Treatment and Recycling of Wastewater from Selected Piggery in Futa Community

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Abstract- The establishment of piggery farms in residential areas is becoming an issue of public health concern owing to the discharge of its contaminated wastewater into the surrounding environment. Due to potential pollutants in these effluents, this study also attempted treating and recycling wastewater from selected piggery in FUTA community. The available piggery farms (medium and small-scale) cannot afford the cost of most existing municipal wastewater treatment plant. In furtherance, designing an effluent treatment plant made from locally available plastic materials which consist of bio-filters such as coarse, fine sand and activated carbon was considered. The water quality characteristics was carried out before the treatment of the wastewater in order to know the present contaminants. Moreover, the microbial-treated water was channeled into the filtration tank, where the larger particles of dirt (gravel and coarse sand) were removed. Also, grease and oil were removed by the activated carbon. The performance of the treatment plant was evaluated on the effluents and the results showed a decrease in Biological Oxygen Demand, Dissolved Oxygen, Phosphorus, Total Nitrogen, Total Dissolved Solids, Total Suspended Solid, Total Solids and Heavy metals (Cadmium, Lead and Zinc). Surprisingly, there was an increase in pH value of the microbial-treated water due to the detention time. The values obtained after treatment were compared to the Food and Agricultural Organization (FAO) water quality standard. This showed that the water is safe for discharge into the environment (waterways) and it can be used for irrigation purposes.

Keywords - Piggery farms, wastewater, detention time, activated carbon, removal efficiency

1. Introduction

Water is a critical resource for credible livestock production, there has been surprisingly little research done to better understand how its use can be optimized. The lack of research on water and its use in swine production has been as a result of the fact that until recently, water supply in most parts of this country has been plentiful and inexpensive, and therefore easily taken for granted. It is for this reason that water has been described as the forgotten nutrient (Thalin and Brumm, 1991).

Water represent 50% of most living organism (Steinfield et al., 2006). Pigs obtain water from three sources: water contained in the feed, metabolic water and water consumed by drinking. They need sufficient quantities of water to maintain optimal production levels. Water is the single largest constituent of the body making up to 82% of a young pig's and 55% of market hog body weight and is also a major component of secretions made by the pig (e.g. milk and saliva).

The establishment of piggery farms in the neighborhood is fast becoming a threat to public health as a result of attendant wastewater generated. It is known to be highly rich in pollutants (Department of Livestock, 2007; Noophan, 2009). Wastewater in this pig house pose serious threat to the environment resulting in unfavorable odour, adding undesired nutrient to the surrounding soil, and result into accumulation of nutrient in the surrounding surface water and in this case a treatment plant will be designed to treat the wastewater, immediately after the water has been automatically pumped and the water showers to the body of the pigs the water needed to conserved and not allowed to waste at all, it will be recycled for reuse in the pig house for cleaning the pen and for wallowing of the pig.

Over the decades the design of the treatment plant has been very costly which makes people prefer getting new water for use rather than wasting money on the technologies but this current design will be very simple and can be easily operated and it is also going to be cost effective enough for the people to afford it for recycling the water for reuse. Research effort to treat the effluent from the piggery is a major solution towards ensuring a clean environment. Hence, this project aimed to design wastewater treatment plant that stabilize the water and in turn filter it through sand media and activated carbon. Moreover, biological treatment of wastewater using non-toxic, biodegradable materials have recently been introduced. Furthermore, to achieve the stated aim, this research will focus on treating and recycling wastewater effluent generated in a selected piggery.

2. Materials and Methods

2.1. Sampling and Analysis

2.1.1. Sourcing of Sample

The sample is obtained at the Piggery Unit, Animal Research Farm, Department of Animal Production and Health, Federal University of Technology Akure, Ondo State, Nigeria. The piggery unit in the Research Farm practices the intensive system of pig rearing. They have different types of pigs; such as boar, sow, litter, grower etc. The practice of supplying water to the piggery house for wallowing, drinking, and cleaning has been manually and there is need for recycling those water coming out of the pig house so that it can be reused for the same purpose. In order to design a suitable low-cost treatment plant, the effluent of the pig house will be analyzed to know the properties of the wastewater at the Department of Chemistry, Federal University of Technology, Akure, Nigeria.

