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Case Study Article

THE EFFECT OF SEWAGE CONCENTRATIONS AND MATERIALS OF CONSTRUCTION OF SEWAGE DIGESTER ON BIOGAS PRODUCTION

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ABSTRACT

The effects of two sewage concentrations and bioreactor types on biogas generation capacity have been investigated. Different bioreactors including plastic, mild and galvanised steel were used. Results obtained show that more than 10 litres of biogas was generated from 0.4kg/l of 15 litres sewage as against 4.6 litres generated from equal volume of sewage of 0.5kg/l concentration. This indicated that an optimum sewage concentration exists, which favours biogas production. Also, while the metallic bioreactors such as mild and galvanised steel as used in this study inhibited biogas production, the transparent plastic bioreactors enhanced its production. Furthermore, it was noticed that increasing ambient temperatures from 28 to 31^{o}C increased the biogas output from the two sewage concentrations.

Keywords: Biogas, sewage, concentration, plastic and metallic bioreactors.

INTRODUCTION

Biogas, as a renewable energy, can be produced from a variety of organic raw materials such as biomass, animal manure, sewage, municipal waste, green waste, plants material, crop residue and sometimes kitchen waste, [1, 2]. Biogas can in fact be generated from vast organic matter which ordinarily are harmful to man and his environment. Sewage for instance, is likely to carry pathogenic organisms that can transmit disease to humans, animals. And when poorly handled as in the case of developing countries, can lead to eco toxicity, [3]. The anaerobic digestion or fermentation of these biodegradable harmful materials is what gives rise to biogas. Environmentally, the benefits that come with production of biogas are a reduction of odour, the level of pathogens and greenhouse gas emissions, [4, 5, 6]. Biogas obtained from the bio-chemical reactions or biodegradation of organic wastes, has been reported to contain methane, carbon dioxide, nitrogen, hydrogen and hydrogen sulphide by different groups of researchers. While one group reported about 60 – 65% methane, [7]. Another group reported 50-75% Methane, 25-50% Carbon dioxide, 0-10% Nitrogen, 0-1% Hydrogen and 0-3% Hydrogen Sulphide, [8, 9]. Methane is usually present in the highest composition and makes it a valuable resource which can be used to offset part of the energy requirements for in-plant and domestic use, [7, 8, 9]. And since biogas is a renewable energy resource obtainable everywhere from renewable sources, biogas production will give room for even rural communities in different countries of the world to actively participate in the power sector bearing in mind that the raw materials for biogas production would be sourced from these communities which, would result in the overall development of such rural areas, [6, 10].

Biogas can be produced using anaerobic digesters which, are fed with biodegradable wastes including sewage sludge and food waste. The digesters are air-tight tank that transforms biomass waste into methane producing renewable energy which, can be used for heating, electricity, and many other operations, [11]. The design and use of bio-digesters should be encouraged and more preferable than landfill gas production. Landfill site that has not been engineered to capture the biogas slowly releases it into the atmosphere. This becomes very hazardous for obvious reasons. Landfill gas becomes explosive when it escapes from the landfill and mixes with oxygen. The lower explosive limit is 5% methane and the upper explosive limit is 15% methane, [12]. The methane content in the biogas is 20 times more potent as a greenhouse gas than is carbon dioxide. Hence, uncontrolled landfill gas, which escapes into the atmosphere, may significantly contribute to global warming. Also, from landfill, volatile organic compounds (VOCs) within landfill gas contribute to the formation of photochemical smog. Anaerobic digester can be controlled to manage industrial or domestic wastes in other to produce bio-fuels for electricity and heat generation, or can be processed into natural gas and transportation fuels that are renewable. A wide range of anaerobic digestion technologies are available today to convert livestock manure, municipal wastewater solids, food waste, high strength industrial wastewater and residuals, fats, oils and grease (FOG), and various other organic waste streams into biogas on a continuous basis, [12, 13].

Three types of bio-digesters made of galvanise steel, mild steel and 20 litres capacity polypropylene bottles were used in this study. The essence was to consider the effect of bio-digesters on the rate of biogas formation and production from two different concentrations of the sewage sludge.

METHODOLOGY

Constructed mild and galvanized steel bioreactors of 12 litres capacity each and 2 X 20 litres plastic bioreactor purchased from a supermarket in Ota were used for this study. They were all air tight bio-reactors to facilitate the anaerobic digestion of the sewage. Two different concentrations (0.4kg/l and 0.5kg/l) of the active solid were prepared by mixing them with the sewage water respectively. The pH and the Biological Oxygen Demand (BOD) of the two sewage concentrations were then carried out and recorded. The four bioreactors were then filled to three-quarter (3/4) of the bioreactor capacity and the weight of the sewage in each of them recorded. The closed bioreactors were equipped with gas hoses to deliver biogas produced over water by downward displacement in graduated gas collection and measurement bottles. The set up was done at ambient temperature as recorded. Daily monitoring of the biogas production rate was done on an hourly basis.

