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Effectiveness of Using Floating Drum Bio-Digester to Treat Domestic Sewage

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Abstract

An anaerobic floating drum digester was used in treating domestic sewage. The volumetric capacity of the digester plant was estimated as 258.99 litres with a 250 litre-gas holder tank. The gas holder tank was fitted into the digester tank with a clearance of about 2cm to allow the former rise freely when biogas is generated in the digester tank. An inlet pipe was introduced for loading the wastes into the digester and an outlet pipe for dislodging, with an overflow pipe which indicates the maximum extent to which the digester could be filled. A gas valve was incorporated at the top of the dome-shaped gas

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holder to control the gas flow. With the aid of a thermocouple wire fitted into the digester and a multimetre, the temperature of the sewage was monitored at a succession of 4 hours for a hydraulic retention period of 42 days. Sewage was obtained from a freshly dug soak away and fed into the bio-digester through the inlet pipe. Physical, chemical and bacteriological analyses were carried out before and during digestion process on daily basis. Results show that Biochemical Oxygen Demand (BOD) of the sewage before and after treatment was 96.50 mg/l and 55.50 mg/l respectively. The Chemical Oxygen Demand (COD) was 81.60 mg/l and 59.00 mg/l, before and after treatment respectively. The dissolved oxygen (DO) reduced from 124.80 mg/l to 84.30mg/l after a hydraulic retention period of 42 days. These results of the resulting treated water agreed to a reasonable level with the standards slated in the World Health Organisation (WHO, 2006) standards for safe disposal of wastewater.

Key words: Anaerobic bio-digester, domestic sewage, dislodging, thermocouple.

Introduction

In Nigeria, laws on waste discharges from homes, industries and agricultural practices into natural water bodies are not strictly followed probably because of the costs of complying with such laws. The gases generated by these wastes are wasted or not effectively utilized which causes pollution of atmosphere by the greenhouse effects causing global warming and climatic changes, as well as the release of foul odour (Halidu, 2007). Survival of aquatic animals is being threatened; pollution of the air causing environmental discomfort and high health hazards of human being and animals by the improper discharging of sewage justifies the interest shown in the application of anaerobic digester in sewage sludge treatment cheaply and efficiently. The gas generated by the organic waste could be collected and stored for further use to minimize the pollution of atmosphere by the greenhouse effects causing global warming and climatic change while the sludge produced by digester is rich in nutrients which can be used as organic fertilizer or fish feed. Sewage includes domestic, municipal or industrial liquid waste products disposed of, usually via a pipe or sewer or similar structure sometimes in a cesspool emptier. The physical infrastructure, including pipes, pumps, screens channels etc. used to convey sewage from its origin to the point of eventual treatment or disposal is termed sewerage. Anaerobic digesters (AD) have been successfully used to generate

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energy since 1857. The first AD was built in a leper colony in India in that year. Lusk (1998) reported that anaerobic digesters first constructed in the United States in the 1970s in response to complaints about odour emanating from a swine farm in Iowa. The energy crisis of the 1970s spurred their growth as an alternative energy source for farms (Turner, 1999). Ever since then, anaerobic digesters have been in use with notable improvement to improve its efficiency till date. Biogas originates from bacteria in the process of bio-degradation of organic material under anaerobic (without air) conditions. Methanogens (methane producing bacteria) are the last link in a chain of microorganisms, which degrade organic material and return the decomposition products to the environment, if in an open system. In this process biogas is generated. Biogas is a mixture of gases which are; methane (CH_4) with 40-70 vol.% composition; carbon dioxide (CO_2) with 30 - 60 vol.% composition; other gases include: hydrogen (H_2) with 0-1 vol.% and hydrogen sulfide (H_2S) with 0-3 vol.% (Morel and Diener 2006). With the rapid increase in the population comes a very high increase in the volume of effluents produced as waste water on daily basis in Nigeria. This waste water, if not treated properly, may release odour, pollute the ground waters, release some greenhouse gases like methane and carbon dioxide and also compromise the good hygienic state of citizens, making the environment really unsafe for man. Also as the world drifts towards the practice of green revolution, which also has to do with the control of greenhouse gases released to the atmosphere to wreck global warming havoc, there is the need to control these gases released from septic tanks and put them in useful forms. This goes a long way in trapping these gases (greenhouse gases) before the water is released to the open environment. Indiscriminate sewage disposal habit necessitated the use an anaerobic digester to treat domestic sewage. The objective of this study was to use an anaerobic floating drum digester to treat domestic sewage.

