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BIOGAS PURIFICATION, COMPRESSION AND BOTTLING

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Abstract

In the present scenario of dwindling petroleum resources and global warming, exploring other avenues for eco-friendly fuels became essential. Biogas which is a clean and environmental friendly fuel emerged as one of the potential alternative fuels. Raw biogas contains about 60-70% methane (CH_4), 30-40% carbon dioxide (CO_2), traces of hydrogen sulfide (H_2S) and fractions of water vapours. But its wide spread use is hampered by the associated problems like low energy density due to the presence of impurities, generation at low pressures and the absence of means for storing and transporting. In this context this work intends to design and establish a facility at the site of biogas production in the campus for purifying, compressing, bottling and making it transportable. This can be done by compressing the gas in cylinders which was possible only after removing its CO_2, H_2S and water vapour components. To increase the energy density of the gas, different experiments were conducted in removing incombustible and corrosive gas. To remove this impurities steel wool, water and silica gel was used. The steel wool is to react with the hydrogen sulphide, the water is to reduce the percentage of carbon dioxide and the silica gel is to reduce the presence of water vapour in the purified biogas. Experiment showed that, the methane concentration available in the raw and purified biogas was 68 ± 2.52 % and 90 ± 1.53 % respectively. Compression of purified biogas was carried out by using a hermetic reciprocating type refrigerant compressor and bottled into normal LPG cylinder. Compression of biogas was carried out up to an absolute pressure of 5 bars in total of 12-14 minutes. In order to evaluate the impact of biogas purification on heating value, purified and raw biogas was used to heat 500 ml of water and took 4.54 ± 0.03 and 5.62 ± 0.02 minutes respectively.

Keywords: Biogas, Purification, Compression, Bottling.

1. Introduction

Biogas is generated when bacteria degrade biological material in the absence of oxygen; in a process known as anaerobic digestion. Since biogas is a mixture of methane (CH_4), carbon dioxide (CO_2), hydrogen sulphide and traces of water vapour. It is a renewable fuel produced from waste treatment. Anaerobic digestion is basically a simple process carried out in a number of steps by many different bacteria that can use almost any organic material as a substrate - it occurs in digestive systems, marshes, rubbish dumps, septic tanks and the Arctic Tundra. Biogas is a gas produced from organic materials such as animal manure, human excreta, kitchen remains, crops straws and leaves after decomposition and fermentation under air tight (no oxygen) condition. Main products of the anaerobic digestion are biogas and slurry. After extraction of biogas (energy), the slurry comes out of the digester as a by-product of the anaerobic digestion system. The main constituents of biogas are the CH_4 and CO_2 gas. The biogas burns very well when the CH_4 content is more than 50% and therefore biogas can be used as a substitute for kerosene, charcoal and fire wood for cooking and lighting. This saves time and money and above all it conserves the natural resources from cutting trees to get 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)

In the above table, we can see that the combustible components of biogas are CH_4 and H_2. Other gases are useless, toxic or harmful and have no energy contribution in biogas. Also, among these two gases only CH_4 is present in a significant amount and hence, is considered in most cases involving biogas. In Ethiopia, major application of biogas has only been in cooking and lighting. Commonly the gas produced in the digester is transported to desired place say kitchen by pipe line, on the pressure developed in the biogas digester dome itself. But this is not sufficient to transport gas to farther distances from the generation site. This is why, uses of biogas are hindered. Moreover, due to its limited use biogas until now is not produced at a persuasive amount. A large scale biogas plant producing a large amount of biogas is often rendered and valueless due to the lack of its effective and efficient use. Due to this lack of portability of biogas there have been no efforts what so ever to commercialize the use of biogas.

Production of biogas could be a continuous process. The utilization of biogas as an efficient energy source depends strongly on its methane concentration. Therefore, biogas purification is essential in order to have more energy per unit volume of compressed biogas and to get rid of the corrosive effect of H_2S. This can be done by compressing the gas into the cylinders, which is possible only after removing carbon dioxide (CO_2), hydrogen sulfide (H_2S) and water vapour. Biogas purification increases the concentration of methane in biogas, in order to have fuel of higher calorific value. This can be achieved by decreasing the concentration of carbon dioxide. Elimination of carbon dioxide from the biogas helps to increase its calorific value as well as to eliminate the greenhouse gas.

