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Anaerobic Co-Digestion of Municipal Sewage Sludge with Cow Dung at Different Ratio

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Abstract- A large amount of sewage sludge is produced through the sewerage system in Bangladesh. A laboratory scale research work was carried out to find the potential of sewage sludge as a source of renewable Bio-Energy. This paper presents the output results of the research work which was carried out to find out the appropriate technology for biogas generation from co-digestion of sewage sludge & cow dung. The study deals with usage of different proportion of sewage sludge, cow dung and domestic sewage for four trials carrying 6% total solid concentration. For all the experiments, sewage and domestic sludge were mixed in 1:1 ratio. Anaerobic digestion was performed for 60 days at room temperature 30±4 ^oC. The pH of the slurry was maintained by the system itself. The inoculum was familiarized with cow dung in the same atmosphere taken for the study and sufficient active biomass was present. It was observed in the research that, when sewage sludge mixed with other co-substrate, the significant increase in gas yield was remarkable. The performances of the reactors were analyzed on the basis of gas yield and methane yield. On the basis of the analysis of the performance of the reactors, it was found that; Trial-2 reactor containing 25% cow dung and 75% municipal sewage sludge and domestic sewage, on total solid (6% TS) of slurry gives optimum result in terms of total gas yield and methane yield (72%). Standards of Trial-2 might choose as an optimum condition for gas generation from municipal sewage sludge.

Keywords: *anaerobic digestion, bio-energy, codigestion, sludge, sewage sludge digestion, sludge treatment, and reuse.*

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Anaerobic Co-Digestion of Municipal Sewage Sludge with Cow Dung at Different Ratio

Shaikh Mahfuzur Rahman [α], Fatema Sultana[σ] & Tushar Chowhan[ρ]

Abstract- A large amount of sewage sludge is produced through the sewerage system in Bangladesh. A laboratory scale research work was carried out to find the potential of sewage sludge as a source of renewable Bio-Energy. This paper presents the output results of the research work which was carried out to find out the appropriate technology for biogas generation from co-digestion of sewage sludge & cow dung. The study deals with usage of different proportion of sewage sludge, cow dung and domestic sewage for four trials carrying 6% total solid concentration. For all the experiments, sewage and domestic sludge were mixed in 1:1 ratio. Anaerobic digestion was performed for 60 days at room temperature 30±4 ºC. The pH of the slurry was maintained by the system itself. The inoculum was familiarized with cow dung in the same atmosphere taken for the study and sufficient active biomass was present. It was observed in the research that, when sewage sludge mixed with other co-substrate, the significant increase in gas yield was remarkable. The performances of the reactors were analyzed on the basis of gas yield and methane yield. On the basis of the analysis of the performance of the reactors, it was found that; Trial-2 reactor containing 25% cow dung and 75% municipal sewage sludge and domestic sewage, on total solid (6% TS) of slurry gives optimum result in terms of total gas yield and methane yield (72%). Standards of Trial-2 might choose as an optimum condition for gas generation from municipal sewage sludge.

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I. Introduction

Sewage sludge contains considerable amounts of various contaminants. If it is not properly handled and disposed of, it may produce large-scale hazards to health and the environment. Anaerobic digestion is a biochemical technology for the treatment of organic residues and wastes. In this treatment process, it is used for the production of biogas, which can be used as a fuel or co-generation of electricity. The main purpose of this research work is to find out the appropriate technology for biogas generation from municipal sewage sludge through a laboratory scale experiment. Experimental result indicates that municipal sewage sludge contains a significant amount of volatile solid responsive for biodegradation. Because of low C\N ratio; municipal sewage sludge alone is not suitable as a substrate for anaerobic digestion. Therefore, different proportion of cow dung and domestic sewage were put to use as co-substrate to achieve an optimum result. The study was carried out using a different proportion of sewage sludge, cow dung and domestic sewage for four trials carrying 6% total solids (TS) concentration. For all trials, sewage sludge and domestic sewage were mixed in 1:1 ratio. Anaerobic Digestion (AD) was performed for 60 days at room temperature 30±4ºC. The inoculum was adjusted with cow dung in the certain environmental condition and the presence of an adequate amount of active organic matter was detected. Thus start-up of the trials was achieved easily. It was observed that, when sewage sludge mixed with other co-substrate, the significant increase in gas yield was remarkable. The performances of the reactors were analyzed on the basis of gas yield and methane yield. In this study potentiality of biogas production from Sewage Sludge has been investigated using a mixture of cow dung and sludge at a different ratio.

