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Treatability Assessment Of Abattoir Wastewater Using *Pennisetum purpureium* Stalks As Filter Media: A Pilot Study

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Abstract

A pilot study was performed using three integrated column bioreactors with elephant grass (*Pennisetum purpureum*) stalks as filter media in treating abattoir effluent. The reactors (50 cm height, 10 cm diameter and a supportive gravel of 5 cm depth at the bottom) with individual volume of 3.5 L and a working volume of 3.1 L were constructed using 15 cm polyvinyl chloride (PVC) pipes. Freshly harvested elephant grass stalks were pre-treated, characterized and chopped to an average length of 20 mm - 40 mm. Wastewater was fed into the bioreactors at a constant flow rate of 0.00024 m^3/hr. using a variable speed peristaltic pump with hydraulic retention times (HRT) of 15, 30, 40 and 60 hours. The results obtained indicated a maximum removal efficiency of 43.03% for BOD, 35.93% for COD, 62.42% for Protein, 39.84% for Alkalinity ($CaCO_3$) and 63.33% for Ammonia nitrogen (NH_4^+) after a retention time of 60 hours. Increase in removal efficiencies with HRT time was observed for all the investigated parameters except pH, which slightly increased from a near neutral value of 5.6 to a slightly acidic value of 6.2. The Total Coliform Count also increased from 3.2×10^5 to 6.9×10^5 CFUs. The column reactor was adjudged to achieve an increasingly stable performance with time; however, further work is required to optimize the system and determine its long-term use. The authors further recommended the use of the treated effluent for irrigation of agricultural crops.

Keywords: Elephant grass, Abattoir, Effluent, Bioreactors, Irrigation.

INTRODUCTION

The Effluent generated and discharged by abattoirs is categorized as high strength with key pollutants mostly exceeding permissible limits. Researchers have consistently reported the inherent environmental and health risk of disposing poorly managed effluent (Benka-Coker et al. 1995; Aniebo et al. 2009; Zabbey et al. 2011). The impact of this practice is mostly felt by communities living near abattoirs as disposed effluent destroys biotic life and distorts natural ecosystems (Adelegan, 2002). Published reports have also traced river and groundwater pollution to the activities of nearby commercial abattoirs (Coker et al. 2001; Adelegan, 2002; Adegbola et al. 2012; Tekenal et al. 2014; Hassan et al. 2014; and Ekanem et al. 2016). To avoid this menace, the effluent requires some form of treatment prior to discharge to watercourse as commonly practiced. Ezeoha et al. (2012) emphasized the need to strategize abattoir wastes management practices in Nigeria to reduce the inherent consequences of poor waste management and environmental impact. Sangodoyin and Agbawe (1992) recommended proper legislation and stern punishment for poor abattoir waste management. Other researchers emphasized the need for proper monitoring and installation of pre-treatment facilities (Desalegn, 2014; Abdurahman et al. 2015; Ekanem et al. 2016)**.** Treatment facilities are often lacking in most abattoirs largely due to government negligence, lack of adequate information and low level of mechanization by operators. This contrasts with developed countries where abattoir activities are well regulated with the provision of adequate treatment facilities (Zabbey and Etela, 2011; Nafarnda et al. 2012).

