

Development of a Small-Scale Biogas Plant Utilizing Organic Wastes for Sustainable Biogas Production

Tahir Sultan, Hafiz Muhammad Saud, Muhammad Umer Farooq

Department of Civil Engineering, Bahauddin Zakariya University, Multan, Pakistan

Abstract: Pakistan faces an energy crisis due to its rapidly growing population and economy, which heavily relies on fossil fuels. The Alternative Energy Development Board (AEDB) is exploring renewable energy technologies to address the crisis. Biomass, a sustainable and easily integrated renewable energy resource, is being considered due to its environmental friendliness and ease of integration. However, deforestation has led to significant environmental deterioration in Pakistan's poor urban and rural populations. To prevent environmental degradation due to deforestation, we built a small-scale biogas plant. For this, we took 4 empty bottles of 20 liters and organic wastes capable of making gas, including eight kilograms of kitchen waste, eight kilograms of cow dung waste, eight kilograms of grass, and eight kilograms of sludge waste. Took 50% water and 50% organic waste. Mixed it thoroughly and containerized it in these bottles. Separate points of inlet and outlet were provided in bottles. These points did not release any trapped gas. These bottles were blackened so that the sun rays did not affect them. Bottles were filled with waste in the absence of oxygen. This gave 0.000182 HM^3 per day from Kitchen Waste, 0.000287 HM^3 from Dung Waste, 0.000087 HM^3 per day from Grass, and 0.000056 HM^3 per day from Sludge Waste. By using these production rates, the production of biogas for a 20-house colony is estimated to be 4.637 HM^3 while their average consumption is 2.6 HM^3 . We have proposed an estimate of a Biogas plant along with components for this colony, and the estimated construction cost is around PKR. 500,616 is turning out quite economical, and the biogas plant shall be eco-friendly, along with minimal maintenance costs.

Keywords: Biogas, Dung Waste, Sludge Waste, Kitchen Waste, Sustainable Energy.

Email: saudmalik4@gmail.com

1. Introduction

Biogas is a mixture of gases produced when organic waste breaks down. Anaerobic digestion is a process that breaks down organic matter through fermentation, producing a gaseous mixture of methane (50-80%) and carbon dioxide (20-50%). Microorganisms help decompose organic waste in the absence of oxygen. Biogas is classified as an advanced biofuel and can be used in large-scale systems to provide heat and electricity, as well as fuel for vehicles [1].

Biogas is an affordable natural gas supply that can be used on-site for energy consumption or supplied to utilities for a profit, provided infrastructure expenditures are covered up front. Unlike other renewable energy sources like solar and wind power, biogas has a constant capability to provide electricity without inherent fluctuations or variations [2].

Reducing methane emissions from current waste disposal systems is the main advantage of using biogas as an alternative fuel. Biogas is considered an environmentally benign energy source due to its ability to address two significant environmental issues: the global waste

problem, which causes daily deadly methane gas releases, and the world's energy demand being met by fossil fuels [3].

In summary, biogas is a natural, affordable, and environmentally friendly alternative to traditional energy sources like solar and wind power. It can be used for heating water, cooking, and lighting, and can be measured in HM3 units (Hectometer).

Biogas is a renewable energy source that uses nature's ability to recycle material into valuable resources by turning organic waste into energy. By treating trash on-site, biogas generation recovers waste products that would otherwise contaminate landfills and avoids the use of hazardous chemicals in sewage treatment plants. It also saves money, energy, and materials. Biogas digesters convert trash into biogas and direct it so that the energy can be used constructively, preventing methane gas from escaping into the atmosphere.

Various plant types and biogas systems have been developed to effectively utilize biogas. The biological process of turning organic waste into biogas is consistent with organic matter fed to biogas digesters, which break down the organic material in an anaerobic environment. Bacterial populations aid in the fermentation of organic matter to produce biogas through four phases: hydrolysis, sugars and amino acids, lactogenic bacteria, and methanogens.

Most biogas is used in commercial agricultural anaerobic digestion plants to generate power at the point of manufacturing. Landfill biogas is one example, and before using it, water washing may be done. Before using the engine, a substance called Sloane, which forms hard deposits inside the gas, may need to be removed. Biogas burns easily in large, robust gas engines that run on diesel fuel in less durable versions. By burning the biogas in the presence of oxygen, the resulting energy can be used directly for cooking [4].

Biogas is a renewable energy source that can be converted from carbon dioxide and water to biomethane (RNG), which can be used as fuel for cars, engines, lamps, and gas stoves. It is easily compressed and can be used as a substitute for petroleum products, reducing the demand on the wood fuel supply and potentially lowering the cost of home wood fuels [5].

Biogas is also used to power portable power plants, with most off-grid homes using portable generator sets. Biogas is cleaned and upgraded to natural gas standards when it becomes biomethane, making it suitable for compression. Many Scandinavian car, truck, and bus users have converted or designed their vehicles to run on natural gas. In many European locations, RNG is directly pumped to a neighboring fueling station from a nearby biogas plant system, bypassing the natural gas pipeline [6].

The direct conversion of biogas into electricity in a fuel cell is another example of its use. The

gas in fuel cells is used to heat a unique type of electrical cell, producing an electrical current or electricity. Although expensive fuel cells and extremely pure gas are needed, there is great potential for this technology in the future. There are now domestic central heating boilers available that not only heat a house with hot water but also function as fuel cells to generate power [7].

Biogas' physical properties, mainly composed of inert carbon dioxide (CO₂) and methane (CH₄), define its potential. However, the term "biogas" refers to a wide range of gases produced by specific treatment procedures, starting with organic wastes from industry, domestic, or animal sources.