II. Methodology

The methodology of this research work can be divided into some parts. The first part was investigating the current situation of sewage sludge treatment system & collection samples. The second part was the preparation of substrate followed by the experimental setup of the AD. Sludge used as substrates was less than 6 mm diameter in size. Domestic sewage was added in the different ratio as a diluent to keep the sludge in suspension to achieve the desired level of flowability in each reactor. Domestic sewage also serves as a source of various microbes which is required for the anaerobic co-digestion process. The domestic sewage was collected from the Jatrabari residential area. Cow dung was also used in different proportion as a co-substrate to maintain the optimum C/N ratio. Predigested residue from earlier AD containing all the essential microorganisms; was used as inoculum for early startup of the biomethanation process [1]. The inoculum was synthesized using cow dung by 6% TS concentration in the laboratory. For our research work, the predigested residue was used as inoculum.

In order to measure biogas, yield from municipal sludge through anaerobic digestion; a simple laboratory-scale methanogenic test procedure was followed with some modification according to technical limitations & resources available in the local market [2].

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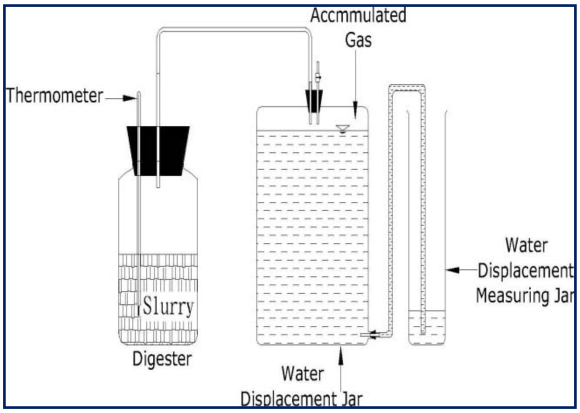


Figure 1: Technical Outline for Experimental Setup

A known amount (6% solids) of the substrate; containing a mixture of organic waste was transformed into a 2-liter capacity conical flux bottle. All conical fluxes were sealed by rubber corks and the other bottle which was filled up with water to collect gas equipped with rubber tubes for gas collection. Solid and moisture content of samples were found out through laboratory experiment.

Organic waste was mixed and added to each conical flux bottle in different proportion to obtain a working volume of 1 liter for all digester. All the reactors contained 6% solid concentration gives optimum biogas yield [3]. The municipal sludge and sewage were mixed by 1:1 basis in all the reactors. Combinations of Waste in different Trial are as follows:

Trial-1: Waste (6% Solid) *[Cow dung (50%) + Municipal Sludge & Municipal Sewage (50%)]* + Inoculum (100 ml) + Water (amount required to be filled up 1000 mL)

Table 1: Slurry Composition on Trial 1

Trial-1	6% Solid			Inoculums	Tap Water	Volume of Slurry
	1.5%	1.5%	3%			
	Municipal Sludge	Municipal Sewage	Cow dung			
	gm	*mL*	*gm*	*mL*	*mL*	*mL*
	82.83	385	192.31	100	395	1000

Trial-2: Waste (6% Solid) *[Cow dung (25%) + Municipal Sludge & Municipal Sewage (75%)]* + Inoculum (100 ml) + Water (amount required to be filled up 1000 mL)

Table 2: Slurry Composition on Trial 2

Trial-2	6% Solid			Inoculums	Tap Water	Volume of Slurry
	2.25 %	2.25 %	1.5 %			
	Municipal Sludge	Municipal Sewage	Cow dung			
	gm	*mL*	*gm*	*mL*	*mL*	*mL*
	124.24	580	96.15	100	165	1000

