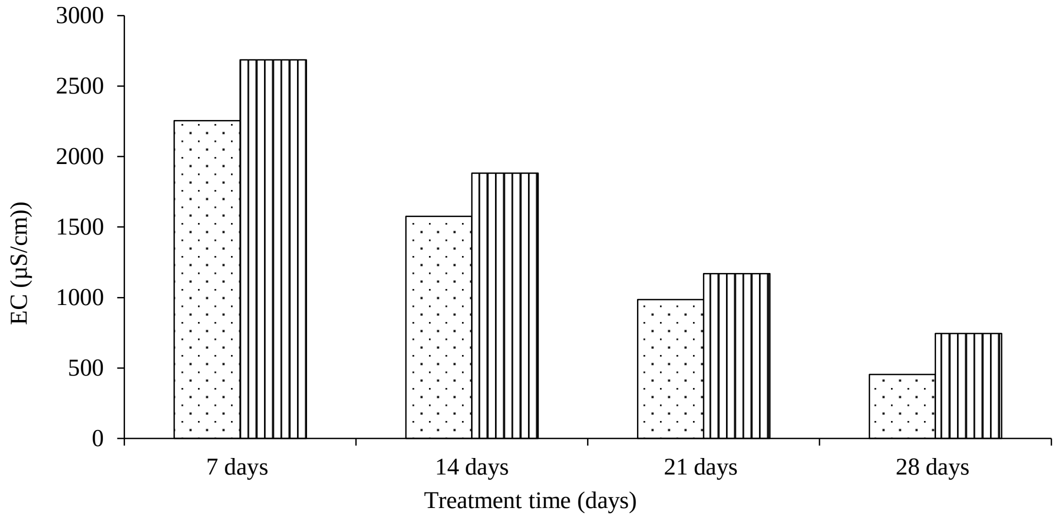

Figure 5. Electrical conductivity of aquaculture effluent.

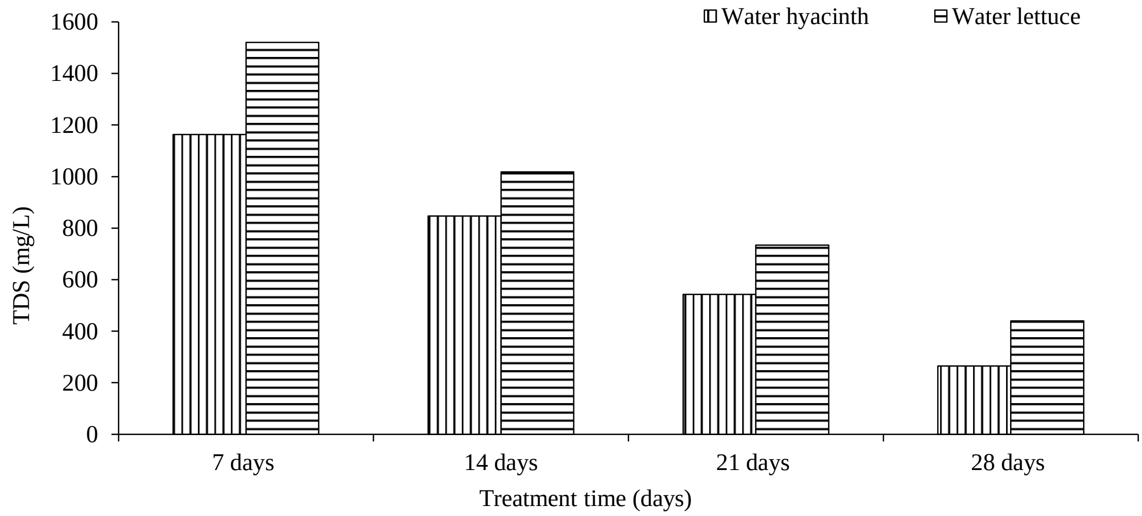

Figure 6. Total dissolved solids concentration of cassava effluent.

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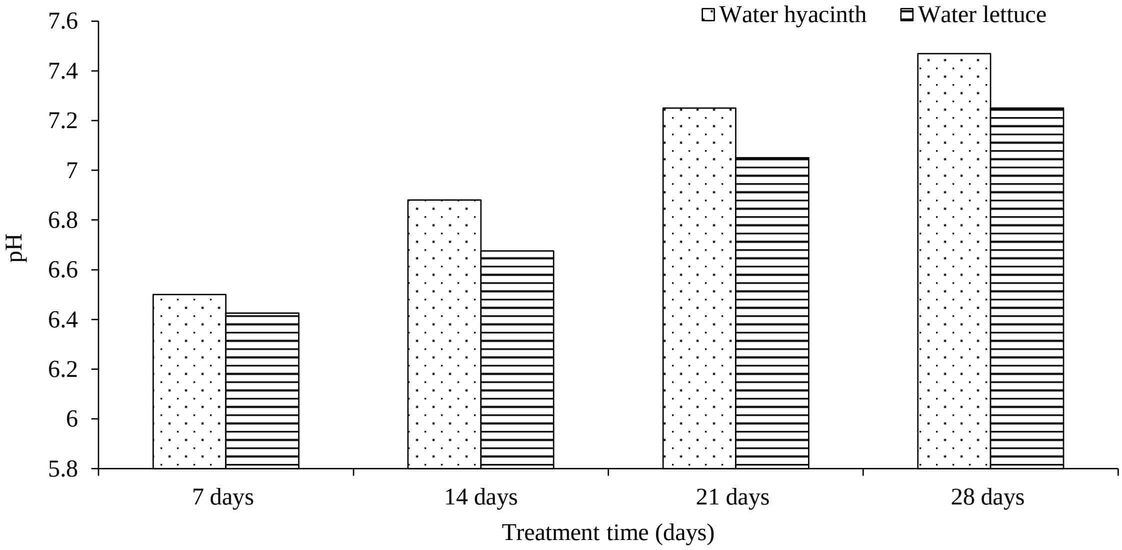

Figure 7. Power of hydrogen of aquaculture effluent.

CONCLUSION

The characterization of aquaculture effluent was found to contain high contaminants and this is higher than acceptable limits set by the World Health Organization standards and national regulations. Therefore, if this effluent is discharged without proper treatment, it will have a negative impact on the environment. The two aquatic plants showed a significant positive influence in reducing the concentration of pollutants over time. The cultivation time of these plants in the aquaculture effluent was found to have a very significant effect on the efficiency of removing contaminants. Some physicochemical parameters results on the 28th day fell within the permissible limits such as Nitrate, ammonium-nitrogen, Chemical Oxygen Demand and pH. The water hyacinth demonstrated better performance in remediating certain physicochemical parameters that were studied. Phytoremediation technique is cost-effective, sustainable, environmentally friendly, and green technology for treatment of wastewater.

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