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Assessment of Water Lettuce and Duckweed in Phytoremediation of Slaughter Effluent

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ABSTRACT

Background and Objective: In Nigeria, it is alarming that all the abattoirs have no wastewater treatment. Huge effluents are being directly discharged on a daily basis to the environment without being checked and controlled creating serious pollution risks to living organisms in the environment. The objective of this study was to characterize the selected abattoir effluent pollutants and also to evaluate the performance of water lettuce and duckweed in removing pollutants from abattoir effluent. **Materials and Methods:** Phytoremediation of slaughter-contaminated river water in Trans Amadi slaughterhouse, Port Harcourt, Rivers State was carried out using hydroponically cultivated water lettuce and duckweed. The physicochemical parameters investigated were physicochemical parameters: Temperature, pH, electrical conductivity (EC), total dissolved oxygen (TDS), total suspended solid (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), turbidity, nitrate (NO^{-3}), ammonia (NH_4^+N) and phosphate (PO_4) were conducted according to the standard methods. **Results:** The percentage increase in pH varied between 13.4 and 29.7% for water lettuce and 12.6 and 32.2% for duckweed. The percentage increase in EC varied between 6.4 and 87.1% for water lettuce and 5.4 and 86% for duckweed. The percentage increase in TDS varied between 15.4 and 82% for water lettuce and 14.6 and 79% for duckweed. The observed differences between the mean values of TDS, TSS, BOD, COD, DO and turbidity values were statistically significant ($p<0.05$) for both plants. **Conclusion:** It can be concluded that discharging abattoir water without prior treatment could lead to serious environmental problems for human beings, aquatic lives and Eco diversity since all pollution indices are far above the tolerance limit.

KEYWORDS

Abattoir wastewater, dissolved oxygen, duckweed, water lettuce, physicochemical parameters

INTRODUCTION

Thousands of animals are slaughtered on a daily basis in Nigeria. However, the huge effluent generated in these slaughterhouses is discharged without any adequate wastewater treatment facilities and this constitutes a grave danger to the environment and public health since there is no policy on abattoir management[1-5]. The abattoir effluent contains a lot of microorganisms which can easily contaminate groundwater, drinking water and water bodies rendering that water unfit for drinking, swimming, irrigation or any other purposes giving rise to a serious risk to living organisms in the environment[6-11].

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Many researchers affirmed that slaughterhouses are characterized by a lack of proper management and planning, no treatment facility, poor disposal mechanism and lack of legislative and monitoring action to handle the huge effluents that have resulted in the discharge of huge pollution loads of effluent from abattoirs directly into the rivers and environment without any prior treatment[11-16]. Wastewater from abattoirs poses a significant risk to both human health and the environment. These effluents have the potential to seep into the soil, contaminating groundwater with harmful substances such as nitrate and bacteria[17].

Studies conducted by Cao and Mehrvar[9] as well as Barrera *et al.*[10] have shown that microorganisms present in abattoir waste can be easily transmitted to individuals who come into contact with contaminated water sources, degrading water quality for drinking, recreational activities, or agricultural use.

It is expedient to create awareness and enlighten the populace in the area of waste and waste management to engender the significance of a global perspective of water resource management[2,18].

The physicochemical and organic characteristics of groundwater especially wells very close to the slaughterhouses were greatly distorted according to the findings of Chen *et al.*[17].

Singh *et al.*[19] and Adeyemo *et al.*[20] reported that wastewater discharges from abattoirs could cause a reduction in oxygen in the recipient water bodies, serious pollution of groundwater and enhanced breeding pathogens multiplication which is highly infectious diseases. Gil and Allende[21], Park *et al.*[22] and Matsumura and Mierzwa[23] reported the approximate quantity of potable water used in slaughter house operations for cattle, swine and poultry is 150 to 450 gal/cow, 15.3 to 320 gal/pig and 3.0 to 4.5 gal/chicken.

The various activities engaged in many abattoirs in Nigeria are not monitored for regulation purposes. The majority of the abattoirs in Nigeria are not developed and facilities for the treatment of abattoir effluents are lacking. The cause of pollution abattoir effluent is the high quantity of blood generated from slaughtering the animals[24]. It is highly imperative to effectively and efficiently treat effluent from slaughterhouses before being discharged to the environment to fulfil the requirements and standards proven by environmental legislation to preserve the ecosystem.

In recent times, many researchers have investigated the utilizations of various green technology plants such as aquatic weed plants in phytoremediation of wastewater for example water lettuce, giant salvinia and water hyacinth for domestic wastewater[25,26]. Other phytoremediation plants were also researched such as water hyacinth for cassava wastewater treatment[27]; Desmodesmus armatus was used to treat cassava wastewater[28]; *Pistia stratiotes* and *Eichhornia crassipes* in bioremediation of fish pond wastewater[29].