Trial-3: Waste (6% Solid) *[Cow dung (12.50%) + Municipal Sludge & Municipal Sewage (87.5%)]* + Inoculum (100 ml) + Water (amount required to be filled up 1000 mL)

Table 3: Slurry Composition on Trial 3

Trial-3	6% Solid			Inoculums	Tap Water	Volume of Slurry
	2.625 %	2.625 %	0.75 %			
	Municipal Sludge	Municipal Sewage	Cow dung			
	gm	*mL*	*gm*	*mL*	*mL*	*mL*
	138.74	770	42.61	100	25	1000

Trial-4: Waste (6% Solid) *[Cow dung (0%) + Municipal Sludge & Municipal Sewage (100%)]* + Inoculum (100 ml) + Water (amount required to be filled up 1000 mL)

Table 4: Slurry Composition on Trial 4

Trial-4	6% Solid			Inoculums	Tap Water	Volume of Slurry
	3.0%	3.0%	0%			
	Municipal Sludge	Municipal Sewage	Cow dung			
	gm	*mL*	*gm*	*mL*	*mL*	*mL*
	158.56	870	0.00	100	10	1000

Biogas production was measured by partial water displacement measure and recorded at every 24-hour interval. After daily gas measurement; a slurry of the conical flux (i.e. digester) was mixed manually. All trials were carried out at a temperature of 30±4 °C for 60 days.

Frequently used anaerobic digestion process parameters included pH, Chemical Oxygen Demand (COD), Volatile Fatty Acid (VFA) concentration, Volatile Solid (VS) destruction, biogas production & composition.

Due to the lack of lab facility; pH, Gas composition & Temperature was measured.

Characteristics of different substrates (solid content, water content, and pH) were determined through laboratory work. Solid and moisture content was measured according to the *standard method for the examination of water & wastewater* [4]. Electronic digital pH meter was used for the determination of pH of the slurry. A buffer solution *(pH water)* containing pH 7 was used to calibrate the digital pH meter. For temperature measurement; a thermometer of range 0~110 °C having an accuracy ±0.5 °C was used. Parameters mention above was checked periodically for 60 days. Daily biogas production of each reactor was monitored using water displacement on a daily basis. The volume of water displaced from the bottle was equivalent to the volume of gas generated at the temperature and pressure that conquered during the study period.

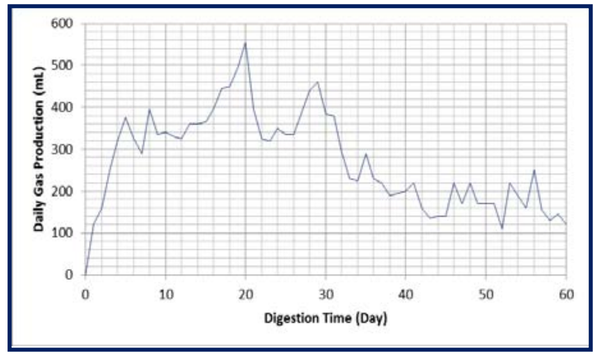
Very concentrated freshly produced KOH solution used to separate carbon dioxide from biogas mixture. The rest amount of gas is considered methane.

Figure 2: Biogas Unit Setup in the Laboratory.

Each digester was loaded with both solid and liquid waste respectively according to Table 1, Table 2, Table 3 and Table 4; after evaluating the substrate composition. Thus the test reactors for four organic loading were constructed. Gas composition and pH was measured weekly. The total amount of gas production and the temperature was measured daily. Biogas composition was measured on every ten days' interval.