Materials and Methods

Methodology

The wastewater used for the test was collected from a freshly dug domestic soak-away pit in Oke-Odo Area Ilorin, Kwara State. The study site is located between Latitude 8° 24′N and 8° 36′N and Longitude 4° 10′ E and 4^o36′E. The collected wastewater was tested for its physical, chemical and biological properties. The digester (Fig 1) was then filled with the wastewater through the inlet pipe (drain plug and pipe arrangement) to ¾ its capacity, which is

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about 195 litres. The batch process was used to treat the water in the digester in the mesophilic ambient temperature range i.e. 20 - 42^{o}C. The resulting treated water was then tested for its physical, chemical and bacteriological characteristics after digestion. Physical, chemical and bacteriological analyses of the wastewater sample before and after digestion were carried out in accordance with standard methods for the examination of water and wastewater (APHA, 2014).

Fig 1: Floating drum digester

Instrumentation

A thermocouple wire was used to determine the slurry temperature in a floating drum digester. The thermocouple wire was first calibrated in the laboratory and then welded and corked tightly to digester side to ensure no air bubble gets out of the bio-digester plant. The two probes of the thermocouple were fitted into the K-type thermocouple terminals of a digital multimeter. With the aid of the digital multimeter, the internal temperature of the slurry was taken at a succession of 4 hours (i.e. 8am, 12pm and 4pm) daily.

Results and Discussion

Temperature Variations

Fig. 2 shows the relationship between ambient and sewage temperature observed in the morning (8:00 a.m.). Fig 2 shows that the sewage temperatures were lower than the ambient temperatures. The temperatures of the sewage taken in the morning (8:00 am) were observed to be lower than the temperature values of the ambient temperature because of the thermal property

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of the bio-digester to absorb more heat from the environment than it is able to emit. Maximum and minimum ambient temperature values of 28°C and 23°C were recorded while maximum and minimum sewage temperature values of 25°C and 21°C were observed for the morning temperature readings. Fig. 3 shows the relationship between ambient and sewage temperature variations observed in the afternoon (12:00 noon.). From the graph, it can be deduced that the sewage temperatures were higher than the ambient temperature. The emissive power of the digester plant was reduced by painting the digester body black, thereby increasing its absorptivity. Minimum and maximum ambient temperatures of 28°C and 35°C were obtained during the period of study, while for the sewage conditions, the minimum and maximum temperatures of 33°C and 40°C respectively. Fig. 4 shows the relationship between ambient and sewage temperature variations observed in the evening (4:00 p.m.). Again Fig 4 shows that the sewage temperatures were higher than the ambient temperature values. This was as a result of black coat on the digester body. This increased the amount of heat absorbed and thereby increases the action of the methanogenic and mesophilic bacteria that majorly carry out the anaerobic digestion process. Minimum and maximum ambient temperatures of 31°C and 38°C were obtained during the period of study, while for the sewage conditions, the minimum and maximum temperatures of 34°C and 41°C respectively.

