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Research Article

Biogas Potentiality Through Waste Management in Bangladesh

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ABSTRACT

This study offers an effective solution to meet the growing demands of biogas plants for energy. This paper presents a model and simulates the digestion process of biogas production from the organic and food processing waste that contains high moisture. Biogas is produced by bacteria through the bio-degradation of organic material under anaerobic conditions. According to the findings, in case of biogas production, the broiler chicken manure is approximately 88 %. From the analysis, it is observed that the chicken broiler waste is approximately 88 % more efficient than the unsorted waste. In addition, in the case of digestate, the cow manure is approximately 6.25 % more efficient than the garden waste. The present study aims to investigate the performance of different types of wastes regarding biogas production. To this end, different types of waste were considered in data analysis. According to the data analysis, biogas production is highly affected by the type of waste.

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1. INTRODUCTION

Natural generation of biogas is an important part of bio-geochemical carbon cycle. It can be used both in rural and urban areas. Biogas contains 40 % to 60 % methane which is an excellent source of renewable energy. Biogas (bio fuel) is a mixture of gases that usually consist of a considerable amount of methane and some other constituents (carbon dioxide, (CO_2) 25-50 %, and some negligible amounts of N_2, H_2, H_2S and O_2). Biogas is produced in situations where organic matters decompose in the absence of Oxygen. Biogas is produced from highly moisturized content, like food wastes and animal manure is essential to the biological treatment method, namely anaerobic digestion. An environment devoid of oxygen is needed for bacteria to activate the anaerobic digestion process. In Bangladesh with a population of 160 million people, the increasing rate of energy consumption due to its industrial development and fast-paced process of urbanization is notable. To maintain and improve economic growth and achieve the Sustainable Development Goal (SDG), energy supply is required. Optimization of the anaerobic digestion process has a huge potential to produce maximum biogas and reduce the environment pollution through waste management within a short period prior to landfill [1]. Electrical Resistivity Tomography (ERT) techniques are applicable to address environmental and engineering issues [2]. Farm-based anaerobic digestion will play a key role in waste management and biomass energy production in the future. Anaerobic digestion technology is a suitable, viable option in the case of biogas productions. In addition, this technology can be used in fuel internal combustion engines to run a generator that produces electricity [3]. Normally, 40 % to 60 % of methane is obtained from manure, after 28 days of fermentation at a temperature of 40 ^oC [4]. The case study of Greece shows that this operation is profitable in 20 years at an energy efficiency level of 33 %. Moreover, biogas production is reduced with increase in the age of waste and disposal [5]. Disposed solid waste made by landfill produces enormous amount of biogas whose main constituent is methane which is responsible for global warming; in this respect regular study and data maintenance are necessary to reduce the green house gas (GHG) emission [6]. The rate and quality of biogas production depend on many factors such as waste type, temperature, humidity, moisturized components, period of fermentation, size of bacteria, and pH [7]. Since biogas can supply 25 % of all required bio-energy, EU has set a goal to provide 20 % of its required energy from renewable energy by 2020 [8]. If 33 % more volatile solids (VS) are added from fats, oil, grease (FOG) and food waste for anaerobic digestion, biogas production will increase to 60 % or more [9]. Biogas production along with anaerobic co-digestion process from animal manure and organic waste not only solves the energy problem but also protects the environment and helps the waste management sector. The biogas components depend on favorable environmental state and type of decomposing materials. Family based biogas plant is a solution to mitigating GHG emissions and decreasing the dependence of dung-based biogas plant, LPG or firewood used as kitchen fuel [10]. Olive oil industries are held responsible for serious environmental repercussions since waste management is a costly arduous task, biogas production can be used as an alternative solution [11]. The quality of biogas is improved by mixing water chestnut, water hyacinth, and cow dung after a period of digestion [12]. A robust methodology to analyze and evaluate energy demand at every