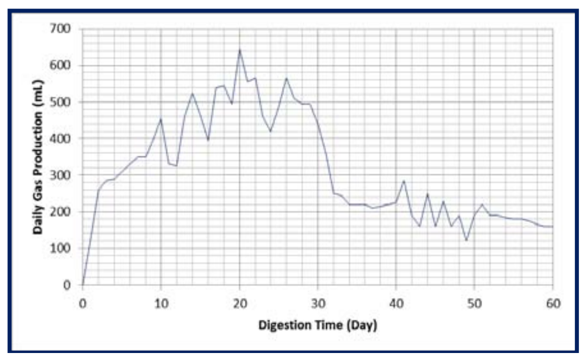
III. Data analysis & Observation

The Graph 1 To 4 represent the volumes of daily gas accumulation with varying amount of sewage sludge in different reactors.



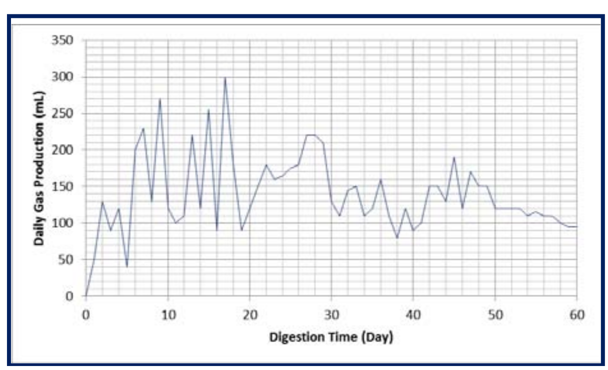
Graph 1: Daily Gas Production Vs. Time Graph for Trial-1

Belt shape trend of daily gas generation for Trial-1 where sludge and domestic sewage was 50% on 6% solids of the slurry, is shown in Graph 1. It was observed that gas generation started at the very next day of charging the digesters with the slurry. The rate of gas generation gradually increased with increasing of the digestion period. In this reactor, the highest gas production of 555 mL was observed on the 20th day. It was observed that; gas production rate considerably declined after 32nd day.



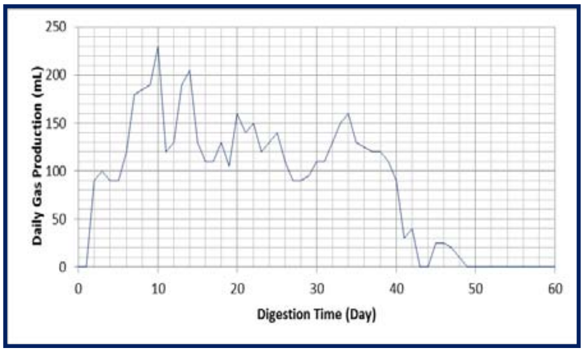
Graph 2: Daily Gas Production Vs. Time Graph for Trial-2

Considering the amount of daily gas generation for Trial-2 which contains 75% of sludge and domestic sewage is shown in Graph 2. In this trial, the generation of gas started from the next day after recharging the reactor with slurry. The highest gas production of 645 ml was observed on the 20th day.



Graph 3: Daily Gas Production Vs. Time Graph for Trial-3

The daily gas production amount in Trial-3 is shown in Graph 3. Trial-3 contains 87.5% sludge and domestic sewage of the total solids of the slurry. The peak gas production was 300 mL; observed at 17th day.

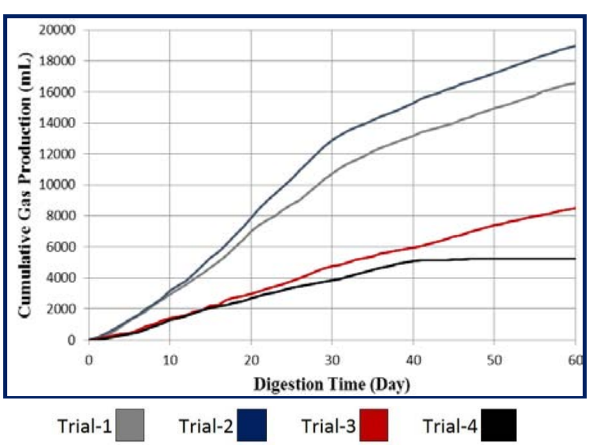


Graph 4: Daily Gas Production Vs. Time Graph for Trial-4

Graph 4 represents the daily gas production for Trial-4, which contains 100% sludge and sewage on 6% total solids. This shows a lower range of gas production. As there is no cow dung in the slurry and the inoculum was used in the slurry originate from cow dung based biogas unit so that in the other reactor. In this trial, the generation of gas started from the second day after recharging the reactor with slurry. The peak gas generation was 230 mL which was observed on the 10th day. Gas production almost ceased at the 42nd day of digestion period.

