Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 7, July, 2021:1065 – 1069

Biogas up-gradation by using packed bed water scrubber

H. G. Katariya [a], H. P. Patolia [b]

[a,b] Birla Vishvakarma Mahavidyalaya, Vallabh Vidyanagar, Gujarat – 388120, India
Gujarat Technological University, Ahmedabad, Gujarat, India.
[a] hgkatariya@bvmengineering.ac.in, [b] hppatolia@bvmengineering.ac.in

Abstract

Biogas is considered a cheap alternate source of energy. Its usage offers many economic and environmental advantages. The composition of biogas generated by anaerobic digestion is 50% to 70% methane, 30% to 50% carbon dioxide, and traces of hydrogen sulfide and water vapour. It is necessary to upgrade methane content in it before using as a fuel for automobile and industrial applications. In this study, packed bed column type water scrubber is developed to upgrade biogas produced from cow dung-based biogas plant. The experimental study focused on methane enhancement in biogas by reducing carbon dioxide and hydrogen sulphide from it using a water scrubbing technique. Water was sprayed from the top section of the scrubber column at atmospheric temperature and raw biogas was fed from the bottom section of scrubber column at generated pressure in a counter-current direction. The water flow rate was varied by 1.56 m3/h, 2.12 m3/h, and 2.60 m3/h. It was reported from the experiment that the highest flow rate of water had given 76.0% of methane content in upgraded biogas...

Keywords: Biogas, Upgraded biogas, Enriched biogas, Water scrubber

1. Introduction

The energy crisis, increasing fuel costs, and environmental degradation by fossil fuels attract researchers to find an appropriate source of alternate and renewable energy. The population of India is about 18% of the world's total population, however energy usage accounts for just 5.6% of the world's total energy usage. [1]. 14 % of global energy demand is generated from renewable energy sources like biomass, biogas, solar and wind [2]. Biogas is a source of renewable energy produced through the anaerobic digestion of various diversified organic waste matter by micro living organisms in the absence of oxygen. The process of anaerobic digestion breaks down the organic input matter to mixture of CH_4 and CO_2, usually known as biogas, and traces of H_2S and water vapour. Anaerobic digestion is also considered one of the forms of waste disposal, and it also supports the campaign of 'clean India' started by the Government of India. Biogas is currently used not only for cooking and lighting applications but also for automobile fuel and power generation applications [3]. It is also called carbon-neutral since the carbon in biogas is derived from organic biomass that derived this carbon from atmospheric CO_2 in a comparatively shorter time [4]. Ministry of New and Renewable Energy (MNRE), Government of India, New Delhi, planned to generate 48.55 MW of energy form biogas by 2022 [5]. Biogas production in India, Europe and the rest of the world has the tremendous potential [6].

The biogas consists of a large amount of CO_2 along with traces of other gases like H_2S, water vapour, oxygen, etc. and they are unrelated to practical applications. The concentration of these impurities is mainly affected by the type of biomass feedstock. This may cause adverse effects on any thermal energy conversion equipment and can result in corrosion, fouling and harmful environmental emissions [7]. Biogas derived from biomass can be used directly for process heating, cooking or power generation purposes, but the higher CO_2 content decreases its heating value and limits economic viability for direct use. Therefore, different steps for the treatment of biogas are highly recommended prior to its end-use.

The aim of this research was therefore to set up an upgrading method for biogas produced from cow dung by spraying water in the packed-bed column at biogas generation pressure. This was experimentally studied that how the system operated by the varying flow rate of water.

2. Biogas upgrading system

Biogas with enriched methane content is a suitable fuel for automobile, stationary engines, storing in biogas balloons/cylinders, or natural gas grid injection. Therefore, the content of CO_2 and H_2S in biogas must be reduced using appropriate techniques [8]. Biogas contains larger amounts of CO_2 which lowers energy density and also restricts its use for applications requiring low energy requirements. The CO_2 content in biogas leads to increased storage space needs, frequent cylinder refill, decreased heating value, and lowered engine output. A process of upgrading or scrubbing of biogas is the enrichment of biogas with methane by minimizing the content of CO_2. H_2S is particularly objectionable in biogas because it creates health issues as well as corrosion of storage tanks, burners, and engine parts [9]. Combustion of biogas having H_2S generates sulfur dioxide (SO_2), it is then reacts with water vapour to form sulfurous acid (H_2SO_3), which causes corrosion of engine parts, burners, etc. [10]. Following are the most commonly used techniques of upgrading biogas: (a) Water scrubbing, (b) Chemical Absorption, (c) Pressure Swing Adsorption, and (d) Membrane Separation [11]. The selection of a specific method is driven by cost effectiveness, amount of gas to be upgraded, and chemicals regeneration possibilities [12]. Water scrubbing technique provides benefits like cost-effectiveness, regeneration possibilities, and the ease of operation. Biogas up-gradation with water scrubbing can be expressed by the following chemical reactions [13]:

$$H_2O + CO_2 \rightarrow H_2CO_3 \quad \ldots(i)$$

$$4H_2O + H_2S \rightarrow H_2SO_4 + 4H_2 \quad \ldots(ii)$$

3. Experiments and methodology

This research aimed to develop a setup for upgrading the quality of cow dung-based biogas through a packed-bed column using water as a scrubbing liquid. A floating drum type (KVIC) digester with capacity of 85 m^3 used cow dung as the feed material and produced biogas. It is located at *Satkaival Gaushala Trust*, at Sarsa village, Dist. Anand, Gujarat, India. The generated biogas is available at a constant pressure of 88 mm of the water column. The biogas up-gradation test setup consisted of 140 mm diameter Mild Steel (MS) pipe with the packed bed height of 2000 mm. The polypropylene pall rings were used as packing material for increasing a contact surface area between water and biogas. Two sieves, one at the top section and second at the bottom section of the column, ware fitted to hold the pall rings in the column. There was provision above the top of the packed column for water inlet pipe, water spray system, and gas outlet pipe. The packed column was equipped with water outlet pipe and gas inlet pipe at just below the bottom section of column. The flow rates of water were varied by providing a valve at inlet to the inlet pipe. Fig. 1 shows an arrangement of water scrubber test setup.

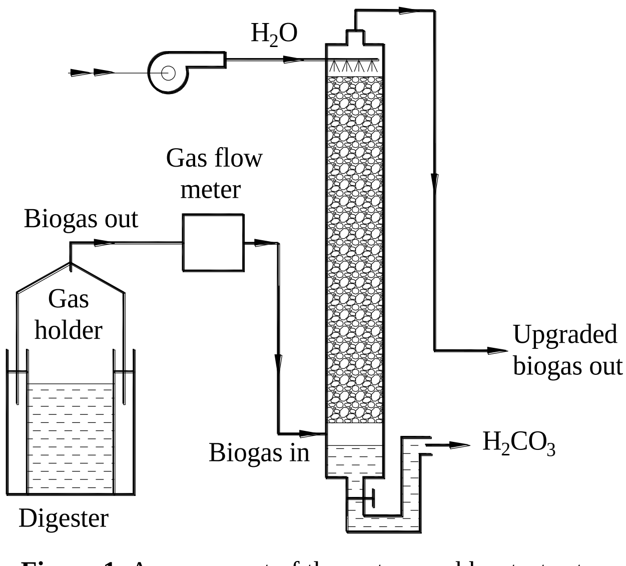

Figure 1. Arrangement of the water scrubber test setup

Water from storage tank was supplied to scrubber by using a water pump from the top of the scrubber column. The water flow rate was varied by operating the valve manually. The water flow rate was measured by measuring the time taken to collect a fixed volume of water at the outlet of the scrubber. The scrubber column was fed with water at flow rates of 1.56 m^3/h, 2.12 m^3/h, and 2.60 m^3/h. Raw biogas was fed from the bottom section of a scrubber column at biogas generation pressure of 88 mm of the water column. The biogas flow rate at the inlet of the scrubber was measured by using mechanical type gas flow meter. Table 1 shows the flow rates of water and biogas. The compositional analysis of up-graded biogas after passing through the packed-bed column was carried out by using biogas analyzer, which measures CH_4 and CO_2 concentration in % by volume. H_2S content was measured in ppm at Sardar Patel Renewable Energy Research Institute (SRERI), Vallabh Vidyanagar by collecting the sample at the outlet. Fig. 2 shows an actual photograph of the water scrubber.

Table 1. Water and Biogas flow rate

Sr. No.	**1**	**2**	**3**
Flow rate of water, m^3/h	1.56	2.12	2.60
Biogas flow rate, Nm^3/h	2.916	1.752	0.960

Figure 2. Water scrubber

4. Results and Discussions

From the experiment, it was found that when the water flow rate increased, automatically biogas flow rate was decreased as shown in Table I. It was due to the fact that at the increased water flow rate, it occupied more area in packed bed column, hence gas flow rate was decreased at generation pressure of 88 mm of the water column.