Several technologies have been used to treat slaughterhouse effluent in bench and pilot-scale experiments. Some of these includes: bench and pilot scale studies on anaerobic filters, anaerobic fluidized bed in a continuously stirred reactor, bench scale up-flow anaerobic sludge blanket reactor with flocculent sludge ($UASB_f$) and granular sludge ($UASB_g$) (Stephenson and Lester, 1986; Sayed et al. 1987; Sayed and de Zeeuw 1988 and Harrison et al. 1991). Researchers have also advanced the use of plant materials for low-cost wastewater treatment. Daifullah et al. (2003) reported the use of rice husk activated carbon for the removal of heavy metals from industrial wastewater. Similarly, documented evidence shows the use of low-cost agricultural by-products in wastewater treatment especially in developing countries where adequate drainage facilities and regular power supply are not readily available. Some of these materials include: cotton stalks, sugarcane waste stalks, rice straw, ficus tree trimming stalks, wood chips, orange trees, date palm fiber, conifer wood chips and conifer bark (Bulena and Belanger, 1990; Lens et al. 1994; Daifullah et al. 2003; Hashem et al. 2009; El Sergany, 2009; El Sergany, 2012 and El Nadi et al. 2014;). Elephant grass is a local perennial fast-growing grass that is abundantly available in the study area at no cost. Local farmers often consider it as forage and often discarded as a weed. It has a good potential to absorb excess nutrients from processing wastewater used for irrigation (Dave et al, 2005). This prompted its selection for the present study. This study, therefore, seeks to evaluate the performance of an integrated pilot-scale bioreactor with elephant grass stalks as filter media.

MATERIALS AND METHODS

Wastewater sample collection and characterization

The abattoir wastewater was collected from an ultra-modern abattoir located at Akinyele Local Government Area of Oyo State, Nigeria. The abattoir slaughters an average of 76 animals per day, which includes goats, sheep and cattle. Samples were collected after a wire mesh that traps solids and fats constituents in a well-defined channel and transported in plastic coolers maintained at 4-5ºC. They were analyzed for pH, BOD, COD, Alkalinity, Ammonia nitrogen (NH_4^+), Protein and Total Coliform Count. Sample analysis was done using procedures detailed in Standard Methods (APHA, 1991).

Experimental Design

Three pilot-scale integrated reactors were constructed using clear polyvinyl chloride (PVC) pipes with plastic screens placed at the bottom of each reactor to hold the media and a baffle placed near the inlet of each reactor to disperse the wastewater as shown in Figure 2B. To prevent leakages, all the joints were sealed with clear silicon sealant. Each reactor has an internal diameter of 10 cm and total height of 50 cm resulting in a total volume 3.5 L and a working volume of 3.1 L. Each reactor was packed with treated elephant grass stalks chopped to a length of 20 mm as reported by El Nadi et al. (2013) to a volume of 2.7 L as shown in Figure 2B. The integrated reactors were fed with wastewater from a 50 litres plastic tank using a Ray-601S series variable speed peristaltic pump as shown in the schematic diagram shown in Figure 1.

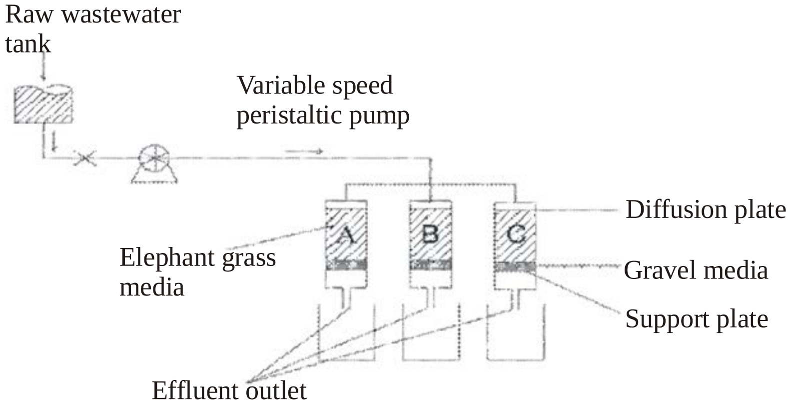

Figure 1. The schematic diagram of the fixed bed anaerobic experimental set-up.