Furthermore, duckweed, water cabbage, water hyacinth and cattail for industrial waste treatment[30], *Azolla filiculoides* and lemna minor for livestock wastewater[31]. Four algae (*Cladophora glomerata*, *Oedogonium westii*, *Vaucheria debaryana* and *Zygnema insigne*) for industrial wastewater treatment[32]. Some hydrophytes were evaluated for industrial wastewater treatment[33]. *Salvinia molesta* was used for the removal of heavy metals from municipal wastes[34]. Ayaz *et al.*[30] evaluated four hydrophytes species such as *Typha latifolia* (cattail), *Eichhornia crassipes* (water hyacinth), *Lemna gibba* (duckweed) and *Pistia stratiotes* (water cabbage) for remediation of industrial waste. The following aquatic plants have been used for domestic wastewater treatment; water lettuce, giant salvinia and water hyacinth[25].

Thus, the objective of this study was to characterize the selected abattoir effluent pollutants and also to evaluate the removal efficiency of pollutants from abattoir effluent by water lettuce and duckweed as phytoremediators.

MATERIALS AND METHODS

Study area: The study area is Trans Amadi slaughterhouse, Port-Harcourt, Rivers State, Niger Delta, Nigeria. It is positioned between Latitudes 40°2" and 60°2" North of the equator, as well as Longitudes 50°1" and 70°2" East of the Greenwich meridian. The study was carried out from June 2022 to July 2022.

Sample collection: The effluent and two aquatic plants were collected between the 10th and 14th of June, 2022. A sterile container was utilized to collect wastewater samples from Trans Amadi slaughterhouse. The sterilized container was employed in an aseptic manner to collect fifteen samples of wastewater from the slaughter drainage system, specifically at the point where it exits the slaughter pavement to discharge to Oginigba River. Subsequently, the collected wastewater was promptly transported to the environmental laboratory; these procedures were conducted in accordance with the recommendation of Abu *et al.*[27].

Water hyacinth and duckweed were harvested from various earthen fishponds each having dimensions of length×breadth (50×50 m) at African Regional Aquaculture Centre (ARAC), Aluu, Obio Akpor Local Government Area, Port Harcourt, Rivers State. The harvested water hyacinth was kept in polyethene bags for onward transport to Agricultural and Environmental Engineering, Niger Delta University, Amassoma, Bayelsa State, Nigeria. The samples were sorted to avoid any trap matters on the plants. Only fresh, healthy and mature plants were selected for the experiment. The selected plants were gently and diligently washed and rinsed with potable water to avoid pollution which the plants might have carried from the natural habitat.

Sample collection: The harvested water hyacinth was kept in polyethene bags for onward to Agricultural and Environmental Engineering, Niger Delta University, Ammassoma, Bayelsa State, Nigeria. The samples were sorted to avoid any trap matters on the plants. Only fresh, healthy and mature plants were selected for the experiment. The selected plants were gently and diligently washed and rinsed with portable water to devoid pollution which the plants might have carried from the natural habitat. The abattoir wastewater was collected from the Swali slaughterhouse downstream end.

Experimental set-up: The circular hydroponic non-flow units with a dimension size of 25 cm and height of 25 cm were used as the cultivation tanks. All the tanks were thoroughly washed using distilled water. Prior to the growing of water hyacinth plants in abattoir effluent, the plant was acclimatized in a plastic tank containing distilled water. Each of the experiments was replicated thrice including control. Thereafter, all 15 hydroponic non-flow units were filled with 5.0 L of effluents for each of abattoir's wastewater samples. The 200 g weight of sorted water hyacinth plants were planted in the different hydroponic non-flow units. Some of the precautions taken were: The test samples were given with adequate aeration and exposed to sunlight. Daily observations were conducted and weekly data were recorded. Most of the plants work during the day within the sunlight sources. The wastewater samples were taken on a weekly basis for a period of 28 days and analyzed for the following physicochemical parameters: pH, temperature, electrical conductivity, total dissolved oxygen (TDS), total suspended solid (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), turbidity, Nitrate (NO^{-3}), Ammonia-Nitrogen (NH_4^+N) and Phosphate (PO_4) were conducted according to the standard method[35,36] (APHA, 1998 and APHA, 2005).

Laboratory analysis: Physicochemical parameters were analyzed by employing the method by APHA[35].

Statistical analysis: The results were subjected to statistical analyses for Analysis of Variance (ANOVA), correlation coefficient matrix and descriptive statistics. Probability significance was affirmed at $p<0.01$, $p<0.05$ and $p<0.001$.

