DEVELOPMENT AND PERFORMANCE EVALUATION OF AN INDIGENOUS WET SCRUBBER UNIT

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ABSTRACT: *This study was taken up to enhance the biogas plant efficiency by purifying the out coming raw biogas to increase the calorific value of methane (CH_4) in biogas. For this purpose a functionally efficient wet scrubbing unit of PVC material was designed and developed, through which biogas was gone by, and then evaluated at different temperature, pressure and flow rates of water. Raw biogas resulted from the biogas plant consist of CH_4, CO_2 and H_2S were 58%, 35% and 62% respectively. After treatment by newly developed wet scrubber the obtained results for CH_4, CO_2 and H_2S were 65%, 25% and 50% respectively. This study led to advancement in biogas technology at agriculture, commercial as well as at common people level by removing the impurities of CO_2 and H_2S from biogas by means of pressurized water.*

Key Words: Biogas, Wet scrubbing unit, Polyvinyl Chloride (PVC), Flow rates.

1.0 INTRODUCTION

The power shortfall in Pakistan lasted no more than 3 or 4 hours a day in 2007. Now days, in awfully warm weather, Pakistanis had to suffer without electricity for 12 to 16 hours a day. Renewable sources of energy are very important for Pakistan due to acute shortage of indigenous fossil fuels, imported fossil being subject to a hyper international market adding to production cost. Among renewable sources, energy produced from fossil fuel is of special worth being abundantly available around the country. The residual material provides valuable manure. Cattle dung is used as fuel which was used for enhancing soil productivity. Biogas technology resolves both these objectives: anaerobic decomposition of wet manure of cattle's, results in fuel (biogas) and organic fertilizer (sludge). Biogas or locally named as "gobar gas" is produced by the decomposition of organic matter generally obtained by dung (animal waste). It is produced during the heating of organic matter in a tank or container without oxygen (anaerobic process). It is composed mainly of methane (CH_4), about 62%; thus 28.3 cubic meter biogas is equivalent to 17 cubic meter of natural gas, 19.7 liters of gasoline and 17.4 liters of diesel oil. Detailed composition of biogas is given as under [1]. A small family of four persons would require 4.25 cubic meter of biogas per day, for cooking and lighting an amount which can be produced from the manure of three cows. It's a less polluted & easily controlled alternate resource of energy which could easily be produced from our daily households and cattle's waste with minimum labor input. Biogas is a good and cheap replacement of firewood and fossil fuels which are growing high in price and falling behind demand [2]. It's in theories that each head of cattle produces 10 kilogram of wet dung per day but the real fact is that 12 to 13 kg dung is produced by a cow in Pakistan. An approximate total of 35 million cattle existing in Pakistan will generate gas at approximately 0.05 cubic meters per kilogram of wet manure. Hence we can meet the entire energy requirements for domestic cooking and lighting of the whole country with adopting biogas technology & making it more efficient & beneficial to general public sector [3]. Biogas from anaerobic digestion of biological wastes is a renewable energy resource. It has been used to provide heat, shaft power and electricity. Typical biogas contains 50 to 65% methane (CH_4), 30 to 45% carbon dioxide (CO_2), moisture and traces of hydrogen sulphide (H_2S). Presence of CO_2 and H_2S in biogas affects engine performance adversely. Reducing CO_2 and H_2S content will significantly improve quality of biogas. In this work, a method for biogas scrubbing and CH_4 enrichment is presented. Chemical absorption of CO_2 and H_2S by aqueous solutions in a packed column was experimentally investigated. The objective of the study was to design, develop and evaluate an efficient and economical water scrubbing unit of PVC material for biogas plant for the removal of CO_2 and H_2S.

