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Engineering Management of Abattoir Wastewater: A Case Study of Onyearugbulem Market, Akure South West Nigeria

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ABSTRACT: This paper presents a sustainable approach to abattoir wastewater management using Onyearugbulem Market abattoir in Akure, South West Nigeria as a case study. The research approach combined both laboratory experiment and field work pilot scale treatment system in establishing engineering parameters required for abattoir wastewater treatment. The result of the pilot scale treatment system shows that the quality parameters (TS, TSS, BOD_5, COD and Conductivity) meet the disposal standards by the National Environmental Standards and Regulation Enforcement Agency (NESREA) after 25 days detention time in anaerobic treatment pond with the exception of dissolved oxygen which was 0.1mg/L against 3.0mg/L recommended. In the abattoir, the required land space for 25 days detention period for 3 anaerobic ponds of 3 m depth is 231 m^2 which will take care of 594 m^3 of wastewater. Three trapezoidal ponds (top width = 7 m; bottom width = 5 m; depth 3 m and length = 11 m, Volume = 594 m^3) is recommended for anaerobic treatment. In order to improve the dissolved oxygen before disposal into receiving water body, it is recommended that the effluent from anaerobic pond should be allowed to pass through a gentle slope with buffers to create a turbulent flow and increase dissolved oxygen.

Keywords: Abattoir wastewater, treatment, anaerobic pond and disposal standard

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INTRODUCTION

Abattoir wastes management is becoming a problem for major cities worldwide. This is especially true in developing countries like Nigeria as a result of the rapid increase in (solid and liquid) wastes generation in abattoir resulting from rapid population growth, urbanization, industrialization and economic development (Suocheng and Kay, 2001). According to Pokhel and Viraraghavan (2005), management of municipal wastes in environmentally acceptable manner has become a global challenge due to limited resources and continuous increase in waste generation. In situations where the generated wastewater or solid wastes cannot be discharged or disposed off to the local municipal facilities, such wastes have to be treated in accordance with the requirements as described in a wide array of legislations such as NESREA (2011) and USEPA (2002). Failure to adhere to government approved disposal procedure or bad management practices could lead to high clean-up and rehabilitation costs.

Wastes include any material arising from human and animal activities that can be in three different forms viz solid, liquid, or gas that are discarded as useless or unwanted. The term as used in this paper is limited to solid and liquid generated

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in an abattoir. Wastes of this nature can either be biodegradable or non-biodegradable. Abattoir wastes can be defined as solid or liquid wastes from abattoir which could contain such materials as animal dung, blood, fat, paunch content, bones, horns and urine. Abattoirs produce large quantities of wastes and effluents containing a lot of organic pollutants. According to Akinro *et al.* (2011) the characteristics of abattoir wastes and effluents vary from day to day depending on the numbers and type of stocks being processed. In many cases, a lot of them are directly disposed into ecosystems without adequate treatment process thereby causing environmental damages and even affecting people's life quality (Mittal, 2006). The major environmental problem associated with abattoir wastewater is the large amount of suspended solids and liquid waste as well as odour generation (Gauri, 2006). The adequate operation of abattoirs is important in order to minimize environmental pollution. Efficient processes to treat wastes from abattoirs are an important stage of production chain that requires special attention.

Abattoirs activities generate wastes that are potential environmental problems. Some of these problems are traceable to improper waste management techniques. Sridhar (1998) reported that a slaughtered cow produces an average of about 328.4 kg waste in form of dung, bone, blood and hoof. Also, 45 percent of live cows consist of non-meat substances (Robert, 2005). Blood is one of the major dissolved pollutants in abattoir wastewater with its COD higher than any effluent from abattoir operations. Olanrewaju and Adewumi (2011) reported that Liquid blood has a COD of about 400,000mg/l and congealed blood has a COD of about 900,000 mg/l. The blood is also high in nutrients, typically 2,400 mg/l of nitrogen and 1,500m g/l of phosphorus. Fluctuations in pH due to the presence of caustic and acidic cleaning agents was also reported (Abebe, 2010).

Chukwu *et al.* (2011) reports that abattoirs in Minna metropolis dispose their wastewater on the nearby streams and ponds thereby giving rise to offensive odour and contribute significantly to the organic and nutrients loads of the streams leading to eutrophication.