RESULTS AND DISCUSSION OF RESULTS

The Effect of Bioreactor type on Biogas Production Yield

The two transparent plastic bioreactors yield a continuous flow of biogas all through the 52 days of study, no biogas was produced from the mild and galvanised steel bioreactors under the same imposed reaction conditions of time, concentration, ambient temperatures and pressure, and closed vessels to promote anaerobic digestion of the sewage. The main difference is in the materials of construction. While the metallic bioreactors were opaque and good conductors of heat, the plastic bioreactors were transparent and poor conductors of heat. This difference maybe be responsible for the biogas production from the transparent bioreactors and none from the opaque metallic bioreactors. The internal surface of the metallic bioreactor may also have inhibiting effect on the methanogenic bacteria. The transparent plastic bioreactors may also absorb heat and light energy from the sun, which helped to activate the sewage digesting micro-organisms or methanogenic bacteria. Being poor conductors of heat, they were also able to retain absorbed heat and light energy for bio-catalysis and sustenance of biogas production at night seasons. This was responsible for the continuous biogas production during the night seasons. Metallic bioreactors did not possess these advantages and hence did not produce any biogas. In fact, the metallic materials of construction only acted as inhibitors or poison to the sewage digesting micro-organisms or methanogenic bacteria. The transparent bioreactors favour and promote bio-chemical reactions for biogas production.

Table 1: Daily Biogas Output from Two Digested Sewage Concentrations using Transparent Plastics as Bioreactors

Time (days)	Temperature (°C)	0.4kg/L concentration		0.5kg/L concentration	
		Gas volume (ml)	Cumulative gas volume (ml)	Gas volume (ml)	Cumulative gas volume (ml)
1	31	150	150	-	-
2	31	200	350	-	-
3	31	220	570	220	220
4	31	260	830	270	490
5	31	320	1150	140	630
6	31	400	1550	230	860
7	31	150	1700	210	1070
8	31	330	2030	400	1470
9	30	210	2240	130	1600
11	30	210	2450	240	1840
12	29	165	2615	40	1880
13	29	285	2900	40	1920
14	28	270	3170	70	1990
15	30	130	3300	150	2140
16	28	100	3400	240	2380
17	29	370	3770	340	2720
18	31	340	4110	440	3160
19	30	230	4340	320	3480
20	30	120	4460	160	3640
21	30	450	4910	380	4020
22	29	280	5190	100	4120
23	28	220	5410	80	4200
24	29	280	5690	100	4300
25	30	290	5980	120	4420
26	28	310	6290	80	4500
27	28	260	6550	60	4560
28	28	180	6730	20	4580
29	28	120	6850	20	4600
30	30	180	7030	20	4620
31	31	280	7310	0	4620
32	31	300	7610	0	4620
33	31	290	7900	0	4620
34	31	270	8170	0	4620
35	30	250	8420	0	4620
36	30	180	8600	0	4620
37	30	160	8760	0	4620
38	29	140	8900	0	4620
39	29	120	9020	0	4620
40	29	120	9140	0	4620
41	29	120	9260	0	4620
42	28	110	9370	0	4620
43	30	140	9510	0	4620
44	30	110	9620	0	4620
45	30	130	9750	0	4620
46	30	100	9850	0	4620
47	29	90	9940	0	4620
48	29	65	10005	0	4620
49	28	40	10045	0	4620
50	28	10	10055	0	4620
51	28	0	10055	0	4620
52	30	0	10055	0	4620

The Effect of Concentration on Biogas Production Yield

It was observed that the activities of the methanogenic bacteria in the sewage concentration of 0.4 kg/l (sample C) were much higher than that in the 0.5 kg/l concentration, (sample D). This was seen in the rate of biogas production from the two sewage concentrations. While sample C began the generation of biogas after nine days of culturing, sample D started in eleven days. The faster rate of digestion in sample C may be attributed to the lower substrate surface areas per litre of sewage making it easier for microbes to digest than the larger substrate surface of sample D. The effects of this can be seen from table 3.1 where there are: (i) time difference of about three days between the two samples in biogas generation and (ii) extinction of the bacteria leading to stoppage of biogas generation just after thirty days. Relatively, table 3.1 for sample C, increased in microbial activities leading to higher cumulative volume of biogas generation, which lasted for fifty-two days. Table 3.1 give the total cumulative volume generated for both samples: 10.06 litres of biogas were obtained from sample C while 4.6 litres were generated from sample D, for a period of 52 days.

