

Water Hyacinth (*Eichhornia crassipes*) as Phytoremediator of Abattoir Contaminated Effluents

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Abstract

The abattoir industry provided meat for more than 170 million Nigerians and job opportunities for teeming population. It has also been categorized as one of the industries responsible for major pollution of soil and water resources. The aim of this study was to analyze the pollutants present in the effluents from the selected abattoir and evaluate the effectiveness of water hyacinth (*Eichhornia crassipes*) in removing these pollutants. The experiment was conducted in the laboratory, where water hyacinth was cultivated hydroponically to remediate the contaminated abattoir wastewater. The findings demonstrated that a number of the abattoir effluent's physicochemical parameters—temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), turbidity, nitrate (NO_3^-), ammonia ($\text{NH}_3 + \text{N}$), and phosphate (PO_4^{3-})—exceeded the recommended limits. The pH ranged from 6.33 ± 0.03 (control) to 8.00 ± 0.03 (28 days). The EC of the abattoir wastewater after 28 days of planting in the effluent ranged from 347 ± 4.23 to $3582 \pm 15.38 \mu\text{S}/\text{cm}$ for the control. The mean values of TDS, TSS, biochemical oxygen demand (BOD), chemical oxygen demand (COD), DO, and turbidity were found to be statistically significantly ($p < 0.05$). These findings indicate that the physicochemical parameters of the abattoir effluent exceeded the permissible levels recommended by international and national environmental agencies. Therefore, discharging this effluent without proper treatment could pose serious environmental problems for humans, aquatic life, and biodiversity.

Keywords: Water quality parameters, industrial effluents, aquatic plant, sustainable water management

INTRODUCTION

The abattoir industry has played a vital role in supplying meat to over 170 million Nigerians and creating job opportunities for a significant number of people [1]. However, it has also been recognized

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as one of the industries contributing to considerable pollution of soil and water resources. This pollution is mainly due to the inadequate treatment of effluent, as highlighted by the US Environmental Protection Agency [2] and Dhanwal et al. [3]. Aniebo et al. [4]. reported the volume of blood obtained from one cow slaughtered is equal to the combined effluent output of 50 people in a day. Despite the potential for economic growth and development that the meat processing industry offers, it poses a significant environmental challenge due to the lack of proper waste treatment facilities. The absence of strong regulatory policies is the cause of this shortage of suitable waste treatment facilities. Slaughterhouses discharge high levels of organic and inorganic pollutants into the environment or nearby rivers without sufficient

pretreatment facilities, surpassing permissible limits [5–7]. Fan et al. [8] highlighted the need of promoting environmental sustainability and trash management. Many researchers opined that domestic and industrial wastewater should undergo proper treatment prior discharged into the environment for the safety of both the public and the environment [9–14]. Wastewater treatment methods are categorized into three areas based on the findings of Shahedi et al. [15]: chemical, physical, and biological processes. Different types of conventional methods have been utilized to eliminate contaminants from industrial and domestic wastewater, such as electrochemical techniques, ion exchange, disinfection, coagulation, chemical precipitation, adsorption, ultraviolet irradiation, membrane filtration, floatation, advanced oxidation processes, and biological treatments [16–29]. These methods have significantly improved contaminant removal, but they come with drawbacks, including high costs, implementation and maintenance, particularly for advanced treatments, as well as the risk of secondary contamination from toxic sludge formation [30]. On the other hand, phytoremediation, which involves using green plants like grass and woody species to clean up polluted soils, groundwater, and wastewater, is considered a cost-effective, energy-efficient, environmentally friendly, and sustainable approach. This technique shows great potential in tropical regions because of the favorable climatic conditions that promote plant growth and microbial activity. Scientists have underscored the efficacy and cost-effectiveness of phytoremediation, emphasizing the significance of choosing plant species capable of thrive in toxic contaminants [31–34]. Hyper-accumulator plants like *Azolla filiculoides*, *Lemna minor*, *Typha latifolia*, and *Eichhornia crassipes* are capable of accumulating heavy metals in their shoots and roots at higher concentrations, making them valuable assets in remediation efforts [35–39].