This study mainly aims at the production of biogas from different types of organic wastes. For this purpose, we prepared four different small biogas plants by using plastic bottles to check the production rate from different organic wastes. Four types of organic wastes were used to produce natural gas, such as kitchen trash, cow dung waste, grass waste, and sludge waste. We took 50% water and 50% organic garbage. After well mixing, I poured it into these bottles to check the production rate [5].

2. Literature Review

2.1. Biogas production from cow dung, poultry waste, and water hyacinth:

2.1.1. Md. Forhad

Md. Forhad (2013) developed a small-scale biogas plant using fermentable materials like water hyacinth, chicken excrement, and cow manure. The biogas produced was compared and examined. The maximum gas production from poultry waste was 0.026 m³ on day 8, while cow dung and water hyacinth produced 0.0263 m³ and 0.012 m³, respectively, on day 26. The methane percentage was almost the same [8].

2.1.2. Tsunatu

Tsunatu's 2014 examined biogas production from agricultural waste inoculated with cow dung or poultry droppings revealed that maize cobs had the highest short-term biodegradability index, while rice straw yielded the most biogas, and sugarcane bagasse had the least [9].

2.2 Biogas Production from Kitchen Waste:

2.2.1. Vunduru Nooka Sai Vikram Kumar

Vunduru (2016) studied that kitchen waste is a promising alternative for biogas production in a university-level biogas plant. It is produced when bacteria degrade organic matter without air, containing 55-65% methane and 30-40% carbon dioxide. The calorific value of biogas is high, around 4700 Kcal. Anaerobic digestion tests show characteristic oscillations in methane

production, possibly due to methylotroph populations in activated sludge [10].

2.2.2. Rama Dhanariya

Rama Dhanariya (2014) explained that biodegradable waste, including kitchen and animal waste, is converted into biogas, a potent greenhouse gas, through anaerobic digestion (AD). This process, which releases methane, produces about 40% of the biogas, which is 40% carbon dioxide and 60% methane, helping to address the energy dilemma [11].

2.3. Biogas production from crops and agricultural residues

2.3.1. Laboya

Laboya (2010) investigated biogas as an alternative energy source using a survey and laboratory experiment. The study found that a mixture of pineapple, plantain, and cassava peelings produced significant biogas when the digester's working parameters were slightly alkaline. The digester temperature remained between 27 and 35.5°C throughout the experiment [12].

2.3.2. Nabila Laskri and Nawel Nedjah

In 2015, researchers Nabila Laskri and Nawel Nedjah studied the degradation of organic matter in sludge from a wastewater treatment plant and biodegradable garbage from landfills. They found that the biogas generated from anaerobic digestion of these substrates is combustible, with a percentage of CH₄ over 64%. The amount of biogas collected from sludge waste was over ten times more than the volume from landfill organic matter. The sludge substrate showed a decrease in COD by 87.3% [13].

2.4. Biogas production from municipal waste, sludge

2.4.1. Ayhan Demirbas et al 2016

In 2016, Ayhan Demirbas introduced biogas as a sustainable clean energy carrier, produced through anaerobic digestion of organic materials like sewage sludge, animal waste, and municipal solid wastes. Biogas is a promising renewable energy source for heat and electricity generation, composed of methane, carbon dioxide, nitrogen, hydrogen, hydrogen sulfide, and oxygen. The optimal C/N ratio for biogas digestion should be between 25 and 35. A 500 m³ biogas plant can produce 20-36 × 10³ Nm³ biogas per year [6].

2.4.2. E. Athanasoulia et al, 2012

In 2012, E. Athanasoulia's study on wastewater treatment plants revealed that the treatment and disposal of excess sludge is a growing concern. Anaerobic digestion is a common method for stabilizing sludge and producing biogas simultaneously. The study found that serial digestion can improve biogas production by 9.5-40.1%, with a biogas selectivity of 0.49-0.06 m³ biogas/kg TVS degraded [7].

3. Methodology

For the production of biogas by using different organic wastes, the following steps were followed:

1. Field Visits to Biogas Plants.
2. Data Collection and Selection of Waste Samples.
3. Equipment of the Plant
4. Preparation of Plant.
5. Procedure for Production of Biogas.

3.1. *Field Visits to Biogas Plants*

We visited a bio-gas production plant in Khanewal, Punjab (Pakistan) and met with farmers. There, we inquired about a bio-gas plant, such as:

- i. How does the bio-gas plant work?
- ii. What are the organic materials used for the production of bio-gas?
- iii. If the production of gas is less, then what is the solution to this problem?

After getting useful information, we visited a bio-gas plant that was being constructed underground. The cow dung was used in the biogas plant to produce biogas for their small farming activity and cooking purposes. The digesters were simple, cheap, robust, easy to operate & maintain, and could be constructed with locally produced materials.

3.2 *Selection of Waste Sample:*

The four types of organic waste.

1. Agricultural waste (Grass)
2. Municipal waste (Sludge)
3. Food waste (Vegetables, Fruits)
4. Animal waste (Cow Dung)

3.3 *Equipment of the Plant*

We have used the following materials to make the Biogas plant setup.

- Digester feed stocks (cow dung, Kitchen waste, sludge, and grass)
- A 20-litre water can
- 1/4" plastic tubing
- Medium-sized tyre tube for gas storage
- Tub for mixing water feedstock
- PVC Pipe 3/4" 2.5 ft.
- T-valve

- Valve
- Silicone glue
- Fine sand
- Soldering Iron
- Black Color Paint

3.4. Preparation of Plant

Then, I used the following five steps to prepare the Biogas plant setup.