Table 2: Biogas Production Rate At Varied Temperature using Transparent Plastics as Bioreactors

Average Temperature (˚C)	Average gas production for 0.4kg/L concentration	Average gas production for 0.5kg/L concentration
28	162	81
29	185	124
30	193	190
31	270	273

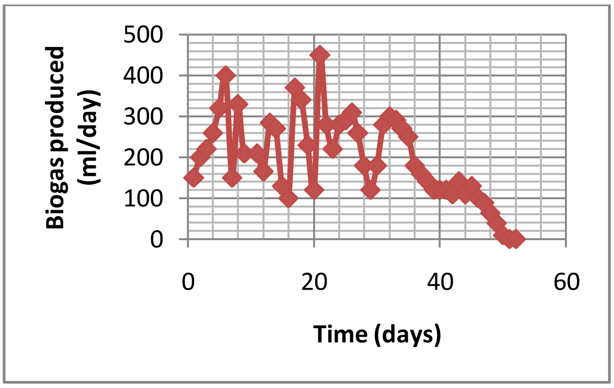

Figure 3.1: Daily Gas Production Rate (ml/day) for sewage concentration of 0.4kg/l using Transparent Plastics as Bioreactors

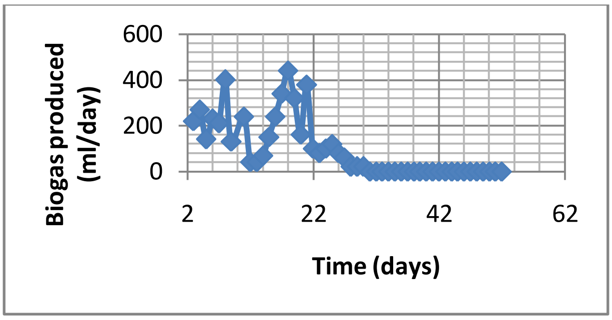

Figure 3.2: Daily Gas Production Rate (ml/day) for sewage concentration of 0.5kg/l using Transparent Plastics as Bioreactors

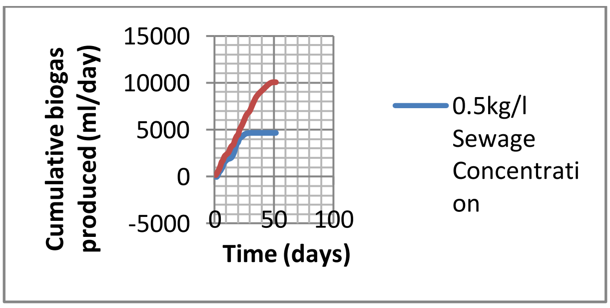

Fig. 3.3: Cumulative Daily Biogas Production (ml) for Two Different Sewage Concentrations

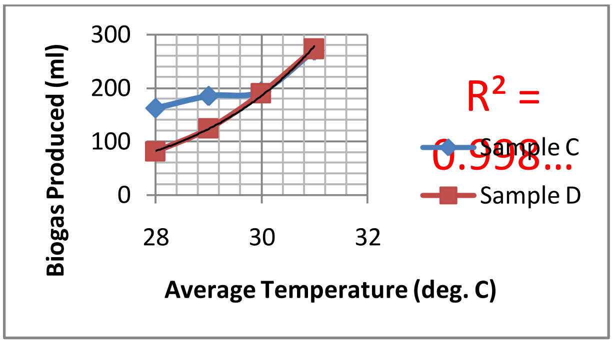

Fig. 3.4: Biogas production variation with temperature.

The Effect of Temperature on Biogas Production Yield

Table 3.2 gives the average volume of gas generated against each temperature in the range of temperature studied. The bioreactors were not thermostated. They were operated at the prevailing ambient temperatures of which the readings varied between 28 and 31^{o}C. Figure 3.4 shows that the average volume of gas produced increased with increasing ambient temperature. Generally, no particular pattern of gas production with respect to temperature was observed. This was because of the unstable weather conditions that gave rise to erratic temperature changes, which also affected the microbial activities in the bioreactors. However, for a particular temperature, the average gas daily output increased by exponential and polynomial correlations for the two sewage samples C and D concentrations of 0.4 kg/L and 0.5 kg/L respectively (see fig. 3.2). Also, it was observed that gas production was greater at night than in the day time, this may be attributed to the fact that the plastic bio-digesters are good insulators, which were able to retain the heat energy absorbed during the day.

CONCLUSION

The study of the effects of various variables on the production of biogas from sewage reveals that:

- The materials of construction of the bioreactors do affect the production of biogas from sewage: While mild and galvanized steel inhibited biogas production transparent plastic materials promoted the biogas generation.
- Increasing volume of biogas was noticed as the ambient temperatures fluctuated and increased from 28 to 31^{o}C.
- Light energy received during the day helped to promote the activities of methanogenic bacteria during the night seasons. Higher biogas output was noticed to have been produced during the night seasons than in the day time.
- There is an optimum sewage concentration that tends to favour higher yield of biogas generation. More than 10 litres of biogas was obtained from a sewage concentration of 0.4kg/l and only 4.6 litres from 0.5kg/l sewage concentration.
- The lag time increased for kick-off of biogas generation as the sewage concentration was increased from 0.4kg/l to 0.5kg/l.

The development of this renewable energy resource in biogas production technology must be encouraged as this would to some extent positively impact on the energy need of most developing nations in Africa.

LIMITATIONS

The study was carried out in a laboratory setting as it was very difficult to completely simulate the real conditions of typical sewage storage tanks. Materials of construction were not lagged hence the fluctuating ambient conditions around the four bioreactors used.

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