2. Materials and Methods

The procedures followed in this experiment involves: Designing and establishing of biogas purification, compression and bottling unit and Executing different tests, namely - amount of carbon dioxide in the biogas test, water acidity test and water boiling test. Due to unavailability of standard measuring instruments (Gas Analyzer) required to verifying the results, experiments were limited and improvements were made through trial and error, i.e. only by the evaluation of amount of CO_2 available in the gas.

2.1 Designed and establishment of biogas scrubbing and storage facility

The designed biogas scrubbing and storage facility is composed of two units, namely – the scrubbing unit and the storage unit. The entire biogas scrubbing and storage facility is schematically represented in Figure 1.

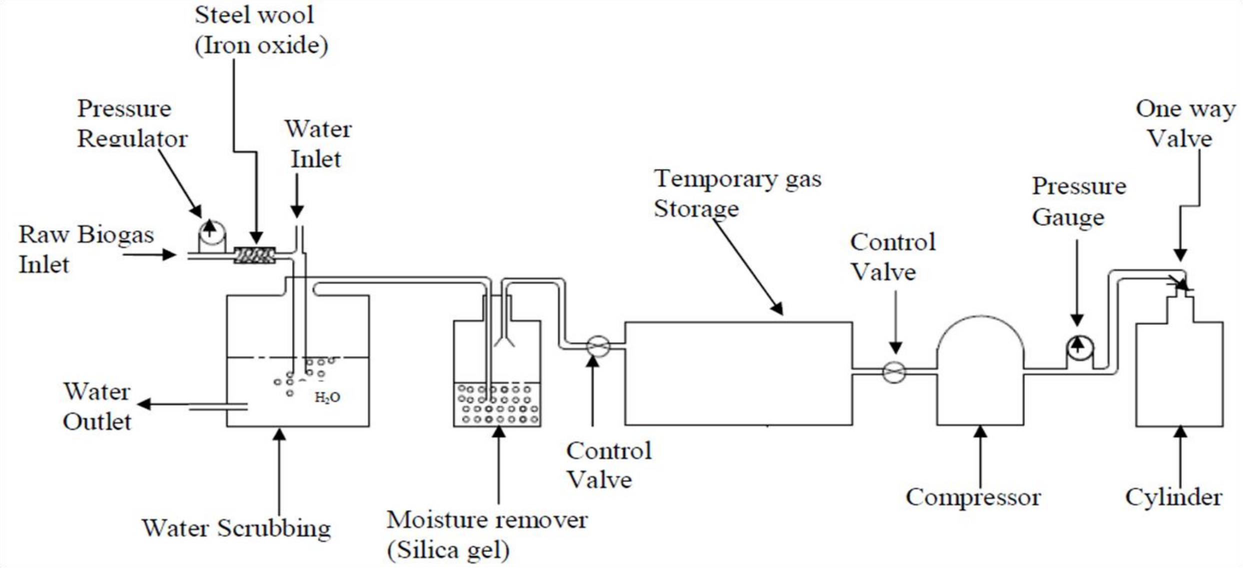

Figure 1: Biogas Purification, Compression and Bottling Unit Layout Diagram

2.2. Biogas Scrubbing

The biogas scrubbing system consists of three units, the hydrogen sulfide (H_2S) removing unit, Carbon dioxide (CO_2) removing unit, and moisture trapping unit. The three units are interconnected with plastic hoses. In the purification process of biogas which was conducted; steel wool, pure water and an adsorbent material (silica gel) were used. The steel wool is to react with the hydrogen sulphide, the water is to reduce the percentage of carbon dioxide and the silica gel is to reduce the presence of water vapour in the purified biogas. The experiment was done by taking the raw biogas with pressure builds up in the digester head and forced through the steel wool on its way to the biogas scrubber unit to remove hydrogen sulphide.