1. Choose the container
2. Make holes
3. Fix the Inlet and Outlet pipes
4. Making the gas holder tank
5. Mix the organic waste
6. Coloring the digester tank

3.4.1. Choose the Container

We chose a correct size container, which acted as a digester tank. The container size was 20 liters.



Figure 1: Choose the Container



Figure 2 In – let and out – let Pipe



Figure 3: Making of Gas Holder



Figure 4: Mixing of Materials

3.4.2. Make Holes

We marked the Inlet and Outlet holes in the digester tank with the help of a soldering iron and heated it to make holes.

3.4.3. Fix the Inlet and Outlet Pipes

We attached the Inlet and Outlet pipe with silicone glue.

3.4.4. Making the Gas Holder Tank

Took a car tire to make a gas holder tank, which was used for gas storage. The tank was fixed with a valve used for gas-fitted purposes. Kept the gas holder tank in good condition so that the pipe does not fail due to a bend.

3.4.5. Mixing Organic Waste

We mixed the organic waste (cow dung, kitchen waste, grass, and sludge) and added 50% water to make a fine slurry. Then put the slurry in the digester tank.

3.4.6. Coloring the Digester Tank

We colored the digester tank so that the sun rays could not affect the tank.

3.5. Procedure for the Production of Biogas

We went to Khanewal to visit the biogas plants. Two types of biogas plants are observed closely. How is biogas produced from these plants? We met with the owner of these plants and got information from them. Then we read literature and acquired information about organic matters that can produce biogas from organic matter. We select four types of waste, including kitchen waste, dung waste, grass waste, and sludge waste.

We took a 50% waste and 50% water and chose four empty bottles of twenty liters to make a digester tank. Then made one in-let and one out-let point on them. A tire tube was connected for gas storage. We put the slurry of the waste into the digester tank and keep it away from oxygen (anaerobic digestion). These bottles were colored black so that the rays of the sun do not affect them. The process of decomposition began. Then we took readings after a week. Using these readings, we finalized the results.

To design a biogas plant for a colony of twenty houses, keeping in view our production rates, Kitchen waste and sludge waste from those houses are used for the production of biogas. The 10,000-kilogram kitchen waste was taken from an external source once in a while, and 300 kilograms of sludge waste are taken from these twenty houses daily. To maximize production, 50 kilograms of kitchen waste is taken from these twenty houses every week.

Put the slurry of this waste into a large plant, and production will start. We used previously collected biogas production rates by using our small-scale setup. We also estimated how much

average gas is required for a house usage from the sui-gas bills, so that we can fulfill their requirement with the production of this plant.

3.6. Procedure of Results

3.6.1. Take Reading

We will note down our production readings in grams at normal temperature (25⁰ -30⁰ °C).

3.6.2. Convert grams to Kilograms.

We will convert grams to kilograms and divide by 1000 to do so. Because the unit of the density of the methane is kg/m³. So, we will convert into kilograms. 1 kilogram is equal to 1000 grams.

$$\frac{\text{grams}}{1000} = \text{kilograms}$$

3.6.3. Convert kilograms to volume

We will convert kilograms to volume and divide by the density of methane. The density of methane is 0.656 Kg/m³. Because we need a volume. So, kilograms divided by the density of methane.

$$\frac{\text{Kilograms}}{0.656 \text{ kg/M}^3} = \text{M}^3$$

3.6.4. Convert M³ to HM³

We will convert M³ to HM³ and divide by 100 to do so. Because the unit of the gas HM³. HM³ is equal to 10⁶.

$$\frac{\text{M}^3}{100} = \text{HM}^3$$

3.6.5. Convert week to day

We will convert the week to days and divide by 7 to do so. Because this would estimate the total usage of gas per day.

$$\frac{\text{Week}}{7} = \text{day}$$

3.6.6. Multiply by the total houses.

We will multiply the value of production for one day by the total number of houses. This would estimate the total usage of gas per day for all the houses.

Production of one day × total number of houses = total production for houses.

4. Results and Discussions

Production of biogas by using different organic materials at normal temperature ($25^0 - 30^0$ °C) for 5 weeks was observed, and the results are summarized in **Figure 5**

Table 1: Production of biogas by using different organic materials

Production of Biogas by Organic Materials					
Sr. No	Weeks	By Kitchen Waste (8 Kg)	By Dung Waste (8 Kg)	By Grass Waste (8 Kg)	By Sludge Waste (8 Kg)
1	0	0 gm.	0 gm.	0 gm.	0 gm.
2	1 st	5 gm.	0 gm.	0 gm.	0 gm.
3	2 nd	40 gm.	28 gm.	9 gm.	6 gm.
4	3 rd	52 gm.	74 gm.	18 gm.	22 gm.
5	4 th	68 gm.	126 gm.	28 gm.	25 gm.
6	5 th	84 gm.	132 gm.	40 gm.	26 gm.

4.1 Convert from grams to kilograms

At this stage, we will convert grams to kilograms and divide by 1000 to do so, and the conversion is illustrated in **Table 2**

Table 2: Convert from grams to kilograms.

Production of Biogas by Organic Materials					
Sr. No	Weeks	Kitchen Waste	Dung Waste	Grass Waste	Sludge Waste
1	0	0 kg.	0 kg.	0 kg.	0 kg.
2	1 st	0.005 kg.	0 kg.	0 kg.	0 kg.
3	2 nd	0.040 kg.	0.028 kg.	0.009 kg.	0.006 kg.
4	3 rd	0.052 kg.	0.074 kg.	0.018 kg.	0.022 kg.
5	4 th	0.068 kg.	0.126 kg.	0.028 kg.	0.025 kg.
6	5 th	0.084 kg.	0.132 kg.	0.040 kg.	0.026 kg.