2.1.2. Physiochemical analysis of the wastewater

The following physicochemical parameters (pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Total Hardness, Total Nitrogen, Phosphorus, Chloride, Cadmium, Copper, Lead, Total Suspended Solid (TSS), Total Dissolved Solid (TDS), and Total Solid (TS)) were obtained during the Laboratory experiment via different chemical methods.

2.2. Materials for Construction

The components of the low-cost wastewater treatment multimedia filter include the followings:

2.2.1. Storage Talk (Facultative Lagoon)

A plastic drum, which absorbs heat better and faster during the day, was used as facultative lagoon of collected wastewater. Facultative ponds degrade organic matter through different processes depending on the depth layer. It has three biologically-active layers. The upper, middle and the lower layer which is 0.5 m in diameter and 0.8 m high has a valve installed just at 0.1 m from its base. The valve was used to metre a predetermined volume of wastewater into the treatment line. The plastic drum was also chosen because of its usefulness in the biological treatment process of water.

2.2.2. Filtration Tank

The filtration tank is cylindrical in shape plastic container with about 1000mm height. The diameter is 300mm with the surface area of about 70.7mm. The tank has three compartments: the filter medium where various filtering materials were placed, the medium which receives the raw wastewater before it is channeled to the filter media and the filtrate compartment where completely treated water is stored. The filter medium compartment is about 320mm from each other. At rear end of the tank's first and the second compartment they are perforated to serve as the strainer plate as shown in Fig. 1.

The operation of the tank will be in the trend of pouring the water that has been subjected to biological treatment into the first compartment of the filtration tank and it goes down through the strainer plate into second compartment which contains the three (3) layers of filter media where the water is filtered and the filtrate goes in the last chamber for collection. It has a valve which helps to close and open the water in the tank as shown in Plate 1 and Figure 1.

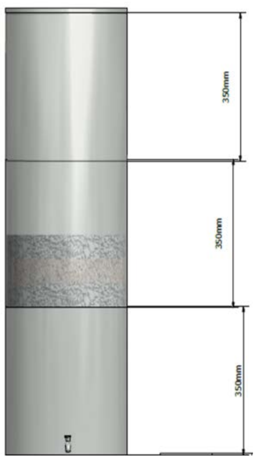


Figure 1: The front view of the filtration tank

2.2.3. Multi-media Filter

This comprises of gravel, coarse sand filter, fine sand filter and activated carbon as shown in Plate 3.6. On the average,

The diameter of gravel – 10, 20mm

The diameters of the coarse sand – 2mm

The diameter of the fine sand – 0.5mm

Activated charcoal were – 0.05mm

The sand media were used to filter solid particles and lighter particles that are contained in the wastewater and activated carbon derived from wood was used to dissolve chemicals such as oil and other oleophilic substances that stick to its surface while the water passes during the treatment process. The activated carbon as shown in plate 3.9 is capable of removing all man-made and naturally occurring substances such as: alachloratrazine, benzene, carbofuran, carbon-tetrachloride, chlorobenzene, dibromochloropropane (DBCP), O, Pdechlorobenzines, forms of dichloroethylens, 1, 2-dechloropropane, cis-1,3-dichloropropylene, toxaphene, chlordane, radon, lindane, simazine, toluene, xylenes and others.

Plate 1: Filtration Tank

2.3. Design Calculations

2.3.1. Design of Filtration Tank

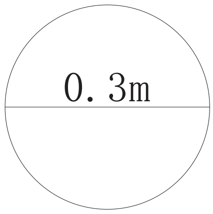
Considering a single pen in the piggery house

The Total Suspended Solids was measured to determine the turbidity of the water in mg/l instead of using the turbidity meter. Total Suspended Solids (TSS) was calculated as follows:

$$Asumming\ daily\ water\ flow = 0.02m^3/day$$

$$Hours\ of\ operation\ per\ day = 2hrs/day$$

Tank Surface area



$$A = \frac{\pi d^2}{4} \dots\dots\dots\dots\dots\dots\dots\dots (3.1)$$

$$= \frac{\pi\,(0.3)^2}{4} = \mathbf{0.0707m^2}$$

$$Flow\ rate(Q)\left(\frac{m^3}{hr}\right) = Tank\ Surface\ area \times Hydraulic\ loading\ rate \dots\dots (3.2)$$

Source: (Barrett *et al.*, 1991)