According to the studies conducted by Katarzyna and Baum [40], Manan et al. [41], Davies et al. [42], and Sharma and Malaviya [43], it has been suggested that phytoremediation technology is gaining more acceptance due to its ability to effectively restore large areas of contaminated land and water caused by human activities. Abu and Davies [44]. have also emphasized the importance of phytoremediation, particularly in tropical regions where favorable climatic conditions promote plant growth and enhance microbial activities. Certain hydrophytes such as *Typha latifolia*, giant salvinia, *Pistia stratiotes*, *Lemna gibba*, and *Eichhornia crassipes* have been identified as effective absorbers of contaminants, especially heavy metals in wastewater [30, 37]. Therefore, the main objectives of this study were to analyze the pollutants present in abattoir effluent and assess the efficiency of water hyacinth in removing these pollutants.

MATERIALS AND METHODS

Study Area

The Trans-Amadi Slaughterhouse in Port Harcourt, Rivers State, Niger Delta, Nigeria, is the location of the study site. It is located between longitudes 50'1" and 70'2" east of the Greenwich meridian and latitudes 40'2" and 60'2" north of the equator.

Collection and Processing of Water Hyacinth (*Eichhornia crassipes*)

Three 50 m × 50 m clay fish ponds at the African Regional Aquaculture Centre (ARAC) in Aluu, Obio Akpor Local Government Area, Port Harcourt, Rivers State, Nigeria, were used to collect water hyacinth. The aquatic plants that had been gathered were then carefully moved to the lab. In order to ensure the purity of the samples, they were meticulously sorted to eliminate any debris or foreign substances present on the plants. Furthermore, precautionary measures were taken to exclusively select fresh, healthy, and mature plants for the experiment. To eliminate any potential pollutants from their natural habitat, the chosen plants underwent a gentle washing and rinsing process using clean water.

Experimental Setup

The water hyacinth plants in the abattoir effluent were grown in circular hydroponic non-flow units measuring 25 cm in size and 25 cm in height. To maintain cleanliness, the tanks were thoroughly washed with distilled water. Prior to being introduced to the effluent, the water hyacinth plants were acclimatized in a plastic tank filled with distilled water. Each experiment was replicated three times,

including a control group. Afterwards, all 15 hydroponic non-flow units were filled with 10.0 L of abattoir wastewater sample. After weighing 125 g and being sorted appropriately, the plants were subsequently placed in the various hydroponic non-flow units. Throughout the trial, sufficient aeration and exposure to sunlight were guaranteed. Data was collected every week and observations were made every day. With sunlight as their primary energy source, most of the plants were active during the day. Over the course of 28 days, waste water samples were taken once a week and subjected to analysis for a number of physicochemical characteristics, including pH, temperature, and electrical conductivity. The analysis was conducted using the standard methodology described by the American Public Health Association (APHA) in 1998 and 2005 [45, 46].

Statistical Analysis

Both descriptive statistics and analysis of variance were examined through statistical analysis of the data. At $p < 0.05$, the significance level was verified.

RESULTS

Power of Hydrogen

The mean pH varied from 6.25 ± 0.02 (control) to 8.00 ± 0.03 (28 days) (Table 1). The effluent is slightly alkaline in nature. The effluent showed the presence of metallic ions in the solution. The percentage increased in the pH of effluent ranged from 21% to 26%. The pH of the control sample showed a slight acidity initially, but as the retention time increased, it gradually became slightly alkaline by the end of the 28th day.

Electrical Conductivity

Following a 28-day treatment period, the electrical conductivity (EC) of abattoir wastewater varied from 347 ± 4.23 on day 28 to 3582 ± 15.38 $\mu\text{S}/\text{cm}$ on day 1 (Table 1). There were statistically significant variations between the mean EC values ($p < 0.05$).

Total Dissolved Solids

Table 1 shows that total dissolved solids (TDS) ranged from 361 ± 8.36 mg/L to 2560 ± 13.72 mg/L. Compared to the control sample, the plant samples had lower concentrations. During the time of cultivation, the plants most likely absorbed some pollutants. There were statistically significant variations between the mean TDS values ($p < 0.05$).

Total Suspended Solids

The control sample's mean total suspended solids (TSS) contents were 2560 ± 13.72 mg/L. The levels of duckweed, lettuce, and water hyacinths in effluent ranged from 521 ± 4.27 to 2167 ± 6.82 mg/L (Table 1).