4.2 Convert from kilograms to volume

At this stage, we will convert kilograms to volume and divide by the density of methane. The density of methane is 0.656 Kg/M^3 , and so the conversion is illustrated in **Table 3**

Table 3: Convert from kilograms to volume.

Production of Biogas by Organic Materials					
Sr. No	Weeks	Kitchen Waste	Dung Waste	Grass Waste	Sludge Waste
1	0	0 M ³	0 M ³	0 M ³	0 M ³
2	1 st	0.0076 M ³	0 M ³	0 M ³	0 M ³
3	2 nd	0.0609 M ³	0.0427 M ³	0.0137 M ³	0.0091 M ³
4	3 rd	0.0792 M ³	0.1128 M ³	0.0274 M ³	0.0335 M ³
5	4 th	0.1036 M ³	0.1920 M ³	0.0426 M ³	0.0381 M ³
6	5 th	0.1280 M ³	0.2012 M ³	0.0609 M ³	0.0396 M ³

4.3 Convert from M³ to hectometer HM³

The unit of gas is HM³. At this stage, we will convert M³ to HM³ and divide by 100 to do so, which is illustrated in **Table 4**

Table 4: Convert from M³ to hectometer HM³

Production of Biogas by Organic Materials					
Sr. No	Weeks	Kitchen Waste	Dung Waste	Grass Waste	Sludge Waste
1	0	0 HM ³	0 HM ³	0 HM ³	0 HM ³
2	1 st	0.000076 HM ³	0 HM ³	0 HM ³	0 HM ³
3	2 nd	0.000609 HM ³	0.000427 HM ³	0.000137 HM ³	0.000091 HM ³
4	3 rd	0.000792 HM ³	0.001128 HM ³	0.000274 HM ³	0.000335 HM ³
5	4 th	0.001036 HM ³	0.001920 HM ³	0.000426 HM ³	0.000381 HM ³
6	5 th	0.001280 HM ³	0.002012 HM ³	0.000609 HM ³	0.000396 HM ³

4.4 Convert from week to day

At this stage, we will convert the week to day and divide by 7 to do so, as illustrated in **Table 5**

Table 5: Convert from week to day.

Production of Biogas by Organic Materials					
Sr. No	Day	Kitchen Waste	Dung Waste	Grass Waste	Sludge Waste
1	0	0 HM ³	0 HM ³	0 HM ³	0 HM ³
2	1 st	0.000011 HM ³	0 HM ³	0 HM ³	0 HM ³
3	2 nd	0.000087 HM ³	0.000061 HM ³	0.000019 HM ³	0.000013 HM ³
4	3 rd	0.000113 HM ³	0.000161 HM ³	0.000039 HM ³	0.000047 HM ³
5	4 th	0.000148 HM ³	0.000274 HM ³	0.000060 HM ³	0.000054 HM ³
6	5 th	0.000182 HM ³	0.000287 HM ³	0.000087 HM ³	0.000056 HM ³

Figure 5: Biogas Production from Different Organic Waste

We can differentiate between the production of biogas from 4 different organic wastes from **Figure 5**, as it shows the highest amount of production is observed from Dung waste, while the lowest production was from grass and other wastes, including vegetables and fruits, while we observed abundant production from kitchen waste.

4.5 Production of Biogas for a Colony

If there is a colony in which there are 20 houses, the average daily requirement of gas for each household is 0.130 m³ per day. We have to provide biogas for these houses by using kitchen waste and sludge (by applying the results of our models). Per day, sludge production from 20 houses is 300 kg (According to the Department of Environment and Science), and kitchen waste production is 50 kg per week from these houses. We required 10,000 kg of kitchen waste from an external source to meet our requirements, and so the production of biogas for 5 weeks was observed and is illustrated in **Table 6**

Table 6 Production of biogas by kitchen waste and Sludge waste

Production of Biogas by Organic Materials				
Sr. No	Weeks	By Kitchen Waste (10,000 Kg at initial stage)	By Sludge Waste (300 Kg per day)	By Kitchen Waste (50 Kg per week)
1	0	0 gm.	0 gm.	0 gm.
2	1 st	6250 gm.	0 gm.	31.25 gm.
3	2 nd	50,000 gm.	225 gm.	250 gm.
4	3 rd	65,000 gm.	825 gm.	325 gm.
5	4 th	85,000 gm.	937 gm.	425 gm.
6	5 th	10,5000 gm.	975 gm.	525 gm.

4.6 Convert from grams to kilograms

At this stage, we will convert grams to kilograms and divide by 1000 to do so, whereas the converted values are interpreted in **Table 7**

Table 7: Convert from grams to kilograms.

Production of Biogas by Organic Materials				
Sr. No	Weeks	Kitchen Waste	Sludge Waste	Kitchen Waste
1	0	0 kg.	0 kg.	0 kg.
2	1 st	6.25 kg.	0 kg.	0.03125 kg.
3	2 nd	50 kg.	0.225 kg.	0.250 kg.
4	3 rd	65 kg.	0.825 kg.	0.325 kg.
5	4 th	85 kg.	0.937 kg.	0.425 kg.
6	5 th	105 kg.	0.975 kg.	0.525 kg.