The wastewater Hydraulic loading rate according to ---- is $(0.4m^3/hr)$

$$Flow\ rate\ (Q) = 0.0707 \times 0.4$$

$$= \mathbf{0.02828m^3/hr}$$

Volume of Tank

$$Volume\ of\ tank = flow\ rate \times time \ldots\ldots\ldots\ldots (3.3)$$

$$= 0.02828 \times 2$$

$$= 0.0565m^3 = 56.5litres \approx \mathbf{57litres}$$

Depth of Tank

$$Depth\ of\ Tank = \frac{Volume\ of\ Tank}{2 \times Surface\ area\ of\ tank} \ldots\ldots\ldots\ldots (3.4)$$

$$\frac{0.057}{2 \times 0.02828} = \mathbf{1.01m}$$

The depth of Tank is 1.01m

Width of Tank

$$Volume = Lenght \times Width \times Depth \ldots\ldots\ldots\ldots (3.5)$$

$$Lenght = 4 \times width\ of\ tank$$

$$V = 4W \times W \times D \ldots\ldots\ldots\ldots\ldots\ldots (3.6)$$

$$W^2 = \frac{V}{4D} = \frac{0.057}{4 \times 1.01}$$

$$Width\ of\ tank = \mathbf{0.12m}$$

Depth of Sand in Tank

The depth of sand bed is determined by the number of years of operation desired before re-sanding is needed and by any constraints on the filter box depth. The year of operation (Barrett *et al*., 1991)

$$Y = \frac{D_i + D_f}{R \times f(sraping)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.7)$$

Y- Years of operation before sand bed rebuilding is necessary

D_i – Initial Sand bed depth (m)

D_f – Final Sand bed depth before rebuilding (m)

R- Sand depth removal for scraping (m/ scraping)

Removal of particles using filters with 1.0m sand bed depth were 97% with 0.5m sand bed removals were 95%

Maximum depth has been determined for first and final sand bed depth before it must be rebuilt (Huisman and Wood, 1974). Thus, it can be from 30cm - 80cm.

$$\text{Di} - \text{Initial Sand bed depth} = 30\text{cm}$$

$$\text{Df} - \text{Final Sand bed depth before rebuilding} = 32\text{cm}$$

$$\text{R} - \text{Sand depth removal for scraping} = 0.05\text{cm/scraping}$$

$$Y = \frac{32 - 30}{0.5 \times 12} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.8)$$

$$Y = 3.33 \approx \mathbf{3years}$$

The sand bed is designed to have a bed life of about 3 years (Barrett *et al*., 1991)

Sand bed head loss

$$Hydraulic\ loading\ rate(HLR) = 0.4m^3/hr$$

$$\Delta z - Depth\ of\ Sand\ filter\ bed = 0.32m$$

$$h_L - Head\ loss\ available\ across\ the\ filter\ bed$$

$$k' - Intrinsic\ hydraulic\ conductivity$$

$$\mu = dynamic\ viscosity\ of\ water\ at\ a\ given\ temp(N.s/m^2)$$

$$\mu(25^0c) = 0.9 \times 10^{-3}\ N.s/m^2$$

$$HRL = \frac{k' \times h_L}{\mu \times \Delta z} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.9)$$

The hydraulic conductive for slow sand filters

$$k' = 6.6 \times 10^{-7} N/m$$

$$0.4 = \frac{6.6 \times 10^{-7} \times h_L}{0.9 \times 10^{-3} \times 0.32}$$

$$h_L = \mathbf{0.05m}$$

A number of design decision are driven by the results of hydraulic analysis. Major hydraulic functions are: To distribute the raw water without erosion of sand bed

To collect water uniformly from the filter

To drain the head water for sand bed scraping

Flow through the Orifice

The header pipe (0.05m) in diameter, with a single outlet into the sand bed (Barrett *et al*., 1991)

$$V = \frac{Q}{A} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.10)$$

$$Q = 0.02828m^3/s$$

$$V = \frac{0.02828}{\pi(0.05^2)/4} = \frac{0.02828}{0.00196}$$

$$V = \mathbf{14.4m/s}$$

2.3.2. Design of Storage Tank

Matured seeds of M. oleifera (Linnaeus) were obtained in Ibadan, Nigeria. The seeds were removed manually by cracking the dry fruit. It was then pulverized using clean mortar and pestle. The seed powder was sieved with a sieve of 0.8 mm mesh size to obtain a fine powder. The fine seed powder obtained was applied to wastewater by preparing a stock solution of one (1) percent suspension. This was done by weighing 2.5g of the seed powder to 250ml of distilled water and then mixed thoroughly, so that 1ml of the