3.0 MATERIALS & METHODS

This study is taken up to enhance the biogas technology in Pakistan for easier and efficient adaptation. Biogas or locally named as "gobar gas" is produced by the decomposition of organic matter generally obtained by dung (animal waste). It is produced during the heating of organic matter in a tank or container without oxygen (anaerobic process). It is composed mainly of methane (CH_4), about 68%; thus 28.3 cubic meter biogas is equivalent to 17 cubic meter of natural gas, 19.7 liters of gasoline and 17.4 liters of diesel oil. These gases have adverse effects on environment and make calorific value of biogas lesser. Water scrubbing is the most commonly used technique to remove the traces of these harmful gases. This study was focused on design and development of an efficient water scrubbing unit, made of PVC, for small scale biogas production plant, which will reduce the cost of water scrubbing at common people level and shine the future of biogas purification in Pakistan [1].

Granite and O'Brien [4] tested that the quality of biogas accountably enhanced by reducing the concentration of CO_2 and H_2S. Many technologies had been applied for separation of CO_2 from raw biogas in the past. Those include absorption by chemical solvents, physical absorption, cryogenic separation, membrane separation and CO_2 fixation by biological or chemical methods.

This research focuses on only one aspect of the PVC wet scrubbing unit for biogas which is technical efficiency. Faisalabad division has a very good overall biomass potential. Biogas data from 'Bio Sole Power' was examined and an analysis was conducted to determine the objectives of the study. This biogas plant is situated on Satiana Road, at 3 km from Faisalabad and has the daily production capacity of 8 – 10 m^3/day. A storage tank was attached with the plant to store biogas and a single stage compressor was also installed to increase the pressure of biogas by compression. In this way, the resulted biogas was used to produce heat and also to generate electricity. Biogas from the plant was treated in scrubbing unit at different pressure (P) and flow rates (F) to determine efficient findings. Samples of purified biogas were taken three (3) times after every five (5) minutes to avoid error and due to temperature change respectively.

2.0 Overall Research Design

This study was conducted to design, develop and evaluate the scrubbing unit, made of PVC material, for the purified separation of methane (CH_4) from the raw biogas. Analysis included an assessment of the technical and economic potential of PVC made scrubber for this application. The technical analysis included temperature, pressure and flow rate to be dealt with to assess the efficacy of the scrubbing unit, made of PVC material.

The statistical analysis was also performed by using PROG GLM (general linear model) procedures of the SAS system and ANOVA (Two way analyses) to examine the efficiency of the scrubber.

2.1 Procurement of Material

A wet scrubber of PVC material was first designed and then developed to conduct the experiment for the findings. It consisted of two inlets; one at the front side above the bottom, for the entrance of raw biogas and other on the top of the tower of scrubbing unit, for the clean water entrance. There were also two outlets in the scrubbing unit, one at the bottom and other on the back side below the top, respectively for dissolved water and purified biogas. Inlet was connected to the storage tanks from where the stored raw biogas was taken to the scrubbing unit for purification. A handle valve and a pressure gauge were fitted between the storage tank and scrubbing unit for controlling and measuring the biogas pressure respectively. Similarly a handle valve was installed between the water pump and inlet for controlling the water flow rate and a Rota meter was also installed there to measure the flow rate of the clean water. A pressure gauge was also mounted at the top of the scrubbing unit to measure the pressure of water just before entering the scrubbing chamber. Water was pumped by a pumping unit having 0.5 hp and was operated at 1400 rpm. A shower was fitted in the wet scrubber and water was showered onto the raw biogas from the top of the scrubber.

The following materials were procured in order to conduct laboratory test on the biogas plant. 1. Pressure gauges, 2. Rota meter, 3. Pumping unit having 0.5 hp electric motor with 1400 rpm, 4. PVC solution, 5. Plastic drum for solution storage, 6. Stainless steel shower, 7. Construction Material for construction of water scrubbing unit.

The table 1 shows the specifications of the material used for the construction of scrubbing unit for biogas plant.