RESULTS

Power of hydrogen (pH): The mean values of pH varied between 6.33±0.03 (control) and 8.21±0.11 on 28th day for effluent treated with water lettuce while the effluent treated with duckweed ranged between 6.33±0.03 (control) and 8.37±0.02 as shown in Table 1 and 2. The percentage increase in pH varied between 13.4 and 29.7% for water lettuce and 12.6 and 32.2% for duckweed. This is an indication that the pH of the control sample is slightly acidic and as retention time progressed the pH turned slightly alkaline in nature at the end of the 28th day retention time for the two aquatic plants. Significant variation of the mean values of pH occurred among different phytoremediation durations at ($p<0.05$).

Electrical conductivity: The mean values of electrical conductivity of abattoir wastewater after 28 days retention time varied from 448±6.19 at 28th retention time 3582±15.38 μs/cm (control) for effluent treated with water lettuce and the mean values for effluent treated with duckweed ranged from 504±7.46 at 28th day retention time to 3582±15.38 μs/cm control as displayed by Table 1 and 2.

The percentage increase in pH varied between 6.4 and 87.1% for water lettuce and 5.4 and 86% for duckweed. The observed differences between the mean values of EC were statistically significant ($p<0.05$).

Total dissolved solids (TDS): The mean concentrations of total dissolved solids varied between 461±8.53 mg/L at 28 days for water lettuce and 2560±13.72 mg/L for control and 528±7.72 mg/L and 2560±13.72 mg/L at 28 days for duckweed (Table 1 and 2). The percentage increase in TDS varied between 15.4 and 82% for water lettuce and 14.6 and 79% for duckweed. The observed differences between the mean TDS values were statistically significant ($p<0.05$) for both plants.

Table 1: Physiochemical properties of slaughter effluent wastewater using water lettuce

	Phytoremediation time (days)				
Effluents parameters	0	7	14	21	28
Temperature °C	29.5±0.07	28.5±0.04	28.4±0.01	29.1±0.02	29±0.03
pH	6.33±0.03	7.18±0.08	7.32±0.07	7.67±0.09	8.21±0.11
Electrical conductivity (μs/cm)	3582±15.38	3354±12.15	2462±16.74	1226±13.78	448±6.19
Total dissolved solid (mg/L)	2560±13.72	2165±11.46	1780±12.19	1042±10.60	461±8.53
Total suspended solid (mg/L)	2673±13.72	2218±15.51	1719±9.28	921±7.48	583±9.17
Dissolved oxygen (mg/L)	1.46±0.02	3.05±0.08	3.±0.06	4.22±0.04	5.83±0.07
Biochemical oxygen demand	1584±10.51	1374±10.23	843±6.26	531±8.71	436±7.58
Chemical oxygen demand (mg/L)	3751±14.72	2763±12.42	1721±10.19	976±8.90	489±7.34
Turbidity (NTU)	28±1.53	23±1.74	19±0.58	17±0.21	15±0.21
Nitrate (NO_3-) (mg/L)	15.31±0.09	11.19±0.07	9.20±0.05	6.68±0.04	4.83±0.03
Ammonium-nitrogen (NH_3-N) (mg/L)	17.83±0.08	10.41±0.08	6.87±0.04	3.67±0.05	0.84±0.03
Phosphate (PO_4) (mg/L)	5.53±0.03	3.86±0.04	1.87±0.03	0.83±0.04	0.62±0.02

Table 2: Physiochemical properties of slaughter effluent wastewater using duckweed

	Phytoremediation time (days)				
Effluents parameters	0	7	14	21	28
Temperature °C	29.5±0.07	28.8±0.06	29.3±0.02	28.6±0.03	28.9±0.05
pH	6.33±0.04	7.13±0.04	7.32±0.06	7.46±0.09	8.37±0.02
Electrical conductivity (μs/cm)	3582±15.38	3389±11.84	2574±10.23	1301±11.31	504±7.46
Total dissolved solid (mg/L)	2560±13.72	2187±10.61	1811±11.29	1123±9.51	528±7.72
Total suspended solid (mg/L)	2673±15.31	2297±13.79	1773±10.56	13.78	624±7.78
Dissolved oxygen (mg/L)	1.46±0.03	2.24±0.02	3.32±0.04	4.36±0.02	5.89±0.03
Biochemical oxygen demand	158±10.51	1335±12.57	875±7.15	642±6.61	494±.57
Chemical oxygen demand (mg/L)	3751±14.72	2686±10.59	1804±14.83	943±11.23	468±6.47
Turbidity (NTU)	28±1.53	2±0.97	18±0.29	16±0.56	13±0.50
Nitrate (NO_3-) (mg/L)	15.31±0.09	10.97±0.09	8.76±0.03	6.41±0.05	4.21±0.02
Ammonium-nitrogen (NH_3-N) (mg/L)	17.83±0.08	11.46±0.06	5.85±0.05	3.47±0.03	0.75±0.05
Phosphate (PO_4) (mg/L)	5.53±0.03	4.32±0.05	1.69±0.04	0.93±0.06	0.57±0.01

Total suspended solids (mg/L): The mean concentrations of total suspended solids of the control sample were 2673±13.72 mg/L, water hyacinths, lettuce and duckweed in effluent were 521±4.27 to 2167±6.82 mg/L, as shown in Table 1 and 2. The concentrations of TSS in the plant samples were lower than in the control. The percentage increase in TSS varied between 17 and 78.2% for water lettuce and 14.1 and 76.7% for duckweed. Some of the TSS was probably taken up by the plants during the period of cultivation.