The cumulative biogas production on test reactors operating at a various organic loading of sewage sludge, domestic sewage, and cow dung; was measured. Calculated data of cumulative gas production for each trial are shown in Graph 5.

Graph 5 shows that highest gas generated for Trial-2 and in most of the digestion period gas generation rate was higher than the others. Even though Trial-2 contained lesser amounts of cow dung then Trial-1, there also a gas generation rate was higher.



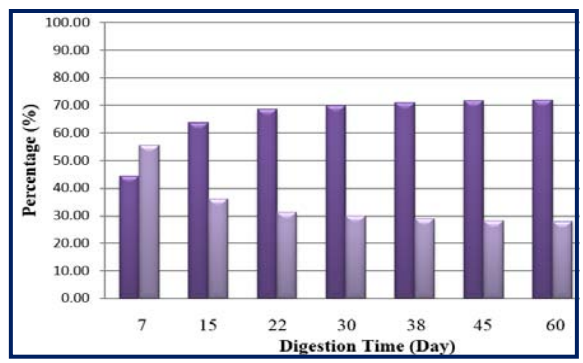
Graph 5: Cumulative Gas Production in Different Trial.

P^H is a very important process monitoring parameter for anaerobic digestion. According to Rahman and Muyeed [5], the desirable pH range is between 6.5~8.0 for anaerobic digestion. The highest gas yield was observed by Chengdu Research Institute for 7.5 to 8.0 pH range. P^H on each trial on a weekly basis is listed in Table 5.

Table 5: Slurry pH During Anaerobic Digestion Period

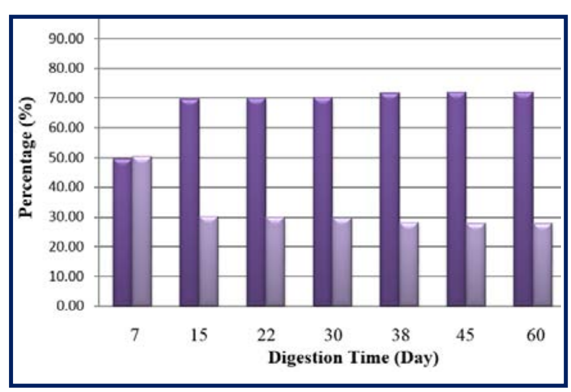
Day	pH			
	Trial-1	Trial-2	Trial-3	Trial-4
(Initial) 0	7.19	7.15	7.46	7.86
6	7.14	7.02	7.44	7.85
12	6.94	6.88	7.38	7.61
18	7.22	7.18	7.04	7.30
24	7.44	7.38	7.12	7.30
30	7.49	7.39	7.00	7.45
36	7.49	7.41	7.42	7.44
42	7.42	7.43	7.38	7.33
48	7.45	7.45	7.30	7.45
54	7.45	7.47	7.32	7.40
60	7.46	7.47	7.32	7.43

Biogas produced from AD usually contains 60% CH_4, 30~35% CO_2 and a little percentage of trace elements, generally H_2S. The composition of produced gas for all trial is shown in Graph 6 to 9.



