Design and Estimation of Biogas Plant for Canteen Waste: A Case Study

Adarsh S[1], Dr M N Shesha Prakash[2], Manasa MP[3], Annaporneshwari M[4]

[1]*Assistant Professor, Department of Civil Engineering, Vidya Vikas Institute of Engineering and Technology, Mysuru, Karnataka, India*
[2]*Vice Principal and Head, Department of Civil Engineering, Vidya Vikas Institute of Engineering and Technology, Mysuru, Karnataka, India*
[3]*Assistant Professor, Department of Civil Engineering, Vidya Vikas Institute of Engineering and Technology, Mysuru, Karnataka, India*
[4]*Former Student, Department of Civil Engineering, Vidya Vikas Institute of Engineering and Technology, Mysuru, Karnataka, India*

---***---

Abstract - *Energy is the means of support of today's society and economy. Traditional fossil energy sources such as oil are ultimately limited and the growing gap between increasing demand and shrinking supply will have to be met increasingly from an alternative primary energy source. With the increasing petroleum prices, rupee-dollar exchange cost and depleting foreign exchange reserves, one of the excellent sources of energy is biogas. Biogas is a fuel which is produced from the breakdown of organic matter.*

This research work focusses on the design and estimation of biogas production from the food waste collected from a canteen in Vidya Vikas Institute of Engineering and Technology (VVIET), Mysuru and also the focal point is on the theoretical estimation of biogas which is an initial step towards establishing a biogas plant at the backyard of the canteen. A model has been designed for the VVIET canteen wherein waste can be effectively used and the energy produced can be efficiently used within the campus. Methane is the main component of natural gas which is also an important greenhouse gas and is a major contributor to the global warming problem. With this background an initiative is taken to produce power from waste by using Fuel cells which generate electricity by an electrochemical reaction in which oxygen and a hydrogen-rich fuel combine to form water. This allows fuel cell to be highly energy efficient and even higher efficiency can be gained with cogeneration. A typical fuel cell produces a voltage from 0.6-0.8 V at full rated load.

***Key Words*: Biogas, Methane, canteen waste, organic manure, Fuel cell**

1. INTRODUCTION

One of the burning problems faced by the world today is management of all types of wastes and energy crisis. Rapid growth of population and uncontrolled and unmonitored urbanization has created serious problems of energy requirement and solid waste disposal (Dhanalakshmi Sridevi V et.al. 2012). Scarcity of petroleum and coal threatens the supply of fuel throughout the world. Further the problem of their combustion leads to research in different corners to get access to the new sources of energy, like renewable energy resources. Solar energy, wind energy, different thermal and hydro sources of energy, biogas are all renewable energy resources. In most of the renewable energy resources, entropy is the main problem which reduces the efficiency of their usage. But, biogas is distinct from other renewable energies because of its unique characteristics of using, controlling and collecting organic wastes and at the same time producing fertilizer and water for use in agriculture. Biogas does not have any geographical limitations nor does it require advanced technology for producing energy, also it is very simple to use and apply (Ziana Ziauddin et.al. 2015). The origin of biogas dates back to 10th century in Assyria for heating bath water. In 17th century that flammable gases could evolve from decaying organic matter. The first digestion plant was built at a leper colony in Bombay, India in 1859. Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Biogas can be produced from different sources like cattle dung, agricultural waste, sewage sludge, kitchen waste, biomass etc. (S. Sharada et.al. 2016). Biogas refers to a gas made from anaerobic digestion of kitchen waste. Methane is a clean energy one of the constituent of biogas which has a great potential to be an alternative fuel. Abundant biomass from various institutions could be a source for Methane production where combination of waste treatment and energy production would be an advantage (Mohan et.al. 2013). Biogas is a flammable gas produced when organic materials are fermented under anaerobic condition. It contains methane and carbon (IV) oxide with traces of hydrogen sulphide and water vapour (Dupade Vikrant et.al. 2013).

Kitchen waste is the best alternative for biogas production in a community level biogas plant. It is produced when bacteria degrade organic matter in the absence of air. Biogas contains around 55-65% of methane, 30-40% of carbon dioxide. The calorific value of biogas is appreciably high (around 4700 kcal or 20 MJ at around 55% methane content). The gas can effectively be utilized for generation of power through a biogas based power-generation system after dewatering and cleaning of the gas. In addition, the slurry produced in the process it provides valuable organic manure for farming and sustaining the soil fertility (Ravi P et.al. 2013).