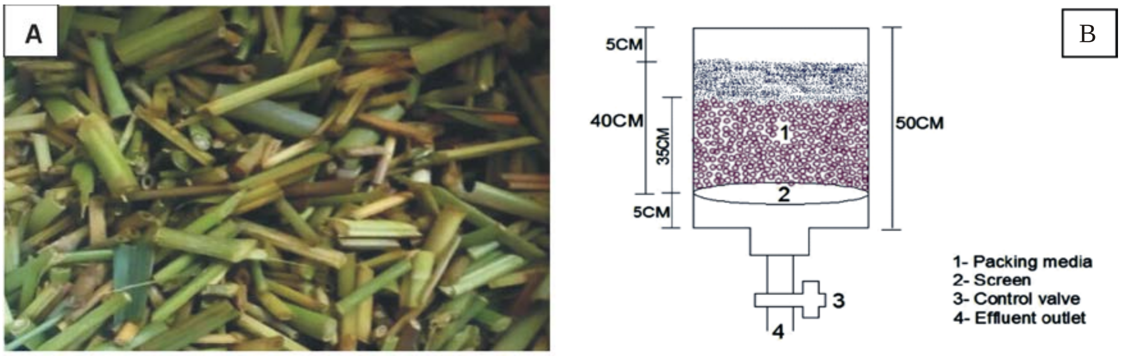

Figure 2. A: Freshly chopped elephant grass stalks; B: Schematic diagram of a single bioreactor.

Seed Sludge and Startup Phase

The loaded reactors were seeded anaerobically with fresh rumen content collected from the abattoir and allowed to stand for a period of 14 days allowing for biomass growth. The reactor was operated on a batch mode for sixty hours achieved by constantly feeding the raw abattoir wastewater into the set-up at a constant flow rate of 0.00024 m^3/hr. The influence of HRT on the removal efficiency of pollutant was investigated by gradually adjusting the hydraulic retention times (HRT) from 15 to 60 hours (15, 30, 45 and 60 hours). Feeding was initially done with dilute effluent to acclimatize the immobilized bacteria on the biofilter media after which raw abattoir wastewater was fed into the set-up with intermittent mixing of the supply tank to ensure a consistent concentration. Gradual growth and attachment of the bacterial mass were visually observed through the clear glass as the treatment progresses. Effluent samples were collected through the outlet ports shown in Figure 1 at regular interval for the different HRT rates. The performance of the set-up was monitored by analyzing treated samples for pH, BOD, COD, Alkalinity, Ammonia nitrogen (NH_4^+), Protein and Total Coliform Count.

RESULTS AND DISCUSSION

Biophysicochemical characterization of raw abattoir wastewater

The Biophysicochemical characterization of raw abattoir wastewater is presented in Table 1. The wastewater was mainly generated from carcass washing, slaughtering slab clean-up and domestic uses. The tested biophysicochemical parameters were mostly beyond the permissible limits set by NESREA (National Environmental Standards and Regulations Enforcement Agency) except for pH and ammonia nitrogen (NH_4^+) which were below the permissible limits. Bioreactor performance was assessed based on the pollutant removal efficiency {R_e (%)}of the various pollutant at different HRT using Equation 1.

$$Re\ (\%) = \frac{C_o - C_f}{C_o} \qquad - \quad - \quad (1)$$

Where:

$\mathbf{C}_f$ and $\mathbf{C}_o$ are the final and initial values of the tested parameter.

An appreciable change in the colour of the treated wastewater was observed after the treatment cycle. Total Coliform Count increased from 3.2 x 10^5 CFU/ml to 6.9 x 10^5 CFU/ml. This was probably due to the favourable condition created by the degrading effluent and filter media. The effect of varying the HRT in terms of removal efficiency is shown in Table 2. A consistent performance in the bioreactor removal capacity with increasing HRT was observed for the selected parameters. Maximum removal efficiencies of 63.33%, 62.42%, 43.03%, 39.84% and 35.93% were recorded for Ammonia nitrogen (NH_4^+), Protein, BOD, Alkalinity and COD after 60 hours of operation. The bioreactor performance was not affected by variations in pH as effluent pH remained between 5.7 and 7.7 for all the HRTs. The wastewater pH was reduced from an acidic value of 5.6 to 6.2. The low removal efficiency for BOD, COD and Alkalinity observed after 60 hours shows the limitations of the reactor capacity and may result from the hydrodynamics of the reactor.

