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GRADUATE RESEARCH ARTICLE

Potentiality of Biogas Production from Waste in Bangladesh

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ABSTRACT

Biogas is treated as a prominent renewable source in the world for mitigating fuel crises in developing countries. Using biogas technology toxic waste can be handled with an anaerobic process helping to generate natural fertilizers. So, it is a major concern for the researchers to find the proper solution by selecting a suitable renewable energy source in the present world. Biogas is treated as a type of biofuel that can be obtained from the fermentation of organic waste. The main goal of this research is to show the potential of a biogas generator in terms of cow dung, vegetable waste, kitchen waste, and poultry to generate biogas. The produced biogas from the decomposition of the organic waste can be utilized in electric power generation to fulfill the power demand of a house. From the analysis, it is seen that cow dung is the most powerful waste for the generation of biogas in comparison to other types of waste. The calculation shows that cow dung is almost 86.75 % more efficient than the kitchen waste and 44.49 % more efficient than the vegetable waste. And some practical data of a biogas power plant has been included to show the potentiality of biogas in the present world.

Keywords: Anaerobic digestion, Landfill, Municipal waste.

1 Introduction

Dependence on energy in Bangladesh is increasing significantly for the rapid economic growth rate and the domestic consumption of its large number of populations. Bangladesh is the 8th densely populated country in the world with 1265 person/km^2 in 2020 [1]. In recent years many industries and factories were established on this small island that uses huge electricity to operate. The government of Bangladesh is set the high ambitious goal of vision 2041 to become a developed nation. In achieving that vision power solution is the main challenge of the stake holder and policy maker. It is predicted that 61GW electricity is required by the year 2041 [2].In a survey conducted by Ministry of Finance (MoF) in 2013 has found that the yearly electricity demand has increased by 8.1% in the last 10 years [3]. In this country 63% of energy is produced from natural gas and the rest is from oil, coal, biomass [4]. Burning fossil fuel produces Green House Gases (GHG) that accumulate in the atmosphere and ultimately warm the globe. Despite the repeated call from scientists and environmentalists around the world to switch primary energy to alternative energy, fossil fuel still shares 84% of the total consumed energy in 2019 [5]. Biogas can be a promising renewable energy source. Biogas can play significant role in replacing the traditional fuel and at the same time to solve the energy crisis in Bangladesh. Huge organic waste which is used to decompose in producing biogas by anaerobic digestion process is also helping to reduce the environment degradation. Biogas contains 50-70% methane (CH_4) although some unwanted gas like carbon dioxide (CO_2) (30-40%) and some other trace gases may be produced [6]–[9]. Biogas is not only a source of electricity but also plays a significant role in maintaining ecological balance through waste management [10], [11]. Anaerobic digestion (AD) plant definitely an alternative power solution in rural areas and waste management [12].Huge waste can be used as a substrate for anaerobic digestion (AD) process for biogas yield in Bangladesh. Municipal solid waste, agricultural waste, food waste, animal manure, fish waste, sewage sludge etc are some of the wastes that can be easily used in biogas plants. Poultry and agricultural wastes can be employed in medium and small size biogas plan in rural areas to solve the energy (mainly heating and electricity) crisis in a particular area. Biogas production will be a fruitful investment as less expensive available feedstock [13]. In addition, numerous conditions were applied to enhance biogas production and to improve the quality of biogas and to reduce the environmental pollution as well. The mixture of different substrates for co-digestion, ratios, feedstock selection, operating conditions plays a positive role to improve the Methane amount of the produced gas [14]–[20]. Using stream waste as raw materials for AD is better as this system reduces the waste while producing energy [21].