Turbidity: The turbidity values will be higher. Turbidity values varied between 15±0.21 for water lettuce treatment at 28-day retention time and 34±1.53 NTU for control sample. The mean values for duckweed treatment varied between 13±0.50 for duckweed treatment at 28 day retention time and 34±1.53 NTU for control sample. The percentage increase in turbidity varied between 17.9 and 46.4% for water lettuce and 21.4 and 53.6% for duckweed. The observed differences between the mean values of turbidity were statistically significant ($p<0.05$).

Phosphate (PO_4): The mean values varied between 0.62±0.02 at 28 days for water lettuce treatment to 15.31±0.09 control sample. The mean values of duckweed-treated wastewater varied between 0.57±0.01 at 28 days for duckweed treatment to 15.31±0.09 control sample. The ANOVA tests indicated that there was a statistically significant difference between the mean values of DO (p 0.05).

Nitrate (NO_3): All the treated effluent was able to have NO_3 concentrations not exceeding the permissible WHO standard except control sample. The mean values varied from 4.11±0.03 at 28 days retention time to 15.31±0.09 for the control sample. The mean values varied from 4.21±0.02 at 28 days retention time to 15.31±0.09 for control sample. The ANOVA tests showed that there was statistically significant difference between the mean values of NO_3 ($p<0.05$).

Dissolved oxygen (DO): The mean concentrations of dissolved oxygen ranged between 1.46±0.02 mg/L (control sample) and 5.83±0.07 mg/L at 28 day retention time as shown in Table 1. The mean concentrations of dissolved oxygen ranged between 1.46±0.02 mg/L (control sample) and 5.89±0.03 mg/L at 28 day retention time as shown in Table 2. The ANOVA tests indicated that there was a statistically significant difference between the mean values of DO (p 0.05). Some contaminants which probably distorted DO earlier were taken up by the plants and were refreshed by oxygen or followed by aeration of the plants' samples. The implication of the observed increase in the DO subsequently improves aerobic environments in wastewater, which enhances the aerobic bacterial activity to break down BOD and COD in the waster water.

Biochemical oxygen demand (BOD): The mean concentrations of biological oxygen demand of the control sample were 1584±10.51 mg/L, water hyacinths, lettuce and duckweed in effluent were 317±4.61 to 1286±8.74 mg/L (Table 1). The effluent characterization revealed that, a mean 1584±10.51 mg/L concentration of BOD was discharged from the environment from slaughterhouse to the environment. The percentage increase in BOD varied between 13.3% and 72.5% for water lettuce and 15.7 and 70.2% for duckweed. This high load of BOD which is beyond the permissible limit could cause stress to aquatic life due to insufficient amount of free available dissolved oxygen.

Chemical oxygen demand (COD): The wastewater characterization showed the mean value of COD 3751±14.72 mg/L was discharged to the environment from slaughterhouse. The mean concentrations of chemical oxygen demand ranged between 402±5.62 to 3751±14.72 mg/L (Table 1). The concentrations of COD of the plant samples were lower than the control. The wastewater characterization revealed the average values of COD ranged between 3751±14.72 mg/L concentration of COD was discharged to the environment from abattoir slaughterhouse to the environment. The percentage increase in COD varied between 26.3 and 87.0% for water lettuce while 28.7 and 87.5% for duckweed. This high load of COD which is above beyond the permissible limit may cause to stress aquatic life owing to a deficient quantity of free available dissolved oxygen. The observed reduction in the COD concentration could be due to the uptake of organics by the plants with increase in retention time. The highest reduction efficiency was found at 28th day retention time. The ANOVA tests indicated that there was a statistically significant difference between the mean values of COD ($p<0.05$).

DISCUSSION

The pH of control sample is slightly acidic and as retention time progressed the pH turned slightly alkaline in nature for the two aquatic plants. It was observed pH values fell within the pliable range for effective performance of aquatic plants for phytoremediation processes of aquaculture wastewater. The pH of the treated effluent met the permissible limits except the 28 day retention time. The permissible limit pH for drinking water according to World Health Organization WHO[37] ranged between 6.5 and 8.0. However, the treated effluent met the Al-Janabi *et al.*[38] permissible limits for irrigation and aquatic life ranging from 6.5 to 9.0. This is an indication that all the treated effluent fell within the recommended limits. The observed high could be attributed to the type of wastes such as dung, stomach content, blood, fat, animal trimmings and urine which are generated from the slaughterhouse[14]. The observed pH values will enhance the optimal performance for microbial activities and nitrification process[39].

