# BIOGAS PURIFICATION, COMPACTING REACTOR SYSTEM

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## ABSTRACT

*In the current scenario of dwindling petroleum resources and global warming, exploring alternate routes for environmentally benign fuels has become crucial. Biogas has emerged as a promising alternative fuel since it is both clean and environmentally benign. 60-70 percent methane (CH4), 30-40 percent carbon dioxide (CO2), traces of hydrogen sulfide (H2S), and water vapour components make up raw biogas. However, accompanying challenges such as low energy density due to impurities, generation at low pressures, and a lack of storage and transportation facilities obstruct its broad use. The purpose of this project is to develop and construct a biogas purification, compression, bottling, and transportation facility on campus. This is done by compressing the gas in cylinders, which was previously only conceivable after the CO2, H2S, and water vapour components had been removed. Various tests were conducted in order to increase the gas's energy density by removing incombustible and corrosive gas. To remove the pollutants, steel wool, water, and silica gel were used. Steel wool is meant to react with hydrogen sulphide, water is supposed to reduce carbon dioxide levels, and silica gel is supposed to reduce water vapour levels in purified biogas. Experiments revealed that the methane concentration in raw and purified biogas was 68 ± 2.52 percent and 90 ± 1.53 percent, respectively. Purified biogas was compressed using a hermetic reciprocating type refrigerant compressor and packaged into a standard LPG cylinder. In total, 12-14 minutes were spent compressing biogas to an absolute pressure of 5 bars. To assess the impact of biogas purification on heating value, purified and raw biogas were used to heat 500 ml of water in 4.54 0.03 and 5.62 0.02 minutes, respectively.*

**Keywords**: *Biogas, purification, compressed, $CH_4$, $H_2S$, $CO_2$*

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## 1. INTRODUCTION

Anaerobic digestion occurs when bacteria degrade biological material without the presence of oxygen. Biogas comprises methane ($CH_4$), carbon dioxide ($CO_2$), hydrogen sulfide (H2S), and trace amounts of water vapour. It's a biofuel created from the treatment of waste. Anaerobic digestion is a basic process carried out in a series of phases by a variety of bacteria that may use almost any organic material as a substrate and occurs in digestive systems, marshes, rubbish dumps, septic tanks, and the Arctic Tundra. In an airtight (no oxygen) atmosphere, organic materials such as animal dung, human excreta, kitchen trash, crop stalks, and leaves decompose and ferment to produce biogas. The principal byproducts of anaerobic digestion are biogas and sludge. After the extraction of biogas, the slurry exits the digester as a byproduct of the anaerobic digestion system (energy). The gases $CH_4$ and $CO_2$ are the most important components of biogas.

When the $CH_4$ content of biogas exceeds 50%, it burns very efficiently and can thus be used as a cooking and lighting substitute for kerosene, charcoal, and firewood. This not only saves time and money, but it also protects natural resources from being cut down for firewood, as shown in table 1.

**Table 1**: Composition of Biogas.

| Substances | Symbol | Percentage |
|---|---|---|
| Methane | $CH_4$ | 50-70 % |
| Carbon dioxide | $CO_2$ | 30-40 % |
| Hydrogen | $H_2$ | 5-10 % |
| Nitrogen | $N_2$ | 1-2 % |
| Water Vapour | $H_2O$ | 0.3 % |
| Hydrogen Sulphide | $H_2S$ | traces |

Source: (Ayoub 2002)

The combustible components of biogas are CH4 and H2, as seen in the table above. Other gases are useless, toxic, or harmful, and they give biogas no energy. Furthermore, only CH4 is present in significant levels in these two gases and is thus taken into account in the vast majority of biogas situations. Biogas has mostly been utilized for cooking and illumination in Ethiopia. Based on the pressure formed in the biogas digester dome itself, the gas produced in the digester is typically routed to a desired location, such as a kitchen. This, however, is insufficient for transporting gas to areas distant from the plant. Biogas applications are hampered as a result. Furthermore, biogas is not produced in significant numbers due to its restricted use. Due to a lack of effective and efficient utilization, a large-scale biogas plant that produces a large amount of biogas is frequently rendered ineffective and worthless. Because of biogas's mobility restrictions, no marketing attempts have been made to promote its use.

It's possible that biogas production will be a continual operation. The methane content of biogas is critical to its usage as an efficient energy source. As a result, biogas purification is necessary to enhance the energy per unit volume of compressed biogas while also removing the corrosive effect of H2S. This is performed by compressing the gas into the cylinders, which is only possible when CO2, H2S, and water vapour have been eliminated. Purification of biogas increases the concentration of methane in the fuel, resulting in a higher calorific value fuel. This can be performed by reducing carbon dioxide levels in the atmosphere. Carbon dioxide is removed from biogas, increasing its calorific value while simultaneously removing a greenhouse gas.

