Bio Plant System in Urban Area: An Ideal Model

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Abstract-Bangladesh is an energy-starved country. Despite its large reservoir of natural gas, demand in the sectors like households and industries is too high to fulfill. Waste management in big cities also becomes a critical problem as more and more people are migrating to urban areas. Biogas can be a promising solution for both the energy crisis and waste management for countries like Bangladesh because of its simplicity, price, and efficiency. But the establishment of bio-plants in an urban area is not so common due to the lack of space, risk of leakage, and social taboos. This study represents an ideal urban system with an integral waste management and biogas production plant to evaluate system feasibility based on the economic benefits and associated risks from energy production. A modern bio-plant arrangement has been proposed for an ideal urban locality having 50 buildings with 10 families each. This study shows that gas usage of such an ideal locality can be fulfilled from the proposed bio plant system by up to 35% of the per day demand. Although the model requires some modification for its real field implementation, this study can pave the way for further research in this arena.

***Keywords*:** Biogas, Human excreta, Kitchen waste, Sulfur treatment, Urban area, Daily demand.

I. Introduction

Biogas is one of today's most prominent sources of renewable energy. It usually refers to a mixture of various gases formed by organic matter breakdown in the absence of oxygen [1]. The source of organic matter can be raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, human waste, green waste, food waste, etc. A biogas plant is a manufacturing plant for the production of biogas. Nowadays, continuous depletion & burning of fossil fuel is creating concern for new sources of energy. Multifarious sources of renewable energy are being observed to meet the ever-increasing energy requirement. Biogas is one of these promising sources that are both cheap and easy to use [2]. The development and disposal of urban waste are becoming an increasingly significant global issue. More and more people are moving to urban areas. As the urbanization trend continues, 54% of the world population expected to live in the cities, and 66% by 2050 [3]. The United Nations and the International Organization for Migration report that about 3 million people move to cities every week [3, 4]. Human activity produces wastes that can pose a grave risk to the atmosphere and people's safety if it is not collected and disposed of properly. These wastes that made up of human excreta, domestic waste, animal excreta, etc. usually dump indiscriminately in open-air outside of the city, on roads, and in the waterways. If Solid Waste Management (SWM) is properly maintained, these effects like health risks can easily be avoided. Waste management has thus become a terrible problem with this growing population in urban areas. The anaerobic process of organic matter decomposition takes in nature. The Assyrians in the 10th century and the Persians in the 16th century make the very first use of biogas. In recent years, both large and small-scale biogas systems revived in the 20th century [5]. In 2014, Hossain, H. Z. et al. supervised that by collecting municipal solid waste from the cities and generate them to energy can be a significant renewable energy source for Bangladesh. And this source can often be used. Of the total municipal solid waste, there is a high proportion of organic matter that is approximately 74.6% [6]. In 2017, Alamgir et al. stated that in major Bangladeshi cities generate averaged 0.387 kg/cap per day by analysis of six major cities here. And there are 74.4% organic matter in the total composition of total waste. It could be very beneficial for the socio-economic situation in Bangladesh by recycling the whole waste in major cities [7]. Vogeli Y. et al. found in 2008 that anaerobic digestion of kitchen and market waste can help to produce gases for burning. It can be a suitable method to treat the household waste in urban areas to alleviate the solid waste crisis and at the same time, with a proper mixture of Carbon dioxide (CO_2) & methane (CH_4) it is possible to use biogas as an energy source for cooking or generating electricity [8]. In 2011, Uddin et al. studied how a large amount of wastage and the growing population can be a potential source of energy. The anaerobic digestion can be applied to landfills and organic waste disposal that can reduce garbage problems and ensure more energy [9]. Anaerobic digestion in the urban building side can deal with organic waste & save transportation costs [10]. By adopting a landfill gas recovery process, it can also produce electricity to cope with the increasing demand of energy [6]. In Denmark, the completely stirred tank reaction (CSTR) plant is applied for the treatment of waste processing. This production of energy can even be comparable to wind energy [11]. Moya, D. et al. assumed municipal solid waste generation rate to increase annually by 2.2 billion tons worldwide by 2025. Emerging technologies should implement in the production of heat, thermal, compost, and biomass fuels [12]. Andriani, D. et al. decided on the use of human waste to produce biogas that can help either the environment or the process [13]. Despite this possibility, biogas systems are rare in urban areas mainly because of social taboos, pollution danger and biohazard, and a lack of space for construction in highly populated areas of an individual plant for each house. Therefore, this study provides an ideal municipal context with an integrated waste collection system and plants to convert biogas into biogas and to monitor the overall viability of this system based on building infrastructure and maintenance and energy efficiency.