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steps is required to improve biogas production at a particular biogas plant [13]. To obtain one unit of biogas, 0.56J non-renewable energy is required [14]. In the case of performance evaluation, data comparison on the routine basis is vital for different plants [15]. Food waste is the most suitable option for anaerobic digestion for its high biodegradability and methane output [16]. 90 % more methane is produced within 40-50 days of fermentation [17]. Large biogas plant can produce significant amount of gas used for industrial purposes [18]. Biogas production in Europe is gaining foothold and growing [19]. Under SNV (Netherlands Development Organization) project 600000 m^3 biogas was yielded from 300000 biogas plants until 2009 [20]. Biogas production is economically viable in Bangladesh [21]. Power produced from municipal and agricultural waste 80 % of which are organic in Hazaribagh (total area 0f 5.65 km^2) as one of the densely populated areas (population density of 32,856/km^2) of Dhaka city, can play a significant role in addressing the electricity crisis in this region through biogas production [22]. Bangladesh, one of the densely populated countries with more than 160 million people, is a 147000 km^2 land, 33 % of which enjoys electricity coverage [23]. The projected energy demands are predicted to be 19000 MW and 34000 MW by 2100 and 2030, respectively [24].

Since industries are still highly dependent on traditional energies (electricity, natural gas etc.), it is the most appropriate time for transition from this energy to renewable energies to solve the electricity crisis and kitchen fuel. The following sections discuss how the biogas production and usage will reduce the load of traditional energies and solve waste management problems, especially MSW problems in Bangladesh.

2. METHODOLOGY

1. Numerous studies on renewable energies were carefully investigated before conducting the actual research.

2. The present paper aims to solve two problems simultaneously: searching for alternative energy and managing waste with emphasis on biogas production and its popularity in Bangladesh.

3. Substrates (MSW, animal manure, food waste, fats, oil, plant waste, etc.) are stored for anaerobic digestion. The anaerobic digestion process is run around 40 days at temperatures of 35-45 ^oC for fermentation. Since the type of mixtures plays a vital role in improving both quality and quantity of gas, substrates of high biodegradability are added even more. After the suggested period of time, the inlet pipe opens to collect gas either already stored or being used, through dehumidified for cooking. It we can be connected to a generator unit so that it can be converted into electricity.

4. A MATLAB simulation was carried out to examine the potential of biogas production. Moreover, some related data were collected from online sources to investigate the overall performance of biogas production with regard to various types of waste.

5. Finally, results were achieved through data analysis.

A flowchart was also presented to show the working scheme throughout the research period (Figure 1).

3. BIOGAS POWER PRINCIPLE

There are a number of factors affecting the biogas production, considering the organic content of waste. These factors include time span and constitution of waste, humidity, temperature, pH-varying with depth of filling, population of microbes, and quality and quantity of alimentary substances [5, 6, 7]. The rate of biogas production is given by the first-order kinetic equation expressed in Equation (1) [6, 7, 9].

$$\frac{dC}{dt} = -kC \quad (1)$$

According to the above kinetic equation and empirical data, a numerical model called "Landfill Gas Emissions Model" was developed under the supervision of EPA (Environmental Protection Agency) and used to measure biogas generation. In the following Equation (2) shows how to measure biogas generation (considering time) [6, 7]:

$$LFG = 2L_0 R (e^{kc} - e^{-kt}) \quad (2)$$

Description of Parameters: LFG =amount of produced biogas during the year, L_0 =potential methane generation capacity (m^3/ton), R =average yearly quantity of waste disposal during the function of the landfill (ton), k =methane generation rate ($year^{-1}$), t= inactive year of the landfill, and c= years passed from the closure of the landfill.