After the hydrogen sulphide was removed by the steel wool, the raw biogas passes into the water scrubbing unit for further purification. When carbon dioxide dissolved in water carbonic acid (H_2CO_3) is formed. It is a weak acid.

$$H_2O + CO_2 \dashrightarrow H_2CO_3$$

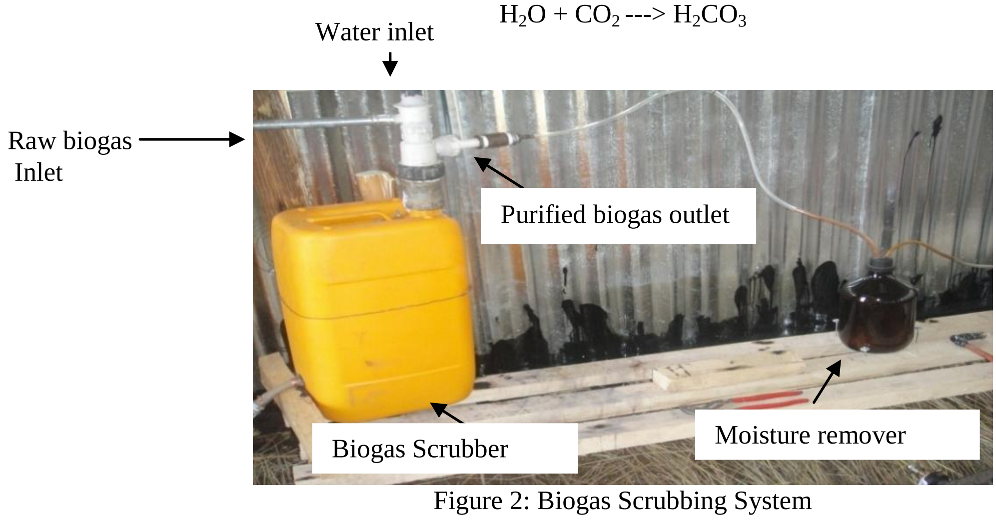

Figure 2: Biogas Scrubbing System

The liquid leaving the scrubbing unit will thus contain increased concentration of carbon dioxide, while the gas leaving the scrubbing unit will have an increased concentration of methane. The purified biogas that was collected at the top of the scrubber unit has some water vapours. Water vapour is the leading corrosion risk factor. To reach water contents as low as in the purified biogas, silica gel was used in this experimental set up. Silica gel is a material that has a capability of absorbing moisture.

2.3. Biogas compression and storage

The biogas storage system consists of three units; a compressor, a pressure gauge and an LPG cylinder. The compressor used in the experiment is a hermetic reciprocating type compressor used in the manufacture of commercial refrigerators with a hydrocarbon refrigerant. The pressure of the gas at various points of compression can be noted using a pressure gauge. For storing the gas after compression, a normal LPG cylinder was used.

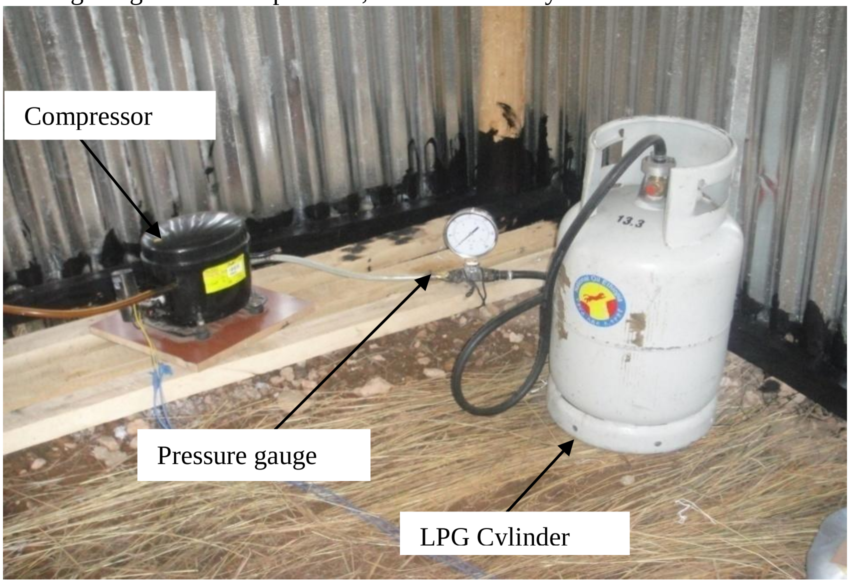

Figure 3: Biogas Compression and Bottling System

3. Results and Discussion

3.1. Purification

Purification of the gas was done using different methods and relative purity of the gas was tested by water boiling test. From this experimental result the amount of methane available in the raw and purified biogas was approximately 68 ± 2.52 % and 90 ± 1.53 % respectively.

