Paper ID: ET-18

Electricity Generation from Poultry Waste in Bangladesh

Md. Wahiduzzaman Sajib[1], Mehadi Hassan, S.M. Najmul Hoque, M. Mourshed
Rajshahi University of Engineering & Technology (RUET), Rajshahi-6204, Bangladesh.
[1]E-mail: sajib122025@gmail.com

Abstract

Biogas is one of the most popular and effective renewable energy sources, which is produced by the decomposition process of organic materials under anaerobic condition. It can be used to run generator to produce electricity besides cooking, running pump for irrigation, incubator etc. This environmental friendly energy source can meet the lack of power of Bangladesh by generating huge electricity. The main purpose of this paper is to design a 50kw biogas plant from poultry waste in order to produce electricity to fulfill the power demand of the poultry farm as well as to supply electricity commercially the rural areas. 5 ton poultry waste, collected from 50000 chickens can produce 40-80 m^3/hr gas. This gas can easily run a 50 KW biogas generator. The plant life is about 20 years and payback period is 5 years. We have also found Net Present Value (NPV) positive and internal rate of return is 19%.

Keywords: *Biogas, poultry litter, electricity generation, technical and cost analysis.*

1. Introduction

Energy, one of the imperative needs of human being plays a key role for the socio-economic development of developing countries like Bangladesh. Energy consumption pattern of any country indicates the state of socio-economic development. Conventional energy (natural gas, oil, coal) is considered as the main energy source in the world. About 35% of world's primary energy consumption comes from natural gas. Recently, the production of fossil fuels has reached up to 79% compared to other energy sources [1]. This is a tremendous thread for the environment. Biomass is considered as the prominent source of renewable energy in Bangladesh as well as in the world. In the low income country like Bangladesh, rural households contribute the largest share of the biomass fuel consumption. Biomass energy is a potentially sustainable and relatively environment friendly source of energy. Biogas is produced from the organic materials from plants and animals such as straw, leaves, weeds, aquatic plants, human and animal excrement etc which may be degraded by various micro-bacteria in presence or absences of air. The decomposition under anaerobic process produces a flammable gas known as biogas. Cattle dung, kitchen waste, crop residue and most importantly poultry dropping are the most profound sources of biogas in Bangladesh. Biogas can be used for cooking as natural gas is used, running pump for irrigation, running metal to get luminous light(0.75m^3 of biogas can light 7 biogas lamps for an hour), running generator to produce electricity running motor vehicles, refrigeration running, running incubator etc. The residue of biogas is a very high quality organic fertilizer. It can be used for fish culture, mushroom culture, pearl culture, producing seeding from seed, Earth-worm culture for poultry and fish feed.

2. Present status of the biogas plant in Bangladesh

Different organization both government and nongovernment are involved in disseminating the biogas technology throughout the country. The total number of biogas plants in the country is about 250000. So far Bangladesh Council for Scientific and Industrial Research (BCSIR) has installed about 22000 biogas plants in the country. Besides, Local Government Engineering Department (LGED) has installed about 116711, Bangladesh Rural Advanced Committee has installed about 1200. Grameen Shakti (GS) has installed about 50012 and Department of Environment has installed about 260 biogas plants in the country. However, the number of biogas plants in the poultry sector is not significant. Out of the total number of biogas plants in the poultry sector BCSIR has installed about 3000 to 3500 biogas plants, whereas the number of biogas plants installed in poultry sector by LGED is 2014 [2].

3. Poultry litter

The poultry litter used in this work is distributed on the floor of sheds that serves for the birds. For this application it can be used various materials such as: wood shaving, peanut hulls, rice hulls, coffee hulls dry grass and chopped corn cobs. The increase of domestic chickens generates large amount of residues and so it becomes necessary to think about treatment alternatives and/or final destination for this, in order to minimize the impacts caused by it. 20% of global emissions of greenhouse gases come from agriculture activities, where the methane and nitrous oxide are the main gases involved. The average production of bed is 2.19 kg per chicken in natural form that means without separation of solids and including the humidity percentage. The quantities produced about the characteristics of poultry litter depend on the base material used, the creation time and bird population density. The litter has long been used as a food source for ruminants, however, due to health problems that occurred in Europe in 2001(as bovine spongiform encephalopathy), the Agriculture ministry of Brazil banning the use in the litter directed to ruminant feed [3].