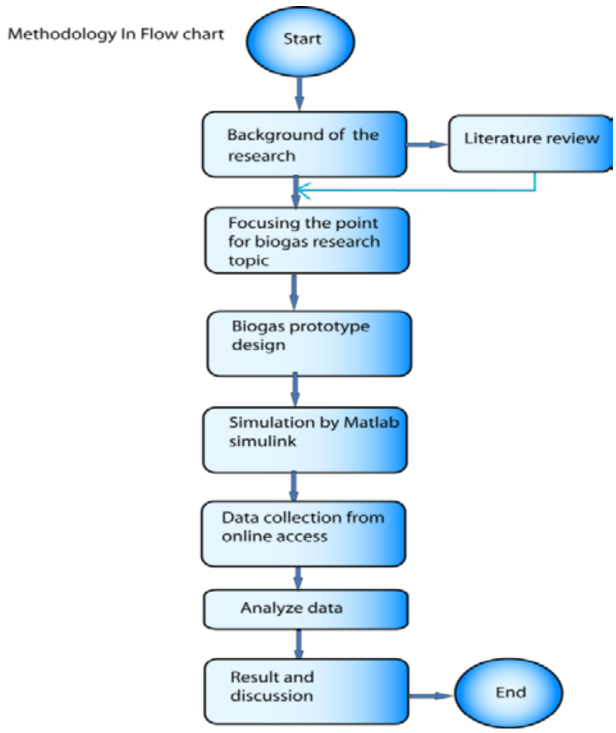

Figure 1. Flowchart of working throughout the research period.

According to EPA ("Landfill Gas System Engineering Design Seminar", 1994), the parameter 'L_0' fluctuates between 140-180 m^3/ton and, also the parameter 'k' experiences fluctuation as in the following:

->For wet climates between 0.1 - 0.35
->For dry climates between 0.02 - 0.1
->For intercalary climates between 0.05 – 0.1

In the case of the landfill of Volos, the following parameters are included to the biogas production model:

L_0= 120 m^3/ton for utmost secure reasons, k=0.05/year, R=70000 ton, t=25 year, and c=20 years.

Figure 2 shows the simulink model for simulating of biogas production. In addition Figure 3 represents the relationship between the amount of produced biogas and amount of methane gas. The amount of methane gas increases as the amount of biogas increases.

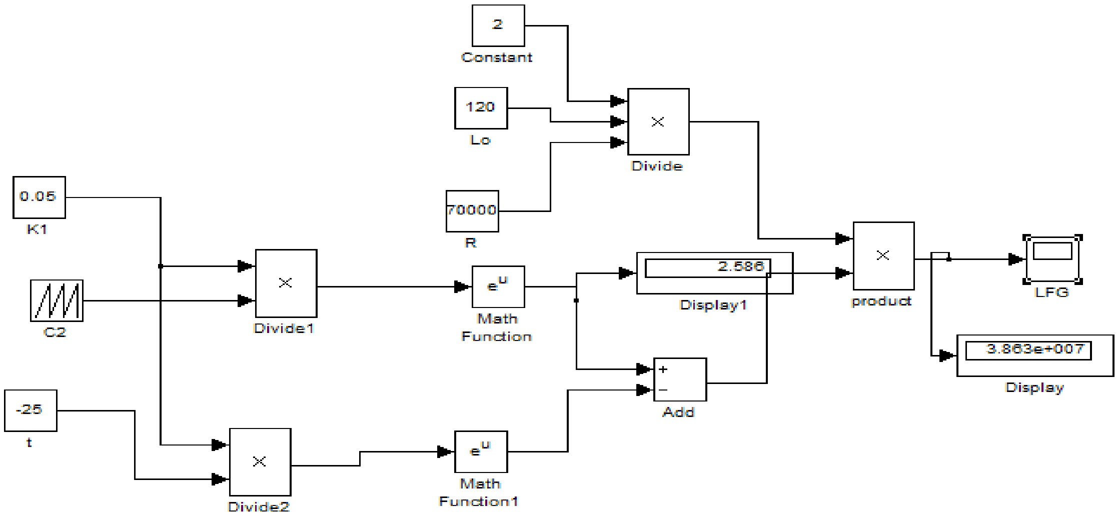

Figure 2. Simulation and calculation diagram.

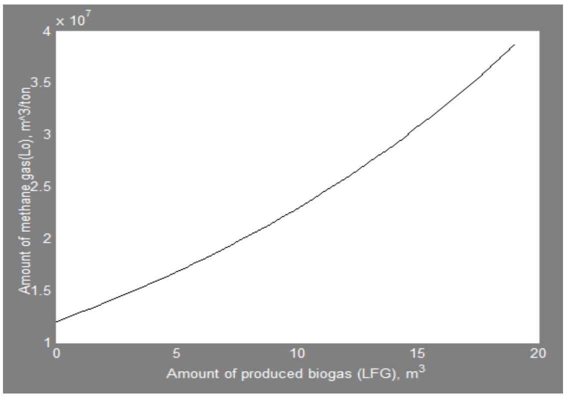

Figure 3. Amount of produced biogas vs amount of methane gas.