The maximum permissible limit for electrical conductivity based on WHO[37] recommendation is 400 µs/cm for drinking water. The analyzed water sample exceeded the recommended limit assigned for drinking water[39-40]. However, treated effluents have EC mean values higher than 750 µs/cm is acceptable by WHO[37] for domestic, recreational and agricultural purposes and soil health except 28th day retention time[41,42]. The most permissible range for TDS in drinking water is 500 mg/L as per WHO[37] standard, only water lettuce treatment at 28-day retention time fell within the permissible limit. According to WHO[39] the maximum permissible limit of TDS for drinking water is 600 mg/L. All the TDS values exceeded the permissible limit as reported by WHO[37] for domestic, bathing and recreational purposes expect 28 day retention for both water hyacinth and duckweed.

According to WHO[39] reported acceptable range of TSS for drinking water is as follows 10 mg/L. The permissible range for TSS is limited to 2000 mg/L, it can be deduced that the treated effluent is suitable for water reuse for irrigation purpose[42].

The increased concentration of TSS has a detrimental effect on the aquatic ecosystem. The presence of a high concentration of TSS could cause stress to aquatic life by obstructing sunlight and impeding photosynthetic activity. Thus, the wastewater discharged from its source requires additional treatment before being released into the environment. The measured TSS values were significantly higher than the drinking water standard of previous studies[41,42]. According to Nuraini and Felani[43] and Davies and Davies[44], the elevated TSS levels can be attributed to factors such as excessive surface runoff, soil erosion, water waste and the decomposition of plants and animals.

According to the drinking water standard recommended for turbidity by WHO[37] should not exceed 5 NTU and none of the treated wastewater met the permissible limits. The analyzed water sample is unsuitable for domestic and irrigation purposes.

The acceptable limit according to WHO[37] for drinking water and aquatic life is 5 mg/L. The implication of excess PO_4 can cause harmful impacts on the ecosystem, such as algae blooms, invasive plants, low oxygen, fish kills and dead zones. Even though there was a reduction in the phosphate concentration with respect to retention time. Haidara *et al.*[45] asserted that the performance of aquatic plants in nutrient uptake improves with respect to the retention time. According to Oh *et al.*[46] affirmed that excess phosphate can impair the growth of any plant.

The acceptable limit recommended by WHO[47] for nitrate concentration in drinking water is 50 mg/L. The obtained mean values of nitrate were much lower than the permissible limit. And corresponding values of 24.08- 68.92 mg/L of a similar study conducted by Rezania *et al.*[14], though, there were significant differences in the results, the values fell within the acceptable limits of WHO. Nitrate concentrations are very harmful when are above stipulated acceptable limits by WHO. According to Aires *et al.*[48] the implication of excess nitrate in the human body could aggravate cancer of the stomach. Haidara *et al.*[45] asserted that the performance of aquatic plants in nutrient uptake improves with respect to the retention time.

The concentrations of BOD in the treated water samples were lower than the control. This could be adduced to the uptake of some contaminants and other substances from their growth medium and consequently lower the pollution concentration of water samples by the plants. According to Ashraf *et al.*[49] reported that roots promote the retention of microbes on the roots by providing them with nutrients. The roots provide oxygen to rhizospheric bacteria to enhance the process of aerobic breakdown of organic matter.

Zhang *et al.*[50] found that trapping in the biofilm of the roots is very significant in the mechanism for particulate matter removal. Hussain *et al.*[51] asserted that the roots of the test plant permit microbial colonies to absorb the carbon compounds, which enhanced the reduction of BOD and COD. Organic pollutants are degraded by microorganisms present on the roots, while some of the organic pollutants are absorbed by the plants.

The World Health Organization standards prescribe approved limit of COD for drinking water should not exceed 4 mg/L[37]. It is evident that the water samples analyzed were deemed unsuitable for drinking, domestic and agricultural use. The WHO guidelines specify that the acceptable limit for COD in drinking water is 200 mg/L[39]. Nuraini and Felani[43] described chemical oxygen demand as the total quantity of oxygen expected to oxidize organic materials chemically, both of which can be biodegradable and non-biodegradable into CO_2 and H_2O. The implication of discharging untreated abattoir effluent could pose a serious threat to the environment, human health, aquatic life and biodiversity. According to Cao and Mehrvar[9] effluent having these substances will have grave adverse effects on human health besides the environment. The water lettuce and duckweed have the ability to significantly reduce the level of contaminants in abattoir wastewater. Water lettuce is more efficient in reducing contaminants than duckweed. The major constraint is the time taken for the two aquatic plants to remediate the abattoir effluent.