Chemical Composition

A density for poultry waste is to use as fertilizer. If applied corrected, it can produced effective result. However, if the application rate exceeds the retention capacity of the soil or the requirements of the crop, the fertilizer can produce concentration of elements at toxic levels to plants, affecting the water resource and leading to the forming of nitrites. The main component of pollutants from the waste of birds is nitrogen and phosphorus. One should take into account the possibility of disease transmission due to the fact that these wastes may contain pathogenic microorganisms. Table 1 presents data of the litter chemical composition, noting that the data refers to a bed of wood shavings after a creating cycle of the 60 days.

Table 1. Chemical composition of poultry litter

Micronutrients and metals	**µg/g**	**Macronutrients**	**µg/100g**
Copper (Cu)	303	Nitrogen (N)	2.08
Iron (Fe)	1,786	Phosphorus (P)	1.01
Manganese (Mn)	294	Potassium (K)	2.61
Zinc (Zn)	217	Calcium (Ca)	2.08
Sodium (Na)	2,629	Magnesium (Mg)	0.53
Chromium (Cr)	5	Sulfur (S)	0.028
Lead (Pb)	22		
Nickel	2		

Alternative for Energy Generation

The remaining material in the process of rearing chickens can become a resource or a pollutant. For the environment impact become minimal, the litter must have proper management and use as best as possible. If not, they can pollute surface and groundwater, can also increase: mineral nutrients, organic substances that require oxygen, suspended matter and sometimes carry pathogenic microorganisms. The creation of chickens can also adversely affect air quality due to emissions of gases such as ammonia, breath odor, and dust production. On way to mitigate the environment impact produced in the production of boilers is to use the bed to produce anaerobic or biogas as fuel to generate electricity directly. The calorific value of the poultry litter depends on the humidity level, however, for air dried samples, this value is in the range of 9 to 13.5Mj/kg (about half the coal calorific value) [3].

4. Electricity generation

Electricity generation from poultry waste is relatively new in Bangladesh. Different types of technologies are being used in different poultry farms in the country. The most common one is to use natural gas generator which uses biogas as fuel. Most of the farms which are producing electricity from poultry waste do not have any hydrogen sulfide removal unit. Hydrogen sulfide is severely corrosive to all metals associated with the transportation of gas and metal parts of engine which are driven by such gas containing H2S. To overcome these problems associated with H2S, GTZ Bangladesh has installed a flagship project at Raj Poultry Farm in Faridpur district which is more scientific than any other technology being used currently [9].Paragon Agro Ltd, a leading agro based company of Bangladesh, has started producing electricity from poultry waste. The farm that mainly does business in poultry, tea and horticulture, set up three plants to generate a total 475 kilowatts (KW) of electricity a year. Paragon started its first bio-electricity plant with a capacity of 50 KW in Gazipur in March last year. The other two plants went into operation in October in Gazipur and Mymensingh. The Gazipur plant has a capacity to generate 300 KW of electricity and the Mymensingh one has a capacity of 125 KW. The company will also make organic fertilizers using the slurry produced as a by-product in the biogas digester [4].

Components of biogas unit

At first the waste are collected in the mixing chamber where the ratio of waste: water=1:2. Then with the help of a screw type pump it is send to the digester where the digestion process takes places. Then the gas produced is stored in the gas storage tank. Then the gas passes through a cooler hydrogen sulfide removing unit for purification. The purified gas goes to the biogas generator and then the mechanical energy converted into electrical energy and electricity produced. For maintaining the temperature inside the digester a hot water tank is provided and the over flow of the digester are collected in the holding tank.

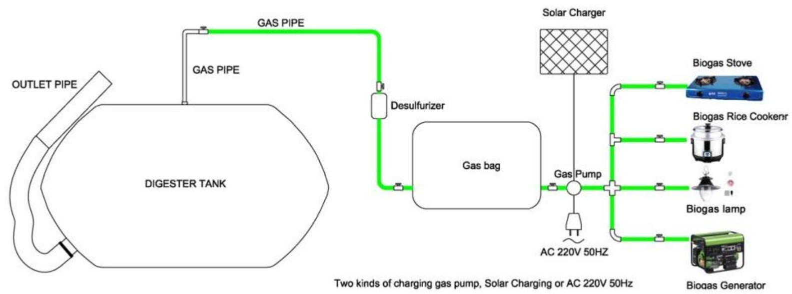

Fig. 1. Flow diagram of electricity generation from biogas (poultry waste)

Size of biogas unit

The amount of manure fed into a digester each day has an important effect on its operation, this is measured by volume added in relation to the volume in the digester, but the actual quantity fed to the digester also depends on the temperature at which the digester is maintained. In order to determine the unit size of a biogas unit, the following mathematical equation must be achieved:

Digester size (m^3) = Daily feed (m^3 dai-1)* Retention time (day) (1)

The digester size can be defined as the total size of the biogas unit, which includes the effective size of any volume occupied by the fermented material and the volume of gas storage. Size of the daily feed -in is the size of a mixture of waste with water added to the digester once daily or several times and the average concentration of total solids of 10%,where mixing the organic wastes with water depends on its water content. In the case of wet animal wastes, such as manure the production of mixing is 1:1. Generally, storage capacity has to be calculated by the average live weight of animals kept in husbandry systems, amount of added water, periods of no fertilization of crops and the animal species. In order to plan a biogas plant and to design a digester, several design parameters must be determined which are: ratio of gathered waste from manure canals to total waste, number of chickens in farm, amount of manure produced by a chicken which is usually 1.8 m^3 chicken-1month-1,quantity of daily liquid organic matter deposition into the digester, hydraulic retention time, density and quantity of daily dry organic matter deposition into digester ,and digester load which is usually 2-4 kg m^{-3} day1.the aforementioned design parameters are used to determine the total volume of the materials that are intended to be stored in the tank and are equal to the internal part of the tank (about 100%) is empty and the substrates should not fill it, because it is the place where the gas will accumulate. even in case of designing other storage tanks (e.g. liquid organic matter tank) it is required to leave 10% of the tank volume empty [5].

Gas collection chamber

In this research a rectangular shaped box, one side of which is made of glass for visibility of the different conditions and the rest five sides are made of M.S. Sheet. It is two chambered box. The partition between the two chambers is 6cm above the bottom so that the slurry may run to the next chamber. The larger chamber is $90\times63\times60$ cm^3 whose one side is glass and is used for storage of slurry as well as gas. Inside length, width and height of the digester are respectively 90 cm, 63 cm and 60 cm. So inside volume=340200 cm^3= 0.3402 m^3

Te outlet port of slurry is 7 cm diameter and 10.16 cm long and which is made by GI. Pipe, is fitted at the side near the bottom. The smaller chamber $15\times63\times60$ cm^3 whose four sides are made of MS. Sheet is used to feed slurry. In this chamber a 70×63 cm^2 sheet is slopping down from the top end of the bottom such that the slurry can easily entre into the chamber A 2-way regulating valve is fitted at the top of the larger chamber. MS. Sheet was welded with the 3/4 angle bar frame to make the system air tight cementing (potting) was placed throughout the joints [6].

Hydrogen sulfide removal system

The system consisted of a one liter sulfide oxidizing unit (SOU) connected to a pilot scale anaerobic digester, a continuous stirred tank reactor (CSTR) with an internal settling zone, that had a working volume of 92 L. The 1.5- inch ID SOU was operated with liquid height of approximately 3 feet. The effluent from the digester was occasionally pumped into the SOU to provide medium for sulfide removal.

Sulfide-laden biogas produced in the digester was mixed with a small amount of air before being forced through a fine diffuser located at the bottom of the SOU. In the SOU, hydrogen sulfide in the biogas dissolved into the medium and reacted with oxygen in the injected air to form chemical sulfur. After passing through foam trap (not shown), sulfide-free biogas excited the system. Hydraulic retention times (HRTs) of the pilot scale digester was controlled at 20 days. The digester was continuously mixed by means of biogas recirculation at the rate of 1.5 L/min (0.016 L/L digester-min) whereas the biogas recirculation rate of the SOU was set to either 0.2 or 0.4 L/min (0.2 or 0.4 L/L SOU–min). Both the SOU and the anaerobic digester were operated at a room temperature of 25±2°C. The liquid and the head space volumes of SOU were 1.05 and 11.1 L, respectively. Initially, the digester was inoculated with anaerobic digester sludge from a local waste water treatment plant and feed with a synthetic organic substrate. Fifteen liters of the synthetic organic substrate consist of 338.1 g of commercial dog food(with minimum 27% of crude protein, minimum of 15 % crude fat, maximum of 4% crude fiber, maximum 4% of moisture by weight), 50 g of $NaHCO_3$ and !5 ml of trace element solution (prepared by adding 10 g of $FeCl_2$. $4H_2O$,2.0g of CoCl2.6H_2O,1 g of EDTA, 500mg of $MnCl_2.4H_2O$,200 mg of Resazurin,142mg of $NiCl_2.6H_2O$,123mg of Na_2SeO_3, 90mg of $AlCl_3.6H_2O$, 50 mg of H_3BO_3,50mg of $ZnCl_2$,50mg of $(NH_4)6MoO_{24}.4H_2O$,38 mg of $CuCl_2.2H_2O$ and 1.0 ml of HCl (37.7% solution) into distilled water to make 1 litter). Substrate preparation was conducted by soaking of dog food for 1 day, adding $NaHCO_3$ and trace element solution and adjusting the volume to 15L by tap water. The substrate was kept in a 4°C refrigerator prior to feeding. The organic and COD 55 loading rate to the digester were approximately 0.8 g-VS/L-day and 1.2 g-COD/L-day, respectively. Prior to the experiments, the anaerobic digester had been operated for more than a year to ensure the steady state condition was reached [7].

