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EVALUATION OF TWO-STAGE SUBSURFACE FLOW CONSTRUCTED WETLANDS FOR ABATTOIR WASTEWATER MANAGEMENT

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ABSTRACT

Abattoir wastewater is high in organic content, the waste recovery and treatment facility is expensive and this results in indiscriminate dumping into streams without adequate treatment. The effectiveness of using a two-stage subsurface flow constructed wetland to treat abattoir effluent was examined in this study. Diluted abattoir wastewater from Lafenwa Abattoir, Abeokuta, Ogun State, Nigeria was fed into a two-stage Vegetated Subsurface Bed Constructed Wetlands (VSBCW). The VSBCW consisted of 500 mm deep 10-15 mm diameter granite with 150 mm thick overlay of well graded sand planted with locally available *Vetiveria nigritana*. Grab samples were collected at selected points along Ogun river and measurement of physico-chemical parameters such as: Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD_5), Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Total Suspended Solid (TSS) of the influent and effluent from the VSBCW were carried out. Irrigation with water and diluted abattoir wastewater to examine the variation in plant growth rate was also investigated. The results revealed a pollution load reduction as the wastewater moves away from the discharge point but inadequate to meet the FEPA (1991) standard for wastewater discharge into rivers. The VSBCW was observed to reduce the concentration of BOD_5, COD, EC, TDS and TSS in the abattoir wastewater by 88.71, 87.28, 45.72, 56.89 and 72.27 % respectively. The growth rate of the *V. nigritana* reduced by 1.9% when irrigated with abattoir wastewater. The study revealed that locally available *V. nigritana* in VSBCW is effective in abattoir wastewater treatment and could be use to curtail the pollution caused by discharge of untreated wastewater into rivers.

Keywords: abattoir, Vegetated Submerged Bed Constructed Wetlands, *V. nigritana,* wastewater and surface water.

INTRODUCTION

The indiscriminate dumping of abattoir waste into streams without adequate treatment leads to air, soil and water pollution. The resultant pollution constitutes serious nuisance to the community and threat to public health; it affects surface water and the wastewater percolates into underground aquifers thereby polluting hand-dug wells. Most abattoirs in Nigeria lack adequate waste recovery and treatment facilities. Moreover, in places where these facilities exist they are largely inadequate (Adeyemo, 2002).

Most slaughter houses in Nigeria discharge their waste into streams and rivers without treatment. Odeyemi (1991) observed untreated slaughter house waste indiscriminately dumped at Oginigba River in River state. Bodija Abattoir in Southwest Nigeria also experienced discharge of effluents into open drains without any treatment (Abiola, 1995). Aniebo (1994) reported that effluents released from Afor ajala slaughter house in Imo State, Nigeria are often discharged into open drains without proper treatment. A study by Akinro *et al*. (2009) reported that waste from the slaughtering and dressing grounds of Araomi abattoir in Akure Ondo state are discharged untreated into open drains. An investigation of nine abattoirs in the North Central part of Nigeria by Chukwu *et al*. (2011) revealed that wastewaters are dumped without adequate treatment. Such wastewater produces offensive odour and the nutrients from the wastewater leads to eutrophication of the stream. The discharge of untreated abattoir wastewater without adequate treatment has adverse effect on human health and aquatic life (Aniebo *et al*., 2009).

Abattoir wastes have been shown to vary in characteristics depending on the number and type of stocks processed (Akinro *et al*., 2009). They are highly organic with blood, gut contents, urine and water; sufficient organic biological nutrients and free of toxic materials (Chukwu *et al*., 2011). Blood and fats constitute the highest concentration in abattoir wastewater. Aniebo *et al*. (2009) equates effluent load from the blood of a cattle to that of total sewage from fifty people per day.

The conventional method of disposal of abattoir wastewater includes rendering, land application, composting and transfer to water treatment plants (Mittal, 2006). Abattoir wastewater undergoes three stages of treatment (Masse and Masse, 2000); the primary, secondary and tertiary stages. Screening to separate the floating and settleable solids occurs at the primary stage, removal of organic matter in the secondary stage; nitrogen and phosphorus removal in the tertiary stage. Immersion chiller effluent by membrane filtration is suggested in Mittal (2006) as a means of reducing abattoir wastewater. These treatment and reduction methods involve the use of mechanized methods and the facilities are costly.