CONCLUSION

This study showed that the chosen aquatic plants (water lettuce and duckweed) were effective and efficient in reducing the concentration of pollution loads from abattoir with respect to retention time. The retention time has a very significant effect on the efficiency of contaminant removal. The majority of results obtained from 28th day fell within the permissible limits for the water lettuce and duckweed. Water lettuce showed better performance in remediating some of the physicochemical parameters studied. Finally, the hydroponic ponds offer a cheap, sustainable, environment-friendly and green technology for phytoremediation of wastewater within a short time. The wastewater characterizations from the abattoir effluent were very high and were not within the permissible limits according to World Health Organization drinking water standards. It can be concluded that discharging abattoir water with prior treatment could lead to serious environmental problems for human beings, aquatic life and Eco diversity since all pollution indices are far above the tolerance limit.

SIGNIFICANCE STATEMENT

Water lettuce and duckweed are invasive aquatic plants that cause significant damage to the environment and biodiversity. Exploring the use of these plants could offer a solution to combat the issues caused by their proliferation. This research focused on analyzing the effluent produced by abattoirs and evaluating the effectiveness of the plants in treating pollution. The results revealed that the characteristics of the abattoir effluent exceeded the acceptable limits set by the World Health Organization for drinking water standards. Discharging untreated effluent could pose a serious threat to the environment, human health, aquatic life and biodiversity. However, the study demonstrated that both water lettuce and duckweed have the ability to significantly reduce the pollution levels in abattoir wastewater.

REFERENCES

1. Adesemoye, A.O., B.O. Opere and S.C.O. Makinde, 2006. Microbial content of abattoir wastewater and its contaminated soil in Lagos, Nigeria. Afr. J. Biotechnol., 5: 1963-1968.
2. Amorim, A.K.B., I.R. de Nardi and V. Del Nery, 2007. Water conservation and effluent minimization: Case study of a poultry slaughterhouse. Resour. Conserv. Recycl., 51: 93-100.
3. Bello, Y.O. and D.T.A. Oyedemi, 2009. The impact of abattoir activities and management in residential neighbourhoods: A case study of Ogbomoso, Nigeria. J. Social Sci., 19: 121-127.
4. Aniebo, A.O., S.N. Wekhe and I.C. Okoli, 2009. Abattoir blood waste generation in Rivers State and its environmental implications in the Niger Delta. Toxicol. Environ. Chem., 91: 619-625.
5. Ezeoha, S.L. and B.O. Ugwuishiwu, 2011. Status of abattoir wastes research in Nigeria. Nig. J. Technol., 30: 143-148.
6. Abu Jabal, M.S., I. Abustan, M.R. Rozaimy and H. El Najar, 2018. The deuterium and oxygen-18 isotopic composition of the groundwater in Khan Younis City, Southern Gaza Strip (Palestine). Environ. Earth Sci., Vol. 77. 10.1007/s12665-018-7335-4.
7. Al-Mutairi, N.Z., M.F. Hamoda and I.A. Al-Ghusain, 2003. Performance-based characterization of a contact stabilization process for slaughterhouse wastewater. J. Environ. Sci. Health, Part A, 38: 2287-2300.
8. Al-Mutairi, N.Z., M.F. Hamoda and I. Al-Ghusain, 2004. Coagulant selection and sludge conditioning in a slaughterhouse wastewater treatment plant. Bioresour. Technol., 95: 115-119.
9. Cao, W. and M. Mehrvar, 2011. Slaughterhouse wastewater treatment by combined anaerobic baffled reactor and UV/H_2O_2 processes. Chem. Eng. Res. Des., 89: 1136-1143.
10. Barrera, M., M. Mehrvar, K.A. Gilbride, L.H. McCarthy, A.E. Laursen, V. Bostan and R. Pushchak, 2012. Photolytic treatment of organic constituents and bacterial pathogens in secondary effluent of synthetic slaughterhouse wastewater. Chem. Eng. Res. Des., 90: 1335-1350.
11. Onajobi, I.B., 2019. Phytotreatment of apalara abaittoir waste water using *Eichhornia crassipes*. FUPRE J. Sci. Ind. Res., 3: 88-101.
12. Chukwu, O., 2008. Analysis of groundwater pollution from abattoir waste in Minna, Nigeria. Res. J. Dairy Sci., 2: 74-77.
13. Nafarnda, W.D., I.E. Ajayi, J.C. Shawulu, M.S. Kawe and G.K. Omeiza *et al*., 2012. Bacteriological quality of abattoir effluents discharged into water bodies in Abuja, Nigeria. Int. Scholarly Res. Not., Vol. 2012. 10.5402/2012/515689.
14. Rezania, S., S.M. Taib, M.F.M. Din, F.A. Dahalan and H. Kamyab, 2016. Comprehensive review on phytotechnology: Heavy metals removal by diverse aquatic plants species from wastewater. J. Hazard. Mater., 318: 587-599.
15. Ediene, V.F. and O.B. Iren, 2017. Impact of abattoir effluents on the pH, organic matter, heavy metal levels and microbial composition of surrounding soils in Calabar municipality. Asian J. Environ. Ecol., Vol. 2. 10.9734/AJEE/2017/33341.
16. Elemile, O.O., D.O. Raphael, D.O. Omole, E.O. Oloruntoba, E.O. Ajayi and N.A. Ohwavborua, 2019. Assessment of the impact of abattoir effluent on the quality of groundwater in a residential area of Omu-Aran, Nigeria. Environ. Sci. Eur., Vol. 31. 10.1186/s12302-019-0201-5.
17. Chen, J., Q. Nie, Y. Zhang, J. Hu and L. Qing, 2014. Eco-physiological characteristics of *Pistia stratiotes* and its removal of pollutants from livestock wastewater. Water Sci. Technol., 69: 2510-2518.

