# Development of Balloon Biogas Plant for Small Farmers

*Arvind* Bodhe[1]*, *Pragati* Dethe[2], *Muneesh* Sethi[3], *Dheeraj* Deshmukh[4], *Anoop Kumar* Vishakarma[5], *Avnish* Chauhan[6]

[1]Professor, G.H.Raisoni University Saikheda (MP), India,
[2] Asstt. Professor, Science College Pauni, (MS), India
[3] Dean R&D, University of Engineering & Technology, Roorkee
[4] Dean Research, G.H.Raisoni University Saikheda (MP), India,
[5]Vibration Analyst, SPM Instrumentation India,
[6]Associate Professor,Graphic Era HillUniversity, Dehradun

**Abstract.** Biogas plants are a sustainable and environmentally friendly way of generating energy from organic waste materials such as animal manure, crop residues, and food waste. In addition to producing biogas, these plants also generate nutrient-rich bio-slurry, which can be used as a fertilizer to improve soil fertility and crop yields.The utilization of natural resources for cooking gas generation has been a long-standing practice in various countries. However, the prevalent issue with existing systems lies in their chambers, which are prone to damage due to low-quality materials. Additionally, their construction often requires skilled labor and high-quality materials, posing challenges in affordability and accessibility. A comparison study conducted by referring problems that lead to troubleshooting in Biogas Plants between various types of biogas and a novel balloon-type biogas system has been designed and developed to address these limitations. The system exhibits cost-effectiveness, weather resistance, and thermophilic characteristics, enabling operation at high temperatures of 50°-55°C, within the range suitable for the digestion of mesophilic bacteria (40°-50°C) that contribute to gas generation. The work also elaborated to enhance biogas efficiency by incorporating a scrubber module capable of removing impurities such as hydrogen sulfide (H2S), carbon dioxide (CO2), and water vapor (H2O).

## 1. Introduction

Access to clean and affordable energy for household cooking is a pressing global challenge, particularly in rural areas where traditional fuel sources are scarce or environmentally unsustainable. Biogas, a renewable energy source produced through the anaerobic digestion of organic waste, has emerged as a viable solution for addressing this energy gap. However, the widespread adoption of biogas systems has been hindered by issues such as high construction costs, complex maintenance requirements, and limited durability [1]. India is According to the Ministry of New and Renewable Energy, as of March 2021, the total biogas-based power installed capacity in India was 5,764.34 MW. In addition, the Ministry has set a target of installing 15 million family-type biogas plants by 2022, which is expected to generate 30 million tons of bio-manure and save 22.5 million tons of fuel wood annually [2]. Figure 01 and Table 01 shows the state of Maharashtra had the largest number of biogas plants in India having weightage of 22%, with over 931 thousand plants as of March 2022. Karnataka ranked second with nearly 513 thousand plants. India had a total of over five million biogas plants [3].

**Table 1.** Status of Bio-Gas Plants in India Statewide

| Sr.No | State | No, of BioGas Plant |
|---|---|---|
| 1 | Maharashtra | 931313 |
| 2 | Karnataka | 512755 |
| 3 | Uttar Pradesh | 501456 |

*Corresponding author: bodhe2013@gmail.com

| | | |
|---|---|---|
| 4 | Gujarat | 435637 |
| 5 | Madhya Pradesh | 379159 |
| 6 | Uttrakhand | 365188 |
| 7 | Telangana | 316727 |
| 8 | Odisha | 271752 |
| 9 | Andhra Pradesh | 268598 |
| 10 | Kerala | 153666 |