Biogas is cost effective and environmentally friendly both in household and commercial use. Using biogas for agricultural production the expenditure is less [22]. In addition, biogas can be used in transport and district heating sector which is cost effective [23]. Though biogas is environmentally friendly it has to compete with the price of natural gas in different countries. So, in AD process a special care is required while choosing substrates and also need to employ improved technology to maximize the CH_4 production [24]. Moreover, it is found that combustible element is possible to increase by 54.38% if it is filtered in a particular way [25]. Setting the biogas plant in rural areas can solve the electricity crisis as well as the energy is usable in cooking and produce a good quality of fertilizer for agricultural purpose which is cost effective and less GHG emissions and help to improve the socio-economic conditions of the people [26].In rural areas of many developing countries are using firewood which is not only destroying the plants but also creating environmental problems and health hazards. So, it's very urgent to develop an alternative energy source that will address the problems and reduce the burden on fossil fuel.

For ground-level work, we have visited some biogas plants and collected their input and output data and amount of biogas and electricity which have been produced by using waste. We visited Bangladesh Livestock Research Institute (BLRI). This institute located in Saver Upazila, Dhaka division, Bangladesh, and founded in 1984. There are some biogas plants (Figure 1), which are used to produce biogas from animal waste. The amount of biogas produced from this plant is 0.034 m^3/kg, 0.058 m^3/kg and 0.014 m^3/kg respectively. Another biogas work is done by using farm animal waste.

Figure 1: *Biogas Plant in Bangladesh Livestock Research Institute (BLRI)*

The farm animals like cows, buffalo, chicken, sheep, etc. are produced to dairy products milk, poultry meat, beef, and mutton. These animals are also given animal manure; researchers are analyzing what amount of animal manure produced in different farms. The calculated manure of this farm is for cattle 10-20 kg/day, for goat and sheep 2-3 kg/day, and for chicken 0.08-0.1 kg/day its mean quantity of manure is 5-6% of body weight/day for cattle, 4-5% of body weight/day for goat and sheep, and 3-4%of body weight/day for chicken. The amount of methane produced from these wastes gives 50-70% of methane, sheep manure gives 40-50% of methane and chicken manure gives 50-70% of methane contained in biogas. The total amount of biogas from this farm is around 4589.493 million m^3/yr. which used a heating value of 8.46×1010 M/yr. This amount of biogas can produce 8.26×109 KWh/yr electricity, which can be used in offices, farms, and society to fulfill energy demand. For biogas production four different types of biogas sources have been selected, sources are cow dung, vegetable waste, kitchen waste, poultry chicken waste. For load calculation different types of household electrical equipment rating has been collected and how much biogas require to fulfill this energy demand of household by using cow dung, vegetable waste, kitchen waste and poultry chicken dung waste and calculated total mass, volume of slurry and actual digester volume.

1.1 Objective

In our country the waste management system is creating major environmental pollution mainly in the municipal area. In the rural areas here agricultural and plants wastes are burning for heating which discharge huge GHG to the atmosphere. Using this biomass creates health hazard especially to the women of rural area. So, it is necessity to stop this pollution and convert this waste into bioenergy. This paper shows how a biogas plant addresses the matter and produces electricity which will help others to take the initiative to set up more plants.

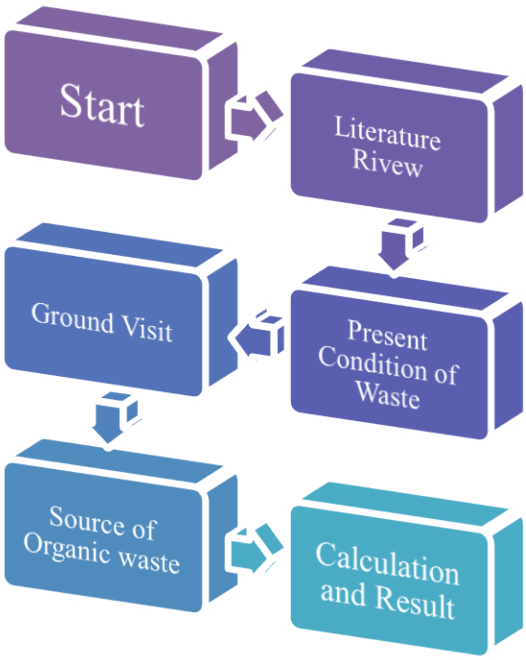

Figure 2: *Process of whole work*

Figure 2 shows the workflow of the research done in this thesis. As a workflow of the whole process, it is observed that literature review was an important task to investigate the importance of this work that has been proposed in this research. Again, a ground visit has been done to collect the information relating to this research so that the potentiality of this research work, that is the potentiality of the biogas energy in the practical life and economy can be realized to a great extent.