## 2. MATERIALS AND METHODS

Designing and installing a biogas purification, compression, and bottling unit, as well as conducting several experiments, including the amount of carbon dioxide in the biogas test, water acidity test, and water boiling test, were all part of this experiment. Experiments were limited due to a lack of standard measurement devices (Gas Analyzers) needed to verify the results, and progress was made through trial and error, i.e. simply evaluating the amount of CO2 available in the gas.

### *2.1 Designed and establishment of biogas scrubbing and storage facility*

The scrubbing unit and the storage unit make up the proposed biogas cleaning and storage plant. The whole biogas cleansing and storage facility is depicted schematically in Figure 1.

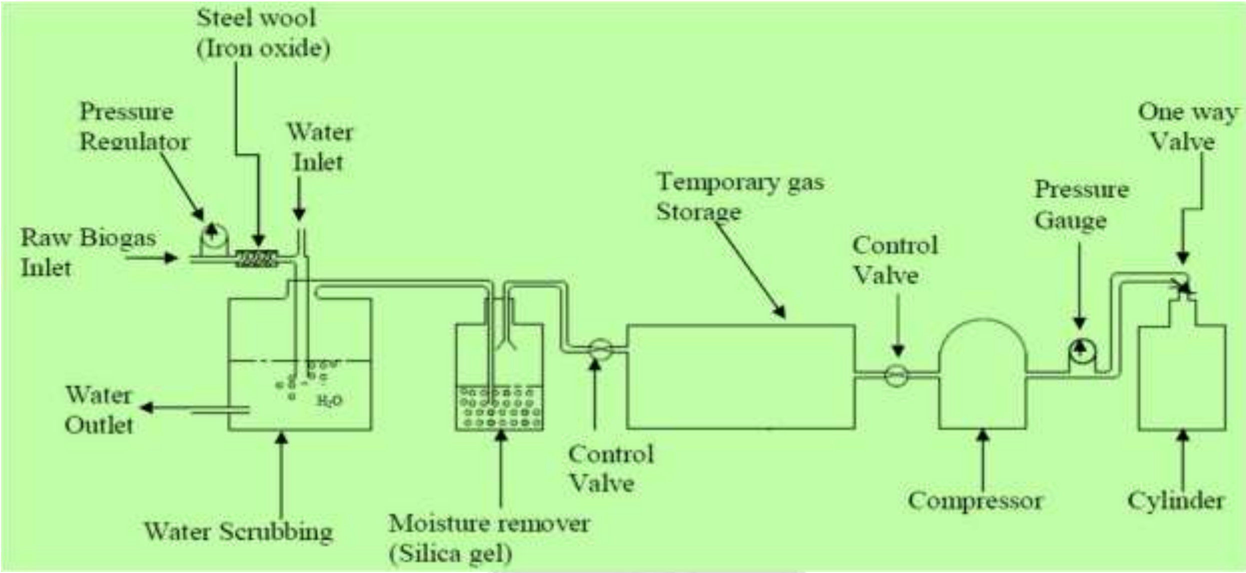


Figure 1: Biogas Purification, Compression and Bottling Unit Layout Diagram

### *2.2 Biogas Scrubbing*

Hydrogen sulfide (H2S) removal, carbon dioxide (CO2) removal, and moisture trapping are the three components of the biogas scrubbing system. Plastic tubes are used to connect the three modules. Steel wool, pure water, and an adsorbent substance (silica gel) were employed in the biogas purification process. Steel wool is meant to react with hydrogen sulphide, water is supposed to reduce carbon dioxide levels, and silica gel is supposed to reduce water vapour levels in purified biogas. The raw biogas was driven through steel wool on its way to the biogas scrubber unit to remove hydrogen sulphide, with pressure built up in the digester head.

The raw biogas is sent to the water scrubbing unit for additional purification after the steel wool has removed the hydrogen sulphide. When carbon dioxide is dissolved in water, carbonic acid (H2CO3) is produced. It's a low-strength acid.


As a result, the carbon dioxide concentration in the liquid leaving the cleaning unit will be higher, while the methane concentration in the gas exiting the scrubbing unit will be higher. The filtered biogas collected at the top of the scrubber unit contains water vapours. The most significant corrosion risk factor is water vapour. Silica gel was used in this experiment to achieve water concentrations as low as those reported in pure biogas. Silica gel is a type of material that can absorb moisture.

### *2.3 Biogas compression and storage*

The biogas storage system consists of a compressor, a pressure gauge, and an LPG cylinder. The compressor employed in the experiment is a hermetic reciprocating type compressor, which is common in commercial freezers that use hydrocarbon refrigerants. A pressure gauge can be used to measure the gas's pressure at various compression points. After compression, the gas was stored in a conventional LPG cylinder.