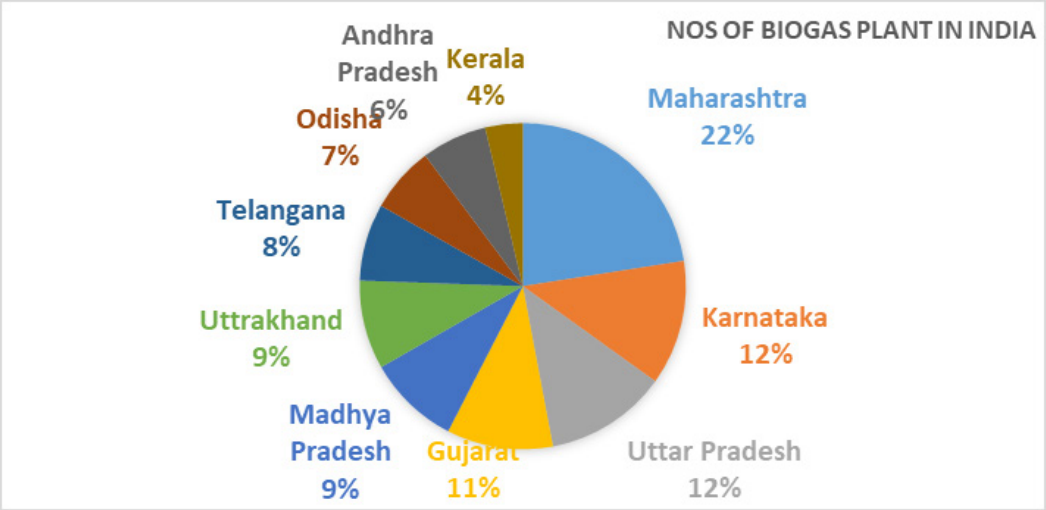


**Fig. 1.** Bio-Gas Plant Availability State vise

## 2. Types of Biogas Plants

The soil and climatic conditions of the research area were studied. For this, in the selected areas, soil There are several types of biogas plants or systems, each with its own design and functionality. Here are some common types of biogas plants [4].

### 2.1. *Continuous Stirred Tank Reactor (CSTR)*

This is the most common type of biogas plant. It consists of a large tank where organic waste, such as agricultural residues, animal manure, or food waste, is continuously added and mixed. The organic material undergoes anaerobic digestion, producing the biogas as in Figure 2.

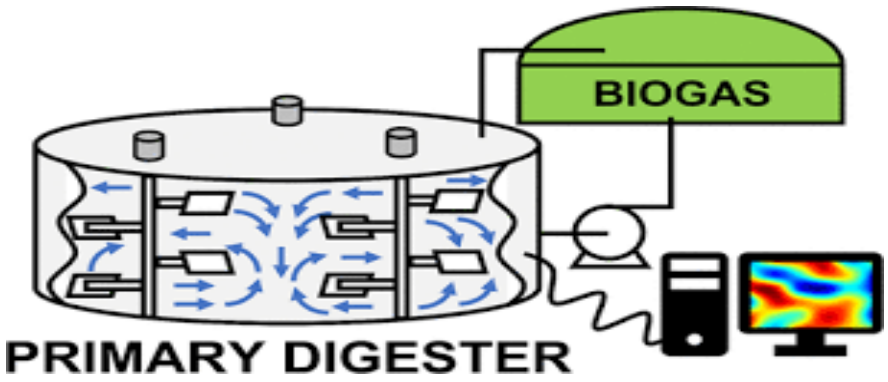


**Fig. 2**. Continuous Stirred Tank Reactor (CSTR)

2.2. *Plug Flow Digester*

In this type of biogas plant, organic waste is fed into a long and narrow cylindrical tank, often underground as in . The waste moves through the digester in a continuous flow, with newer material displacing older material. This design allows for better control of the digestion process as in Figure 3.

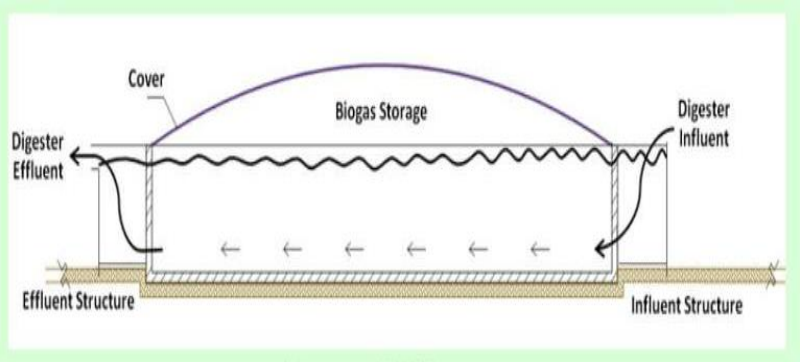


**Fig. 3.** Plug Flow Digester

2.3. *Fixed Dome Digester*

This is a simple and low-cost biogas plant design. It consists of a large underground chamber or digester where organic waste is added. The digester is sealed with a dome-shaped gas holder, which rises as biogas is produced as in Figure 4. The pressure from the rising gas displaces the gas holder, which can be connected to a gas stove or other appliances [6].