CO_2 was absorbed by water and consequently, converted to mild carbonic acid. It was found that when water flow rates were changed, the CH_4 content in biogas at the outlet of scrubber changed. Thus, at higher flow rates of water, it absorbed more CO_2. Table II provides detailed comparison of the raw biogas contents and upgraded biogas contents. Fig. 3 gives a graphical representation of the contents of raw biogas and upgraded biogas.

From Table 2, it was observed that this method would improve the methane content when the water flow rate was high, but at the same time the biogas flow rate was low. Therefore, it has been found that both the flow rate of biogas and the flow rate of water can have an effect on the performance of the biogas upgradation process. H_2S content in raw biogas was 4 ppm, which was equivalent to 5.575 mg/m^3. It is within the permissible limit as per IS:16087 (2013) and does not require any treatment for its removal [14]. From the experimental results, it was found that water scrubbing removed 50% of H_2S from the raw biogas, i.e., 4 ppm to 2 ppm. Other gases present in raw biogas and upgraded biogas might be O_2, N_2, water vapour, etc. It is observed from Table 2 that the content / quantity / proportion of other gases increases with an increase in water flow rate, it may be due to the addition of water vapour and dissolved O_2 present in water.

Table 2. Content of raw biogas and upgraded biogas

Content	% volume in raw biogas	Upgraded biogas for Sr. No. in Table 1					
		1		2		3	
		% by volume	% rise or % removal efficiency	% by volume	% rise or % removal efficiency	% by volume	% rise or % removal efficiency
CH_4	56.4	64.6	14.54	68.7	21.81	76.0	34.75
CO_2	41.6	28.9	30.52	21.6	48.08	11.8	71.63
H_2S in ppm	4	2	50	2	50	2	50
Other gases	2	6.5	-	9.7	-	12.2	-