Scrubbing is an operation that removes H_2S from raw biogas; as a result the hydrogen sulphide is converted into black iron sulphide by the steel wool. The steel wool used before and after scrubbing is shown in figure 4.

a) Steel wool before scrubbing

b) Steel wool after scrubbing

Figure 4: Hydrogen Sulphide Remover

The colour of the silica gel was changed from blue to pink colour after absorbing the moisture from the purified biogas.

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

In order to clarify the impact of purification on the heating value and cooking time of the purified biogas, purified and raw biogas were used to heat 500 ml of water as shown in table 2. Due to unavailability of gas analyzer, calorific value of raw biogas and purified biogas were compared by heating 500 ml of water.

Table 2: Time for boiling 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

The reduced heating time required by the purified biogas means the calorific heating value of the purified biogas was more than that of raw biogas. This is because only methane contributes to the combustion property where as the other mixture is useless, toxic or harmful. Therefore it is very necessary to remove CO_2 from raw biogas in order to increase its calorific value.

3.3. Water acidity test

This experimental test was done to know whether carbon dioxide dissolves with water or not. During biogas scrubbing, carbon dioxide dissolves with water and gives carbonic acid. Carbonic acid is a weak acid. Measuring its pH value is helpful in determining the acidity of water outgoing from the scrubbing unit. The pH value of pure water and water outgoing from the scrubbing unit was 6.6 ± 0.21 and 4.9 ± 0.15 respectively. From the test result we conclude that carbon dioxide was dissolved in water and removed from raw biogas.

3.4. Compression and Storage

The storage of biogas may also be a problem, as it is always with gaseous products. Biogas could not be stored easily, as it does not liquefy under pressure at ambient temperature. Its critical temperature and pressure are -82.5°C and 47.5bar. Compressing the biogas reduces the storage requirements, offers concentrated energy content and gives pressure to overcome the resistance to gas flow. Most commonly used biogas storage options are in propane or butane tanks and commercial gas cylinders up to 200bar. Depending on the application of biogas (e.g. vehicle fuel, domestic cooking) the storage facilities vary (Demirbas,M.F et al, 2006).

Biogas is not typically produced at the time it is needed or in the quantity needed to satisfy the conversion system load that it serves. Therefore, compression and storage of biogas is important in order to smooth out variations in gas production, gas quality and gas consumption. The storage component also acts as a reservoir, allowing downstream equipment to operate at a constant pressure. Finally, the purified and dried biogas was compressed into an LPG cylinder by using a refrigerant reciprocating compressor up to an absolute pressure of 5 bars in total of 12-14 minutes.

4. Conclusions

- Traces of impurities are present in biogas. Removal of these impurities (such as water vapor, CO_2 and H_2S) is essential prior to using as fuel for various applications. We have established the setup required for the purification and compression. Hence further study must be continued to develop commercial purification and compression units.
- Presently, biogas is mainly used for cooking and lighting purpose in Ethiopia. In order to use full potential of biogas, need emerges for its commercialization by making it transportable. Therefore biogas scrubbing and compression at high pressure for storage in cylinders are essential.
- It is proved that the concentration of methane available in the purified biogas was higher than that of raw biogas. The approximate methane concentration for purified and raw biogas was 68 ± 2.52 % and 90 ± 1.53 % respectively.
- It is proved that biogas can be purified, compressed, stored and made transportable. Biogas was compressed up to an absolute pressure of 5 bars in total time of 12-14 minutes in an LPG cylinder.
- There is large potential of biogas generation in Ethiopia to make it an alternative renewable energy source. Therefore biogas produced in large size biogas plants should be upgraded before bottling for storage and mobile purpose, as upgraded biogas has more calorific value than raw biogas.

5. Recommendations

- Biogas is no more just the renewable energy source of rural population but it is also an abundant and appropriate source of energy for urban population, having potential to replace fossil fuel. Hence research and proper interest must be given towards advanced use of biogas.
- Compression must be carried out at higher pressure to prove it as an appropriate alternative source of energy.

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