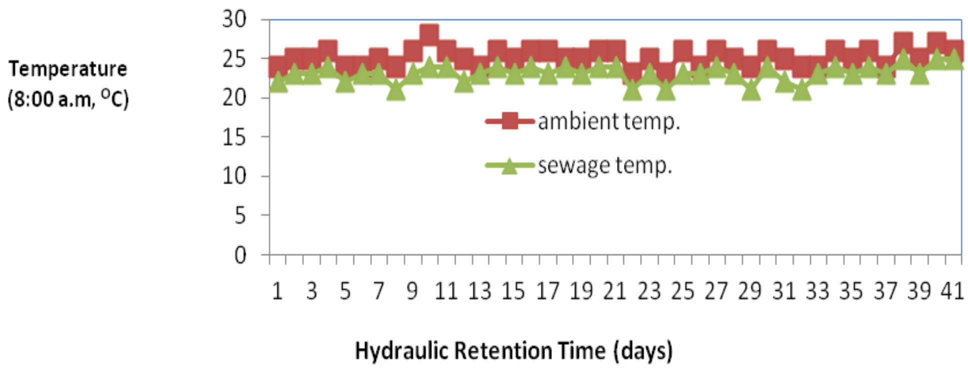

Fig. 2: Relationship between ambient temperature sewage temperature (8:00 am)

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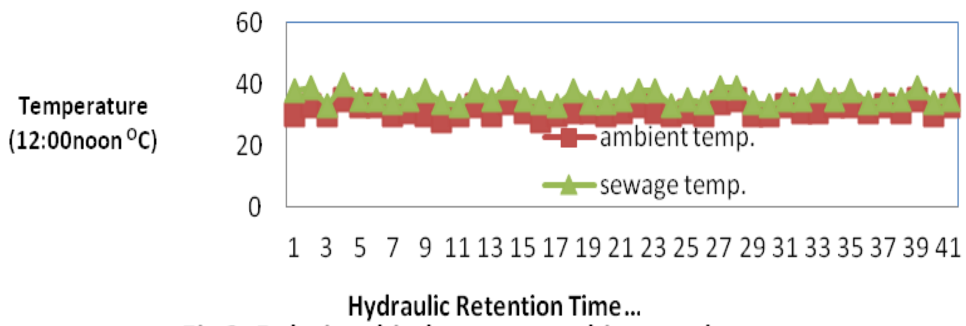

Fig 3: Relationship between ambient and sewage temp.(12:00 noon)

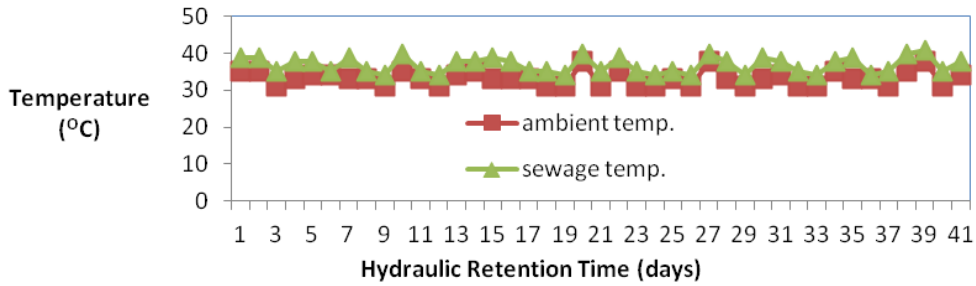

Fig. 4: Relationship between ambient temperature sewage temperature (4:00 pm)

Volumetric analysis

At a succession of 4 hours, the rise in the height of the gas holder was recorded and computed as the volume of gas generated at that point in time. For the first week of anaerobic digestion, which amounted to a total of six days (because there was no observable rise of the gas holder on the first day), there was a rapid evolution of a gas which extinguished fire when the gas valve was opened and the end of the gas hose was ignited. The gas was tested and observed to be CO_2. The volume of the CO_2 was 415litres for the first week as a result of the anaerobic activities of the acetogenic and acidogenic bacteria. However, the CO_2 concentration gradually reduced within the first 6 days, creating room for mesophilic disintegration of the solids and consumption of dissolved oxygen by anaerobic bacteria to increase the

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percentage of methane gas production. The reduction in CO_2 was tested by opening the gas valve and igniting the end of the gas hose to check how blue the flame was. Table 1 shows the daily gas production volumes. Table 1 shows that volume decreased as the retention time increases. This is as a result of lack of pH regulation, consumption of dissolved oxygen by anaerobic bacteria and less sunshine time for optimum heat generation.