4.7 Convert from kilograms to volume

At this stage, we will convert kilograms to volume and divide by the density of methane. The density of methane is 0.656 Kg/m³, and the calculated values are shown in **Table 8**

Table 8: Convert from kilograms to Volume

Production of Biogas by Organic Materials				
Sr. No	Weeks	Kitchen Waste	Sludge Waste	Kitchen Waste
1	0	0 M ³	0 M ³	0 M ³
2	1 st	9.527 M ³	0 M ³	0.476 M ³
3	2 nd	76.25 M ³	0.342 M ³	0.3810 M ³
4	3 rd	99.08 M ³	1.257 M ³	0.4954 M ³
5	4 th	129.57 M ³	1.428 M ³	0.6478 M ³
6	5 th	160.06 M ³	1.486 M ³	0.8003 M ³

4.8 Convert from M³ to hectometer HM³

Since the unit of gas is HM³. At this stage, we will convert M³ to HM³ and divide by 100 to do so, and the calculations are interpreted in **Table 9**

Table 9: Convert from M³ to HM³

Production of Biogas by Organic Materials				
Sr. No	Weeks	Kitchen Waste	Sludge Waste	Kitchen Waste
1	0	0 HM ³	0 HM ³	0 HM ³
2	1 st	0.09527 HM ³	0 HM ³	0.000476 HM ³
3	2 nd	0.7626 HM ³	0.00342 HM ³	0.00381 HM ³
4	3 rd	0.9908 HM ³	0.01257 HM ³	0.00495 HM ³
5	4 th	1.2957 HM ³	0.01428 HM ³	0.00674 HM ³
6	5 th	1.6006 HM ³	0.01486 HM ³	0.00800 HM ³

4.9 Convert from week to day

At this stage, we will convert weeks to days and divide by 7 to do so in **Table 10**

Table 10: Convert from week to day

Production of Biogas by Organic Materials				
Sr. No	Weeks	Kitchen Waste	Sludge Waste	Kitchen Waste
1	0	0 HM ³	0 HM ³	0 HM ³
2	1 st	0.01361 HM ³	0 HM ³	0.000068 HM ³
3	2 nd	0.1089 HM ³	0.000488 HM ³	0.00054 HM ³
4	3 rd	0.1415 HM ³	0.000795 HM ³	0.00070 HM ³
5	4 th	0.1851 HM ³	0.00204 HM ³	0.00096 HM ³
6	5 th	0.2286 HM ³	0.002122 HM ³	0.00114 HM ³

4.10 Multiply with Twenty Houses (20)

At this stage, we will multiply each value by the total number of houses (20). This would estimate the total usage of gas per day for all houses and is interpreted in **Table 11**

Table 11 Multiply with Twenty Houses (20)

Production of Biogas by Organic Materials				
Sr. No	Weeks	Kitchen Waste	Sludge Waste	Kitchen Waste
1	0	0 HM ³	0 HM ³	0 HM ³
2	1 st	0.272 HM ³	0 HM ³	0.00136 HM ³
3	2 nd	2.178 HM ³	0.00976 HM ³	0.0108 HM ³
4	3 rd	2.830 HM ³	0.15914 HM ³	0.0140 HM ³
5	4 th	3.702 HM ³	0.0408 HM ³	0.0192 HM ³
6	5 th	4.572 HM ³	0.04244 HM ³	0.0228 HM ³

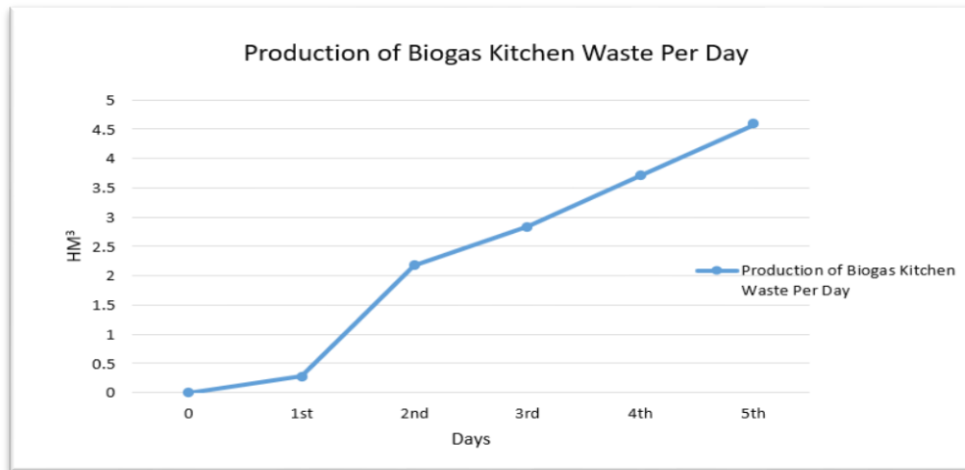


Figure 6: Biogas Production from Kitchen Waste of the colony per day

Here, **Figure 6** interprets the daily production of Biogas from Kitchen Waste, and the production trends can be seen rising steadily day by day, whereas **Figure 7** shows production from sludge waste.