2 Present Waste Condition

Bangladesh is one of the overpopulated countries, huge waste was produced every day but only small amount of these were collected properly. Due to poor waste management system a serious environmental problem has been experiencing over the years. 2,500 tonnes of municipal waste are damped in Matuail everyday [27],whereas a total 4,500 tons household wastes are produced daily in the city corporation of Dhaka city [28].Matuail is one of the largest landfills which is just 8 km away from the zero point of Dhaka city. According to the emission tracking company GHGsat.inc in that landfill on April 17, 4000kgs of GHG is emitted by an hour [29].

Figure 3: *Matuail Landfill, waste condition with potentiality [24]*

Figure 3 shows the pictures of the field visit to investigate the power potentiality of the biogas in Bangladesh. From this figure it is clear that there is a huge potential to produce biogas, a good energy source for mitigating fossil fuel energy in the future.

Table 1:*Biogas Power Plant Input and Output data table*

ID	Input 1	Input2	Input 3	Input 4	Output 1	Output 2	Output 3
477700	BDT1,450,000	8	3000	666	1200	100	484
477701	BDT 1,450,000	8	2000	444	1150	65	294
477705	BDT 1,450,000	4	2000	444	1250	65	247
477708	BDT 1,450,000	5	1640	311	750	56	267
477710	BDT 1,450,000	3	1950	433	1100	65	309
477711	BDT 1,450,000	8	3200	710	1400	100	499
477781	BDT 1,150,000	8	1700	377	800	52	170
477795	BDT60,000,000	8	16000	3108	4100	600	2096
478028	BDT 1,000,000	2	2160	480	350	83	414
478095	BDT 1,430,000	8	2000	222	500	60	140
478047	BDT 2,000,000	8	2000	444	500	60	263
478048	BDT 1,450,000	8	1700	377	450	60	247
478054	BDT 1,5000,000	2	5500	1027	675	192	192

Table 1 shows the input of investment cost for generating the biogas as well as the electricity with some measurement of produced fertilizer whereas table 2 shows the name of indicators shown in table 1. From table 1 it is observed that the maximum generated biogas energy is 600 m^3 against 2096 kWh of electric energy and 4100 kg of fertilizer.

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Table 2: *Input and Output Factors table*

Set	Indicator	Unit
Input 1	Total Investment Cost	[BDT]
Input 2	Labor	[h/d]
Input 3	Fresh Water Consumption	[l/d]
Input 4	Energy Input of Substrate	[h/d]
Output 1	Fertilizer	[Kg/d]
Output 2	Biogas Production	m^3
Output 3	Utilized Energy	[kWh/d]

Table 3: *Biogas Potential table*

Dairy farm (total)	58,081.00	Per farm ($\mathbf{m^3/d}$)	average farm size (heads)	Total ($\mathbf{m^3/d}$)
Dairy farm (greater than 50 heads of cattle)	2,910.00	67.20	168	195,552
Dairy farm (30 to 50 heads of cattle)	5,148.00	19.60	49	100,901
Dairy farm (11 to 29 heads of cattle)	5,119.00	11.60	29	59,380
Dairy farm (3 to 10 heads of cattle)	44,904.00	3.60	9	161,654
No. of Buffalo farms (total)	**1,924.00**			
No. of farms with more than 30 buffalos	612.00	32.40	81	19,829
No. of farms with 11 to 29 buffalos	614.00	11.60	29	7,122
No. of farms with 3 to 10 buffalos	698.00	3.60	9	2,513
Potential based on total No. of cattle and buffalos	**60,005.00**	**1,367,129.00**		**546,852**

Table 3 shows that total 546852 m^3 gas is produced in a day in the firm where 67.2 m^3 gas is generated as the maximum level of daily production per farm. Table 4 shows that the price of the produced gas in these firms is amounted Tk 3,376,250 against the expenditure cost just Tk 20,750. Table 5 shows that 314,685m^3 gas is produced for only 500-999 size birds firm. Again, it is seen from the table that around 596,399 m^3 gas is produced in a day as the maximum level which shows a great potentiality of the biogas production.