Ponds are the most commonly used wastewater treatment system at both animal slaughtering and rendering plants. A common pond system involves anaerobic pond followed by suitable system of improving dissolved oxygen before finally disposed off. The anaerobic pond is deep and a crust is encouraged to form on the surface to reduce the interchange of air with the pond surface and reduce offensive odours (EPA, 2003). Organic matter in the water is broken down by anaerobic bacteria and solids settle to the bottom. The detention time required in the anaerobic pond is dependent on the biological oxygen demand (BOD) loading in the effluent.

Cow dung accumulates in the cow pen must be dried and scraped for composting. Composting is the aerobic process through which biodegradable organic materials undergo a partial mineralisation and profound transformations due to the metabolism of a complex microbial population. Kiyohiko *et al.* (2005) reported that the biologically stable and humified end product of compost can be applied as fertilizer in agriculture. Composting is a well-known system for rapid stabilization and humification of organic matter (Adani *et al*., 1995), as well as an environmentally friendly and economical alternative method for treating solid organic waste (Huang *et al*., 2006). During composting, readily degradable organic matter is used by microorganisms as a source of carbon and nitrogen. The end product (compost) consists of transformed, slowly degradable compounds, intermediate breakdown products and the cell walls of dead microorganisms, which are classified together as humic substances (Zimin *et al.,* 2007). Effects of inoculation on municipal solid wastes compost has been

investigated and shows clearly that inoculation have positive effect on composting, especially in thermophilic stage process (Bolta *et al*., 2003; Xi *et al*., 2005; Kiyohiko *et al.*, 2005; Barrena *et al*., 2006). This paper develops an environmentally sound and sustainable abattoir wastewater treatment technology appropriate for Onyearugbulem market abattoir in Akure, South-western Nigeria to minimize environmental pollution and offensive odours resulting from indiscriminate disposal of abattoir waste water.

MATERIALS AND METHODS

Description of the Study Area

Akure is the capital of Ondo state in the Southwestern Nigeria. It is located between Latitude 7°12'N -7^{0}12`N and between Longitude 5°15'E - 5°17'E. Onyearugbulem market is located along Akure - Owo express way. The city has a population of approximately 420,000 inhabitants. The climate of Akure is subtropical with two main distinct seasons: raining season and dry season. Rain falls throughout the year but the onset (significant rainfall amount) is during the month of March and cessation (sharp decrease in amount) is during the month of November (Adewumi, 2003). The mean annual rainfall ranges between 1300 - 1600 mm. Temperature ranges between 27^{o}C - 32^{o}C. The coolest months are August and September with temperature of 27^{o}C. The humidity of the air masses over the city varies from 60% in January to 80% in July (NIMET, 2003).

The Onyearugbulem market abattoir was selected as the study area because of its location in the low density area of the town with enough land space in nearby proximity to develop sustainable treatment units. The abattoir is about 50 meters off Ilesa-Akure-Owo express way adjacent Shagari village.

Methodology

The methodology adopted in this study involves both laboratory and field work to obtain design parameters for the wastewater treatment pond. The laboratory work involves analysis of raw and treated wastewater was carried out at the Chemistry and Postgraduate Research Laboratories in the Federal University of Technology, Akure, Nigeria.

Wastewater Sampling

Samples of wastewater for laboratory analysis were collected for the analysis of specified physicochemical parameters in accordance with the prescribed Standard Methods for the Examination of Water and Wastewater (APHA, 1989). During collection the materials used include: Hand protective gloves (for personal protection), sterilized plastic bottles (for wastewater sample collection), pH meter (to measure the degree of acidity and alkalinity of the wastewater), dissolved oxygen meter (to measure dissolved oxygen) and thermometer (to measure wastewater temperature). Samples taken were placed in ice packed coolers to maintain low temperature of about 4^{o}c to 10^{o}c and transported to the laboratory for analysis.

Sample Analysis

Conductivity and total dissolved solids were measured insitu using HACH conductivity/TDS Meter. pH and dissolved oxygen were determined on site using Hanna instrument pH 210 micro processor pH meters and Hanna dissolved oxygen meter respectively while temperature was measured with mercury thermometer.

Other analyses were carried out within 72 hours of sampling in the laboratory. The physical and chemical parameters of the wastewater samples examined were total suspended solid, total solid, BOD_5, COD, ammonia- N, Phosphorus and Alkalinity. Laboratory Analysis was done in accordance with the Standard Methods for Examination of Water and Wastewaters (APHA, 1989).