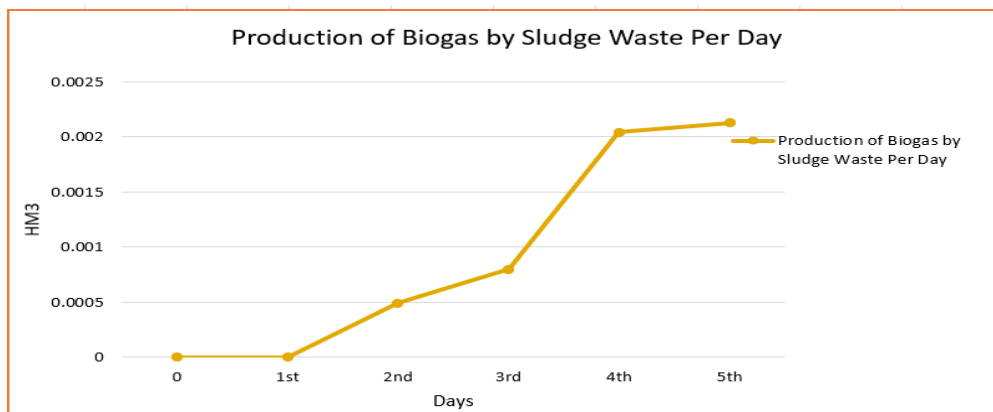


Figure 7: Biogas Production from Sludge Waste of the colony per day

4.11 Total estimation of production of Biogas and Consumption of Gas

Table 12: Total estimation of production of biogas and consumption of gas

Sr. No	Weeks	Total production of biogas	Consumption of biogas in the colony
1	0	0 HM ³	0 HM ³
2	1st	0.27356 HM ³	0 HM ³
3	2nd	2.1985 HM ³	0 HM ³
4	3rd	3.003 HM ³	2.6 HM ³
5	4th	3.762 HM ³	2.6 HM ³
6	5th	4.637 HM ³	2.6 HM ³

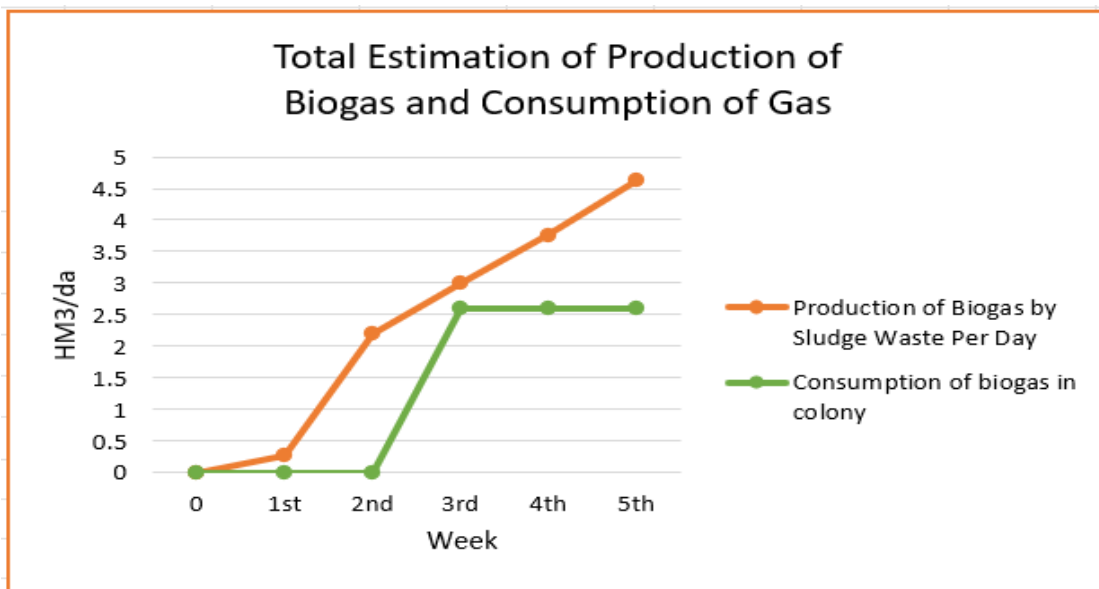


Figure 8: Total Estimation of Production of Biogas and Consumption of Gas

Here, **Figure 8** emphasizes that upon reaching the 6th week, the production of biogas is much more than the consumption of biogas in the colony, hence we have sufficient production of biogas and it can be implemented in the whole colony to meet its consumption requirement.