Table 4: *Expenditures and income table*

Activity	Daily Amount	BDT/unit	BDT/activity/day	BDT total/day
Purchase of raw material	13,000 kg	1.00	13,000.00	
Supervisor	1	650.00	650.00	
Labor and other staff	9	300.00	2,700.00	
Other expenses			500.00	
TOTAL EXPENDITURES				17,350.00
Net income/day				6,650.00
Net income/year				2,427,250.00

Selling of CBG	300 m^3	35.00	10,500.00	
Selling of Bio-fertilizer	2,700 kg	5.00	13,500.00	
			TOTAL INCOME	24,000.00
Selling of CBG (storage capacity)	400 m^3	35.00	14,000.00	
Selling of Bio fertilizer	2,700m^3	5.00	16,000.00	
			TOTAL INCOME	30,000.00
Purchase of raw material	16,000	1.00	16,000.00	
Supervisor	1	650.00	650.00	
Labor and other staff	12	300.00	3,600.00	
Other expenses			500.00	
			TOTAL EXPENDITURES	20,750.00
			Net income /day	9,250.00
			Net income / year	3,376,250.00

Table 5: *Biogas Potential table revised and updated version February 2017*

		Per farm (m^3/d)	Average farm size (heads)	Total (m^3/d)
Farms (more than 1,000,000 birds)	2.00	10,500.00	1,500,000	21,000
Farms (400,000-999,999 birds)	17.00	6,999.99	999,999	119,000
Farms (50,000-399,999 birds)	213.00	2,799.99	399,999	596,399
Farms (20,000-50,000 birds)	1,500.00	350.00	50,000	525,000
Farms (10,000-19,999 birds)	1,200.00	139.99	19,999	167,992
Farms (5,000-9,999 birds)	8,000.00	69.99	9,999	559,944
Farms (1,000-4,999 birds)	12,000.00	34.99	4,999	419,916
Farms (500-999 birds)	45,000.00	6.99	999	314,685

3 Load Analysis

In the data analysis part data has been collected from a 2900 sq ft house every regular based electrical component power rating and consumption to calculate how much energy need per day and per month and to fulfill this energy how much amount of biogas need.

Data table 6 shows that there are 10 celling fans in the house and the rating of the fan is 75 watt each and daily use is around 16 hours. The number led light in house is 12 and the rating is 8.5 watt and daily uses around 10 hours. The LED Tube Light number is 7 and the rating of the light is 20 watt and daily uses around 10 hours. In the house 2 television rating is 100 watt each and daily uses 2 hours. In house 2 Refrigerator power rating is 182 watt each and daily uses 24 hours. There are 3 AC in the house 1.5 ton each and rating is 1864 daily uses around 2 hours. The number oven is 1 and rating is 1400 watt daily uses around half an hour. There is 1 washing machine and 1 electric water filter, and their rating is 350 watts, and 35 watts daily uses where wing machine uses 1 hour, and water filter uses 24 hours. There are 3 geysers in the house each of this rating is 2000 watt and daily uses around half an hour. One water pump in the house and rating of the water pump is 2237 watt daily uses around 2 hours. Also 2 computers available in the house rating of the computer is 250 watt each daily use 6 hours. In the house 1 blender and 1 hair dryer are also available. The rating is 200 watt and 800 watts respectably and daily uses around 20 minutes each.

