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Low-cost Gas Purifying Unit for Small Scale Biogas Plants

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ABSTRACT

In Sri Lanka biogas has been introduced as a renewable energy source as well as inexpensive energy source for rural areas and agricultural areas.But for many instances rawbiogas is directly sent to the stoves withoutpurifying and hence it affects the combustion process. Therefore to increase the effectiveness of biogas and toincrease the efficiency of the combustion process, unnecessary gas contaminations should be removed. Due the presence of H_2S and CO_2 in the biogas, there can be detrimental effects on health, tendency of corrosion of the components of the burning system and also it can lower the calorific value of biogas. Therefore the study was aimed at designing and developing a low cost bio gas purification unit for biogas plants operated at institutions or individual houses. Basically, the proposedpurifying unit consists of individualunits for eliminating carbon dioxide, hydrogen sulfide and water vapor in the biogas. Calcium Hydroxide Pellets and Activated Carbon were used to remove CO_2, Ferric Oxide pellets was used to remove Hydrogen Sulfide and Silica Gel was used to remove water Vapor. The gas purifying unit is designed, fabricated and installed for 8m^3 biogas plant located at orphanage situated in Galle district in Sri Lanka. The quality of biogas was tested before and installing the unit. The test results revealed that methane content was within the range of 80 - 82% after purifying the biogas where as it was within the range 60-61% for raw biogas.

Key words: Anaerobic digestion, Biogas, Methane, Biogas plants, Biogas purification

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1. INTRODUCTION

As sustainable clean energy carrier biogas is an important source of energy in heat and electricity generation, it is one of the most promising renewable energy sources in the world. Biogas is produced from the anaerobic digestion of organic matter, such as manure, municipal solid waste, sewage sludge, biodegradable wastes, and agricultural slurry, under anaerobic conditions with the help of microorganism. Biogas is composed of methane (55–75%), carbon dioxide (25–45%), nitrogen (0–5%), hydrogen (0–1%), hydrogen sulfide (0–1%), and oxygen (0–2%). [1] The presence of CO_2 and H_2S may affect the quality of biogas and hence, its removal before its use is important.

2. RATIONALE FOR STUDY

Biogas formedby anaerobic digestion process,mainly contains methane and presence of other ingredients such as carbon dioxide, hydrogen sulfide, water, water vapor and small amounts of nitrogen and oxygen may lower the energy value of biogas.The calorific value of biogas is about 6 kWh/m^3 and this corresponds to about half a litre of diesel oil. The net calorific value depends on the efficiency of the burners or appliances. Methane is the valuable component under the aspect of using biogas as a fuel [2]. When rawbiogas is used for cooking purposesthere can be several adverse effects such as lowering the calorific value of burning gas, difficulty in obtaining a uniform flame due to the presence of water vapor, unpleasant smell due to H_2S. Therefore the objective of this study was to design and develop a low cost, gas purifying unit for small scale biogas plants in Sri Lanka.

Preliminary study was carried out collecting data on domestic biogas plantsas well as plants located at orphanages within the area of down south of the country.The selected biogas plant for this pilot study is located at orphanage situated in Galle districtwhere one of the down south districts in Sr Lanka.The digester is a fixed dome type with a 8m^3 capacity, use kitchen waste as the main feedstock and raw biogas is used for the cooking purposes of the orphanage.Digester is fed daily and sewage lines have alsobeen diverted to the digester. Kitchen waste is mixed with

water and added to the digester through inlet line. There is special filtering method to remove the slurry.The biogas flowrate was observed as 45m^3/hr and total gas produced is used for cooking. During the visit it was observedthat there is a possibility of increasing combustion efficiency if biogas are purified before it use.

3. METHODOLOGY

Presently there are different biogas purification technologies available and after evaluating them, low cost and most appropriate methods were selected to remove water vapour, hydrogen sulphide and carbon dioxide from the generated biogas. After calculating design parameters of each unit, model was designed by using the CAD software and SolidWorks 2012.

Design of Water Vapor Removing Unit

Biogas line was diverted through the Silica Gel pack to remove the water vapor. To fabricate water vapor removing unit 300mm length PVC pipe was used mainly to make the silica gel container. Two holes were drilled on surface of the pipe to fix 20 mm PVC sockets. Required quantity of silica gel was calculated by using a standard equation [3] and therefore 540g of Silica Gel was inserted to the pipe cell. The top and bottom of the pipe cell is closed by 63 mm PVC end caps.

Design of Hydrogen Sulfide (H_2S) Scrubber

Hydrogen Sulfide is a chemical compound with the formula H_2S. It is a colourless gas with the characteristic of foul odour rotten eggs; it is heavier than air, very poisonous, corrosive, flammable and explosive. After considering several methods of removing H_2S from biogas, it was decided to use Ferric oxide (Fe_2O_3) pellets as Fe_2O_3 is cheap material thus economical to use.When raw biogascomes into contact with steel wool / chips, iron oxide gets converted to elemental sulfur [3]. Ferric oxide pellets as shown in the Fig. 1, were produced using steel wooland weight of the ferric oxide pellets was estimated as 765.72g.

Fig. 1 Pellets of Fe_2O_3

In H_2S Scrubber the inner strainer as shown in Fig. 2 is used as Fe_2O_3 pellet container and it is fabricated by using PVC flexible mesh. After Ferric Oxide pellets were filled to the strainer it was properly closed by the lid. Finally, strainer is inserted into the outer cell of the H_2S Scrubber and outer cell was properly closed by PVC 110 mm end caps.