1.1 Statement of the Problem

The purpose of this study is to find out how the food waste from VVIET canteen could be converted into biogas and to design an anaerobic digester which uses food waste to generate the biogas. The waste generated in kitchen in the form of vegetable refuse, stale cooked and uncooked food, waste milk and milk products could all be processed in this plant. Research has shown that one to five kg of kitchen waste can produce 237.25 $m^3$of biogas/year. Thus the efficient disposal of kitchen waste can be eco- friendly as well as cost effective.

1.2 Biogas

Biogas is produced by bacteria through the bio-degradation of organic material under anaerobic conditions. Natural generation of biogas is an important part of bio-geochemical carbon cycle. It can be used both in rural and urban areas (Anand Kumar Singh et.al. 2018).

Table-1: Composition of Biogas

Component	Concentration (by volume)
Methane (CH_4)	55 - 60 %
Carbon dioxide (CO_2)	35 - 40 %
Water (H_2O)	2 - 7 %
Hydrogen sulphide (H_2S)	20 - 20,000 ppm (2%)
Ammonia (NH_3)	0 - 0.05 %
Nitrogen (N)	0 - 2 %
Oxygen (O_2)	0 - 2 %
Hydrogen (H)	0 -1 %

1.3 Fuel Cell

Fuel cells produce electrical energy by chemical reaction. While they can use such feeder fuels as alcohol, gasoline or methane, fuel cells used in spacecraft and other specialized applications use hydrogen to fuel the creation of electricity because it reacts with oxygen to produce water as a by-product. To understand how a fuel cell works, a simple fuel cell with mostly common house-hold materials can be built (Adarsh S et.al. 2015).

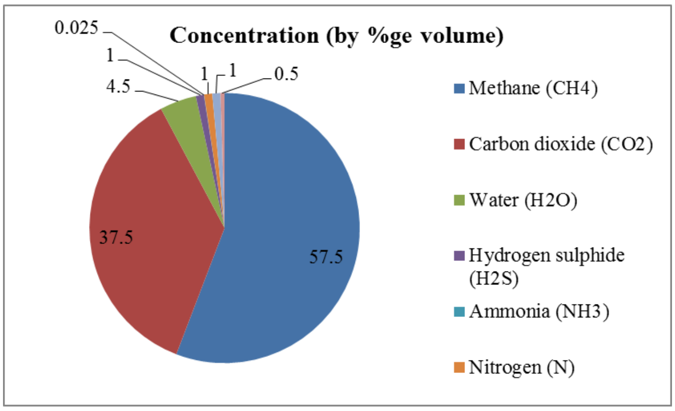

Chart-1: Composition of biogas showing the concentration of volume by percentage

2. METHODOLOGY

2.1 Description of Study Area

Vidya Vikas Institute of Engineering and Technology (VVIET) is located in Alanahalli midway, (12⁰18'13.3''N 76⁰42'36.9" E) between Mysore and Malavalli, and is spread over a sprawling campus of 65 acres with academic and administrative buildings that are surrounded by a lush green ambience. VVIET is known for disciplined academic ambience. Since its inception, Vidya Vikas Educational Trust (VVET) has catapulted into one of the leading educational institutions ranging from primary schools to undergraduate and post graduate colleges covering the Arts, Commerce, Hospitality, Nursing, Social Work, Law, and all facets of Engineering in the districts of Mysuru. Fig 1 depicts the Aerial view of study area.

Fig-1: Aerial view of Vidya Vikas Institute of Engineering and Technology (Courtesy, Google maps)

2.2 Materials and Specification

The VVIET Canteen waste is used in this study to generate biogas. The pilot study is carried out to degrade the canteen waste in anaerobic digester. Initially one biogas plant is installed at the backyard of the canteen as a pilot plant. Study based on the result obtained and waste generated it is proposed to design and construct three more biogas plant to effectively use the canteen waste. The materials required to construct biogas plant is as shown in table 2 and the specifications required to run the biogas plant is shown in table 3.

Table-2: Materials required for the construction of Biogas plant

Sl.No	Material list	Quantity in No's
1	PVC Tank of Capacity 750L	1
2	PVC Tank of Capacity 500L	1
3	75mm PVC Pipe (6kg/cm^2)-10.00 Feet	1
4	75mm PVC Male Threaded Adaptor (MTA)	2
5	75mm PVC Female Threaded Adaptor (FTA)	2
6	75mm PVC –Tee (heavy)	1
7	75mm PVC-Elbow (heavy)	1
8	90mm X 75mm PVC Reducer Collar (heavy)	1
9	1/2" GI Collar (ISI)	1
10	1/2" GI 'Tank' nipple (ISI)	1
11	200mL Solvent	1
12	Teflon Tape	5
13	M-Seal	5
14	1" UPVC Tank Nipple	1
15	Washer (Flange washer 80mm)	5
16	Drip Tee 16mm	3
17	Drip Valve 16mm	3
18	¾" Stainless steel Hose Clamp	12
19	Shellock	1
Approximate Estimated Cost		**13000**