Table 6: *Household loads table*

Types of Loads	No of Loads	Rating of Loads (W)	Daily Use (t)h
Celling Fan	10	75	16
LED Light	12	8.5	10
LED Tube Light	7	20	10
TV	2	100	2
Refrigerator	2	182	24
AC (1.5 ton)	3	1864	2
Oven	1	1400	0.30
Washing Machine	1	350	1
Electric Water Filter	1	35	24
Geyser	3	2000	0.30
Water Pump	1	2237	2
Computer	2	250	6
Blender	1	200	0.20
Hair Dryer	1	800	0.20

4 Calculation and Result

Here the amount of total energy required, and the amount of biogas demand have been calculated by using different types of organic wastes.

Table 7: *Household total power and energy consumption table*

Types of Loads	No of Loads	Rating of Loads (W)	Total Power Consumption P (W)	Daily Use (t)h	Total Energy $\mathbf{E = P \times t}$
Celling Fan	10	75	750	16	12000
LED Light	12	8.5	102	10	1020
LED Tube Light	7	20	140	10	1400
TV	2	100	200	2	400
Refrigerator	2	182	364	24	8736
AC (1.5 ton)	3	1864	5592	2	11184
Oven	1	1400	1400	0.30	420
Washing Machine	1	350	350	1	350
Electric Water Filter	1	35	35	24	840
Geyser	3	2000	6000	0.30	1800
Water Pump	1	2237	2237	2	4474
Computer	2	250	500	6	3000
Blender	1	200	200	0.20	40
Hair Dryer	1	800	800	0.20	160
Total energy			18670 W		45824 W

Table 7 represents the data for a single day. In this table the daily total energy needs 45.824 kw/h for household and total power is 18.67 kW daily.

Total power P =18670 W
Total energy E=45824 Wh
=45.824kWh
1kwh=3.6×10^6j
Daily energy consumption=$45.824 \times 3.6 \times 10^6$J
=164966400j

During calculation to find the amount of biogas required there are four types of organic waste used.

- Cow Dung
- Vegetable Waste
- Kitchen waste
- Poultry Chicken manure

Each of these organic wastes has a different amount of biogas production per kg of waste.

- For cow dung, the production of biogas/ 1 kg of fresh dung=0.09 m^3 [30]
- For vegetable waste, the production of biogas / 1 kg of waste=0.05 m^3
- For kitchen waste, the production of biogas / 1 kg of waste=0.012785m^3 [30]
- For poultry chicken dung, production of biogas / 1 kg of waste=0.065m^3[30]

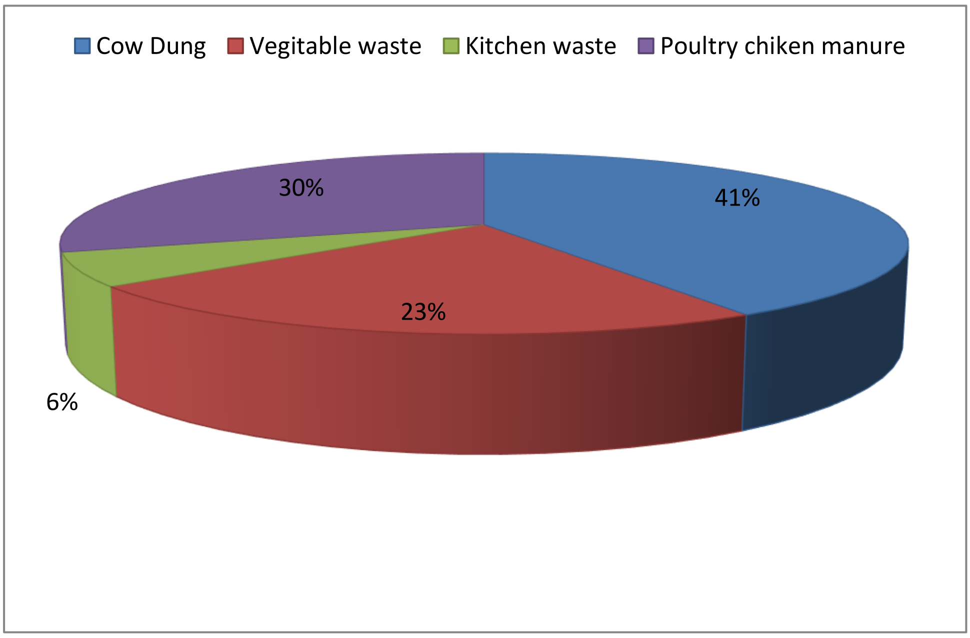

Figure 4: *Bar chart of biogas production from different types of wastes*

Figure 4 shows the percentage of waste in different categories. Out of these all sources of waste, cow dung is at the highest level of 41 %. Poultry waste is also another important source of waste for biogas production. Finally vegetable waste is at the third level of the potential source of the waste.