In most developing countries, high cost of wastewater treatment plants and non-enforcement of pollution control regulations are major reasons for non existence of wastewater treatment facilities (Kivaisi, 2001). Stabilization ponds are the most widely used treatment facility in developing countries due to its low installation and minimal maintenance costs coupled with favourable climate condition in the tropics (Kivaisi, 2001). Effluent from stabilization ponds however, contains residue nutrients which causes euthrophication, and contaminates downstream ground and surface water making it unsafe for domestic uses.

Lafenwa Abattoir is one of the largest in Abeokuta, Southwest Nigeria. It is located 30 m from Ogun River, at 7^{o} 9' 6'' N and 3^{o} 19' 43'' E, 129 m above sea level. The abattoir slaughters an average of 195 cattle per month. The abattoir has an open slaughtering slab; blood, urine, faeces, guts, fats and water used in washing the slab are discharge into open drain leading to Ogun River (Fig. 1).

Figure 1: Discharge of Abattoir waste into Ogun River South West Nigeria

Specific characteristics of wetland ecosystem favourable for wastewater treatment are emphasized in Constructed Wetlands (CW) for water quality improvement (Kadlec and Wallace, 2009). CW is a natural treatment process, in comparison to the stabilization pond it could be used to remove the organic content and nutrients load of the wastewater effectively. CW systems are easily operated, requiring minimal construction and maintenance cost. CWs consist of engineered systems designed and constructed to utilize natural processes. They are constructed in various hydrologic modes; Free Water Surface (FWS), Horizontal Subsurface Flow (HSF) and Vertical Flow (VF) wetlands.

The various categories of CW can be designed to operate different flow patterns, varying substrate sizes and macrophytes of different species. The flow could be intermittent with fill and drain mode as reported by Poach and Hunt (2007). The pattern of flow could also be continuous downflow or continuous sprinkling (Badejo *et al*., 2012a) and intermittent flow (Badejo *et al*, 2012b). The pattern of flow could be erratic and intermittent in event driven systems (Kadlec and Wallace, 2009).

Plants have been shown to have a positive effect and perform a significant role on wastewater pollution removal in CW (Brisson and Chazarenc, 2009; Akratos and Tsihrintzis, 2007). The transport systems of macrophytes in CW take up nutrients and contaminants from the substrates and water. According to Truong (2003) and Lavania (2004) wastewater treatment with vetiver is a 'recycling process' not a treatment process *per se*, as in the process of treatment the vetiver plant absorbs essential plant nutrients and stores them for other uses.

Vetiver grass is a tall, fast growing, perennial, tropical grass. It has massive and complex root system, which penetrates to deeper layers of soil making it appropriate for aeration of CW basins. It forms a dense layer when planted closely in rows (Yehua *et al*, 2000). The locally available specie of vetiver grass in Nigeria is *Vetiveria nigritana.* Troung (2003) reported that the unique morphological characteristics and tolerance of vetiver to adverse environmental conditions makes it effective for wastewater treatment. This study therefore examined the removal efficiency of the locally available macrophytes *Vetiveria nigritana* used in a two-stage CW for abattoir wastewater treatment.

METHODOLOGY

The pilot CW consisted of six 1000 x 1000 x 1200 mm plastic basins (Fig. 2 and Fig. 3) located at the Civil Engineering Department, Federal University of Agriculture, Nigeria (N7o 14' 1.3" E 03o 26' 1.4"). Each pilot CW was made of 500 mm deep 10-15 mm diameter granite with 150 mm thick overlay of well graded sand (Cu = 1.15, Cc = 6.8). The hydraulic conductivity of the substrate was 0.002 m/s. Each of the beds was planted with transplanted rhizomes of *Veteveria nigritana* from the experimental plot of the Olabisi Onabanjo University, Ogun State Nigeria. Outlet drains were provided at the base of the tank and inlet was through pipes, uniformly perforated to provide uniform irrigation of the macrophytes. The stage difference between the CW basins was provided using 900 mm high sandcrete block. Two CW basins were connected together in series as shown in Figure 2. The remaining two CW basins were used to monitor the effect of abattoir wastewater on the growth of the macrophytes. The macrophytes (*Vetiveria nigritana*) were planted at 300 mm centre-to-centre to produce a high density bed.