Table 1. Physicochemical parameters of abattoir effluent treated with water hyacinth.

Effluent parameter	Phytoremediation time (days)				
	0	7	14	21	28
Temperature ($^{\circ}\text{C}$)	29.5 ± 0.09	28.8 ± 0.02	29.1 ± 0.01	28.7 ± 0.02	28.1 ± 0.04
pH	6.25 ± 0.02	7.36 ± 0.03	7.86 ± 0.02	7.59 ± 0.05	8.00 ± 0.07
Electrical conductivity ($\mu\text{S}/\text{cm}$)	3582 ± 15.38	3263 ± 10.41	2134 ± 9.65	1089 ± 12.33	347 ± 8.41
Total dissolved solids (mg/L)	2560 ± 13.72	2089 ± 17.53	1736 ± 8.06	963 ± 5.23	361 ± 8.36
Total suspended solids (mg/L)	2246 ± 13.72	2167 ± 6.82	1672 ± 7.45	894 ± 5.37	521 ± 4.27
Dissolved oxygen (mg/L)	1.46 ± 0.02	2.13 ± 0.10	3.48 ± 0.08	4.31 ± 0.06	6.37 ± 0.07
Biochemical oxygen demand (mg/L)	1584 ± 10.51	1286 ± 8.74	615 ± 5.08	362 ± 5.23	317 ± 4.61
Chemical oxygen demand (mg/L)	3751 ± 14.72	2541 ± 10.14	1583 ± 9.85	836 ± 5.41	402 ± 5.62
Turbidity, NTU	28 ± 1.53	21 ± 1.43	18 ± 0.39	16 ± 0.75	14 ± 0.31
Nitrate NO_3^- -N mg/L	15.31 ± 0.09	9.27 ± 0.05	7.63 ± 0.01	5.01 ± 0.06	4.11 ± 0.03
Ammonia-nitrogen (mg/L)	17.83 ± 0.08	9.31 ± 0.04	5.32 ± 0.02	2.45 ± 0.01	0.62 ± 0.05
Phosphate (mg/L)	5.53 ± 0.02	3.27 ± 0.03	1.41 ± 0.01	0.76 ± 0.02	0.53 ± 0.01

Turbidity

Turbidity values ranged between 14 ± 0.31 (28 days) and 34 ± 1.53 NTU (control). The turbidity level in the analyzed water sample exceeded the World Health Organization (WHO)-recommended standard of 5 NTU, making it unsuitable for domestic and irrigation purposes as none of the treated wastewater met the permissible limits.

Phosphate (PO_4^{3-})

The mean phosphate values varied from 4.11 ± 0.03 (28 days) to 15.31 ± 0.09 (control). The results of analysis of variance indicated that the mean values of phosphate at different retention time proportions showed significant difference at $p < 0.05$.

Nitrate

With the exception of the control sample, all treated wastewater contained NO_3^- amounts that were within the allowable WHO limit. The mean values varied from 4.11 ± 0.03 (control sample) to 15.31 ± 0.09 (28 days retention time).

Dissolved Oxygen

With the exception of the control sample, all treated wastewater contained dissolved oxygen (DO) amounts that were within the allowable WHO limit.

Biochemical Oxygen Demand

The control sample's mean biological oxygen demand (BOD) values were 1584 ± 10.51 mg/l. The levels of duckweed, lettuce, and water hyacinths in effluent ranged from 317 ± 4.61 to 1286 ± 8.74 mg/L (Table 1). According to the effluent characterization, the average BOD concentration released into the environment from the abattoir slaughterhouse was 1584 ± 10.51 mg/L.

Chemical Oxygen Demand

The control sample's mean chemical oxygen demand (COD) values ranged from 402 ± 5.62 to 3751 ± 14.72 mg/L (Table 1). Compared to the control sample, the plant samples had reduced COD concentrations. According to the wastewater characterization, the average concentration of COD released into the environment from the abattoir slaughterhouse was 3751 ± 14.72 mg/L.