Table 1: Physical, chemical and bacteriological properties of the sewage

S/N	Parameters	Before treatment	Week one	Week two	Week three	Week four	Week five	After treatment
1	Suspended solids (mg/l)	384	380	373	330	292	248	215
2	Dissolved Solids (mg/l)	896	894	882	851	823	792	751
3	Total Solids (mg/l)	1280	1210	1100	1015	910	860	820
4	pH value	7.60	7.63	7.95	8.20	8.55	8.76	8.90
5	NH_3 (mg/l)	12.50	12.51	12.90	13.00	13.20	13.22	13.44
6	Total Hardness (mg/l)	64.20	64.00	63.15	59.74	51.00	45.00	38.00
7	Total Alkalinity (mg/l)	148.00	145.00	139.00	136.20	128.00	125.00	115.00
8	(COD) (mg/l)	81.60	80.00	75.00	73.00	69.00	62.00	59.00
9	(BOD) (mg/l)	96.50	94.30	87.00	75.00	69.00	61.00	55.50
10	E.colicfu/100ml (counts)	2.5E6	2E6	1.65E6	1.23E6	9E5	8.56E5	7.10E5
11	Total Coliform cfu/100ml	2960	2950	2910	2850	2700	2610	2400
12	Turbidity (NTU)	594	590	500	410	390	200	110
13	Electrical Conductivity (mg/l)	1868.00	1800	1650	1400	1270	1190	1030
14	Dissolved Oxygen (mg/l)	124.80	120.20	110	103.50	95.92	89.53	84.30
15	Acidity (mg/l)	0.84	1.23	1.57	2.30	2.90	3.90	4.50
16	Nitrates (mg/l)	82	81.00	79.00	73.00	65.00	58.00	49.00
17	Sulphates (mg/l)	124.20	123.50	118.00	115.00	112.00	106.00	92.00
18	Chlorides (mg/l)	24.60	24.30	22.00	21.50	19.80	18.7	17.00

Volumetric calculation

The volumetric calculation of the CH_4 gas produced during the study was done as stated below:

Volume of pure CO_2 that evolved for a retention period of 42 days, V_c = 415 litres.

Total volume of gas that evolved for a retention period of 42 days, V_t = 2654.91 l.

Volume of CH_4 gas + some gases like H_2S, H_2 e.t.c. (insignificant), $V_m = V_t - V_c$

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Percentage composition of CH_4 gas = V_m/ V_t× 100 = 2239.91 / 2654.91 × 100= 84.4%.

However, this percentage composition of CH_4 contains elements of H_2 gas and H_2S in insignificant percentages. These gases may be removed by the introduction of a scrubber into the set-up and also secondary bio-digestion treatment of wastewater.

Analyses of the sewage samples

Sewage was obtained from a freshly dug soak away and fed into the bio-digester through the inlet pipe. Sample of the fresh sewage was taken to the laboratory and physical, chemical and bacteriological analyses were carried out before digestion treatment. Samples were taken weekly during bio-digester treatment and taken to the laboratory to test for the effectiveness of the digestion process. Table 1 presents the laboratory results of the tests. Figs. 5 and 6 show the significant declination in the gradients of the curves. This implies that there was effective reduction in BOD throughout the entire digestion period of 42 days. Also, the steady slope of the COD graph indicates a steady reduction in COD content of the waste throughout the entire digestion period. The result obtained showed that gas (majorly CO_2) production occurred during the first five days of loading the digester tank with the sewage. The steady reduction in the biogas production of the methane gas could be attributed to lack of pH regulation during the digestion process as the final pH of the treated sewage (8.90) differs significantly from that of the influent producing gas. Ntengwe et al., (2010) reported that pH in the range 6.8-8.0 is favourable for gas production. The amount of solar radiation in form of heat, anaerobic bacteria present and amount of dissolved oxygen available for consumption by the bacteria are also factors that determine the effectiveness of the bio-digestion process and hence, the reduction of BOD and COD. At the end of the hydraulic retention period of 42 days, the BOD of the loaded sample which had a value of 96.50 mg/l was reduced to 55.50 mg/l, while the initial COD value of 81.60 mg/l was also reduced to 59 mg/l at the end of the process. Fig.7 shows the reduction of solids against retention weeks. Samples were collected through the outlet pipe at the end of every week for physical, chemical and bacteriology analyses. The graph shows a steady reduction of dissolved solids (DS), suspended soils (SS) and Total solids (TS) against the digestion period. Total solids value before treatment was 1280 mg/l and after treatment, it was 820 mg/l. Suspended solids reduced