18. Moses, D.R. and D.O. Augustina, 2014. Some physical and mechanical properties of water lettuce (*Pistia stratiotes*) briquettes. Am. J. Sci. Technol., 1: 238-244.
19. Singh, A.L., S. Jamal, S.A. Baba and M. Manirul Islam, 2014. Environmental and health impacts from slaughter houses located on the city outskirts: A case study. J. Environ. Prot., 5: 566-575.
20. Adeyemo, O.K., I.G. Adeyemi and E.J. Awosanya, 2009. Cattle cruelty and risks of meat contamination at Akinyele cattle market and slaughter slab in Oyo State, Nigeria. Trop. Anim. Health Prod., 41: 1715-1721.
21. Gil, M.I. and A. Allende, 2018. Water and Wastewater Use in the Fresh Produce Industry: Food Safety and Environmental Implications. In: Quantitative Methods for Food Safety and Quality in the Vegetable Industry, Pérez-Rodríguez, F., P. Skandamis and V. Valdramidis (Eds.), Springer, Cham, Switzerland, ISBN: 978-3-319-68177-1, pp: 59-76.
22. Park, J., J.H. Oh and T.G. Ellis, 2012. Evaluation of an on-site pilot static granular bed reactor (SGBR) for the treatment of slaughterhouse wastewater. Bioprocess Biosyst. Eng., 35: 459-468.
23. Matsumura, E.M. and J.C. Mierzwa, 2008. Water conservation and reuse in poultry processing plant-A case study. Resour. Conserv. Recycl., 52: 835-842.
24. Barana, A.C., D.D. Lopes, T.H. Martins, E. Pozzi, M.H.R.Z. Damianovic, V. del Nery and E. Foresti, 2013. Nitrogen and organic matter removal in an intermittently aerated fixed-bed reactor for post-treatment of anaerobic effluent from a slaughterhouse wastewater treatment plant. J. Environ. Chem. Eng., 1: 453-459.
25. Mustafa, H.M. and G. Hayder, 2021. Evaluation of water lettuce, giant salvinia and water hyacinth systems in phytoremediation of domestic wastewater. H_2Open J., 4: 167-181.
26. Dhote, S. and S. Dixit, 2009. Water quality improvement through macrophytes-A review. Environ. Monitor. Assess., 152: 149-153.
27. Abu, H.C., R.M. Davies and O.A. Davies, 2022. Phytoremediation of cassava wastewater by water hyacinth. Trends Appl. Sci. Res., 17: 1-6.
28. Okpozu, O.O., I.O. Ogbonna, J. Ikwebe and J.C. Ogbonna, 2019. Phycoremediation of cassava wastewater by *Desmodesmus armatus* and the concomitant accumulation of lipids for biodiesel production. Bioresour. Technol. Rep., Vol. 7. 10.1016/j.biteb.2019.100255.
29. Sayago, U.F.C., 2019. Design of a sustainable development process between phytoremediation and production of bioethanol with *Eichhornia crassipes*. Environ. Monit. Assess., Vol. 191. 10.1007/s10661-019-7328-0.
30. Ayaz, T., S. Khan, A.Z. Khan, M. Lei and M. Alam, 2020. Remediation of industrial wastewater using four hydrophyte species: A comparison of individual (pot experiments) and mix plants (constructed wetland). J. Environ. Manage., Vol. 225. 10.1016/j.jenvman.2019.109833.
31. Hazmi, N.I.A. and M.M. Hanafiah, 2018. Phytoremediation of livestock wastewater using *Azolla filiculoides* and *Lemna minor*. Environ. Ecosyst. sci., 2: 13-16.
32. Khan, S., I. Shamshad, M. Waqas, J. Nawab and L. Ming, 2017. Remediating industrial wastewater containing potentially toxic elements with four freshwater algae. Ecol. Eng., 102: 536-541.
33. Khan, H.N. and M. Faisal, 2018. Phytoremediation of Industrial Wastewater by Hydrophytes. In: Phytoremediation, Ansari, A.A., S.S. Gill, R. Gill, G.R. Lanza and L. Newman (Eds.), Springer, Cham, Switzerland, ISBN: 978-3-319-99651-6, pp: 179-200.
34. George, G.T. and J.J. Gabriel, 2017. Phytoremediation of heavy metals from municipal waste water by *Salvinia molesta* Mitchell. Haya: Saudi J. Life Sci., 2: 108-115.
35. APHA, 1998. Standard Methods for Examination of Water and Wastewater. 20th Edn., American Public Health Association, American Water Works Association and Water Environment Federation, Washington, DC., ISBN-13: 978-0875532356, Pages: 1220.
36. APHA, A.D. Eaton, AWWA and WEF, 2005. Standard Methods for the Examination of Water and Wastewater. 21st Edn., American Public Health Association, Washington, D.C.
37. WHO, 2006. Guidelines for Drinking Water Quality. 3rd Edn., World Health Organization, USA, Pages: 668.