Field Work

Field work involves a reconnaissance survey to the abattoir with the aim of identifying a suitable location for a pilot scale wastewater treatment facility and the experimental set up of a pilot scale treatment unit to determine the efficacy of the use of anaerobic pond to treat abattoir wastewater

Pond Design

No of cows slaughtered daily = 20 – 40 cows

Daily water usage in the abattoir = 2000 – 3500 liters per day (on-site assessment)

In this design, the quantity of wastewater to be treated in the biological pond should be equal to the quantity of water used in processing the cow. However, due to infiltrations and additional water used in the abattoir to maintain sanitary and other purposes, additional 30% is added as suggested by Fair *et al*. (1991).

Therefore, average flowrate = 3,500 + (0.3 x 3,500) = 4,550 litres/day

The size of the pond is based on the daily average flow of effluent; the BOD of the effluent which was analyzed in the laboratory; the desired BOD percentage of 95% removal and the tropical climate of the area. In general, according to Garg (2005) the capacity of the pond should be at least 4 times greater than the flow of effluent while 2% of the average flow is allowed for desludging.

4 x 4,550 + (4,550 x 0.02) = 18,291 litres/day

Therefore, the design average flowrate = 18.291m^3/day ≅ 18.3m^3/day

According to Mara (2008), depths are typically 3 m in anaerobic ponds (range 2 to 5 m) and 1.5 m in facultative ponds (1 to 2 m). A depth of 3 m was chosen for this pond.

In other to select a suitable detention time that will achieve the effluent quality required for safe disposal, a pilot scale treatment plant was constructed onsite to monitor pollution removal efficiency of the pond at 5 days interval for 30 days.

Six anaerobic ponds were constructed in series within the abattoir premises. A thick polythene bag was used to cover the ponds to mimic anaerobic condition. Each pond is trapezoidal in shape and their engineering properties are as indicated in Figure 1. They were constructed of sandcrete blocks with mortar rendering to ensure impermeability.

Each of the six ponds was manually filled with abattoir wastewater up to a depth of 1m before sealing the top with a thick polythene bag. Four Samples were collected from each pond as follows:

Pond 1: Sample collected on 5 days

Pond 2: Sample collected on 10 days

Pond 3: Sample collected on 15 days

Pond 4 Sample collected on 20 days

Pond 4 Sample collected on 25 days

Pond 6: Sample collected on 30 days

Separate pond was used for different days in order to maintain the anaerobic condition in the pond.

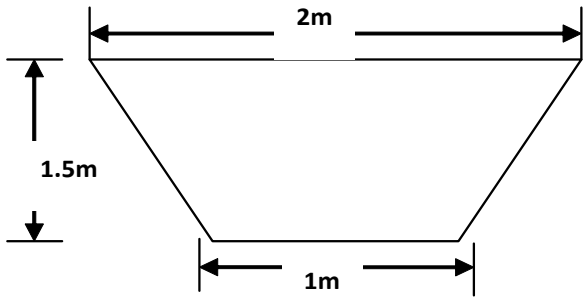

Figure 1: Cross section of pilot scale abattoir wastewater treatment pond

RESULTS AND DISCUSSION

Raw Wastewater Characterization

The results of the physicochemical analysis carried out on the raw wastewater are shown in Table 1. The table revealed that only pH and temperature are within the permissible limit of National Environmental Standards and Regulation Enforcement Agency (NESREA). This is a clear indication that the abattoir raw wastewater produce in the abattoir and dispose into the environment is capable of causing environmental pollution. This is evident by the offensive odours generated at the disposal site, hence; there is need to provide a good wastewater treatment facility in the abattoir. As stated earlier and with the availability of sufficient land, biological treatment of the abattoir wastewater will reduce organic load and to some extent nutrient levels, thereby allowing safe discharge into surface water systems or even its use for irrigation under controlled conditions.

Treated Wastewater Characteristics

The result of the pilot scale wastewater treatment pond is shown in Table 2. When compare these result with the raw wastewater quality (Table 1), the removal efficiency of the pond after 25 days detention time in anaerobic pond were 94% TS removal; 89% TSS removal; 98% BOD removal; 97% COD removal; 81% ammonia-N removal; 84% Nitrate removal and 73% Conductivity removal. This indicates that the pilot scale pond is effective in removing the essential pollutants in the abattoir wastewater before safe disposal to stream. Only dissolved oxygen fell below disposal standard. In order to improve the dissolved oxygen before disposal into receiving water body, the effluent from anaerobic pond should be allowed to pass through a gentle slope with buffers to create a turbulent flow and increase dissolved oxygen. This is to protect the aquatic fauna in the receiving water body.

