

Low Cost Biogas Purification System for Application Of Bio CNG As Fuel For Automobile Engines

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Abstract

Energy is an essential prerequisite for accelerated economic development and improved quality of life for citizens of any country. Due to rapid industrialization and urbanization in last few decades, there is a huge pressure on depletable crude oil, coal and other fossil fuels. This resulted into need for finding some alternative sources of energy. About 70% population of India lives in rural areas and majority of them are engaged in agriculture, animal husbandry and small scale rural industries. In agriculture there is tremendous increase in energy consumption with increased use of tractor, bore well, irrigation pumps and farm machineries etc. Biogas is produced by anaerobic digestion of biomass such as cattle dung, vegetable waste, poultry droppings, industrial waste water, municipal solid waste, and landfill etc. In rural areas cattle dung and vegetable waste whereas in cities and urban area municipal solid waste are available in abundant quantity, from which biogas can be generated. Biogas is constituted of different component gases, the majority of them being methane (CH₄), Carbon Dioxide (CO₂) with traces of Hydrogen Sulfide, and moisture. It is possible to improve quality of biogas by removal of CO₂, H₂S and enriching its methane content up to the natural gas level. After methane enrichment and compression it can be used as vehicle fuel like compressed natural gas (CNG). Any low cost technique to remove carbon dioxide and hydrogen sulfide from biogas can make biogas a techno-commercially viable fuel. In this paper low cost biogas purification system is proposed and is shown that using this system we can convert raw biogas into bio CNG which can be used as a vehicular fuel

Keywords: *Raw Biogas, Biogas Enrichment, Chemical scrubbing.*

1. Introduction

Energy is an essential prerequisite for accelerated economic development and improved quality of life for citizens of any country. Due to rapid industrialization and urbanization in last few decades, there is a huge pressure on depletable crude oil, coal and other fossil fuels. This

resulted into need for finding some alternative sources of energy. Biogas is one of the most important renewable sources of energy which may cope up to cater for heating and power.

Biogas is produced by anaerobic digestion of biomass such as cattle dung, vegetable waste, municipal solid waste, poultry droppings, industrial waste water and landfill etc. Main products of the anaerobic digestion are biogas and slurry. In composition of biogas methane, carbon dioxide, hydrogen sulfide, nitrogen, oxygen, ammonia, chlorinated organic matter, silanes, siloxanes, volatile phosphorous substances and other volatile trace compounds are found.

At present biogas is used mainly in cooking and lighting. Produced biogas is generally stored in large impermeable bags at biogas plant site. The gas produced in digester is transported by piping to nearby kitchens on pressure developed in digester. But this pressure is not sufficient to transfer gas to farther distances from the biogas generation site. This is why use of biogas has been restricted to few locations. Most digesters will have limited capacity to store biogas produced. If there is any large capacity biogas plant, sometimes produced biogas is not used in full quantity locally (when demand is less than production) resulting into interrupted operation of biogas plant. For commercialization of biogas, it is important to make it portable and compatible for various commercial purposes.

The main problem of biogas is its low energy content and it is difficult and costlier to liquefy it. This requires compression of biogas to as higher pressure as possible. Storage of the gas is another concern as cylinder becomes heavy and bulky for higher pressures. This may increase weight of the cylinder and hence affect its portability. So to increase energy content, other techniques like removing incombustible gases are to be checked. So that due to

increased % of methane, energy content of particular volume of biogas also gets improved.

V.K.Vijay^[1] has reported that natural gas has 75 to 98 % methane with small percentage of ethane, butane, propane whereas biogas has about 60% methane and about 40 % carbon dioxide. It is possible to improve quality of biogas by removal of CO₂, H₂S and enriching its methane content up to the natural gas level. After methane enrichment and compression it can be used as vehicle fuel like CNG. When biogas is produced from cattle dung, hydrogen sulfide content is usually less than one per cent. The concentration of hydrogen sulfide more than this level should be removed before use in engines.^[2]

Biogas cannot be stored easily as it does not liquefy easily under pressure and at ambient temperature. Its major constituent is methane. Critical points of methane recorded is -82 ° C and 46 bar. This means methane will not liquefy at temperature above 82 ° C, whatever the pressure implying that at any ambient temperature, methane is a gas. Liquid methane at atmospheric pressure would have a temperature of 111.5 K or -161.6° C. Thus a better way of storing it too has to be used.^[3]

Any low cost technique to remove carbon dioxide and hydrogen sulfide from biogas can make biogas a techno-commercially viable fuel.