38. Al-Janabi, Z.Z., A.R.A. Kubaisi and A.H.M.J. Al-Obaidy, 2012. Assessment of water quality of tigris river by using water quality index (CCME WQI). Al-Nahrain J. Sci., 15: 119-126.
39. WHO, 2017. Guidelines For Drinking-Water Quality, 4th Edition, Incorporating The 1st Addendum. 4th Edn., World Health Organization, Rome, Italy, ISBN: 978-92-4-154995-0, Pages: 631.
40. Vyas, V.G., M.H. Mohammad, S.I. Vindhani, H.J. Parmar and V.M. Bhalani, 2015. Physicochemical and microbiological assessment of drinking water from different sources in Junagadh City, India. Am. J. Microbiol. Res., 3: 148-154.
41. Rahman, A., I. Jahanara and Y.N. Jolly, 2021. Assessment of physicochemical properties of water and their seasonal variation in an urban river in Bangladesh. Water Sci. Eng., 14: 139-148.
42. Zobaidul Kabir, S.M. and S. Momtaz, 2014. Sectorial variation in the quality of environmental impact statements and factors influencing the quality. J. Environ. Plann. Manage., 57: 1595-1611.
43. Nuraini, Y. and M. Felani, 2015. Phytoremediation of tapioca wastewater using water hyacinth plant (*Eichhornia crassipes*). J. Degraded Min. Land Manage., 2: 295-302.
44. Davies, R.M. and O.A. Davies, 2013. Effect of briquetting process variables on hygroscopic property of water hyacinth briquettes. J. Renewable Energy, Vol. 2013. 10.1155/2013/429230.
45. Haidara, A.M., I.M. Magami and A. Sanda, 2018. Bioremediation of aquacultural effluents using hydrophytes. Bioprocess Eng., 2: 33-37.
46. Oh, Y.M., P.V. Nelson, D.L. Hesterberg and C.E. Niedziela, 2016. Efficacy of a phosphate-charged soil material in supplying phosphate for plant growth in soilless root media. Int. J. Agron., Vol. 2016. 10.1155/2016/8296560.
47. WHO, 2004. Guideline for Drinking Water Quality. 3rd Edn., World Health Organization, Geneva, Switzerland.
48. Aires, A., R. Carvalho, E.A.S. Rosa and M.J. Saavedra, 2013. Effects of agriculture production systems on nitrate and nitrite accumulation on baby-leaf salads. Food Sci. Nutr., 1: 3-7.
49. Ashraf, S., M. Afzal, M. Naveed, M. Shahid and Z.A. Zahir, 2018. Endophytic bacteria enhance remediation of tannery effluent in constructed wetlands vegetated with *Leptochloa fusca*. Int. J. Phytorem., 20: 121-128.
50. Zhang, L., J. Zhao, N. Cui, Y. Dai, L. Kong, J. Wu and S. Cheng, 2016. Enhancing the water purification efficiency of a floating treatment wetland using a biofilm carrier. Environ. Sci. Pollut. Res., 23: 7437-7443.
51. Hussain, F., R. Tahseen, M. Arslan, S. Iqbal and M. Afzal, 2018. Removal of hexadecane by hydroponic root mats in partnership with alkane-degrading bacteria: Bacterial augmentation enhances system's performance. Int. J. Environ. Sci. Technol., 16: 4611-4620.