Table 1: Onyearugbulem Abattoir Wastewater Physico-chemical Characteristics

Quality Parameters	Unit	Values Obtained		USEPA	NESREA
		Range	Average		
Physical					
Temperature	^{o}C	22 - 27	25	35	32
Total Solid (TS)	mg/L	560 - 1100	950	NA*	NA
Total Suspended Solid (TSS)	mg/L	205 - 441	330	50.0	NA
Total Dissolved Solid (TDS)	mg/L	332 - 815	610	2000.0	NA
Chemical					
pH	-	7.3 – 7.6	7.5	6 - 9	9.0
Biochemical Oxygen Demand (BOD_5)	mg/L	750 - 1895	1250	100.0	30
Chemical Oxygen Demand (COD)	mg/L	1015-2400	1800	NA	80
Dissolved Oxygen (D.O)	mg/L	2.0 – 2.5	2.3	5.0	3.0
Ammonia - N	mg/L	53-96	78	50.0	NA
Phosphorus	mg/L	18 - 24	21	NA	1.0
Alkalinity as $CaCO_3$	mg/L	610 – 750	700	400.0	NA
Conductivity	µohms	2500 – 3400	3000	NA	1000
Nitrate	mg/L	40 - 60	50	40	10

**NA means not Available*

Table 2: Effluent Quality of Pilot Scale Wastewater Treatment

Quality Parameters	Unit	Detention Period						USEPA Standard	NESREA Standard
		5 days	10 days	15 days	20 days	25 days	30 days		
Physical									
Temperature	°C	27	29	27	30	32	31	35	32
TS	mg/L	618	220	190	125	50	42	NA	500
TSS	mg/L	210	145	122	105	35	25	50.0	100
Chemical									
pH	-	7.3	7.6	7.5	7.4	7.2	7.6	6 – 9	9.0
BOD_5	mg/L	650	410	205	85	25	10	100.0	30
COD	mg/L	980	530	300	92	40	21	NA	80
DO	mg/L	1	0.5	0.3	0.2	0.1	Nil	5.0	3.0
Ammonia	mg/L	65	52	32	20	15	10	50.0	NA
Phosphorus	mg/L	24	20	18	15	9	5	NA	1.0
Alkalinity as $CaCO_3$	mg/L	630	540	450	320	210	115	400.0	NA
Conductivity	µohms	2300	1845	1200	985	810	752	NA	1000
Nitrate	mg/L	48	35	23	15	8	4	40	10

Recommended Engineering Parameters for the Onyearugbulem Abattoir Wastewater Treatment Ponds

Depth = 3m
Top width = 7m
Bottom width = 5m
Length = 11m
Anaerobic pond area = Top width x lenght
$7m \times 11m = 77m^2$
Therefpre, landed area required for 3 ponds =
$77 \times 3 = 231m^2$
Volume of the pond = side area x lenght

$$\text{Side area} = \frac{\text{Top width} + \text{Bottom width}}{2} \times \text{depth} = \frac{7+5}{2} \times 3 = 18m^2$$

Volume of the pond = $18 \times 11m^3 = 198m^3$
Therefore, the volume of 3 ponds =
$198 \times 3 = 594m^3$

The total volume of pond required to treat $18.3m^3$/day of wastewater for 25 days = $457.5m^3$
Since $594m^3 > 457.5m^3$, therefore the design is adequate.
All the three ponds are to be constructed in series with average retention time of 9 days.

CONCLUSION

Large volume of wastewater is generated from abattoir activities that pose health and environmental challenges if not properly handled. This paper presents a pragmatic solution to the problem associated with wastewater management in Onyearugbulem abattoir market in Akure, South West Nigeria. The research approach involves the use of both laboratory and field work. The laboratory analysis revealed the strength of wastewater generated in the abattoir while a pilot scale treatment unit was developed to determine appropriate pond detention time to produce the desire effluent quality. The result of this research will assist the abattoir operators to evolve a sound, safe and economically viable wastes management technique.

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