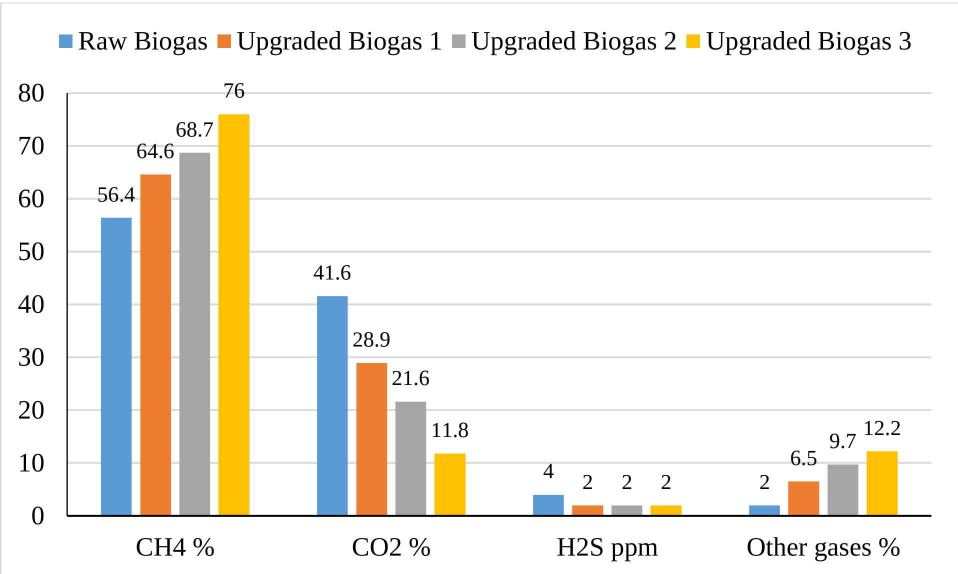

Figure 3. Content comparison between raw biogas and upgraded biogas

5. Conclusion

The present research was carried out to develop a biogas upgrading system that can be used without increasing biogas pressure to upgrade the quality of biogas in cow dung-based digester using packed-bed water scrubber. Methane and carbon dioxide present in biogas have been measured by a biogas analyzer before and after water scrubbing. The water flow rate used in the scrubbing comprised 3 levels: 1.56, 2.12, and 2.60 m^3/h, while the gas flow rates automatically adjusted according to available flow area, the biogas flow rate, were 2.916, 1.752, and 0.960 Nm^3/h. Test with the water flow rate 2.60 m^3/h and biogas flow rate 0.960 Nm^3/h, resulted in the highest CH_4 value of 76.0%. The low biogas flow rate had resulted in to increased absorption of CO_2 with large amounts of water. More is the contact of water with the biogas; greater is the degree of absorption. Water scrubbing can also remove H_2S, results showed that reduction of H_2S content from 4 ppm to 2 ppm. The test scrubber required very less power for the operation, i.e., power only for pumping the water. Upgraded biogas with 76% of CH_4 is acceptable fuel for the stationary I. C. engines for power generation purpose or for process heating purposes. In view of the cost constraints and usage by rural Indian farmers, extra purification was eliminated. However, additional enrichment methods can be considered for further upgradation of bio-gas equivalent to natural gas quality for automotive fuel or injecting into natural gas grids..

References

[1] BP statistical review of world energy 67th edition, 2018. [Online]. Available: https://www.bp.com/content/dam/bp/en/corporate/pdf/%0Aenergy-economics/statistical-review/bp-stats-review-2018-full-report.pdf.

[2] A. Demirbas, "Global renewable energy projections," Energy Sources, Part B Econ. Plan. Policy, vol. 4, no. 2, pp. 212–224, 2009, doi: 10.1080/15567240701620499.

[3] R. Chandra, V. K. Vijay, P. M. V. Subbarao, and T. K. Khura, "Performance evaluation of a constant speed IC engine on CNG, methane enriched biogas and biogas," Appl. Energy, vol. 88, no. 11, pp. 3969–3977, 2011, doi: 10.1016/j.apenergy.2011.04.032.

[4] O. W. Awe, Y. Zhao, A. Nzihou, D. P. Minh, and N. Lyczko, "A Review of Biogas Utilisation, Purification and Upgrading Technologies," Waste and Biomass Valorization, vol. 8, no. 2, pp. 267–283, 2017, doi: 10.1007/s12649-016-9826-4.

[5] http://www.mnre.gov.in/mission-and-vision-2/achievements posted 30/03/2016 (accessed Oct. 20, 2018).

[6] D. Bona et al., "The Biorefinery Concept Applied to Bioethanol and Biomethane Production from Manure," Waste and Biomass Valorization, vol. 9, no. 11, pp. 2133–2143, 2018, doi: 10.1007/s12649-017-9981-2.

[7] N. Abatzoglou and S. Boivin, "A review of biogas purification processes," Biofuels, Bioprod. Biorefining, vol. 6, no. 3, pp. 42–71, 2009, doi: 10.1002/bbb.117.

[8] R. Kadam and N. L. Panwar, "Recent advancement in biogas enrichment and its applications," Renew. Sustain. Energy Rev., vol. 73, no. September 2016, pp. 892–903, 2017, doi: 10.1016/j.rser.2017.01.167.

[9] D. R. Shah and H. J. Nagarseth, "Low Cost Biogas Purification System for Application Of Bio CNG As Fuel For Automobile Engines," Int. J. Innov. Sci. Eng. Technol., vol. 2, no. 6, pp. 308–312, 2015.

[10] D. R. Shah, H. J. Nagarsheth, and P. Acharya, "Purification of Biogas using Chemical Scrubbing and Application of Purified Biogas as Fuel for Automotive Engines," Res. J. Recent Sci., vol. 5, pp. 1–7, 2016.

[11] R. Muñoz, L. Meier, I. Diaz, and D. Jeison, "A review on the state-of-the-art of physical/chemical and biological technologies for biogas upgrading," Rev. Environ. Sci. Biotechnol., vol. 14, no. 4, pp. 727–759, 2015, doi: 10.1007/s11157-015-9379-1.

[12] M. B. Kulkarni and P. M. Ghanegaonkar, "Methane enrichment of biogas produced from floral waste: A potential energy source for rural India," Energy Sources, Part A Recover. Util. Environ. Eff., vol. 41, no. 22, pp. 2757–2768, 2019, doi: 10.1080/15567036.2019.1571126.

[13] A. Srichat, R. Suntivarakorn, and K. Kamwilaisak, "A Development of Biogas Purification System Using Calcium Hydroxide and Amine Solution," Energy Procedia, vol. 138, pp. 441–445, 2017, doi: 10.1016/j.egypro.2017.10.196.

[14] "IS 16087 (2013): Biogas (Biomethane) - Specification [PCD 3: Petroleum, Lubricants and their Related Products]," 2013