2. Biogas Composition

Biogas is constituted of different component gases the majority of them being methane (CH₄), Carbon Dioxide (CO₂) with traces of Hydrogen Sulfide, and moisture. Composition of a typical biogas sample is given in following table:

Table 1 Composition of Biogas.

Constituent	% in Biogas
Methane (CH ₄)	50-70%
Carbon Dioxide (CO ₂)	30-40%
Hydrogen Sulfide (H ₂ S)	Traces
Water Vapor (H ₂ O)	0.3

Natural gas has 75-98% methane with small percentages of ethane, butane, propane whereas biogas contains about 60% methane and 40 % carbon dioxide. It is possible to improve quality of biogas by enriching its methane content up to the natural gas.

Methane is important constituent present in raw biogas and is combustible. Raw biogas contains so many impurities. Among which removal of carbon dioxide, hydrogen sulfide and moisture are important for upgrading biogas for vehicular application.

3. Need of removing impurities from raw biogas.

a) Need of Removing H₂s from Biogas:

The presence of H₂S makes biogas corrosive to metal parts. Regulators, gas meters, valves and mountings can quickly become corroded. Combustion of biogas containing H₂S produces sulfur dioxide (SO₂). When SO₂ combines with water vapor, it produces sulfuric acid that corrodes the exhaust pipes of burners, gas lamps and engines. The gaseous SO₂ also dissolves in engine oil causing the oil to become acidic and lose its ability to lubricate, damaging the engine and shortening time between oil changes. SO₂ is considered more dangerous than H₂S because it is hazardous for health and environment, as it produces smog and acid rain .

Requirements for H₂S removal for biogas vary depending on the biogas utilization technology. H₂S levels below 1000 ppm are necessary for use in boilers to produce heat. Levels less than 250 ppm are necessary to avoid excessive corrosion and expensive deterioration of lubrication oil. The H₂S limit for electricity production by internal combustion engines is 100 ppm. Compressed biomethane (CBM), equivalent to compressed natural gas (CNG), for use as a vehicle fuel should have levels of H₂S below 16 ppm . If biogas is to be used as natural gas and injected into the grid, the hydrogen sulfide levels need to be less than 4 ppm .

b) Need of Removing CO₂ from Biogas:

Carbon dioxide is present in raw biogas with very high concentration. This decreases energy content per unit mass /volume and limits its use for low quality energy applications. Presence of carbon dioxide in biogas is undesirable to use it as a vehicular fuel because it lowers the power output from the engine and occupies additional space in gas storage cylinders. This may require frequent refilling of fuel tank of vehicle. Presence of carbon dioxide in biogas can cause problem of freezing at valves and metering points. So removal of carbon dioxide from biogas is essential to increase use of biogas for wider range of applications.^[4]

c) Need of Removing Moisture from Biogas:

Presence of moisture in biogas to be used as fuel may corrode metallic parts of engine and fuel supply system. Also this moisture may react with SO₂. This reaction

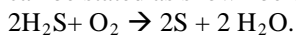
produces sulfuric acid that corrodes the exhaust pipes of burners, gas lamps and engines.

4. BASIC OF TECHNIQUES USED FOR REMOVAL OF IMPURITIES FROM BIOGAS:

To upgrade biogas to bio CNG first of all sulfur must be removed from biogas. It is to be carried out first because most processes of CO₂ removal from biogas act antagonistically towards hydrogen sulfide; the smaller concentration of hydrogen sulfide, the better effects of carbon dioxide removal from biogas. H₂S removal can be done in the same process line used for CO₂, but it should be done first^[5]

a) Removal Of H₂S From Raw Biogas:

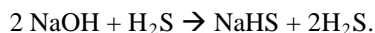
Removal of sulfur from biogas involves oxidizing hydrogen sulfide with atmospheric oxygen. A small amount of air (3-6% volume of produced biogas) can be introduced directly into a bio-reactor filled with digested matter. This can be done by pumps that supply suitable amounts of air. Chemical reaction for this oxidation process can be stated as shown below:



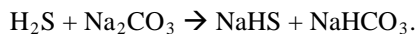
Hydrogen sulfide can be removed using catalyst iron oxide in the form of oxidized steel wool or chips of iron cut from lathe operation of any workshop. When raw biogas comes into contact with steel wool / chips, iron oxide gets converted to elemental sulfur. The chemical equation for this process is as shown below:

- i) $\text{Fe}_2\text{O}_3 + 3\text{H}_2\text{S} \rightarrow \text{Fe}_2\text{S}_3 + 3\text{H}_2\text{O}$.
- ii) $2\text{Fe}_2\text{S}_3 + 3\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3 + 6\text{S}$.

In wet technique used for sulfur removal from biogas, solution of NaOH can be used.



Hydrogen sulfide reacts with sodium carbonate present in solution, forming sodium hydrosulfide as described by reaction:

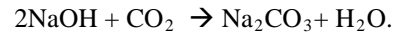


The hydrated iron oxide introduced in to solution reacts as follows:

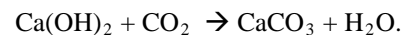


b) Removal Of CO₂ From Raw Biogas:

For this, solution of NaOH and water in 40: 60 ratios (by weight) can be prepared in a container. When NaOH and water are mixed together enormous amount of heat will be generated due to exothermic reaction. When heat gets disappeared, raw biogas may be allowed to pass through the solution. This will reduce carbon dioxide present in biogas.



In alternate arrangement, solution of limestone and water in 40: 60 ratios (by weight) can be prepared in a container. When limestone and water are mixed together enormous amount of heat will get generated due to exothermic reaction. When heat gets disappeared, raw biogas can be allowed to pass through the solution. This will reduce carbon dioxide present in biogas.



c) Removal Of Moisture From Raw Biogas:

To remove moisture from raw biogas, silica gel can be used as it has very good moisture absorbing capacity. In market silica gel is available as white silica gel and blue silica gel. Blue silica gel is somewhat costlier compared to white silica gel due to its better properties compared to that of white silica gel. Silica gel will absorb moisture from biogas. These silica gel crystals must be replaced based on purity of biogas obtained in terms of moisture content in it

5. PROPOSED LOW COST BIOGAS UP GRADATION SYSTEM:

The experimental work is carried out at biogas research centre of Gujarat Vidhyapeeth at Sadra having a biogas plant of Dinbandhu Model of capacity 3 meter cube per day .This plant is fed per day 60 kg cattle dung, 15 kg kitchen waste and 75 kg water. Produced biogas can be used as fuel for i) gas stove for heating ii) spark ignition type dedicated biogas engine (Make: Siya Instruments) run generator of capacity 500 kW iii) compression ignition type dual fuel engine (Make : Field Marshal)run generator of capacity 3kW. The centre also has air compressor, pressure regulators, CNG cylinder, biogas analyzer (Make: Siya Instruments) to measure methane and carbon dioxide content in biogas



Fig.1 Photograph of experimental setup for chemical scrubbing of biogas

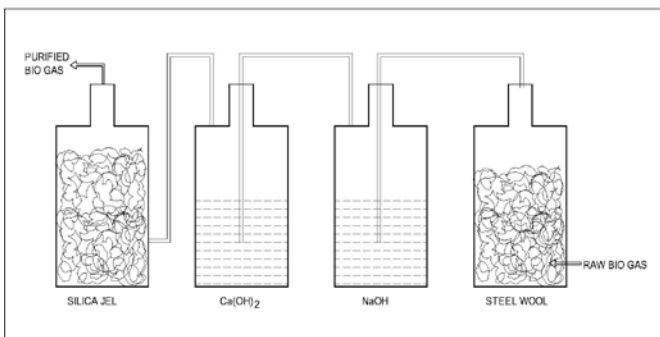


Fig.2 Schematic arrangement of experimental setup chemical scrubbing of biogas

As shown in above shown fig. 1 , four plastic bottles (used for storing Reverse Osmosis processed potable drinking water) with necessary pipe fittings were used in this experimental work.

