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BIOGAS UP GRADATION FOR POWER GENERATION APPLICATIONS IN PAKISTAN

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ABSTRACT

Biogas from anaerobic digestion of biological wastes is a renewable energy resource. Typical biogas contains 50-65% methane (CH_4), 30-45% carbon dioxide (CO_2), moisture and traces of hydrogen sulphide (H_2S) and can be used for power generation through internal combustion engine. Reducing CO_2 and H_2S content will significantly improve engine performance. Different techniques such as water scrubbing system, pressure swing adsorption, chemical absorption method; cryogenic separation & membrane separation available for up gradation of the biogas are compared. The biogas up gradation using the different absorbent solutions such as sodium hydroxide, calcium hydroxide & potassium hydroxide is studied in pilot plant scale. The results showed the up gradation in the methane (3-4 %) and decrease in the carbon dioxide (4-5%) & hydrogen sulfide (40-45 ppm) after the chemical absorption method.

Keywords: *Anaerobic digestion, Biogas, Chemical absorption method, Cow dung, Scrubbers.*

1) INTRODUCTION

The conventional sources of energy are depleting day by day and this fact is leading to concentrate on the renewable energy resources. Renewable energy comes from natural resources which include wind, biomass, biogas, tides, geothermal heat & sunlight, these are naturally replenished

(Bhattacharya, et al; 1998) In this regard, biogas is one of the cheapest renewable resources of energy. Biogas is not only utilized for the power production applications but also it helps in solid waste management. The world is emphasizing greatly on the establishment of this technology for energy production. Most of the countries like Germany, Italy, China, and India etc. have used this technology in their rural areas. In China, more than 5 million small biogas digesters have been constructed, at present; over 20 million persons use biogas as a fuel. In 2002, India had about 3.4 million small scale biogas plants in which each plant is used to serve single family (Khapre, 1989) In Pakistan the biogas technology is about 35 years old. Till the end of 2006, approximately, six thousand digesters have apparently been installed throughout the country as against the technical potential of five million digesters based on its appropriate climate and accessibility of feedstock, the cattle dung. In 1974, a comprehensive biogas plan started by the Pakistan government and commissioned 4,137 biogas units by 1987 in the country. PCRET, Pakistan Council of Renewable Energy Technologies is leading to publicize biogas technology and by the end of 2006 it has supported in setting up of about 1600 biogas. But still the awareness of this technology is scarce among people in Pakistan.

Tippayawong and Thanompongchart, (2010) used the method of chemical absorption for the up gradation of biogas. Chemical absorption of CO_2 and H_2S by aqueous solutions in a packed column was experimentally investigated. The aqueous solutions employed were sodium hydroxide (NaOH), calcium hydroxide ($Ca(OH)_2$) and mono-ethanolamine (MEA). Liquid solvents were circulated through the column, contacting the biogas in countercurrent flow. The results showed the up gradation in the methane up to 95% & decrease in the carbon dioxide up to 4%. Abdel-Hadi, M.A used a simple apparatus for biogas quality determination. The results obtained from the experiments can be used to analyze the quality of biogas as a function of its CO_2 percentage. Díaz, I.et al', (2010) performed for the removal of hydrogen sulphide in severely polluted biogas produced during the anaerobic digestion of sludge by employing pure oxygen, air and nitrate as oxidant reactive supplied to the bio digester.

A general approach to solve the sulphur problem in the MCFC is to prevent the formation of hydrogen sulphide at the source: favouring conditions that inhibit its production during fermentation. (Ciccoli, R. et al., 2010).

Wastes in millions of tons are produced from municipal, agricultural, and industrial sources every year. Agricultural wastes, together with livestock manure, are a further resource of solid waste which could be utilized to generate biogas. Biogas can produce by the anaerobic digestion from this solid waste to handle the energy crises in the country as well as solid waste management. However, biogas contains 30-40 % carbon dioxide & 50-3000 ppm amount of hydrogen sulfide (Alonso-Vicario et al., 2010). Hydrogen sulphide is considered as hazard to human being and animals because of its toxic nature. If biogas is used without removal of hydrogen sulphide, it may become a cause of environmental pollution due to its contribution towards acid rain production. Carbon dioxide is there in large quantities and that is further inverted in terms of combustion. The requirement to remove these gaseous components is different for the different applications of biogas up gradation & utilization as described in Table 1.

Table 1: Requirements to Remove Gaseous Components depending on the Biogas Utilization (Alonso-Vicario et al., 2010).

Application	**Carbon Dioxide**	**Hydrogen Sulphide**
Gas heater (boiler)	No	<1000 ppm
Vehicle fuel	Suggested	Yes
Natural gas grid	No	Yes
Combine Heat & Power Engines (CHP)	Yes	<1000 ppm
Kitchen stove	No	Yes

Another reason for the removal of carbon dioxide is that it is greenhouse gas and larger emissions of it may lead to produce warmer environment. If these unwanted gases like carbon dioxide and hydrogen sulfide removed from biogas, this will result in increase of methane content in gas. Also biogas can be made transportable by removing the carbon dioxide and hydrogen sulphide from the gas because the presence of these gases will badly affect the performance of engine. After removing these gases from biogas, its properties are comparable to natural gas. Hence it can be used as a fuel for the same applications, previously utilizing natural gas. Furthermore, due to the expanding prices of oil and gas, there is a need to emphasize on biogas production and up gradation which is a dually beneficial alternative resource. In this article, the up gradation of biogas produced from animal manure at the pilot plant installed at Kala Shah Kaku Campus of University of Engineering &

Technology Lahore, has been carried out and the experimental results are reproduced.