Table-3: Specification of 1 to 5 kg/day organic/kitchen waste biogas plant

Input to the plant	1 to 5 kg of kitchen waste
Area required	$4m^2$
System elements	Digester, gas holder, gas flow pipe line, moisture trap system, biogas burner
Type of feed	Kitchen waste like rice starch , wash water of rice, used tea powder, coffee powder, waste atta, left out rice, sambar, over ripened fruits, vegetable waste, waste edible oil and other cooked waste from kitchen

2.3 Experimental Setup

The methane gas was passed to the conical flask containing activated charcoal which separates hydrogen molecules from the carbon molecules. The separated hydrogen molecules passed to the fuel cell setup where the electrolysis process takes place and the positively charged hydrogen molecules generating voltage in the multimeter. The experimental setup is as shown in Fig. 2.

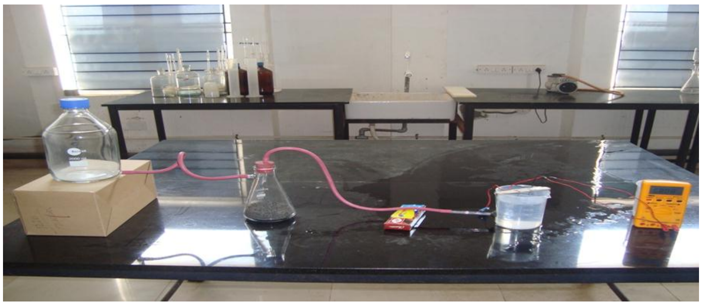

Fig-2: Fuel Cell Connection to the Setup

3. RESULTS AND DISCUSSION

3.1 Biogas Generation

For a daily canteen waste of one to five kg, it is estimated that 0.65 m^3 of biogas is generated every day.

3.2 Power Generation using Fuel Cell

Table 4 depicts that 0.6 m^3 of methane gas is passed to obtain a voltage of 0.9 V, 0.835 V, and 0.815 V respectively which is the maximum efficiency that can be obtained using a Hydrogen fuel cell. As per survey it is observed that hydrogen fuel cell is the cheapest and same voltage can be obtained compared to the other fuel cells.

Table 4: Table Showing Power Generation

Cycle No	Volume (m^3)	Power Generated (volts)
1	0.6	0.9
2	0.6	0.835
3	0.6	0.815

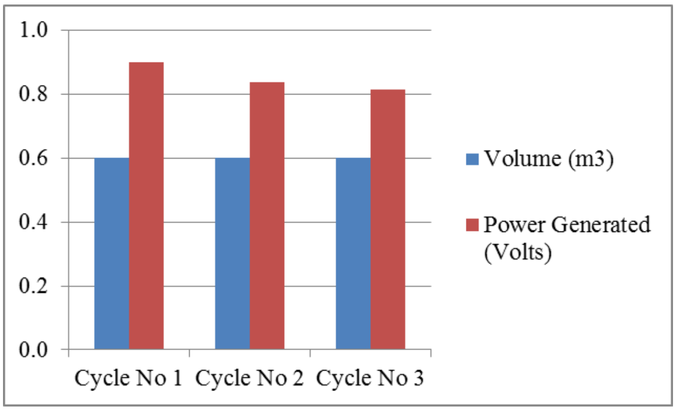

Chart-2: Power generation with respect to volume/cycle

3.3 Design and Estimation

It is estimated that around 20kg of canteen waste is being produced daily from VVIET canteen, in order to effectively use the waste, four biogas plant of each 5kg capacity has to be installed which costs around Rs.60,000/-. The detailed estimation of construction and installation of biogas plant is as shown in table 5. The returns or savings that can expected from the biogas installation is estimated in detail is as shown in table 6.