Raw biogas first enters from bottom of the first chamber containing iron filings (chips available from lathe operations) and comes out from top. This will remove H₂S and somewhat moisture.

In second chamber solution of NaOH with water is prepared with concentration of 40 % , due to exothermic reaction very high amount of heat is produced. That heat will dissipate gradually. Now biogas enters from top of the chamber containing solution of Sodium Hydroxide. Gas is allowed to bubble in that solution and certain amount of H₂S and CO₂ will get removed.

In third chamber solution of Ca(OH)₂ with water is prepared with concentration of 40 % . Due to exothermic reaction very high amount of heat is produced. That heat will dissipate gradually. Now biogas enters from top of the chamber containing solution of Sodium Hydroxide,

Ca(OH)₂. Gas is allowed to bubble in that solution and certain amount of CO₂ will get removed.

In forth chamber silica gel is kept. For this experiment, blue silica gel was used. Biogas will enter from bottom and will come out from top of the chamber. This will remove moisture from biogas. Composition of biogas before treatment and after scrubbing obtained by laboratory test report is as summarized below:

Table 2: Composition of Raw Biogas and Scrubbed Biogas

CONTENT	RAW BIOGAS	SCRUBBED-BIOGAS [USING NaOH & Ca(OH) ₂]
Methane %	61.22	94.69
Carbon Dioxide%	32.01	3.05
Hydrogen Sulfide, ppm	986	87
Oxygen %	2.76	1.07
Moisture%	3.91	1.07

6. CONCLUSION:

Using above described system, carbon dioxide present in raw biogas can be reduced from 32.01 % upto 3.05 % and methane content present in raw biogas can be raised from 61.22 % to 94.69% . Also hydrogen sulfide and moisture content can be reduced. Natural gas has 75-98% methane. Purified biogas obtained is known as bio CNG as its composition is matching with that of CNG. Based on these following applications of purified biogas are possible:

Biogas after removing H₂S can be used as fuel for stationary internal combustion engine for better engine performance compared to raw biogas.

After removing H₂S, moisture and CO₂ from raw biogas, purified biogas can be used without compression,

1. For cooking purpose for improved heating compared to raw biogas.
2. To run stationary internal combustion engine used for irrigation for better engine performance compared to raw biogas. For this purpose if engine is to be run at distance from biogas plant, biogas balloons can be used.

After removing H₂S, moisture and CO₂ from raw biogas, purified biogas can be compressed and bottled into cylinders. Bottled purified biogas can be used as replacement to,

1. Compressed natural gas used in automotive engines
2. Liquefied petroleum gas which is for cooking purpose.
3. Liquefied petroleum gas which is for gas cutting /welding purpose.

The methane enrichment of biogas to biomethane quality and its feeding into natural gas grid /compression in cylinder is an effective way of integrating the biogas into energy sector. Thus it can be successfully used as substitute to natural gas and transportation fuel, combined heat and power and electricity generation applications.

References:

- 1 V.K.Vijay , S.S.Kapdi: Biogas Purification and bottling into CNG cylinders : Producing BioCNG from biomass for Rural Automotive Applications ‘, The second joint international conference on “ Sustainable Energy and Environment “ Bangkok , Thailand. (2006)
- 2 V.K.Vijay Studies on utilization of biogas for improved performance of duel fuel engine. M E (Ag.) thesis. CTAE Udaipur.(1989)
- 3 C. Offori-Boateng and E.M.Kwofe : Water scrubbing : A better option for biogas purification for effective storage .World Applied Science Journal 5(special issue for environment) : 122-125, 2009.
- 4 R.Chandra, V.K.Vijay and P.M.V. Subbarao : Vehicular Quality Biomethane Production from Biogas by using an automated water scrubbing system, International Scholarly Research Network ISRN Renewable Energy Volume 2012, Article ID 904167.
- 5 Jan Cebula : Biogas Purification by sorption techniques, “Architecture, Civil Engineering , Environment , The Silesian University of Technology no. 2/2009.