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Parameter	Range	Mean value	NESREA Maximum Permissible Limits
pH	5.6	5.6	9
BOD* (mg/l)	2085 - 2105	2093.3±10.41	30
COD* (mg/l)	3879 - 3940	3917.0±33.15	60
Alkalinity $CaCO_3$ (mg/l)	5.5 - 5.8	5.6±0.15	ns
Ammonia nitrogen (NH_4) (mg/l)	15 - 20	16.7±2.89	44
Protein (%)	6.1 - 6.4	6.3±0.15	ns
Total Coliform Count (CFUs)	3.2×10^5	3.2×10^5	400

*COD: Chemical Oxygen Demand; BOD: Biochemical Oxygen Demand; ns: not stated.

The concentration of the bacterial isolates from the raw and treated wastewater are presented in Table 3. Bacillus spp. is the most dominant microorganisms while Pseudomonas and Escherichia coli are moderate in the raw wastewater. The overall removal efficiency of the system was substantially low compared to other similar studies probably due to the low hydraulic retention time and the change from an alkaline to an acidic medium. This observation was collaborated by Bitton, 2005. The inhibitory effect of slightly acidic medium on the methanogenic bacteria can also have a substantial effect on the bioreactor performance. Physical degradation of the chopped filter media was observed after the experiment. This was evaluated based on changes in some chemical composition before and after the experiment as presented in Table 4. The pH decreased slightly from 6.8 to 6.0 while total nitrogen, organic carbon, organic phosphate (PO_4) and potassium (K^+) increased after the treatment cycle. Some absorbed nutrients from the wastewater might be responsible for this increase.

Table 2: Bioreactor performance at various hydraulic retention times.

HRTs (h)	Removal Efficiency (%)				
	BOD	COD	Alkalinity ($CaCO_3$)	NH_4^+	Protein
15	30.50	22.65	15.19	20.00	51.24
30	34.70	27.86	21.89	33.33	57.62
45	38.90	32.02	28.99	46.67	60.68
60	43.03	35.93	39.84	63.33	62.42

Table 3: Bacterial isolates from the raw and treated abattoir wastewater.

Bacterial Isolates	Microscopic Grading	
	Raw Wastewater	Treated Wastewater
Bacillus	+++	++
Pseudomonas	++	+
Enterobacter	+	++
Aeromonas	+	++
Staphylococcus	+	+
Escherichia coli	++	+++

+ = low; ++ = moderate; +++ = high (grading adapted from *Balogu et al. 2014)*

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Physical observation revealed a slight degradation of the elephant grass stalk. This might have reduced the system porosity and ultimately lowered the system performance capacity. During operation, an appreciable amount of carbon dioxide is produced in the system which accounts for the slightly acidic pH; this is responsible for the production of ammonia gases that enhance the production of ammonium ion during bio-degeneration (Middlebrooks et al. 1999).

Table 4: Some characteristics of fresh elephant grass stalk

Parameter	Before Use	After Use
Total Nitrogen (%)	1.26±0.02	2.04±0.03
pH (10% Slurry)	6.8±0.01	6.0±0.02
Organic Carbon (mg/l)	61.3±0.30	69.2±0.15
P as PO_4 (mg/l)	260.0±0.03	313.0±2.89
K^+ (mg/l)	33.3±2.89	43.3±2.90

CONCLUSION

Elephant grass (*Pennisetum purpureum*) stalk, as an agricultural material, is a promising biofilter media for abattoir wastewater treatment, especially in areas lacking sanitation and treatment facilities. It can offer substantial economic gains with appreciable environmental benefits. The result indicated an increase in system performance with increase in the HRT for all the selected parameters. The system removal efficiency ranged from 15.19% to 63.33%. The results compare well with other studies but with lower reduction efficiencies which may be due to operating conditions. Therefore, an in-depth study is recommended to optimize the system and attain higher removal efficiencies. Further study is also needed to investigate the long-term application of elephant grass (*Pennisetum purpureum*) stalk and its potential application to treat other industrial wastewater. Since the treated wastewater contains essential plant nutrients, its safe use for agricultural purposes should also be investigated.

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