Table-5: Estimation and Costing for Biogas Plant

SL.NO	COMPONENT	COST / PLANT (Rs)	COST FOR 4 PLANTS (Rs)
1	Materials	13,000/-	52,000/-
2	Labour and Installation	2,000/-	8,000/-
TOTAL AMOUNT		**15,000/-**	**60,000/-**

Table-6: Returns or Savings that Can Expected From the Biogas Installation

Input to the plant	***1 to 5 kg of Canteen waste***	
Area required	$4m^2$	
System Elements	Digester, Gas Holder, Gas flow pipe line, Moisture trap systems, Biogas Burner	
Type of feed	*Canteen waste like rice starch, wash water of rice ,used tea powder, coffee powder, waste atta, left out rice, sambar, over ripened fruits, vegetable waste, waste edible oil and other cooked waste from Canteen*	
Application	Bio gas for cooking at Canteen Slurry as manure for gardening	
Daily biogas and manure	Generation of biogas per day (Max.)	$0.65m^3$→*(1)*
	LPG Equivalent of biogas per day	0.26 kg →*(2)*
	Savings through LPG per day	Rs.25.40 →*(3)*
	Savings through manure per day	Rs.1.20
	Total returns per day through biogas and manure	**Rs.26.60**→*(4)*
Monthly biogas and manure	Generation of biogas per month	$19.50\ m^3$
	LPG Equivalent of biogas per month	7.80kg
	Savings through LPG per month	Rs.761.90
	Savings through manure per month	Rs.36
	Total returns per month through biogas and manure	**Rs.797.90**
Annual biogas and manure	Generation of biogas per year	$237.25\ m^3$
	LPG Equivalent of biogas per year	97.90 kg (5 Cylinders)
	Savings through LPG per year	Rs.9269.83
	Generation of Manure per year	146 Kg
	Minimum cost of manure per kg	Rs.3/-
	Savings through manure per year	Rs.438
	Total returns per year through biogas and manure	**Rs.9707.83**

4. CONCLUSIONS

From the observations made and obtained results, the following conclusions are drawn:

- Biogas digester systems provides a residue organic waste, after its anaerobic digestion(AD) that has superior nutrient qualities over normal organic fertilizer, as it is in the form of ammonia and can be used as manure.
- Hydrogen can be produced in an environmentally friendly manner.
- Fuel cells can be developed for portable electronic devices.
- The cell create energy through electrochemical process, and do not burn fuel, they are fundamentally more efficient than combustion systems.
- A typical fuel cell produces a voltage from 0.6V to 0.9V at full rated load. A hydrogen fuel cell produces electricity without any pollution in environmental friendly manner.
- It is estimated that around 20kg of canteen waste is being produced daily from the canteen, in order to

effectively use the waste four biogas plant has to installed which costs around Rs.60,000/-.

- As per estimation around 548 Kg manure, 949 cubic meter of biogas, 20Kw of power is generated per year from 4 biogas plants. Where in manure produced can be used for green belt available within the campus, biogas produced can be used to cook food in canteen which saves around 20 LPG per year and the power generated can be used to lite LED and small capacity CFL bulbs with the camps.
- As per estimation Rs 38,828/- is saved per year from 4 biogas plants on a one time investment of Rs 60,000/-.

REFERENCES

[1] Adarsh S, Meghana M Kumar, Chaitra M G, Nitin Pal Singh and Vidyashree "power generation using hydrogen fuel cell from biogas," International Research Journal of Engineering and Technology (IRJET) Volume: 02 Issue: 03, June-2015.

[2] Anand Kumar Singh1, Amarika Singh, P. K. Pathak "Biomethanation of kitchen waste," International Journal of Technical Research and Science (IJTRS) Volume 3, Issue 5 June 2018.

[3] Dhanalakshmi Sridevi V. and Ramanujam R.A. "Biogas Generation in a Vegetable Waste Anaerobic Digester: An Analytical Approach," Research Journal of Recent Sciences Vol. 1(3), 41-47, March (2012).

[4] Dupade Vikrant, Pawar Shekhar "Generation of Biogas from Kitchen Waste -Experimental Analysis," International Journal of Engineering Science Invention Volume 2 Issue 10 October. 2013 PP.15-19.

[5] Ravi P. Agrahari1, G. N. Tiwari "The Production of Biogas Using Kitchen Waste," International Journal of Energy Science (IJES) Volume 3 Issue 6, December 2013.

[6] S. Mohan, K. Jagadeesan "Production of Biogas by Using Food Waste," International Journal of Engineering Research and Applications(IJERA) Vol. 3, Issue 4, Jul-Aug 2013, pp. 390-394.

[7] S. Sharada, Mr. G. Surendra Babu, K.Hema Latha "production of biogas from kitchen waste," International Journal of Scientific Development and Research (IJSDR) Volume 1, Issue 7 July 2016.

[8] Ziana Ziauddin, Rajesh P "Production and Analysis of Biogas from Kitchen Waste," International Research Journal of Engineering and Technology (IRJET) Volume: 02 Issue: 04 July-2015.