II. METHODOLOGY

2.1 Basic Biogas Plant

A typical biogas plant has components such as a reception tank, digester or fermenter, gas holder, overflow tank, waste mixer, etc. Aerobic digestion is usually a viable way in which cooking or other organic waste can be turned into renewable energy and even the nutrient recycling nitrogen and phosphorus. A chain of separate unit processes in a biogas plant must work without interruption in series. Figure 1. Presents a schematic of a typical biogas plant. The first part of biogas processing is the receipt of waste material from households and other sources. During this process, solid and liquid waste materials are dumped in a tank that pulls the materials into their depths. The tank is referred to as a reception tank. The waste mixture is then brought into the digester. The receiving tank remains on the ground, but the digester is constructed underground.

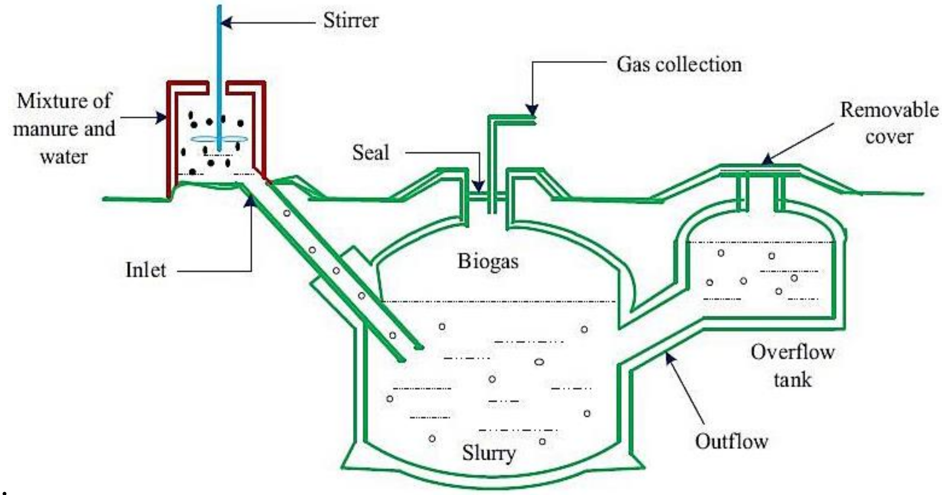

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FIGURE 1. Schematic Diagram of Typical Biogas plant [14]

The digester tank is made of concrete or steel. The tank has a large ceiling like a dome. The digester ceiling is attached to the gasholder with an outlet valve. The size and retention time of the digester is defined by the amount of waste. Biogas is generated in the digester tank and moved into the gas holder tank. The outlet chamber opens into a small overflow tank from the top. The working principle of a biogas plant is given below:

- Feed bacteria that can produce biogas from waste.
- Fermentation into the digester tank where biogas is produced from waste.
- Residues of fermentation in the reservoir.
- Take the digestate that can be used as a fertilizer of high-quality.
- Use the plant's biogas gathering for a different purpose.

2.2 Proposed Methodology

The ideal urban locality is assumed to have 50 buildings and 10 families in each building and 5 members of each family. In total, 500 families live in this ideal city consisting of 2500 people. The integrated waste management and biogas plant design will mainly collect human excreta and cooking waste for this urban area. The whole process is shortly described in the flow chart in Figure 2. The process should go on daily according to the figure. In that way, nature will keep safe and the gas can collect every day. In each of the septic tanks of the building, the human waste will be stored. The septic tank outlet is opened every day at a set time so that this waste can pass through a pipeline. In this process, a pump is used to extract waste from the septic tank into a central pipe. For this reason, every building will have a single pump therefore, 50 pumps will be necessary. Then the waste passes the pipeline and is stored in a receiving tank. The tank may be constructed from metal, plastic, or concrete. Then the human waste is stored here for a while. Then a second pipeline passes through and falls into the main digester. This can be done by introducing a slope into the arrangement using the water gravity flow from the septic tank. If not, all waste can only be removed by flow, a standby pump can be used to transfer them into the main digester. The main digester is 6-8 feet subterranean and the pipe from the septic to the primary tank has a slope of approximately 10-15 degrees to allow easy and smooth passing of the waste. The second pipeline is also set up at 10-15 degrees for smooth passing from the reception tank to the digester. Every day, door to door the kitchen waste is collected and dumped directly into the reception tank. The collection and dumping of both human and cooking waste will, therefore, take place every day in a cycle. The gas is mainly stored in a reservoir after the gas is produced from the waste. The gas then passes through the sulfur treatment plant from the reservoir. Sulfur is extracted and the odor removed in the sulfur treatment plant. The gas then passes through another reservoir from which the households receive the gas.