**Fig. 4.** Fixed Dome Digester

2.4. *Floating Drum Digester*

Similar to the fixed dome digester, the floating drum digester also uses an underground chamber for digestion. However, the gas holder in this design is a floating drum that moves up and down with the gas production. As the biogas is generated, the drum rises, and as gas is used, it sinks as in Figure 5.

**Fig. 5.** Floating Drum Digester

2.5. *Horizontal Digester*

In this design, organic waste is loaded into a long, horizontal container made of concrete or steel. The digester is sealed, and the waste undergoes anaerobic digestion to produce biogas. Horizontal digesters are often used for large-scale biogas production as in Figure 6.


**Fig. 6**. Horizontal Digester

2.6. *Balloon-Type Digester*

This type of biogas plant is characterized by a large balloon-shaped digester made of flexible material, such as reinforced plastic or rubber. The organic waste is added to the digester, and as biogas is produced, the balloon expands. The gas can be collected from the top of the balloon and used for various purposes as in Figure 7.

**Fig. 7.** Balloon-Type Digester

**Table 2.** Troubleshooting in Biogas Plants and compare with various biogas plants

| Troubleshooting in Biogas Plants | Continuous Stirred Tank Reactor (CSTR | Plug Flow Digester | Fixed Dome Biogas Plant | Balloon Type Biogas Plant | Floating Drum Biogas Plant | Community-Scale Biogas Plant |
|---|---|---|---|---|---|---|
| Scum Formation | Moderate to High | Low to Moderate | Low | Low | Low to Moderate | Low to Moderate |
| Cracks in Bio-digester | Moderate | Low to Moderate | Low | Very Low | Low | Moderate |
| Leakage from Gas Pipes & Fittings | Moderate | Low to Moderate | Low | Low | Low to Moderate | Moderate to High |
| Inadequate Bio-digester Feeding | Low to Moderate | Low to Moderate | Low to Moderate | Low | Low to Moderate | Moderate |
| Improper Feed Composition | Moderate to High | Moderate | Moderate to High | Low | Moderate to High | Moderate to High |
| Ammonia Content | Moderate to High | Moderate to High | Moderate | Low | Moderate | Moderate to High |
| Heavy Metals | Low | Low to Moderate | Low | Low | Low | Moderate |
| Temperature Gain | Flexible | Moderate | Moderate | High | Moderate | Flexible |
| Scum Formation | Moderate to High | Low to Moderate | Low | Low | Low to Moderate | Low to Moderate |

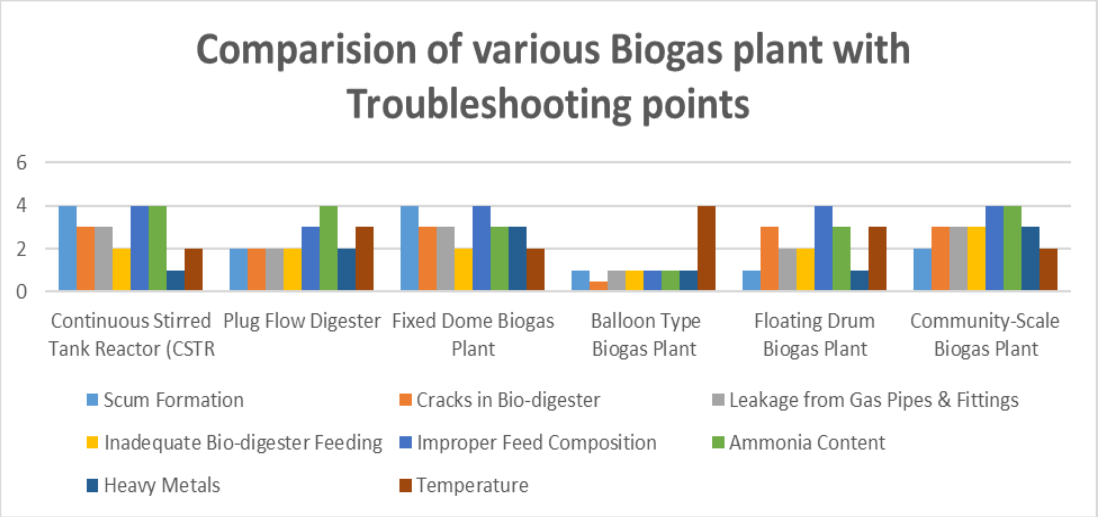


**Fig. 8**. Graph showing the Comparisons between various biogas plants and troubleshooting in it

Determining the best type of biogas plant depends on various factors, including the specific requirements and constraints of the project or application. Each type of biogas plant has its advantages and disadvantages by referring Figure 8.