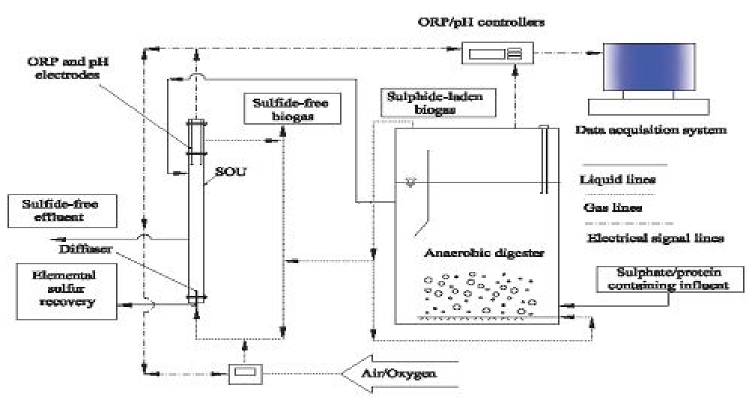

Fig. 2. Schematic of the sulfide removing system

5. Technical and Cost analysis

Load calculation of the farm

The total number of sheds in the farm is 50 (each having 4 bulbs of 40w) and the total number of lights is 250. The lights are used for 4 hrs per day which consumed 10,000 watts of electricity. The farm has 3 office rooms. The total number of lights and fans are respectively which consumed 300 watts of electricity. So the total electricity consumed in the farm is 10300 watts or 10.3 kilo watts.

Amount of poultry waste collected per day

The number of sheds in the farm is 50 and each shed contain about 1000 chickens. The amount of waste collected from each chicken is about 100gm 0r 0.1kg. The total number of chickens is (50*1000) 50,000 and total waste collected per day is (50,000*0.1) 5000kg or 5 ton.

Parameters of digester

Fixed dome type digester is used. The ratio of waste to water is 1:1, retention time is 30 days. [8] And density of the poultry waste is 765.6 kg/m^3.

Digester size (m^3) =Daily feed-in (m^3/day)*Retention time (day)……. (1)
Daily feed-in=Volume of poultry waste + Volume of water…… (2)

$$=(\frac{m}{\rho})\text{ waste} + (\frac{m}{\rho})\text{ water} = \frac{5000kg}{765.6kg/m3} + \frac{5000kg}{1000kg/m3} = 6.53+5=11.53\ m^3$$

From equation (1) we have,
Digester size =11.53*30=346 m^3 ……….. (3)
The digester is of cylindrical shape and the diameter (d) to depth (1) ratio is 2:1.
Volume of digester=$\pi r^2 l$……… (4)
Assume depth of the digester (l) =x m and diameter (d) =2x or radius (r) =x
From equation (2) and (3) we have,
346=$\pi r^2 l$ or, 346=πx^2 *x or, x=5m (approximate)
So, the depth of the digester is 5m and diameter is 10m. The building material of the digester is concrete and the capacity is about 150 ton. The p^H inside the digester is 7 and temperature always kept above 35°c.

Biogas generator

The amount of biogas produced 40-80 m^3/hr. [9] which can efficiently run the 50kw, 400V/230V, 50/60Hz, AC three phase biogas generator.