4.1 Cow Dung Calculation

Biogas Require:

The Calorific Value for the biogas production = 20 $\frac{Mj}{m^3} = 20 \times 10^6 \frac{j}{m^3}$

Total amount of biogas required=$\frac{164966400}{20 \times 10^6}$=8.24832$m^3$/day

For cow dung, generation of biogas / 1 kg of fresh dung=0.09 m^3

Total amount of cow dung $=\frac{8.24832\mathrm{m}^3}{0.09\mathrm{m}^3/\mathrm{kg}}$=91.648kg

Slurry ratio=1:1

Total Mass of slurry per day = (amount of cow dung + amount of water) = (91.648+91.648) $\mathrm{kg/day}$ =m=183.296 $\mathrm{kg/day}$

Density of the slurry, D=1000$\mathrm{kg/m^3}$

Volume of the slurry $\mathrm{V = m/D}$=$\frac{183.296\mathrm{kg/day}}{1000\mathrm{kg/m^3}}$=0.183$\mathrm{m^3/day}$

For retention time of 30 days, the digester Volume = Volume of the slurry × Retention time = $0.183\mathrm{m^3/day} \times 30\mathrm{day}$=5.49 m^3

For proper digestion process, actual volume should be 10% more than probity [30]. Actual digestion value=5.49 ×10%+5.49=6.039 $\mathrm{m^3}$

Table 8: *Digester volume table*

Name of waste	Total amount of biogas requires ($\mathbf{m^3/day}$)	Total Mass ($\mathbf{kg/day}$)	Volume of slurry ($\mathbf{m^3/day}$)	Digester volume ($\mathbf{m^3}$)	Actual digester volume ($\mathbf{m^3}$)
Cow Dung	8.2483	183.29	0.183	5.49	6.039
Vegetable waste	8.2483	329.932	0.32993	9.8998	10.88
Kitchen waste	8.2483	1290.3	1.29	38.71	45.58
Poultry chicken	8.2483	253.8	0.253	7.614	8.3754

Table 8 shows the overall performance for different types of waste to produce the same amount of biogas. From the table it is seen that the cow dung performance is best to generate the biogas. As a measurement of calculation from the data of table, it is seen that around 85.794 % of total mass for daily use will be reduced if cow dung can be used rather than the kitchen waste.

5 Conclusion

For the future concern of global warming and climate change, fossil fuel burning needs be to reduce and this step should be started from the root level by every household its own energy production. Biogas is the best alternative to fossil fuel burning reduction. Biogas mainly produces different types of organic waste. The production of biogas varies in different types of organic waste in kg per meter cube. To fulfill the household energy demand four types of best organic waste source has been selected that are cow dung, vegetable waste, kitchen waste, poultry chicken dung. Each of these wastes has a different amount of slurry volume, digestion value and mass. From the analysis, it is seen that around 44.494% of digester volume can be saved if cow dung can be used rather than the vegetable waste which is a major factor to reduce the cost of biogas power plant. The required amount of biogas is 8.24832 $\mathrm{m^3}$/day which will be fulfilling a 2900 sq ft household energy consumption of 45.824 kWh load.

6 Declarations

6.1 Study Limitations

No external fund to execute the biogas power plant. For this reason, we need to rely on online data to execute the research.

6.2 Acknowledgements

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6.3 Competing Interests

We, the authors, declare that there is no conflict of interest in this work.

6.4 Publisher's Note

AIJR remains neutral with regard to jurisdictional claims in published institutional affiliations.

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