The Continuous Stirred Tank Reactor (CSTR) offers moderate to high scum formation, moderate cracks in the bio-digester, moderate leakage from gas pipes and fittings, and moderate to high ammonia content. However, it has flexible temperature maintain and low presence of heavy metals

On the other hand, the Plug Flow Digester has low to moderate scum formation, low to moderate cracks in the bio-digester, low to moderate leakage from gas pipes and fittings, and moderate presence of heavy metals. It also has a moderate temperature get.

The Fixed Dome Biogas Plant has low scum formation, low cracks in the bio-digester, low leakage from gas pipes and fittings, low presence of heavy metals, and processes at moderate temperature.

The Floating Drum Biogas Plant has low to moderate scum formation, low cracks in the bio-digester, low to moderate leakage from gas pipes and fittings, low presence of heavy metals, and moderate temperature get.

The Community-Scale Biogas Plant has low to moderate scum formation, moderate cracks in the bio-digester, moderate to high leakage from gas pipes and fittings, moderate to high improper feed composition, moderate to high ammonia content, moderate presence of heavy metals, and flexible temperature get.

The Balloon Type Biogas Plant has low scum formation, very low cracks in the bio-digester, low leakage from gas pipes and fittings, low ammonia content, and high temperature Maintain [7].

## 3. Factors of not accepting the Bio-gas plant in the village

The soil Lack of Technical Knowledge and Skills: Operating and maintaining a biogas plant requires certain technical knowledge and skills. If the villagers lack the necessary expertise or training, they may be hesitant to accept a biogas plant due to concerns about its operation and maintenance.

Lack of Awareness: Many villagers may not be aware of the benefits and advantages of biogas plants. They may not understand how biogas can be a sustainable and environmentally friendly energy source. Lack of awareness can lead to resistance or reluctance to accept biogas plants.

Infrastructural Limitations: In remote or underdeveloped areas, there may be infrastructural limitations such as inadequate transportation networks, lack of access to water supply, or insufficient space for biogas plant installation. These limitations can make it challenging to implement and maintain biogas plants effectively.

Financial Constraints include the installing and maintaining a biogas plant requires initial investment and ongoing operational costs. In villages where financial resources are limited, the upfront costs may be perceived as a barrier. Lack of access to financing or subsidies for biogas plant installation can also be a deterrent.

## 4. Design of a small bio-gas plant for a village

It created a design of a balloon digester using SolidWorks software to assess the size and capacity of the digester. It is a semi-hollow cylinder balloon constructed of FRP (fiber-reinforced polymers) for manufacture. It is 5700mm in length and 2400mm in diameter. Which is useful for farmers as in Figure 9.

**Fig. 9.** Photo of actually installed plant

Length or height of the balloon digester = 5700mm.
Diameter of the balloon digester = 2400mm.
Radius of the balloon digester = 1200mm.
Volume of the balloon or cylinder = V= $\pi r^2 h$
V = $\pi(1200)^2$*5700 .
V = 2.578*1010mm3.
V = 25.78m3.
For semi hollow cylinder divided by 2
V = 12.89m3.

4.1. *Calculation for gas formation and analysis*
Cow Manure Production from Dairy Plant
Production of the manure from 40 cattels = 400 kg.
50% of the cow manure is not feasible for biogas production.
Percentage of total Solid and volatile solid.
Total solid =19.38%*200 = 3876 kg/day.
% Volatile solid = 15.06%*200 = 3012 kg/day.
Biogas volume (BP) Production = 0.04 m3/kg*3876 kg/day = 155.04m3/day.
The rate of gas production m3/day is
R = 65%*155.04
R = 10077.6m3/day.

4.2. *Findings and analysis of functioning of biogas plant*
Production of the biogas has been increases rapidly in the duration of the 55-70 days. It is producing 12000 liters methane gases as shown in Figure 10. Cooking time also increasing with respect to production of the methane gas as shown in Figure 11.

