# DESIGN OF MINIATURE PROTOTYPE FOR ORGANIC WASTE BASED COMPRESSED BIOGAS PRODUCTION AND PURIFICATION

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Biogas Production, Purification, Compression, Compressed biogas (CBG)


## Introduction

The Design of Organic Waste-based Compressed Biogas Production and Purification Prototype innovatively utilizes organic waste, such as kitchen scraps and cow dung, to generate clean and renewable biogas. Diverging from conventional methods, this project integrates biological processes for the conversion of raw biogas into a more efficient fuel source. It incorporates purification techniques using basic agents like silica gel, calcium hydroxide, and steel wool to remove impurities such as carbon dioxide, hydrogen sulphide, and water vapour, ensuring a cleaner end product. The purified biogas is then compressed into cylinders using a refrigerator compressor, enhancing its storage and transportation capabilities for versatile applications. This portable digester facilitates decentralized energy production through anaerobic digestion, making it both energy-efficient and cost-effective compared to traditional methods. Compressed biogas (CBG) offers higher energy density and reduced greenhouse gas emissions, significantly improving environmental sustainability over raw biogas. By demonstrating the technical feasibility of small-scale CBG production, the project promotes circular economy principles and highlights the economic and environmental benefits of using organic waste as a renewable energy source. Ultimately, this initiative contributes to a more sustainable energy landscape and mitigates the environmental impact of waste disposal.

## Objectives

1. To develop a biogas production system from organic waste
2. To maintain the optimum conditions for biogas production and storage
3. To purify the biogas using basic agents
4. To implement biogas compression for storage

## Methodology

The lab-scale study, four 250 ml conical flasks were used for anaerobic digestion, initially employing balloons for biogas capture. However, due to balloon bursts disrupting anaerobic conditions, an alternative gas collection method was needed. Kitchen waste, primarily vegetable peels from a college canteen, was used for the feedstock slurry. The waste was weighed (200 g), blended with water (200 ml) into a fine slurry, and stored in covered beakers in a refrigerator. Each slurry was mixed with 40 g of cow dung and 160 ml of water to create a 15% biogas slurry, repeated for all four flasks to ensure uniformity in the digestion process.

For the pilot-scale setup, a 30 L blue plastic can serve as the anaerobic digester, equipped with a ball valve for precise gas flow regulation. Gas storage was managed using a tire tube connected by a rubber pipe, with Teflon tape ensuring all connections were airtight. Kitchen waste, primarily vegetable peels including beetroot and pumpkin, was collected from the college canteen. A total of 4.5 kg of kitchen waste was mixed with 4.5 L of water, ground in batches, and transferred to the digester. Additionally, 3.5 kg of cow dung mixed with 3.5 L of water was added. To achieve a 15% biogas slurry concentration, extra water was Incorporated, completing the preparation process.

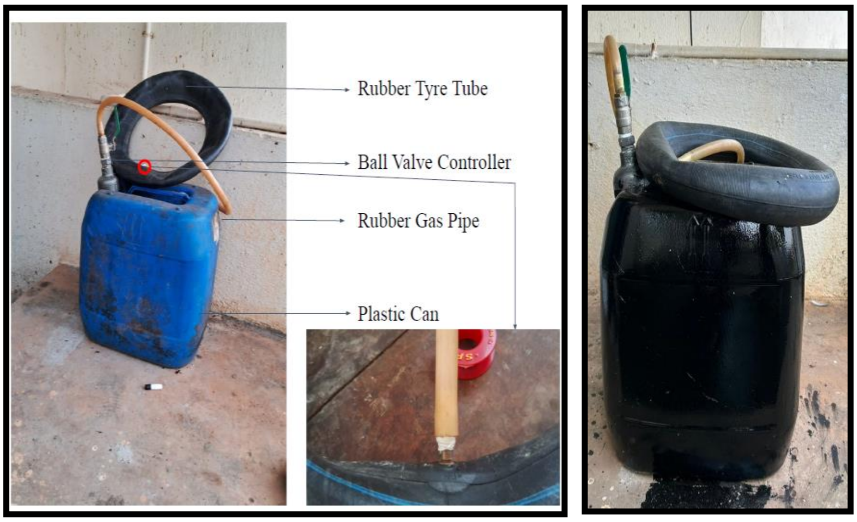


**Fig. 2 Pilot Scale Digester**

Prototype Construction:

- Upscaled to build the prototype using a supporting structure stand
- Built purification unit with plastic casings filled with purifying agents: steel wool, calcium hydroxide solution, and silica gel beads
- Built compression unit with a refrigerator compressor and pressure gauge connected to a gas cylinder
- Conducted optimization to ensure system integrity, addressing potential leakages for enhanced performance and safety.