The equation below can be used in determining the area of the facultative lagoon according to Mara (1998).

$$A = \frac{Q}{DK_1}\left[\frac{L_{i-}L_e}{Le}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.11)$$

Source: (Mohammed, 2006)

The rate constant varies with the temperature because it is temperature sensitive

Arrhenius Equation of the form

$$K_T = K_{20\,\emptyset^{T-20}} \ldots\ldots\ldots\ldots (3.12)$$

Source: (Mohammed, 2006)

Ø; The Arrhenius constant is between 1.01 and 1.09 for the wastewater treatment process but for waste stabilization ponds, Ø is betwen1.05 and 1.09. The pond depth is 0.8m with an initial range value of 1.75 mg/l to 2mg/l

From equation (2)

$$K_1 = 0.3 * (1.05)^{21-20}$$

$$K_1 = 0.347$$

From equation (1):

Substitute all the values in the equation to produce

$$A = \frac{0.025\ (16.54 - 1.75)}{0.8 \times 1.75 \times 0.347}$$

$$A = 0.7611m^2$$

Detention Time

Wastewater flow rate: A suitable amount of water is required for the pigs and the rate at which the water flow out is about

$$Q = 31 litres/day$$

$$Q = 0.031m^3/day$$

Design value for facultative lagoon is about 80%w of the flow rate (Mohammed, 2006)

$$Detention\ time(t) = \frac{A \times D}{Q} \ldots\ldots\ldots\ldots\ldots\ldots (3.13)$$

$$\frac{0.7611 \times 0.8}{0.025}$$

$$Detention\ time = 24.35\ \approx \mathbf{24 days}$$

3. Results and Discussion

3.1. Effluent Characteristics

In order to access and compare the performance of multimedia filtration tank (activated carbon, gravel, and sand filter), the analysis of the wastewater effluent from the research farm was carried out and the corresponding values were obtained as in table 1.

The outlet pipe has no sieve which meant that the water coming out directly was not subject to proper preliminary treatment. The compositions of the effluent appeared to be the major contributor to the deterioration of surface water quality. During the analysis of the effluent, the pH value remained fairly stable, while the BOD value decreased due to rapid depletion of oxygen during the detention period of the wastewater.

3.2. Treatment Analysis

The analysis was carried out to show the efficiency of the treatment plant. Value obtained after treatment was compared to the one before treatment, thus indicating the plant has removed the particle to a minimal level.

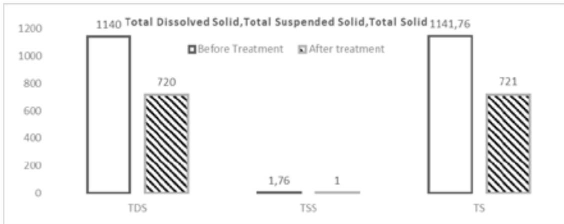


Figure 2: Chart showing the TDS, TSS and TS before and after treatment

Figure 3: Chart showing the BOD and DO before and after treatment

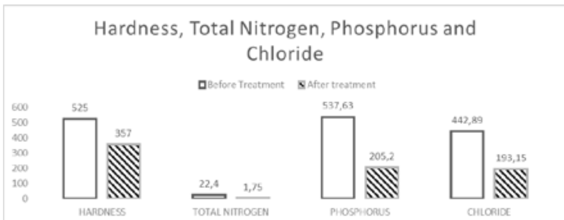


Figure 4: Chart showing hardness, total nitrogen, phosphorus and chloride of water before and after treatment

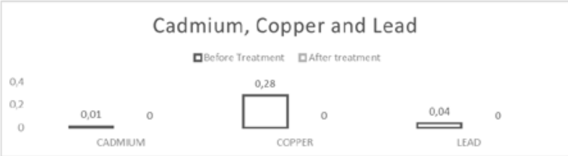


Figure 5: Chart showing the Cadmium, Copper and Lead in the water before and after treatment

3.3. Chemical Constituent Analysis

In order to show the efficiency of the multimedia filter medium, the Removal efficiency was calculated for Biological Oxygen Demand (BOD), Dissolved Oxygen (DO), Total Dissolved Solid, Total Suspended Solid, Total Solid, Total Hardness, Total Nitrogen, Phosphorus and Chloride. The Removal Efficiency was calculated by the formula below:

In order to show the efficiency of the multimedia filter medium, the Removal efficiency was calculated for Biological Oxygen Demand (BOD), Dissolved Oxygen (DO), Total Dissolved Solid, Total Suspended Solid, Total Solid, Total Hardness, Total Nitrogen, Phosphorus and Chloride. The Removal Efficiency was calculated by the formula below:

$$Removal\ Efficiency = \frac{C_b - C_a}{C_b} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots . (4.1)$$

Where C_b - concentration of waste water before treatment

C_a - concentration of wastewater after treatment

Table 1: The removal efficiency of the multimedia filtration tank

S/N	Physiochemical parameters	Before Treatment	After Treatment	Removal Efficiency (%)
1.	pH	6.97	7.94	__
2.	Dissolved Oxygen	97.57 mg/l	43.43 mg/l	55.49
3.	Biological Oxygen Demand (BOD)	48.54 mg/l	24.82 mg/l	48.87
4.	Total Hardness	525 mg/l	357 mg/l	32
5.	Total Nitrogen	22.40 mg/l	1.75 mg/l	92.18
6.	Phosphorus	537.63 mg/l	202.20 mg/l	61.82
7.	Chloride	442.89 mg/l	193.15 mg/l	56.39
8.	Cadmium	0.01 mg/l	ND	__
9.	Copper	0.28 mg/l	ND	__
10.	Lead	0.04 mg/l	ND	__
11.	Total Suspended Solid (TSS)	1.76 mg/l	1 mg/l	43.16
12.	Total Dissolved Solid (TDS)	1140 mg/l	720 mg/l	36.84
13.	Total Solid	1141.76 mg/l	721 mg/l	36.85

The table 1 showed that total nitrogen has very high removal efficiency (%) compared to other contaminants in the treated effluent. This indicated that the rate at which the multimedia filter removed the solids in the wastewater was considerably low.

Figure 6: Chart showing the percentage removal efficiency of the filter media

Table 2 showed the Food and Agricultural Organization (FAO) standard for water quality in terms of permisible amount of metals that should be in it for drinking, irrigation purposes and aquatic life protection. The following elements below were not detected in the water after treament:

Copper: This is a toxic element that is harmful to both plant and animal. It was observed in the water during the pretreatment analysis but was not detected in the wastewater after it has been treated.

Lead: This is another poisonous element which is harmful to both plant and animal. It was also not detected after treatment of the wastewater. This water is suitable for irrigation purpose.

Cadmium: This was detected in the water before treatment though it is non - significant, nevertheless, after treatment the metal was not detected in the water.

Table 2: FAO Standard for water quality

	Criteria Measurement (mg/l)		
CONSTITUENTS	Drinking water standard	Irrigation guideline Standard	Aquatic life protection limits
Arsenic	50	100	46
Boron	-	-	-
Cadmium	10	10	10
Chromium	50	100	11
Iron	300	500	-
Lead	50	5000	0.9
Lithium	-	2500	-
Manganese	50	200	-
Nickel	600	10	650
Zinc	-	2000	47

Source: Adapted from (Medramootoo et al., 1997; Vigneswaran and Sundaravadivel, 2004).

The amount of residue in the wastewater after treatment, which value had been analyzed according to table 2 was compared to the standard for irrigation reuse of wastewater, and the data obtained from the analysis falls within the range and guideline level of Food and Agricultural Organization (FAO).

4. Conclusion

Conclusively, the designed wastewater treatment plant which effects its treatment through locally available materials such as sands, gravel, and activated carbon was efficient in the removal of the following physiochemical contaminants such as (Biological Oxygen Demand (BOD), Total Solids (TS), Total Nitrogen, Phosphorus, Chloride, Cadmium, Copper, and Lead). It was deduced the Total Nitrogen has the highest removal efficiency of 92.18%.

Moreover, the value obtained after the treatment of the effluent was compared to the Food and Agricultural Organization (FAO) water quality standard and it showed the treated effluent is suitable for irrigating farmland.

The analysis carried out on the effluent showed the wastewater can be recycled and regenerated back into useful water for irrigation, animal drinking and industrial use if it is subjected to further treatment. Although the project provides solution to suit irrigation purpose only, therefore the research work is not a final solution to the piggery effluent treatment.

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