Table 1. Biogas production and energy scenarios of Bangladesh [23, 25].

Waste category	Biogas (m^3)	Electricity (MW)	Percentage of generated electricity
Cattle dung	8670000	12211	50.4
Municipal waste	1634000	2301	9.5
Poultry waste	2153400	3033	12.5
Human excreta	4736000	6670	27.5
Total	17193400	24215	EMRED ~ 100

4. DESIGN OF BIOGAS PRODUCTION

According to Figure 4, biogas is pumped from sewage pump and the waste comes to the biogas chamber, in biogas chamber, the organic matters will break down in the absence of oxygen casing to generate biogas. Then gas passes through the pipe and comes to the gas dehumidification/elaboration chamber where moisture and humidity are reduced. Following the biogas production the rest of the waste will pass out the outlet, which can be used in agricultural fields as a fertilizer. There are two pipes connected to the gas dehumidification; one for cooking purposes and the other connected to the gas generator.

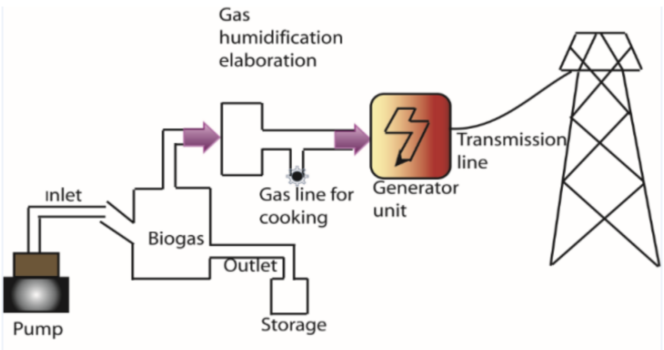

Figure 4. Proposed biogas system.

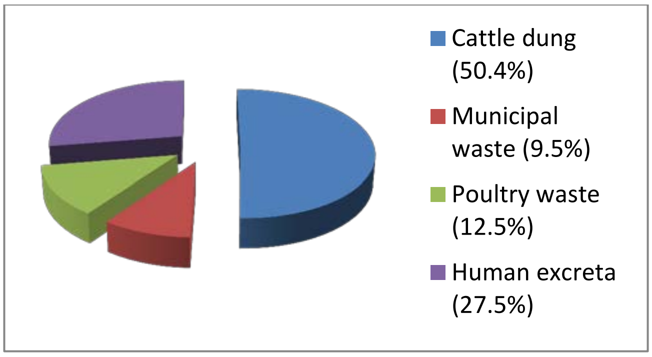

Figure 5. Amount of electricity production from different wastes.

According to Figure 5, maximum amount of electricity is produced (50.4 %) from cattle dung using 23 million cattle in 2011. In addition, Table 1 shows the possibility of producing a considerable amount of electricity and biogas. Biogas can be used as an alternative to kitchen fuel and other needed energies in Bangladesh with more than 64 % [26] of people living in rural areas.

5. ESTIMATION

The biogas production, with considering various wastes, is estimated by biogas estimator software called Anaerobic Digestion Calculator [27].

Table 2. Biogas estimation for vegetable waste.

Amount of waste (tons/year)	Total digestate (tons/year)	Biogas production (m^3/year)	Electricity production (kWh/year)	Capacity of biogas power plant (kW)
50	39.5	6,412.5	12,636	1.44
100	79	12,825	25,272	2.88
150	118.5	19,237.5	37,908	4.33
200	158	25,650	50,544	5.77
500	395	64,125	126,360	14.42
1,000	790	128,250	252,720	28.85
2,000	1,580	256,500	505,440	57.70

Table 2 shows that the efficiency of the to-be-digestated waste is around 90 %, whereas biogas production rate can reach 256500 m^3/year for the annual waste of 2000 tons.