3.1 Parameters

For analysis purposes, the major parameters were: Temperature (T), Pressure (P) and Flow rate (F) and there are three main sections of scrubber are:

Top Section: It was consisted of cover, pressure gauge, shower and inlet line of water solution. Shower was connected to the inlet line of water and a Rota meter was installed on it to check the flow rate of water which was controlled by a safety valve. A pressure gauge was also installed to measure the pressure.

Middle Section: There was 3 – 5 cm layer of small stone between the mesh net in the middle section of unit to interconnect the water and raw biogas, so there was more solubility of raw biogas in water

Bottom Section: Raw biogas was passed through the bottom section which was 4 inch in diameter and 1.5 feet in height. A check valve was attached with it to divert the raw biogas to the scrubbing unit from the storage plant.

3.2 Data Collection:

Raw Biogas: Firstly raw biogas samples were taken from storage tank and tested to obtain actual percentage of the components gas. Then it was treated in the scrubber and the samples of purified gas were again taken from the exit point of the scrubber. The pressures of raw biogas and purified biogas were noted with the pressure gauge. The samples was stored and then transported to laboratory in balloons.

Pressure, Temperature and Flow rate: A pump of 0.5 hp at 1400 rpm was used to pump the water into the scrubber. Pressure of water was noted with the help of pressure gauge installed just before the entry point and flow rate was controlled with a handle valve.Temperature data was recorded of raw biogas, purified biogas and clean water with the help of a digital thermometer. For the temperature of raw biogas, a T-point was inserted between the storage tank and scrubber. Pin of thermometer was inserted in the pipe and reading was noted. Similarly temperature of treated

Table 1 Materials used for the Scrubbing Unit

1	Metal handle valve 1/2" (2 Nos.).	6	PVC socket 6" x 4" (1 Nos.).	11	5 feet PVC pipe of 2" dia
2	G.I L-bows pipe nipples	7	PVC socket 4" x 2" (1 Nos.).	12	2 feet PVC pipe of 4" dia.
3	1/2" T-section	8	PVC sieve 2" (1 Nos.)	13	5 feet PVC pipe of 6" dia.
4	Joint clamps of 3/4" and 1/2" of dia	9	Iron sieve 6" (1 Nos.).	14	Flexible transparent pipe of 3/4" dia
5	PVC socket 2" x 1/2" (1 Nos.)	10	PVC L-bows 2" x 2" (5 Nos.).	15	Top cover of PVC of 6" dia

biogas was recorded. Temperature of clean water was controlled by a cooling unit attached to the pumping unit. Water was cooled at different temperatures and effect of temperature on purification was also studied. The daily production capacity of plant was 8 to 10 m^3/day. A storage tank was attached with the plant to store raw biogas and a single stage compressor was also installed to increase the pressure of biogas by compression.

4.0 RESULTS

This study was conducted to investigate the feasibility of PVC made wet scrubber based on efficiency, reliability and economy. Biogas is a great renewable energy resource; efforts were done to develop a wet scrubber which was made of PVC material to purify the raw biogas. Assessment of efficiency and cost effective was done by comparing it with other scrubbing units and also experiments were made to justify the study. Raw biogas produced from the biogas plant was stored in the storage tank and analyzed. Then it was passed through the PVC made scrubber and treated with clean water at different pressures (P) and flow rate (F) for different temperature (T) of the gas. Samples of the biogas, raw and purified, were collected in balloons and taken to the University of Engineering & Technology where they were tested in laboratory of Chemical Engineering Department. Results were obtained and tabulated. After then the statistical analysis was also applied by using PROG GLM (general linear model) procedures of the SAS system (1989) and ANOVA (Two way analyses). The results obtained are discussed as follows.