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from 384mg/l to 215mg/l after the digestion period. Dissolved solids were 896 mg/l before treatment and were reduced to 751 mg/l. Fig. 8 shows a steady reduction in the amount of E-coli concentration in the sewage sample. E-coli is one of the essential parameters for the determination of tolerance limit for discharge of wastewater in surface water bodies. Sewage generally contains a very high degree of E-coli as a result of faecal deposits, coliforms and bacteria in large quantities. The E-coli value of 2.5E6 counts before treatment was reduced to 7.10E5 counts. However, this seems large compared to the WHO (2006) standards presented in Table 2. This is as a result of the non-uniform weather condition, fluctuations in temperature values, amount of heat trapped and majorly, the watery nature of the sewage. Table 2 presents the comparison of the analytical results obtained from the digestion treatment with the WHO (2006) standards for the disposal of treated sewage. Table 2 shows that the bio-digestion reduced to reasonable levels physical, chemical and bacteriological properties of the sewage.

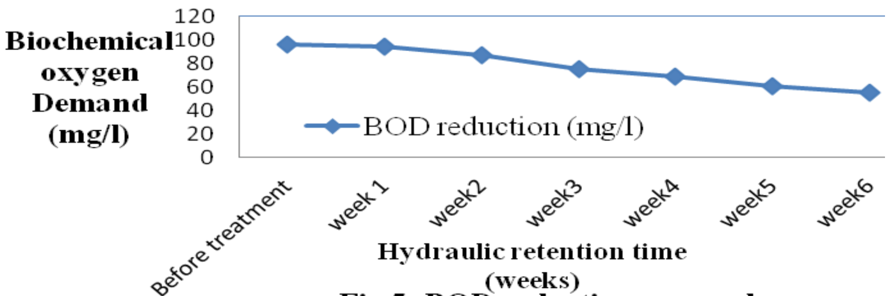

Fig 5: BOD reduction per week

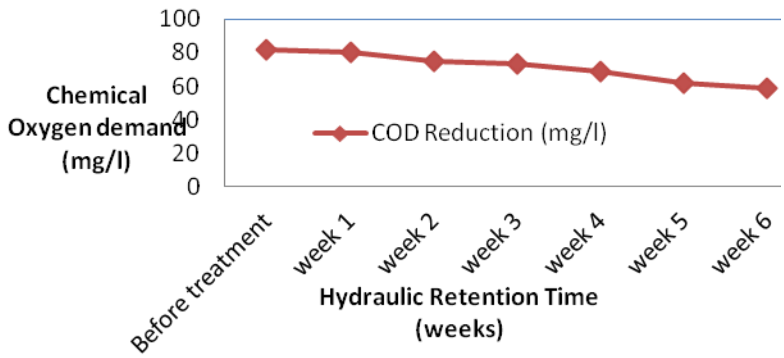

Fig 6:COD Reduction per week

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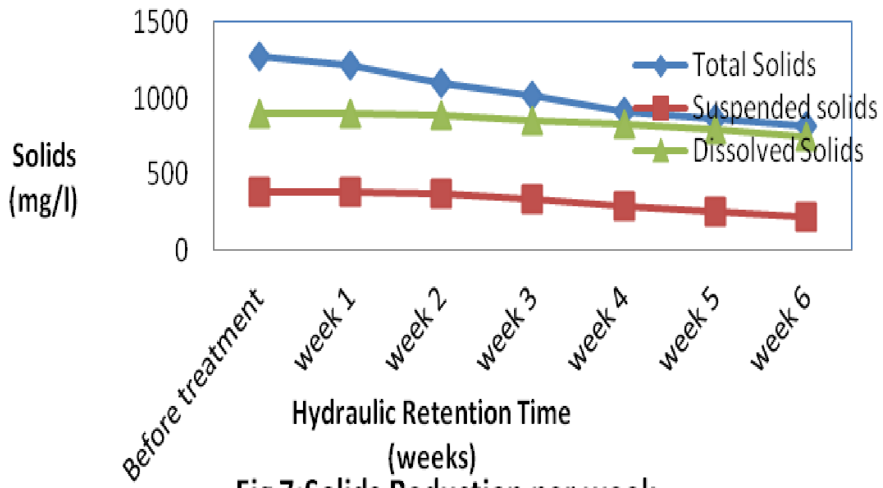

Fig 7:Solids Reduction per week

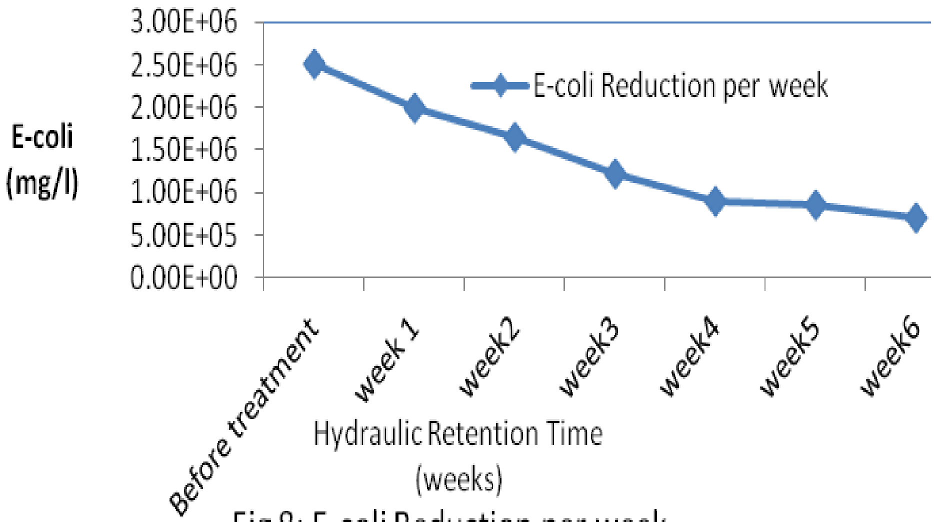