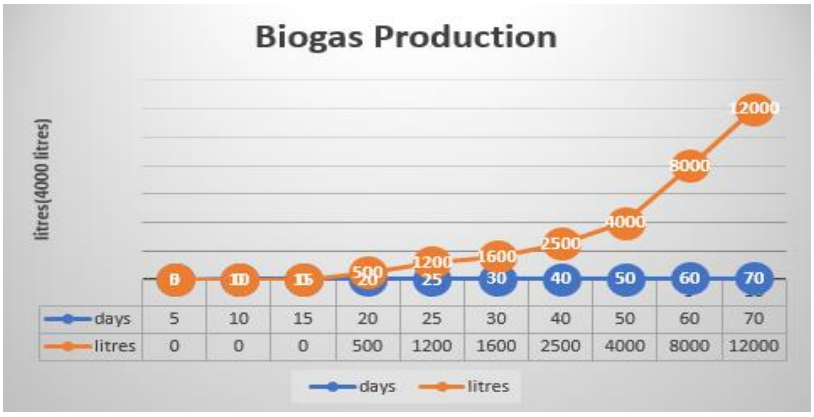


**Fig. 10**. Graph of Biogas Production chart (days vs litres)

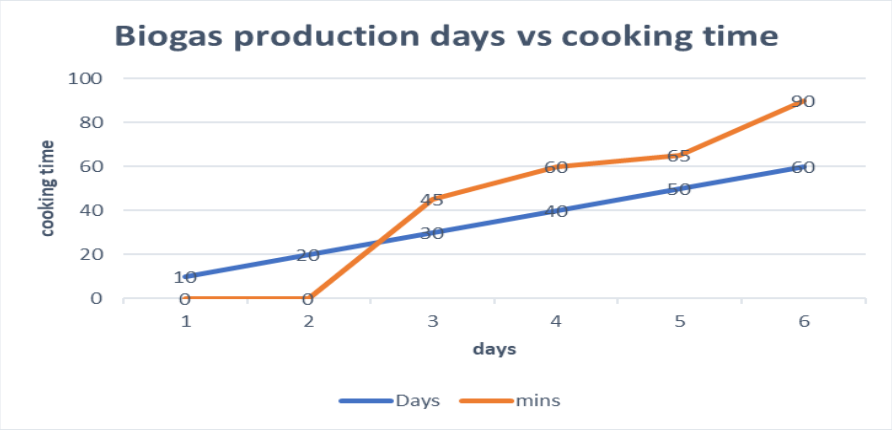


**Fig. 11.** Graph between gas production and cooking time.

Above graph shows the number of days and the corresponding biogas production in liters for a specific biogas plant. Here is the interpretation of the data. On days 5, 10, and 15, there is no biogas production, indicating that the digestion process has not started or has not reached a significant level.
On day 20, 500 liters of biogas are produced. This suggests that the digestion process has begun, and a small amount of gas is being generated
On day 25, the biogas production increases to 1200 liters, indicating that the digestion process is progressing, and more gas is being generated
The biogas production continues to increase steadily on days 30, 40, and 50, reaching 1600 liters, 2500 liters, and finally 4000 liters, respectively
On day 25, the biogas production increases to 1200 liters, indicating that the digestion process is progressing, and more gas is being generated.
From day 60 onwards, there is a significant jump in biogas production. On day 60, the production reaches 8000 liters, and on day 70, it further increases to 12000 liters. This suggests that the digestion process has matured, and more gas is being produced due to the increased availability of organic waste.

## 5. Conclusion

1. It is observed that the occurrence of scum formation in the Balloon Type Biogas Plant is low. The Balloon Type Biogas Plant has a very low occurrence of cracks in the bio-digester.
2. The Balloon Type Biogas Plant has a low occurrence of leakage from gas pipes and fittings.
3. It has a low occurrence of inadequate bio-digester feeding. It has a low occurrence of improper feed composition. It has a low ammonia content as attached to an ammonia trapper. It has a low presence of heavy metals. The Balloon Type Biogas Plant has got sufficient heat from the sun.
4. Based on these factors, the Balloon Type Biogas Plant appears to have several advantages, such as low scum formation, low cracks and leakage, and low occurrences of inadequate feeding and improper feed composition. It also has low ammonia content and a low presence of heavy metals. However, it gets high temperatures
5. The Balloon Type Biogas Plant was chosen for specific reasons based on the above characteristics and advantages to enhance the awareness among the people to install the same and utilize the best-suited form of energy.
6. The installed Balloon Bio-gas plant generating 12000 liters of biogas with negligible troubling shooting. This type of portable type balloon biogas plant may resolve the issues of small farmers of disliking the previous bio-gas plants.

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