4.1 Analysis of CH_4, CO_2 and H_2S

Main component of biogas is Methane (CH_4). Methane gives the highly flammability its react with Oxygen and burn. Its quantity depends upon lower percentage of CO_2 and H_2S. The quality of CH_4 was checked by using portable biogas analyzer. The data collected were analyzed using PROG GLM (general linear model) producers of the SAS system. The untreated biogas contains 60% methane, 38 % carbon dioxide and 95 % hydrogen sulphide. Vijay [5] conducted a study on use of biogas for enhanced performance in duel fuel engine and he revealed the almost same results of untreated biogas mixture were about 50-63% of methane (CH_4), 30-45% CO_2 and traces of H_2S and a small portion of moisture.

Figure 1 shows that the percentage composition of hydrogen sulphide and carbon dioxide decreasing as temperature of water is increasing but on the other hand percentage composition of methane is increasing. It means that showering of hot water in scrubber has significant effects for all three gases (H_2S, CH_4 and CO_2).

Tynell [6] also described the separation of CO_2 and CH_4 with the help of absorbent, which was the basic technique of scrubbing method. The water was used as a physical absorbent: bio-gas washed by water under high pressure to separate CO_2. Biogas was entered though the bottom of the scrubbing unit, at a pressure of 1000 to 2000 kPa. From the top of column, water was added to obtain a gas liquid counter flow. No economical consideration was taken in that study.

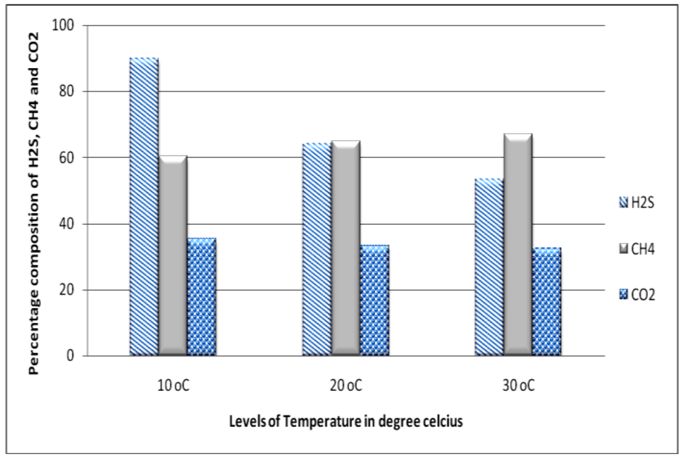

Figure 1. Effect of temperature on percentage composition of H_2S, CH_4 and CO_2

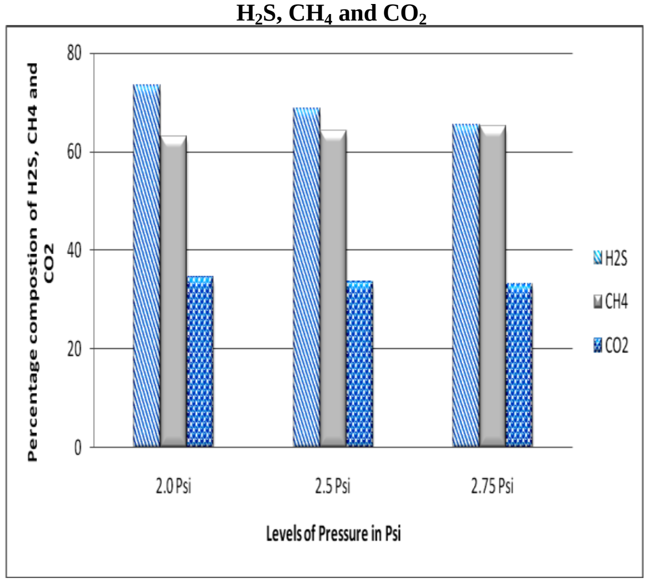

Figure 2. Effect of pressure on percentage composition of H_2S, CH_4 and CO_2

Figure 2 shows that the percentage composition of hydrogen sulphide and carbon dioxide decreasing as pressure of water is increasing and on the other hand percentage composition of methane is increasing. It means that showering of high pressure water in scrubber has significant effects for methane and sulpher dioxide and non significant effect for carbon dioxide.