Fig 8: E-coli Reduction per week

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Table 2: Volumes of gas generated at 8am, 12pm and 4pm daily, as a function of the rise in height of the gas holder tank.

Days	Volume rise (lit.)				
	8am	12pm	4pm	Daily volume	Weekly volume
1	-	-	-	-	
2	-	23.26	25.94	49.20	
3	-	23.26	23.26	46.52	
4	19.24	24.60	20.58	64.42	
5	23.26	31.30	25.94	80.50	
6	33.97	33.97	31.30	99.24	
7	23.26	28.62	23.26	75.14	1st= 415 liters
8	25.94	28.62	25.94	80.50	
9	20.58	28.62	23.26	72.46	
10	23.26	28.62	28.62	80.50	
11	20.58	25.94	28.62	75.14	
12	-	36.65	25.94	62.59	
13	-	23.26	23.26	46.52	
14	23.26	23.26	25.94	72.46	2nd= 490.17 liters
15	20.58	20.58	20.58	61.74	
16	20.58	23.26	20.58	64.42	
17	20.58	25.94	23.26	69.78	
18	20.58	28.62	33.97	83.17	
19	20.58	23.26	25.94	69.78	
20	-	20.58	23.26	43.84	
21	20.58	20.58	23.26	64.42	3rd = 457.15 lits.
22	20.58	23.26	23.26	67.10	
23	19.24	21.92	23.26	64.42	
24	20.58	25.94	31.30	77.82	
25	25.94	25.94	31.30	83.18	
26	25.94	23.26	20.58	69.78	
27	-	23.26	20.58	43.84	
28	31.30	28.62	23.26	83.18	4th = 489.32 lits.
29	36.65	23.26	25.94	85.85	
30	20.58	28.62	28.62	77.82	
31	-	23.26	25.94	49.20	
32	23.26	23.26	25.94	72.46	
33	-	23.26	25.94	49.20	
34	-	25.94	31.30	57.24	
35	-	23.26	20.58	43.84	5th = 435.61 lits.
36	20.58	28.62	31.30	80.50	
37	25.94	23.62	28.62	77.82	
38	-	25.94	28.62	54.56	
39	-	20.58	20.58	41.16	
40	-	23.26	25.94	49.20	
41	-	20.58	20.58	41.16	
42	-	-	23.26	23.26	6th = 367.66 lits.
				TOTAL VOL.=	2654.91 litres