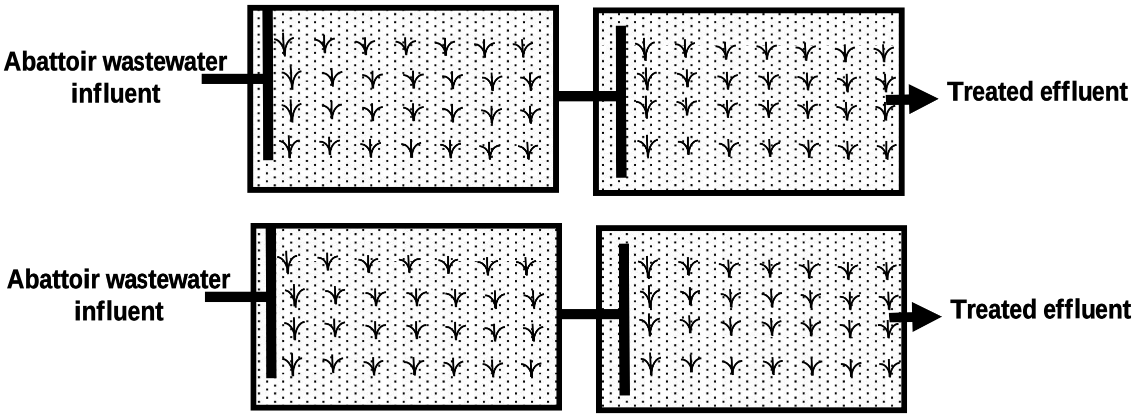

Figure 2: Schematic diagram of two stage Constructed Wetland system

Figure 3: Experimental Setup of the Constructed Wetland system

V. nigritana was allowed to mature for three months before sampling of wastewater began. The abattoir wastewater was diluted in ratio 2 to 8 of water to avoid high concentration that might destroy the plants and samples collected after a retention time of 7 and 21days. Job (1992) reported that limitation of BOD_5 and TSS of wastewater fed into CW systems reduces clogging.

Sampling

Internationally accepted procedures and standard methods (APHA, 2005) were adopted in sampling and analyzing the abattoir wastewater. Grab samples were collected at four different points: the slaughter slab discharge point, 10 m and 20 m away from the point of discharge and 10 m upstream of the discharge point. Insitu analysis of pH, EC, Total Dissolved Solids (TDS), temperature and dissolved oxygen (DO) were done on site and other parameters taken to the laboratory at temperature of 4^{o}C for analysis. The physico-chemical parameters analyzed include Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD_5), Electrical Conductivity (EC), Temperature, Total Dissolved Solids (TDS), Sulphate, Nitrate and pH.

RESULTS AND DISCUSSION

Table 1: Physico-chemical parameters in abattoir wastewater sample against W.H.O standard

Parameters (mg/l)	Abattoir Effluent	W.H.O standard
pH	7.42	6.0 – 9.0
Temperature (^{0}C)	27	27 – 30
EC (μS/cm)	246.50	317 – 335
Nitrate	59.22	45
Sulphate	310	250
TSS	5124	30
TDS (mg/l)	2387	200
BOD (mg/l)	925.64	20
COD (mg/l)	11093	1000

The average results of the physico-chemical parameters analyzed against the WHO (2004) standard are shown in Table 1. The reduction in pollution load along the stream and a point upstream is shown in Table 2. This gave an insight to the average pollution load that surface water bodies adjoining slaughter houses receives. This is consistent with reports of various researchers that most slaughter houses in Nigeria discharge their waste into streams and rivers without treatment (Odeyemi, 1991; Abiola, 1995; Aniebo, 1994; Chukwu *et al*., 2011). The pollution has an adverse effect on the aquatic organisms and renders the water bodies unfit for human use. The pollutants also have a tendency of percolating into the nearby aquifer and polluting nearby wells (Aniebo *et al*., 2009).