**Fig. 3 Prototype**

Test run using Atmospheric Air:

In this experiment, before testing the prototype with raw biogas, we aimed to test atmospheric air using a setup comprising a storage, purification, and compression unit. Initially, we filled a tyre tube with atmospheric air using a refrigerator compressor. However, we encountered a leakage issue due to a connector mismatch, which we resolved by installing an O-ring washer. We then carefully inspected and ensured all fittings and connections were secure to prevent further leaks. Once everything was in order, we initiated the compression process with a target pressure of 15 bar for filling the cylinder with compressed air. However, as a safety precaution, we halted the process at 7 bars during the compression phase.

In the compression phase of the process, it took 8 minutes to increase the pressure inside the cylinder to 7 bars. Once the compression was completed, it took only 1 minute to release the compressed air from the cylinder. These were results obtained from multiple trials that were performed using atmospheric air.

Test run using a Raw Biogas:

A successful test run utilised atmospheric air, which paved the way for the utilisation of raw biogas. The raw biogas was collected from SVT Gaushala, Karkala. The raw biogas underwent a purification process employing purifying agents (steel wool, calcium hydroxide solution, and silica gel beads) to ensure its quality. Prior to the purification and compression stages, the empty weight and biogas filled in the tyre tube were recorded, which will be the storage unit. And also, the empty weight of the cylinder was noted. Subsequently, the raw biogas was introduced into the purification unit, where it underwent purification, thereby enhancing its quality. Following this, the compression phase commenced, where the purified biogas was compressed to a pressure of 10 bar utilizing a refrigerator compressor.

**Results:**

1. Successful biogas production was carried out
2. Pilot scale digester and Prototype was constructed successfully
3. Successful confirmation of biogas purification through various indicators such as colour changes in silica gel beads, precipitate formation in calcium hydroxide, and rusting in steel wool, reaffirmed the effectiveness odour purification techniques in removing impurities and enhancing biogas quality
4. Purified Biogas was compressed successfully and compressed biogas (CBG) was obtained

**Conclusions:**

1. The study demonstrated that compressed biogas (CBG) is more efficient and economically viable than raw biogas. Laboratory-scale and proximate analyses provided crucial insights into slurry preparation and optimization, enhancing biogas production efficiency.
2. Furthermore, the study explored the purification unit, revealing that basic purification setups can be implemented at minimal cost. This has implications for household prototypes, offering a cost-effective solution for purifying biogas for domestic use.
3. The compression unit showed promising results in efficiency and affordability, achieving up to 10 bars using second-hand refrigerator compressors. This enables the storage and transportation of purified biogas, enhancing its energy content and facilitating diverse applications.

Overall, the study underscores the potential of CBG as a sustainable energy source, offering both economic and environmental benefits. By optimizing production processes and implementing cost-effective purification and compression methods, biogas can be harnessed effectively for household and community-level applications, contributing to a greener and more sustainable future.

**Scope for future work:**

1. The project's initial aim to construct a prototype for domestic use presents a promising foundation for future scalability and expansion. Considering factors such as cost, materials, gas quantity produced, compression pressure, and purification agent costs, there is ample scope for upscaling the project to meet broader energy needs.
2. In rural areas of Karnataka and similar regions, traditional biogas methods highlight the potential for a shift to sustainable fuel sources. Promoting biogas from agricultural waste can revolutionize energy use, while production by-products like fertilizer enhance agricultural sustainability.
3. Government initiatives like the SATAT program and enhanced support for biofuels, including biogas, promote the adoption and production of Compressed Biogas (CBG) plants through subsidies and incentives. These measures align with India's commitment to renewable energy, supporting the growth of the biogas industry and its integration into mainstream energy systems.
4. The future of biogas holds promise across household, industrial, and transportation sectors, supported by ongoing research, innovation, and government policies. Biogas is positioned to play a significant role in the global transition towards a greener and more resilient energy landscape amid the intensifying shift towards renewable energy.