Fig. 2 Inner strainer with Fe_2O_3 Pellets

Design of Carbon Dioxide Removing Unit

Among the technologies available for eliminating CO_2 from the gases, ab-sorption is the only presently available commercialized process. $Ca(OH)_2$ aqueous solution isused as an effective solvent to absorb CO_2 because of its variousadvantageous features. First, Ca is inexpensive, abundant, and non-hazardous. $CaCO_3$ precipitation from the carbonation of $Ca(OH)_2$ aqueous solution is a very familiar and classic reactioncommonly observed in nature.Second, reclamation andregeneration are available to dispose the produced $CaCO_3$. Therefore, biogas was sent through mixture of $Ca(OH)_2$ and activated carbon since the activated carbon also has the property of absorbing CO_2. Assuming biogas contains 40% of carbon dioxide, required quantity of $Ca(OH)_2$ was calculatedas 242.5g [4] and 2kg of Activated carbon is also used with Ca $(OH)_2$. Solution of $Ca(OH)_2$ was prepared by mixing Calcium Oxide with Water.

When fabrication of CO_2 scrubber 110 mm PVC pipe with 600mm long is used to fabricate the outer cell. Inner strainer is divided to six layers in 100 mm intervals. The inner strainer is filled with Ca $(OH)_2$ and Activated carbon as layers. Then inner strainer is interested into the PVC outer cell. Finally, outer cell is closed by 110 mm PVC end caps.

Final Assembling and Testing of the Gas Purifying unit

After designing of each component, the whole unit was modelled as shown in the figure. The Fig. 3 shows the fabricated and assembled unit as per the dimensions decided by the design calculations.

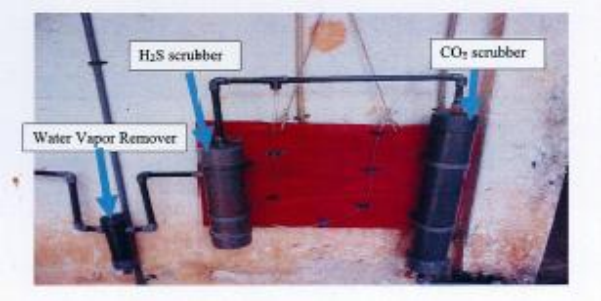

Fig. 3 Purifying Unit after assembling

The purifying unit was installed between the digester and the end user point. Biogas which comes from the digester first go through the water vapour removing unit and there water vapor is captured and then biogas goes into H_2S scrubber and CO_2 scrubber subsequently. The manometer which is located between H_2S and CO_2 scrubbers indicated the pressure variation. Finally, the purified biogas was directly supplied to cooking appliances used in the kitchen of this orphanage

4. RESULTS AND DISCUSSION

Initially the purifying unit was tested for leakage. The manometers have been attached to the gas line in order to measure pressure difference of the system. The biogas was analysed for five consecutive days before and after installation of gas purifying unit, using a gas analyser and results are depicted in Fig 4 and Fig 5. The results shows that before installing the unit, methane content in the biogas is within 60-62% whereas methane content increased to the range of 80-82 % after installing the unit. Similarly, percentage of carbon dioxide was within 38–39% before and after it decreased to the range of 16 - 17%.

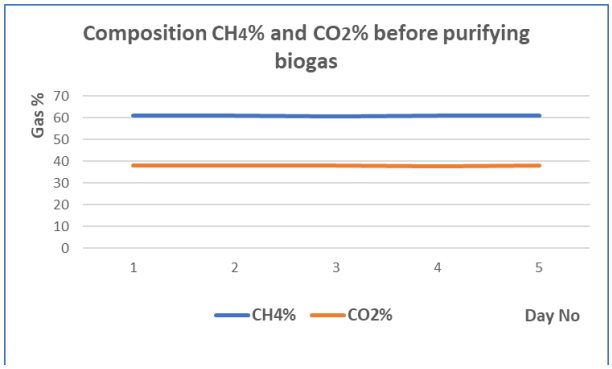

Fig. 4 Composition of CH_4 and CO_2 before purifying the biogas

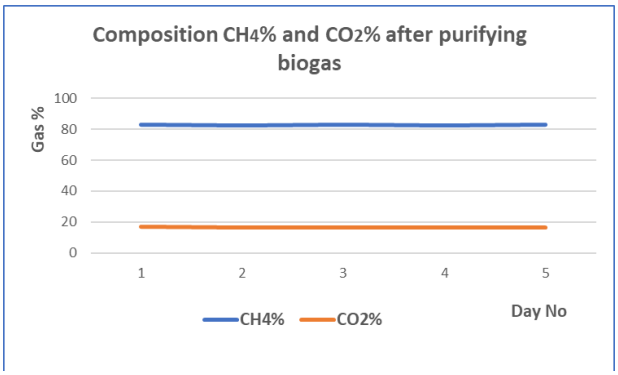

Fig. 5 Composition of CH_4 and CO_2 after purifying the biogas

5. CONCLUSION

Presently biogas is used for cooking purposes in Sri Lanka. If biogas is used as a fuel gas, gas purification before its use is essential in order to increase the effectiveness of the biogas. If biogas contains water vapor, it is difficult to obtain uniform flame as well as with CO_2 and H_2S, it is difficult to get blue colour flame. During the study it was observed that flame of the cooker was not uniform and pale yellow colour with the supply of raw biogas but the flame was quite blue colour and uniformafter supplying the purified gas. It was proven that content of watervapor, CO_2 and H_2S in the biogas are minimum after installing the unit. Also revealed that there was no smell of the biogas. Finally it can be concluded that developed low-cost gas purification unit works properly.

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