Table 2: Results of analysis at selected points along Ogun river

Parameters	P 1	P 2	P 3	P 4	P 5
pH	7.42	7.34	7.22	7.13	7.01
T(^{0}C)	27.3	28.0	28.5	27.6	28.0
EC (μs/cm)	246.5	201.0	118.9	115.50	77
Nitrate (mg/l)	59.22	43.71	21.62	20.54	18.1
Sulphate (mg/l)	310.00	233.87	7.90	6.61	4.03
TSS (mg/l)	5124.45	4356.06	2846.68	341.35	198.10
TDS (mg/l)	2387	2246	760	503	330
BOD (mg/l)	925.64	836.07	458.34	210.04	65.42
COD (mg/l)	11093	9680	3626.0	320.0	427.0

P1 = Point within the slaughter house before discharge
P2 = 10 m away from P1 along the stream before discharge into Ogun river
P3 = (Pt of discharge into Ogun river) 20 m away from P1
P4 = 20 m upstream of point of discharge
P5 = 20 m downstream of point of discharge

The pH of the abattoir wastewater before discharge into the river was within the WHO (2004) and FEPA (1991) tolerance limits of 6.0 – 9.0 for discharge of wastewater into streams. The values of pH at other points away from the discharge point (Table 2) were within the recommended limits of WHO (2004).

The Electrical Conductivity (EC) indicates the dissolved solids in water, the concentration of ionic species determine the conduction of current in electrolyte (Mwendera, 2006). The concentration of the EC at the slaughter slab was 246.5 μs/cm, this might not pose health risk of defective endocrine functions and total brain damage with prolonged exposure as reported by (Hunter *et al*., 2009) as it fell within the WHO (2004) and FEPA (1991) recommended limit.

The nutrients value at the slaughter slab exceeded the WHO limits of 45 mg/l for nitrate and 250 mg/l for sulphate, average values of 59.22 and of 310.00 mg/l were obtained for nitrogen and sulphate at the slaughter slab. Nitrate in combination with other compounds can stimulate excessive growth of algae leading to eutophication. They also harm aquatic wildlife through toxic effects and oxygen depletion (Reilly *et al*., 2000).

The TSS and TDS of wastewater at the slaughter slab exceeded the recommended limit of WHO (2004) and FEPA (1991) for wastewater discharged into the stream. The TSS and TDS obtained were 5124 and 2387 mg/l respectively. This revealed that the wastewater was heavily loaded with colloidal, organic, inorganic and suspended matters (Akinro *et al*., 2009).

Table 3: Effluent result at 7 and 21 days retention period

Parameters	Raw	7	21
pH	7.4	7.34	7.2
Temperature (^{0}C)	28.5	28.9	28.8
EC (μs/cm)	143.7	115.22	78
Nitrate (mg/l)	39.4	31.46	28
Sulphate (mg/l)	31.00	21.66	18
TSS (mg/l)	1215.3	480.04	337
TDS (mg/l)	863	508.80	372
BOD (mg/l)	267.4	106.43	30
COD (mg/l)	409.2	190.69	52

COD is an important water quality parameters, the more organic content in the wastewater the more the COD. This study obtained a mean value of 11093 mg/l for COD, this was higher than WHO (2004) recommended standard limits of 1000 mg/l for the discharge of wastewater into the rivers. The BOD obtained was 925.64 mg/l which exceeded the recommended limit of 20 mg/l. Wastewater high in BOD depletes oxygen in receiving waters due to bacteria that breaks down organic materials, causing fish kills and ecosystem imbalance (Ogunfowokan *et al*, 2005).

The results of the wastewater concentrations for the different parameters analyzed in the CW after a retention period of 7, and 21 days is shown in Table 3.