DISCUSSION

There was a notable difference in the average pH values across various phytoremediation durations at a significance level of $p < 0.05$. The treated effluent's pH levels complied with the acceptable limits, with the exception of the 28-day retention time. According to the WHO [47], drinking water should have a pH of 6.5 to 8.0. Nonetheless, according to Al-Janabi et al. [48], the treated effluent was within the range of 6.5 to 9.0, which was the allowable limit for irrigation and aquatic life. This shows that every treated effluent stayed within the suggested ranges. The average EC values of all treated effluents exceed $750 \mu\text{S}/\text{cm}$, with the exception of the 28th day retention time, in accordance with the guidelines set forth by WHO [49], Rahman et al. [50], and Nuraini and Felani [51] for domestic, recreational, agricultural, and soil health applications.

According to WHO, the acceptable range of total suspended solids (TSS) for drinking water is 10 mg/L. The acceptable limit for TSS in water intended for irrigation reuse should not surpass 2000 mg/L. Thus, it can be concluded that the treated wastewater is suitable for reusing in irrigation. The aquatic ecology may suffer as a result of the elevated TSS levels. By obstructing sunlight and reducing photosynthetic activity, high TSS levels can stress aquatic life [50, 51]. Therefore, before being released into the environment, wastewater that is discharged from its source must first undergo extra treatment. It was discovered that the measured TSS levels were noticeably greater than the drinking water standard. Numerous reasons, including excessive surface runoff, soil erosion, water waste, and the decomposition of plants and animals, are responsible for the elevated levels of TSS, according to Nuraini and Felani [51] and Davies and Davies [44]. The drinking water and aquatic life must adhere to the acceptable

limit of 5 mg/L, as stated by WHO [49]. Exceeding this limit can have detrimental effects on the ecosystem, including the growth of algae blooms, invasive plants, depletion of oxygen, fish mortality, and the formation of dead zones.

There was significant decrease in phosphate concentration over time, Haidara et al. [12] emphasized that the effectiveness of aquatic plants in absorbing nutrients improves as the retention time increases. Oh et al. [52] confirmed that an excess of phosphate can hinder the growth of any plant. However, these values were significant differences and fell within the allowable limits of WHO [49]. The WHO has set a permissible level of 10 mg/L. When nitrate concentrations exceed the WHO's tolerable levels, they can be extremely dangerous. Excess nitrate in the human body may exacerbate stomach cancer, according to a study by Aires et al. [53]. The detected DO values were below the 7.50 mg/L drinking water permitted limit set by Priya and Selvan [54] and the WHO [47]. The treated effluent samples had lower BOD contents than the control. This may be attributed to the plants' absorption of certain pollutants. Ashraf and associates. [55] found that roots play a crucial role in retaining microbes by providing them with essential nutrients. Additionally, roots supply oxygen to rhizospheric bacteria, which aids in the aerobic decomposition of organic matter [56, 57].

The acceptable limits for COD according to WHO [47] stipulated 500 mg/L for drinking water. Davies et al. [44] provide a definition of COD as the overall amount of oxygen that is anticipated to chemically oxidize organic substances, including both biodegradable and non-biodegradable materials, resulting in the production of CO₂ and H₂O. The implication of high COD concentration in the water will result to depletion in the dissolved oxygen thereby causing stress to aquatic organisms.

CONCLUSION

In this study, the abattoir effluent was characterized by measuring the physicochemical parameters, including phosphate, nitrate, ammonia, chemical oxygen demand, electrical conductivity, total dissolved oxygen, and pH. It was found that all the physicochemical parameters assessed were at variance with permissible limits as recommended by international and national agencies. Water hyacinth is proficient in remedying abattoir effluent with regards to cultivation time. The effectiveness of eliminating pollutants is significantly impacted by the duration of culture. Some of the physicochemical parameters of treated abattoir effluent at the end of 28 days fell within international and national permissible limits, including nitrate, ammonium-nitrogen, pH, electrical conductivity, biochemical oxygen demand, and chemical oxygen demand. According to these results, the phytoremediation method is economical, environmentally benign, and sustainable. Thus, it is imperative to treat the effluent prior the discharge to the environment to avoid menacing environment problems for human beings, aquatic lives, and ecodiversity.

Recommendation

The study utilized the longest cultivation period for water hyacinth in the abattoir effluent, which lasted for 28 days. The possible advantages of prolonging the culture period in terms of successfully eliminating pollutants require more investigation. In this experiment, 100 g of water hyacinth was used per 10 L of abattoir effluent. Exploring the effects of increasing the weight of water hyacinth could be beneficial for future studies.

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