Table 3 suggests that unsorted waste is 7.59 % more efficient than the wet vegetable waste with respect to digestate. However, vegetable waste is around 50.4 % more efficient than the unsorted waste regarding biogas production.

Table 3. Biogas estimation for unsorted waste.

Amount of waste (tons/year)	Total digestate (tons/year)	Biogas production (m^3/year)	Electricity production (kWh/year)	Capacity of biogas power plant (kW)
50	42.5	4,263.5	8,401.5	0.95
100	85	8,527	16,803	1.91
150	127.5	12,790.5	25,204.5	2.88
200	170	17,054	33,606	3.84
500	425	42,635	84,015	9.6
1,000	850	85,270	168,030	19.2
2,000	1,700	170,540	336,060	38.36

Table 4. Biogas estimation for cow manure.

Amount of waste (tons/year)	Total digestate (tons/year)	Biogas production (m^3/year)	Electricity production (kWh/year)	Capacity of biogas power plant (kW)
50	42.5	4,275	8,424	0.96
100	85	8,550	16,848	1.92
150	127.5	12,825	25,272	2.88
200	170	17,100	33,696	3.85
500	425	42,750	84,240	9.62
1,000	850	85,500	168,480	19.23
2,000	1,700	171,000	336,960	38.46

Table 4 represents almost the same amounts of manure as the ones shown in Table 3, while Tables 5 and 6 show an almost similar amounts of manure to the ones listed in Table 2. Finally, Table 7 shows that chicken broiler waste is the most efficient of all other wastes, as discussed in this paper.

Table 5. Biogas estimation for garden waste.

Amount of waste (tons/year)	Total digestate (tons/year)	Biogas production (m^3/year)	Electricity production (kWh/year)	Capacity of biogas power plant (kW)
50	40	6,080	11,980.5	1.37
100	80	12,160	23,961	2.73
150	120	18,240	35,941.5	4.1
200	160	24,320	47,922	5.5
500	400	60,800	119,805	13.68
1,000	800	121,600	239,610	27.35
2,000	1,600	243,200	479,220	54.7

Table 6. Biogas estimation for organic waste.

Amount of waste (tons/year)	Total digestate (tons/year)	Biogas production (m^3/year)	Electricity production (kWh/year)	Capacity of biogas power plant (kW)
50	40	6,056.5	11,934	1.36
100	80	12,113	23,868	2.72
150	120	18,169.5	35,802	4.09
200	160	24,226	47,736	5.45
500	400	60,565	119,340	13.62
1,000	800	121,130	238,680	27.25
2,000	1,600	242,260	477,360	54.49

Table 7. Biogas estimation for chicken broiler.

Amount of waste (tons/year)	Total digestate (tons/year)	Biogas production (m^3/year)	Electricity production (kWh/year)	Capacity of biogas power plant (kW)
50	38	8015.5	15,795	1.8
100	76	16,031	31,590	3.61
150	114	24,046.5	47,385	5.41
200	152	32,062	63,160	7.21
500	380	80,155	157,950	18.03
1,000	760	160,310	315,900	36.06
2,000	1,520	320,620	631,800	72.12

6. CONCLUSIONS

Biogas is one of the important economical and environmentally-friendly energy sources used for the electricity generation. Biogas is considered an appropriate alternative to fossil fuel since biogas has no detrimental impacts on the environment. In addition, counted as its most notable advantage, it can be used to produce electricity and reduce the excessive demand for fossil fuels. The present study aims to show potential of wastes' to produce biogas. Among six different types of waste considered in this study, the chicken broiler waste has shown maximum efficiency. The data analysis suggests that vegetable waste has better efficiency than garden and organic wastes. Vegetable waste is available Bangladesh. Therefore, vegetable waste can be collected from urban and rural areas to produce a large amount of electricity. Besides, cow manure is also efficient in biogas production. Where the cow firm is available, electricity can be produced through biogas generation from cow manure at lowers costs. The demand for Biogas is increasing at a high level coping with the increment of total energy demand. Considerable numbers of biogas plants have already been established in the rural and urban areas by the municipality in Bangladesh, the related data of which are shown in Table 1 and Figure 4. The application of this system will significantly reduce global warming and greenhouse effect.

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