The concentration of the abattoir wastewater to be used in irrigating the CW macrophytes was reduced to minimize the risk of clogging (Job, 1992). Platzer and Mauch (1996) also reported that lower risk of clogging occurs at lower concentrations of wastewater and higher hydraulic load. The result of the concentration of abattoir wastewater after diluting to ratio 2 to 8% water and treatment efficiency of the staged CW is shown in Table 3.

The study showed that sand and gravel bed of VSBCW was very effective in removal of BOD, COD, TSS and TDS from abattoir wastewater. The beds were not excessively loaded, so the risk of surfacing or clogging in the bed was completely eliminated. The EC reduced by 21.31 and 45.72 % in 7 and 21 days respectively.

The Nitrate and sulphates were observed to reduce by (20.15, 28.93%) and (30.23, 41.97%) after a retention period of 7 and 21 days respectively in the Vegetated Submerged Bed CW. The removal efficiency obtained in this study was reduced when compared to 80% reduction in Reilly *et al*., (2000). Plant uptake, adsorption and volatilization coupled with the activities of bacteria are the ways through which Nitrogen is removed in CW (Kadlec and Wallace, 2009; Al-Omari and Fayyad, 2003). Research also showed that vegetation in matured state and available carbon played important roles in nitrate removal in CW (Reilly *et al*., 2000). Increased density of macrophytes and increased maturation period is therefore required to obtain high nitrogen removal rate. The nitrogen removal efficiency also depends on the type of vegetation (He and Mankin, 2002). The study reveals that *V. nigritana* is not as efficient as *P. karka* in wastewater treatment as opined by Badejo *et al*, (2012b).

Reduction of the solids, both TSS and TDS were observed to be 72.27 and 56.89% after 21 days in the CW. According to Robuste (2004) at the initial years of CW operations for domestic wastewater treatment TSS about 35% was observed. This was attributed to ponding at the outlet which results in clogging within the substrate. Ponding and clogging were not observed in this study which brought about an increased removal rate. Increase efficiency of the treatment facility could be obtained by providing a filter prior to loading into the CW basin.

The two parameters that express the removal of organic matter in constructed wetlands are BOD and COD. The CW was observed to be efficient in BOD_5 and COD removal. The organic load of the abattoir wastewater was observed to drastically reduce after 21 days of retention in the CW. The BOD reduced by 88.71% after 21 days and the COD reduced by 87.20%. The *V. nigritana* root structure provides a better performance by providing the necessary surfaces for bacteria to grow; the root also provide oxygen to the bacteria. A linear relationship has been observed between the loading rate and the removal rate of BOD_5 in CW (Ayaz, 2008). The desirability of a reduced BOD to a level that will not adversely affect the growths of the macrophytes was also discussed in Badejo *et al*., (2011). However, matured V. nigritana as reported by Troung, (2003) has unique morphological characteristics that made the plant tolerance to adverse environmental condition. Increased percentage reduction is expected as the CW system matures.

The results of the growth rate of *V. nigritana* when irrigated with water as compared with when irrigated with abattoir wastewater confirmed the conclusion of Troung (2003), as a difference in growth of 1.9 % was observed in the leaves and stem. *V. nigritana* irrigated with abattoir wastewater stabilized after maturation.

CONCLUSION

The results showed the negative impact of the abattoir wastewater on the Ogun river. The TSS, TDS, BOD_5 and COD of the abattoir effluent discharged into the Ogun river was observed to be above the WHO (2004) and FEPA (1991) recommended limits for discharge into river. The study revealed a need for a wastewater treatment facility before discharge into the stream to avoid health risk to the nearby users of Ogun river. Furthermore, the study discovered that CW using locally available macrophytes *V. nigritana* is efficient in the management of abattoir wastewater; the macrophytes are locally available, easily operated and more efficient to maintain compared to conventional methods of abattoir wastewater treatment.

The study showed that CW using *V. nigritana* in a gravel and sand substrate can be effective in removal of organic substances, suspended solid, Nitrates and Sulphate from abattoir wastewater. CW wastewater treatment facility is sustainable, effluent from it could be used as swamp fisheries, public recreation and harvested plants for biomas production. CW system being a low cost technology system can serve as a potential alternative or supplementary system for abattoir wastewater treatment in developing countries.

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