4.12 Proposed Design of Biogas Plant:

Design of the layout of a digester for twenty houses

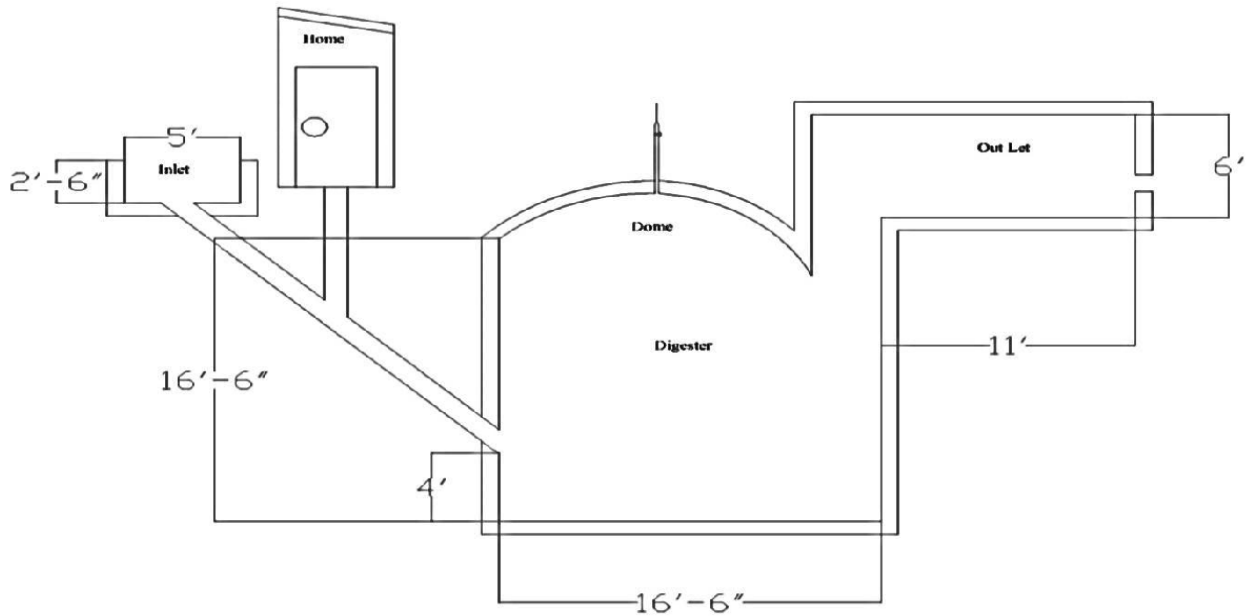


Figure 9. Proposed Design of the Layout of a Digester

4.12 Cost Estimation of Plant Estimation of in-let Tank

Table 13 Estimation of in-let Tank

Sr. No	Description	No	Length	Width	Height	Quantity
1	Excavation for the tank	1	5 ft	5 ft	2.5 ft	62.5 cft
2	Excavation of foundation	4	5 ft.	1 ft.	1 ft.	20 cft
3	P. C.C. for wall bed 1:3:6	4	5 ft	1ft	0.5 ft	10 cft
4	P. C.C. for floor bed 1:3:6	1	5 ft	5ft	0.5 ft	12.5 cft
5	Brick work	4	5 ft	0.75 ft	2.5 ft	37.5 cft
6	Plaster	4	5 ft	_	2.5 ft	50 sft

4.13 Construction Cost of in-let Tank

The construction cost of the in-let tank is calculated by using the Market Rates System (MRS), 2nd BI-ANNUAL-2024 by the Punjab Finance Department for District Multan, Pakistan, and the estimated cost is shown in **Table 14**, whereas the estimated quantity is shown in **Table 13** [14]

Table 14 Construction Cost of in-let Tank

Sr. No	Description	Quantity	Unit Rate	Total Cost
1	Excavation for the tank and foundation	82.5 cft	Rs. 15.84/cft	Rs. 1,306/-
2	P.C.C. for foundation and floor bed (1:3:6)	22.5 cft	Rs. 401.73/cft	Rs 9,039/-
3	Brick work (1:5)	37.5 cft	Rs. 370/cft	Rs. 13,875/-
4	Plaster ½” (1:5)	50 sft	Rs. 44.66/sft	Rs. 2233/-
			Total Cost = PKR. 26,453/	

4.14 Estimation of Digester Tank

The construction cost of the Digester tank is also calculated by following the MRS rates in **Table 16**, and so its quantities are estimated in **Table 15**

Table 15 Estimation of Digester Tank

Sr. No	Description	No	Length	Width	Height	Quantity
1	Excavation of the Digester	1	254.34 sft	—	17 ft	4323.78 cft
2	P. C.C. for bed (1:3:6)	1	254.34 sft	0.5 ft	—	127.17 cft
3	Brick work (1:5)	1	28.26 sft	—	16.5 ft	466.29 cft
4	Plaster ½” (1:5)	1	25.90 ft	—	16.5 ft	427.43 sft
5	Dome	1	56.52 sft	—	1.57 ft	88.73 cft

4.15 Construction Cost of Digester Tank

Table 16: Construction Cost of Digester Tank

Sr. No	Description	Quantity	Unit Rate	Total Cost
1	Excavation of the Digester	4323.78 cft	Rs. 15.84/cft	Rs. 68,488/-
2	P. C.C. for bed (1:3:6)	127.17 cft	Rs. 401.73/cft	Rs. 51,088/-
3	Brick work (1:5)	466.29 cft	Rs. 370/cft	Rs. 172,527/-
4	Plaster ½” (1:5)	427.43 sft	Rs. 44.66/cft	Rs. 19,089/-
5	Dome	88.73 cft	Rs. 650/cft	Rs. 57,674/-
			Total Cost = PKR. 368,866/-	

4.16 Estimation of Outlet Tank

Table 17 Estimation of Outlet Tank

Sr. No	Description	No	Length	Width	Height	Quantity
1	Excavation for the tank	1	10 ft	10 ft	6 ft	600 cft
2	P. C.C. for floor bed 1:3:6	1	10 ft	10ft	0.5 ft	50 cft
3	Brick work (1:5)	4	10 ft	0.75 ft	6 ft	176.25 cft
4	Plaster ½” (1:5)	4	10 ft	–	6 ft	235 sft

4.17 Construction Cost of Outlet Tank

Table 18: Construction Cost of Outlet Tank

Sr. No	Description	Quantity	Unit Rate	Total Cost
1	Excavation for the tank	600 cft	Rs. 15.84/cft	Rs. 9,504/-
2	P. C.C. floor bed (1:3:6)	50 cft	Rs. 401.73/cft	Rs. 20,086/-
3	Brick work (1:5)	176.25 cft	Rs. 370/cft	Rs. 65,212/-
4	Plaster ½” (1:5)	235 sft	Rs. 44.66/cft	Rs. 10,495/-
			Total Cost =	PKR. 105,297/-

4.18 Total Cost of Project

Table 19: Total Cost of Project

Sr. No.	Item Name	Quantity	Prices
1	Property	2.5 Marla	Rs. 1,000,000/-
2	Construction		Rs. 500,616/-
3	Kitchen waste for initial stage	10,000 kg	Rs. 0/-
4	Sludge	300 kg	Rs. 0/-
5	Kitchen waste per week	50 kg	Rs. 0/-
6	Amount of transportation of kitchen waste		Rs. 8000/-
7	Cleaner	per week	Rs. 1500/-
Total Amount			PKR. 1,510,116/-

Hence, the total cost of project including complete Biogas Production and its supply comes out to Rs. 1,510,116 out of which property expense has been estimated of Rs. 1,000,000 whereas the construction cost of Biogas plant is estimated to be Rs. 500,616 and so maintenance has been calculated in **Table 19** which is a one-time cost and is quite economical.