## 3. RESULTS AND DISCUSSION

### *3.1 Purification*

Several processes were used to purify the gas, and a water boiling test was used to evaluate its relative purity. The amount of methane included in raw and purified biogas was around 68 2.52 percent and 90 1.53 percent, respectively, according to the testing results.

Scrubbing removes H2S from raw biogas, and the steel wool transforms the hydrogen sulphide to black iron sulphide as a result. The steel wool used before and after washing is shown in Figure 4.


a) Steel wool before scrubbing b) Steel wool after scrubbing

Figure 4: Hydrogen Sulphide Remover

After absorbing moisture from the purified biogas, the color of the silica gel changed from blue to pink.

a) Ready to use silica gel b) Silica gel turns pink once it has soaked up moisture.

Figure 5: Moisture Absorber

### *3.2 Effect of purification on heating value*

Purified and raw biogas were used to heat 500 mL of water to evaluate the effect of purification on the heating value and cooking time of purified biogas, as shown in table 2. The calorific value of raw and filtered biogas was determined by boiling 500 cc of water due to the lack of a gas analyzer. Table 2 shows the time it takes to boil 500 mL of water.

| Energy Source | Time (minutes) for boiling 500 ml of water |
|---|---|
| Raw biogas | 5.62 ± 0.02 |
| Purified biogas | 4.54 ± 0.03 |

Purified biogas has a higher calorific heating value than raw biogas because it took less time to heat. This is because only methane contributes to combustion, while the rest of the mixture is ineffective, poisonous, or destructive. As a result, eliminating $CO_2$ from raw biogas is necessary to increase its calorific value.

### *3.3 Water acidity test*

The goal of this experiment was to see if carbon dioxide dissolves in water. When carbon dioxide dissolves in water during biogas scrubbing, carbonic acid is generated. Carbonic acid is a very inactive acid. The pH value can be used to determine how acidic the water leaving the cleaning unit is. Pure water had a pH of 6.6 0.21, whereas water entering the scrubbing machine had a pH of 4.9 0.15. We can presume that carbon dioxide was dissolved in water and removed from raw biogas based on the findings of the tests.

### *3.4 Compression and Storage*

Storage of biogas, as with all gaseous products, may be a difficulty. Because biogas does not liquefy under pressure at ordinary temperature, it is difficult to store. -82.5°C and 47.5bar are the critical temperatures and pressures, respectively. Compressing biogas reduces the amount of space needed for storage, increases the energy content, and provides pressure to overcome gas flow resistance. Propane or butane tanks, as well as commercial gas cylinders with a capacity of up to 200bar, are the most common biogas storage options. The storage facilities vary depending on the biogas use (e.g., automotive fuel, domestic cookery) (Demirbas,M.F et al, 2006).

Biogas is frequently not produced on time or in sufficient quantities to meet the conversion system load. As a result, compressing and storing biogas is essential for smoothing out fluctuations in gas production, quality, and consumption. The storage component also serves as a reservoir, ensuring that downstream equipment operates at consistent pressure. Finally, using a refrigerant reciprocating compressor, the filtered and dried biogas was squeezed to an absolute pressure of 5 bars in an LPG cylinder for 12-14 minutes.

## 4. CONCLUSIONS

- Pollutants can be found in biogas. Certain pollutants (such as water vapor, $CO_2$, and $H_2S$) must be eliminated before it may be used as a fuel for certain applications. We've put together the filtration and compression equipment we'll need. As a result, more study is required before practical purification and compression devices can be developed.
- Biogas is now utilized mostly for cooking and lighting in Ethiopia. It is vital to commercialize biogas by making it transportable in order to fully harness its potential. As a result, biogas purification and high-pressure compression for cylinder storage are essential.
- The concentration of methane in purified biogas was found to be higher than that in raw biogas. Purified biogas had an estimated 68.52 percent methane, while raw biogas included an estimated 90.53 percent methane.
- Biogas can be cleaned, compressed, stored, and transported, as has been proved. Biogas was compressed to an absolute pressure of 5 bars in an LPG cylinder for 12-14 minutes.
- Biogas generation has a lot of potential to become a renewable energy source in Ethiopia. As a result, because enhanced biogas has a larger calorific value than raw biogas, biogas produced in large-scale biogas plants should be upgraded before bottling for storage and transit.

## 5. RECOMMENDATIONS

- Biogas is no longer just a renewable energy source for rural areas; it's also a reliable and acceptable source of energy for urban areas, with the potential to replace fossil fuels. As a result, more study and attention must be directed to improving biogas utilization.
- To demonstrate its usefulness as an alternative energy source, compression must be undertaken at a higher pressure.

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