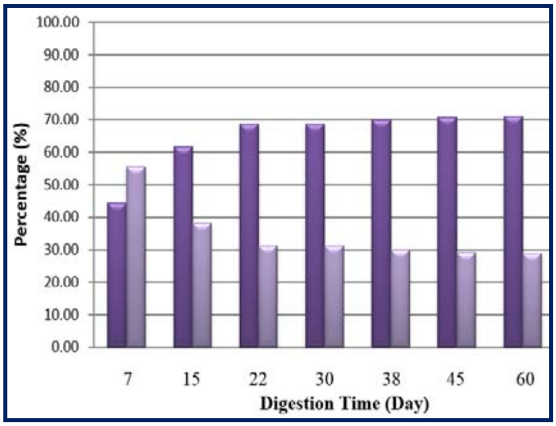
Graph 6: Variation of Gas Composition with time for Trial-1

Graph 6 shows the percentage of methane and carbon dioxide content for Trial-1. Methane content for Trial-1 was 44.4% to 71.98%.



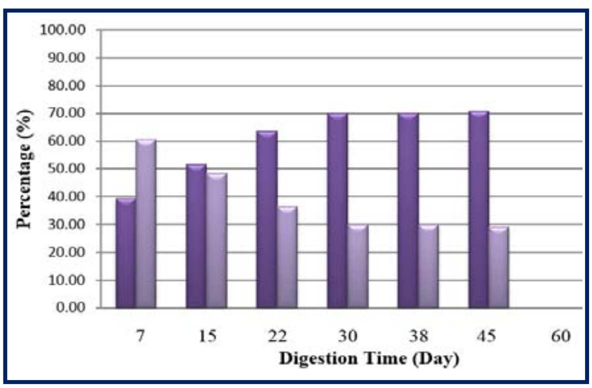
Graph 7: Variation of Gas Composition with time for Trial-2

Graph 7 shows the percentage of methane and carbon dioxide content for Trial-2. Methane content for Trial-2 was 49.66% to 72.08%.



Graph 8: Variation of Gas Composition with time for Trial-3

Graph 8 shows the percentage of methane and carbon dioxide content for Trial-3. Methane content for Trial-3 was 44.44% to 70.81%.



Graph 9: Variation of Gas Composition with time for Trial-4

Graph 9 shows the percentage of methane and carbon dioxide content for Trial-4. Methane content for Trial-4 was 39.4% to 71.98%.

Summary of the Observation

- Sewage sludge with cow dung and sewage is a highly potential substrate for biogas generation.
- Among four trials, maximum gas was produced by Trial-2 on which 75% of the TS of the slurry were municipal sludge and domestic sewage. Domestic sewage and sludge were mixed in a 1:1 ratio.
- Municipal sludge with a certain amount of cow dung is potential enough for gas generation than using more cow dung.
- P^H ranges were the favorable range for an AD for all trials. The highest gas production was for the pH ranges from 6.88 to 7.47 for Trial-2.

IV. Conclusion & Recommendations

From the above observation we have concluded:

- Municipal sewage sludge with cow dung and domestic sewage is a very prospective substrate of biogas generation by anaerobic digestion.
- Even Trial-4 which contains only sewage sludge and domestic sewage on the total solids of the slurry has been shown considerable results. Methane content in biogas generated from different reactors varied from 71% to 72%.
- For optimum gas generation from sewage sludge; all the criteria for Trial-2 reactors can be adopted as it has been given the best performance.
- The optimum conditions for biogas generation from sewage are: 6% total solid concentration, pH 6.88 to 7.47 and temperature 30°±4 °C cow dung and domestic sewage will need to be used as co-substrate. 25% of the total solids of the slurry will be cow dung and 75% will be sewage sludge and domestic sewage in the ratio of 1:1. Water needs to be added to maintain the described volume of the slurry.

Recommendation for further study

- Only one solid concentration was taken into account in this study, various solid concentrations can be studied.
- Only one percent of inoculums was used in this research. Using various proportions of inoculums, reactors can be set up for finding the optimum result.
- COD, VFA, VS, C/N ratio measurement of waste is recommended for future study.
- For gas composition measurement, using a modern gas analyzer (Orsat gas analyzer) is recommended.
- Special arrangement to maintain the optimum temperature of 35 °C for gas generation is recommended.
- A pilot-scale field research on the basis of the output of this paper is recommended.

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