FIGURE 2. Schematic Diagram of Proposed Biogas Processing for Urban Areas

III. RESULTS AND DISCUSSIONS

The reduction of human excreta may differ according to age. Normally human reduces 0.10-0.40 kg of excreta every day [13]. Every human reduces 0.40 kg of human excreta every day. 1 kg of human excreta contains $0.07m^3$ of biogas [7]. Therefore, from 2500 people we get about = (2500*0.4*0.07) m^3 biogas = 70 m^3 biogas. Again in the cities of Bangladesh, a person generates about 0.387 kg of waste where the organic percentage is about 74.6%., which can be converted into biogas [7]. So, a total of 2500 people will generate about 967.5 kg of kitchen waste every day. Where organic waste is about 719.82 kg. One kilogram of kitchen waste, if well digested, yields 0.3 m^3 of biogas [15]. From the kitchen waste, it generates about 216.53 m^3 of biogas every day. Every day in total biogas generate from that locality= (216.53+70) m^3 = 286.53 m^3. Also, in major cities of Bangladesh, per capita, solid waste generation is about 0.5 kg [16]. So, for a total of 2500 people about 1250 kg of kitchen waste will generate. Where organic waste will be 932.5 kg. From this kitchen waste, about 279.75 m^3 of biogas will generate. So, in total the biogas generates from that locality= (279.75+70) m^3 = 349.75 m^3. Figure 3. Presents the graphical representation of the above-mentioned calculations.

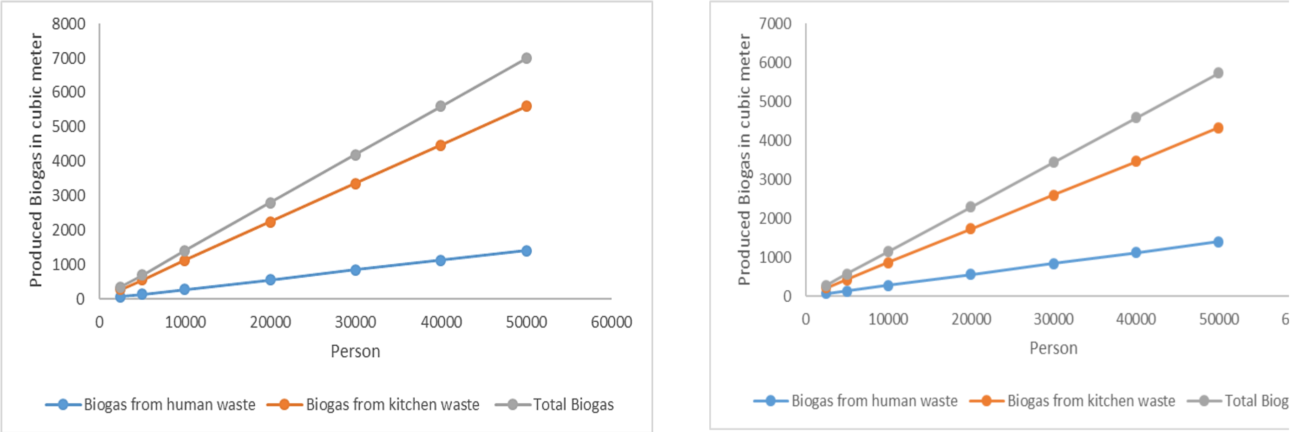

FIGURE 3. Biogas Production Profile

The biogas flow required for one oven burner is 200 liters/hour. This is an approximate flow (consumption) since it depends on nozzle size, gas pressure, etc. It means that 1 cubic meter of biogas could be used for 5 hours of cooking using one burner or half time for 2 burners. For one person there is needed not more than 0,2-0.4 cubic meters biogas per day only for cooking. So, the generated biogas can be used for cooking = (286.53/0.4) people ≈ 716 people. Gas usage consumed = (716/2500) * 100% ≈ 28.65%. Again, for another calculation, the generated biogas can be used for cooking = (349.75/0.4) ≈ , 874 people. For this gas usage consumed = (874/2500) * 100% ≈ 35%. Therefore, from this production process, about 349.75 m^3 or 12351.30 ft^3 gas will be produced. About 874 persons in that area can use this gas easily. Also, from other calculations, about 286.53 m^3 or 10118.71 ft^3 gas will be produced and about 716 people of that area can use this gas. Therefore, we can fulfil about 28.65% - 35% of total gas demand in that area.

IV. Conclusion And Recommendation

Bangladesh's biogas production in the urban side is very important. Since Bangladesh is densely populated, the rising energy demand can, therefore, be met with this production of biogas in each locality, and pressure on the national grid is also reduced. Being environment-friendly this model can lead to sustainable green development. Waste management of the entire project is also a critical aspect. All wastage can be used as decomposed bio-fertilizer in the agricultural field which also increases the overall profit of the project. There may be some uncertainty and possibility of error in estimating the gas production as the input parameters can have some changes on day to day basis.

- Gas treatment is a major issue for suitable domestic use. Cost-effectiveness and the complexity of a sulfur treatment plant should be the prime concern of further research in this field.
- The model locality that has been proposed in this study may vary in different aspects and scenarios. Therefore, the adaptability of the current study can also be an area of future research.

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