Wellinger and Lindeberg [7] described that the water scrubbing technique was famous for CO_2 removal from biogas plants which were based on sewage sludge in Sweden, France and USA. The obtained results showed that approximately 5–10% of CO_2 remained in the biogas after scrubbing.

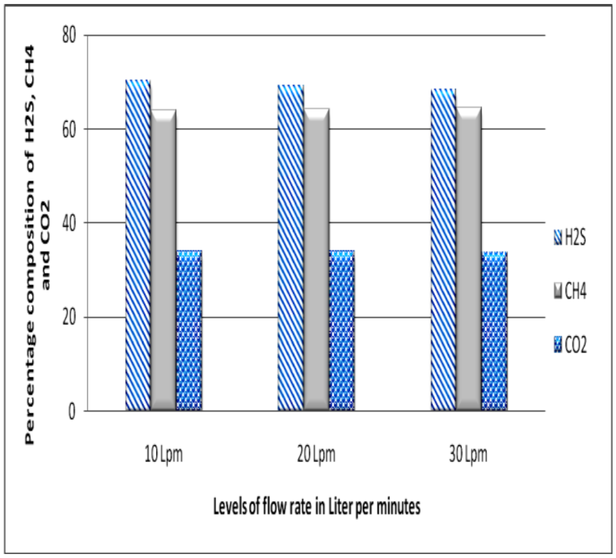

Figure 3. Effect of flow rate on percentage composition of H_2S, CH_4 and CO_2

F1 = 10Lpm F2 = 20Lpm F3 = 30Lpm

Figure 3 shows that the percentage composition of hydrogen sulphide and carbon dioxide decreasing in very small percentage (1% to 3%) as flow rate of water is increasing and on the other hand percentage composition of methane is increasing slightly (1% to 2%). It means that showering of high flow rate of water in scrubber has non significant effects.

5.0 DISCUSSIONS

Biogas from anaerobic digestion of cow dung and biological wastes is a renewable energy resource. It has been used to provide heat and electricity. Typical biogas contains 50 to 65% methane (CH_4), 30 to 45% carbon dioxide (CO_2), moisture and traces of hydrogen sulphide (H_2S). Presence of CO_2 and H_2S in biogas affects engine performance adversely. Reducing CO_2 and H_2S content will significantly improve quality of biogas. Carbon dioxide is soluble in water. Water scrubbing uses the higher solubility of CO_2 in water to separate the CO_2 from biogas. This process is done under high pressure and removes H_2S as well as CO_2. In this work, a method for biogas scrubbing and CH_4 enrichment is presented. Removal of CO_2 and H_2S by high pressure and flow rate of water in PVC made wet scrubbing unit was experimentally investigated. Test results revealed that the treated biogas was enriched with CH_4 and reduce the quantity of CO_2 and H2S. At 10-30^{o}C temperature, 2.0-2.75 psi pressure and 10-30 lpm flow rate the results of CH_4, CO_2 and H_2S were 58 to 69%, 37 to 32% and 95 to 52% respectively. Eltawil and Belal [8] found the almost same results of methane and carbon dioxide using scrubbing technique. They determined that the value of CH_4 and CO_2 after treatment were 69 to 75 % and 37 to 31 % respectively. Krich [9] also explained the phenomenon of scrubbing and showed that methane (CH_4) came at higher concentration with biogas while it was passed through water and percentage of CO_2 and H_2S was decreased due to absorption in water. The purified biogas exited from the top of the column.

6.0 CONCLUSIONS

Following results are seen after studding data:

- Wet scrubbing technique is highly affected to reduce CO_2 and H_2S and enrichment of CH_4.
- Temperature and pressure are more effective than flow rate in reduction of CO_2 and H_2S level and enrichment of CH_4 level.
- At 30^{o}C temperature and 2.75 psi pressure shows best results in increasing CH_4 level and reducing CO_2 and H_2S levels.

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