Cost analysis

Initial cost

1. Biogas Generator (50KW)=70,00,000tk [10]
2. Pump (5KW)=40,000tk [10]
3. Digester= 1,65,000tk
4. Holding tank=87,500tk
5. Hydrogen sulfide removing unit=250,000tk
6. Cooler=100,000tk [10]
7. Hot water tank=200,000tk [10]

Total initial cost 78,42,500tk
Replacement and maintenance cost: [6]
Digester cleaning=50,000tk/2years or, 25,000tk/year (Assume) [9]
Pipe replacement=60,000tk/year (Assume) [9]
Employee salary/month: Including one engineer and one operator total salary of the employee around is around 60,000tk/month [9]. In one year, 60,000*12=7,20,000tk
Generator maintenance cost: [11]
Major overhauling cost =2,00,000tk/73000hr = 20,000tk/7300hr or per year (Generator runs 20hr/day)
Top overhauling cost =1,00,000tk/36500hr = 20,000tk/3650hr or per year
Total maintenance cost of generator per year = 20,000tk+20,000tk=40,000tk
Total replacement and maintenance cost per year = 60,000tk+25,000tk+720,000tk+40,000tk = 8,45,000tk
Payback period:
Electricity consumed in the farm per day is (50kw*4hr) 200 unit, cost per unit is 4.73tk [12] so cost of 200 unit is 946tk (commercial bill). Electricity that could be supply per day is (50kw*16hr) 800 unit, cost per unit is 7tk (Assume) so cost of 800 unit is 5600tk. Total amount of electricity per day is 1000 unit. Total cost per day is (946tk+5600tk) 6546tk. Total cost per year is (6546tk*365) 23,89,290tk. So per year income is 23,89,290tk
Net annual cash inflow=23,89,290tk-845,000tk=15,44,290tk
Simple payback period = $\frac{\text{Investment required}}{\text{Net annual cash inflow}} = \frac{78,42,500}{15,44,290}$ =5.07=5 years
Net present value (NPV): (Life time of the project=20 years) Insert rate (Average)=13% [5]. The net present value found is 3005,753.68 tk. Since the net present value is positive so, the project is feasible.
Internal rate of return: Internal rate of return is 19%

6. Recommendation for future work

More research should be made for the simplification of the biogas plant in design construction, operational aspects and raw materials. Future work may be done to analyze the component of the biogas produced from the chicken waste and supplying electricity to fulfill the farms need and selling electricity commercially. Depreciation cost may also be calculated precisely for better economic benefit.

7. Conclusion

This paper is an attempt to design a 50kw biogas plant from poultry waste in a poultry farm. So that the plant can supply electricity to fulfill the farms need as well as the project become profitable. Finally the following statements can be concluded-

i. Number of chickens in the farm is 50000 and the amount of poultry waste collected per day is about 5 ton.
ii. This 5 ton waste produces 40-80 m3/hr gas. This gas can easily run 50 kw biogas generator.
iii. Payback period is 5 years. The investment and the running cost of the plant is recovered in about 5 years and the plant life is about 20 years. So we get profit after the 5 years.
iv. Net present value (NPV) is positive, so the project becomes feasible.
v. Internal rate of return is 19%.

There is a potential to produce electricity from poultry waste and high interest from farmers to produce the electricity. This interest has come due to the fact that all the poultry farms experience load shedding throughout the day mostly in the evening which hampers the production of the farms. Electricity can be produced from poultry waste for the daily consumption of most of the poultry farms.

8. REFERENCES

[1] Nasir NF, Daud WRW, Kamarudin SK, Yaakob Z. Process system engineering in biodiesel production: a review. Renew Sustainable Energy Rev 2013; 22:631–9.
[2] Grameen Shakti, Bangladesh. www.gshakti.org/
[3] International Conference on Renewable Energies and Power Quality (ICREPQ)'12, Santiago de Compostela (Spain), accessed on 28th to 30th March,2012.
[4] The Daily Star, 06 May, 2012.
[5] Retrieved from www.bangladesh-bank.org/econdata/intrate.php accessed on 29.12.13.
[6] Mohammad Rashedul Islam, K.M. Ibrahim Shohag, "Design and construction of a portable biogas plant", Undergraduate thesis paper department of Mechanical Engineering RUET, Rajshahi, Bangladesh. March 2008
[7] Thanapong Duangmanee, "Micro-aeration for hydrogen sulfide removal from biogas" Graduate thesis paper, Iowa State University, Ames, Iowa, 2009.
[8] Sheikh Ashraf Uz Zaman, "The potential of Electricity Generation from poultry waste in Bangladesh. A case study of Gazipur district" Graduate thesis paper, University of Flensburg, Germany, August 2007.
[9] Poultry waste based electricity plant, Paragon Agro Limited, Gazipur, Dhaka, Bangladesh.
[10] Energypac, Bangladesh. www.energypac.com/power_gen.php, Consulted on 23.12.13.
[11] Shikalbaha power station, Shikalbaha, Chittagong, Bangladesh.
[12] Bangladesh Power Development Board, Retrieved from www.desco.org.bd/?page=tariff-rate-2 accessed on 23.12.13