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Table 3: Comparison of Analytical results with WHO (2006) Standards for safe disposal of wastewater into the environment

S/N	Parameter	Analytical Result	WHO (2006) Standards
1	Suspended solids	215	220
2	Total dissolved Solids (mg/l)	751	2000
3	Total Solids (mg/l)	820	NS
4	pH	9.8	6.5-8.5
5	NH_3 (mg/l)	13.44	NS
6	Total Hardness (mg/l)	38	NS
7	Total Alkalinity	115	NS
8	Chemical Oxygen Demand(COD) (mg/l)	59	1000
9	Biochemical Oxygen Demand (BOD_5) (mg/l)	55.50	50
10	E.colicfu/100ml	7.10E5	0
11	Total Coliform cfu/100ml	2400	10
12	Turbidity (NTU)	110	5
13	E. Conductivity (uc/cm)	1030	1000
14	Nitrate (mg/l)	49	45
15	Sulphate (mg/l)	92	250
16	Chlorides (mg/l)	17	5

Conclusion

The study shows floating drum anaerobic digesters can be to treat domestic sewage. The physical, chemical and bacteriological properties of the treated sewage were comparable with the WHO (2006) standards for safe wastewater disposal. Thus domestic sewage can be successfully treated with anaerobic digester and biogas generated can be bottled for generating wealth in developed nations of the world like Nigeria.

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References

American Public Health Association (APHA), (2014). Standard methods for the examination of water and wastewater. Updated Errata list for 22nd Edition of Standard Methods. http://www.standardmethods.org/ViewArticle.cfm?articleID=98.

Halidu, M.T. (2007). How Lagos Residents pollute the environment: Threats to the Nigerian Environment. *Nigerian Environmental Issues*. www.ngenvirons.blogspot.com.

Lusk, P. (1998). Methane Recovery from Animal Manures: The Current Opportunities Casebook. National Renewable Energy Laboratory 1617 Cole Boulevard Golden, Colorado 80401-339. A National Laboratory of the U.S. Department of Energy Managed by Midwest Research Institute for the U.S. Department of Energy under contract No. DE-AC36-83CH10093. http://www.nrel.gov/docs/fy99osti/25145.pdf.

Morel, A. & Diener, S. (2006). *Greywater Management in Low and Middle-Income Countries., Review of different treatment systems for households or neighbourhoods*., Dübendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (Eawag).

Ntengwe, F.W., Njovu, L., Kasali, G. & Witika, L.K. (2010). Biogas Production In

Cone-Closed Floating-Dome Batch Digester Under Tropical Conditions. International Journal of ChemTech Research CODEN(USA): *IJCRGG*, 2(1), 483-492.

Turner, J. A. (1999). Energy Viewpoint: A Realizable Renewable Energy Future. *Science.* Vol. 285. www.sciencemag.org.

World Health Organization (WHO, 2006). WHO Guidelines for the safe use of wastewater, excreta and greywater Volume 2, Wastewater use in Agriculture, World Health Organization, Geneva.

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