5. Conclusion

This study effectively illustrates the viability of utilizing organic wastes in a small-scale biogas plant to generate sustainable energy in Pakistan. The findings indicate that a variety of organic waste sources can produce biogas at rates that are promising for meeting the energy needs of a colony of 20 houses. The suggested biogas plant provides an affordable (PKR 500,616) and environmentally beneficial option, lessening the negative effects of deforestation on the environment and lowering dependency on fossil fuels.

5.1 Key Findings

1. The rates at which biogas was produced varied from 0.000087 to 0.000287 HM³/day.
2. Upon scaling up for a 20-house colony, the predicted production was 4.637 HM³, surpassing the average consumption of 2.6 HM³.
3. The estimated cost for the construction of a biogas plant for the colony is PKR 500,616.

6. Recommendations

- The widespread installation of biogas plants in both rural and urban regions.
- The search for new sources of organic waste and the optimization of mixing ratios.
- Policy framework creation and integration with the current energy infrastructure.

7. Acknowledgment

First and foremost, praise and gratitude to the Almighty—the Weaver of galaxies, the Composer of existence. With reverence, we honor the luminous legacy of Prophet Muhammad (peace be upon him), whose footsteps echo across centuries, guiding hearts through tempests. We are grateful to the owner of the biogas plant in Khanewal for their valuable guidance.

References

- [1]. S. SriK and P.A Sangeetha, “33 COMPARISON OF VIABILITY OF BIOGAS FROM POULTRY WASTE AND MIXTURE OF POULTRY WASTE AND FISH WASTE Comparison of Viability of Biogas from Poultry Waste and Mixture of Poultry and Fish Waste,” *Int. J. Innov. Res. Technol. Sci.*, pp. 2321–1156, (2014).
- [2]. M. Sohail Bashir, A. Safdar, S. Zaheer, A. R. Farooqi, and M. Jamil, “Muhammad Sohail Bashir et al Production of Biogas from Kitchen Waste with Inoculum and Study the Effect of Different Parameters,” *J.Chem.Soc.Pak*, vol. 41, no. 04, p. 563, (2019).
- [3]. M. Benali, T. Hamad, and Y. Hamad, “Experimental Study of Biogas Production from

- Cow Dung as an Alternative for Fossil Fuels,” *J. Sustain. Bioenergy Syst.*, vol. 09, no. 03, pp. 91–97, (2019).
- [4]. K. C. Oibileke, S. Mamphweli, E. L. Meyer, G. Makaka, N. Nwokolo, and H. Onyeaka, “Comparative Study on the Performance of Aboveground and Underground Fixed-Dome Biogas Digesters,” *Chem. Eng. Technol.*, vol. 43, no. 1, pp. 68–74, (2020).
- [5]. A. J. Dere, S. R. Kalbande, and V. P. Khambalkar, “Recent Review on Biogas Production from Different Waste,” *Int. J. Curr. Microbiol. Appl. Sci.*, vol. 6, no. 10, pp. 3452–3457, (2017)
- [6]. A. Demirbas, O. Taylan, and D. Kaya, “Biogas production from municipal sewage sludge (MSS),” *Energy Sources, Part A Recover. Util. Environ. Eff.*, vol. 38, no. 20, pp. 3027–3033, (2016)
- [7]. E. Athanasoulia, P. Melidis, and A. Aivasidis, “Optimization of biogas production from waste activated sludge through serial digestion,” *Renew. Energy*, vol. 47, pp. 147–151, (2012)
- [8]. M. F. I. Al Imam, M. Z. H. Khan, M. A. R. Sarkar, and S. M. Ali, "International Journal of Natural and Applied Science Original Article Development of Biogas Processing from Cow dung, Poultry waste, and Water," *Dev. Biogas Process. From Cow dung, Poult. Waste, Water Hyacinth*, vol. 2, no. 1, pp. 13–17, (2013).
- [9]. T. D. Yavini, K. Silas, M. B. Grema, and J. A. Luria, “Kinetic Study of Agricultural Wastes Conversion to Biogas using Cow Dung/Poultry Droppings as Inoculums,” *IOSR J. Environ. Sci. Toxicol. Food Technol.*, vol. 8, no. 1, pp. 46–51, (2014)
- [10]. B. S., “Production of Biogas Using Kitchen Waste,” *Int. J. Res. Eng. Technol.*, vol. 05, no. 06, pp. 304–308, (2016).
- [11]. R. Dhanariya, S. Sharma, A. K. Sharma, and S. Verma, “A Review on Biogas Production from Food Waste,” *Int. J. Pharm. Chem. Sci. Issn*, vol. 3, no. 4, pp. 899–904, (2014).
- [12]. I. R. Ilaboya, F. F. Asekame, M. O. Ezugwu, A. A. Erameh, and F. E. Omofuma, “Studies on Biogas Generation from Agricultural Waste; Analysis of the Effects of Alkaline on Gas Generation,” *World Appl. Sci. J.*, vol. 9, no. 5, pp. 537–545, (2010).
- [13]. N. Laskri and N. Nedjah, “Comparative study for biogas production from different wastes,” *Int. J. Bio-Science Bio-Technology*, vol. 7, no. 4, pp. 39–46, (2015).
- [14]. “Uwc finance department,” vol. 2024, no. 021, p. 632005, (2020)