2) BIOGAS UP-GRADATION TECHNIQUES

A number of techniques are available for the up gradation of biogas. These techniques include chemical absorption method, high pressure water scrubbing, pressure swing adsorption, cryogenic separation and membrane separation method. There are two different approaches for the up gradation of biogas, named as one step approach & two step approaches respectively. Various researchers have worked for the removal of H_2S & CO_2 separately, while a number of authors have done the research of techniques for the combine removal of these elements for the up gradation of biogas to use in the power generation applications.

Shannon, 2000 worked for physical absorption technique. Bhattacharya et al., 1988 also worked for the water scrubbing process. With the help of this method, pure methane almost 100% can be get depending upon different factors e.g. size of scrubbers used in tower, pressure of the gas, water streaming speed & water cleanliness. Vijay, 2004 using locally accessible packing materials designed a scrubbing mechanism, which removed 30-35 & carbon dioxide as compared with a system without the packed bed. Khapre, 1989 intended a scrubber system of counter flow type whose pressure was 0.47 bars and the flow rate of gas was 1.764 m^3 & in flow rate of water was 0.670 m^3. It constantly removes the carbon dioxide about 30% from the gas. The G.B. Pant University of Agriculture and Technology, Pantnagar, India 2000, designed a tower for scrubbing with height of about 6m, which packed with the packing material of spherical balls shape of 25mm diameter up to height of 2.5 m. the non-treated biogas was compressed at a pressure of about 6 bar with the water circulation from the tower. By this method there is removal up to 87.5% carbon dioxide present in the raw gas. Wellinger, 1999, used the water scrubbing system in manure slush type biogas plants in France, America & Sweden. There is about 20-30% removal of carbon dioxide in the biogas by this method. Biswas et al., 1977, done the experimental work by the biogas bubbling with the ten percent solution of mono-ethanolamine, and hence there is decrease in carbon dioxide from 40% to 0.7%. An important advantage of using MEA is that it can be reutilized after boiling five mints. Membrane separation technique is another possible method for the biogas up-gradation. With the help of a thin membrane some gas

elements from the unrefined biogas could be transported. Normally the elements with less than 1 mm thickness separated by the membrane, while the other keep hold as it is. Due to the difference in the partial pressure the respective components are transported through the membrane, which is depending upon the component's permeability in the membrane. Cryogenic process for the up gradation of biogas includes the partition of the mixtures of the gas by partial condensation and distillation with low temperature. The main advantage of this technique is that it permits to recover the up graded component in liquid form, which is easily transportable. This work was carried out in Los Angeles County Sanitation, who tried for the removal of carbon dioxide but couldn't get the required results. The drawback of this system is that it requires high capital cost and utility demands (Berndt, 2006).

Biogas can be converted into bio methane with the help of two steps; a cleaning process to remove the trace components and an upgrading process to adjust the calorific value. Upgrading is generally performed in order to meet the standards for use as vehicle fuel or for injection in the natural gas grid (Ryckebosch, E., et. al., 2011).

2.1) Comparison of Techniques:

Different methods have been described for the removal of the unwanted elements from biogas. Chemical absorption technique seems to be efficient for the up gradation because absorbent are available specifically for the removal of the different gas species, in which normally no risk of methane removal. An imperative benefit of this technique is that it does not require any special environmental conditions. This process normally carries at the atmospheric conditions. Almost all hydrogen sulfide elimination carried out by using this method. But there is need of safety precaution before using this technique because of the presence of toxic gases; due to which there is chance of chemical leakage.

In high pressure scrubbing of water the effects of dissolution of gases take place physically. Due to the solubility difference in the water hydrogen sulfide & carbon dioxide dissolves in the water, whereas methane does not dissolved. A large amount of water needed for the water scrubbing technique. This technique is not suggested, when the compositions of the hydrogen sulfide are high, since the water can turn out to be polluted with plain sulfur which can cause operational troubles.

The pressure swing adsorption techniques divide some of the gas contents at some specific pressure of the gases mixture. Hydrogen sulfide adsorbed by the adsorbent material in irreversible way. The major disadvantage of this technique is that it requires a separate mechanism or set up for the removal of hydrogen sulfide. Next technique was cryogenic separation in which different gases present in the biogas distillated under the cryogenic conditions. These gases can be liquefying at certain temperature and pressure. By using this process comparatively larger quantities of the products with high purity rates can be achieved. The drawback of this method is that it involves the use of several equipment and devices, for example: compressors, heat exchangers, turbines, insulators, and columns.

Another possible method for the up gradation of biogas is through membrane separation. Due to filter present in the membrane carbon dioxide & hydrogen sulfide go through the membrane while methane does not. This technique is simple, but the problem with the cost of the membranes which are costly.

3) EXPERIMENTAL SET-UP

3.1) Materials:

Cow dung used as input material for the production of biogas. Different scrubbers were used for the up gradation of the biogas. The objective was to remove the carbon dioxide and hydrogen sulfide from the biogas. H_2S & CO_2 scrubbers were installed at pilot scale plant. Biogas produced at the plant passed through these scrubbers. One scrubber contained Iron Sponge for the removal of hydrogen sulfide & the other contained Activated Charcoal for the removal of carbon dioxide from the biogas. Similarly, the biogas reacted with the different solutions of hydroxides for up gradation. One molar Solutions of Sodium Hydroxide (NaOH), Potassium hydroxide (KOH) & Calcium hydroxide ($Ca(OH)_2$) were prepared. The gas passed through these solutions & the up gradation of the biogas recorded after this process.

3.2) Plant Description:

The present work was carried out the pilot plant of Biogas installed at KSK Campus, University of Engineering & Technology Lahore. The plant

producing the biogas average $7m^3$ per day. Cow dung used as input resource at the plant. Plant is shown in the Figure 1 below. The average temperature of the digester was 30~35°C & pressure of 90-120 mbar. The cow dung & water used in the mixing tank unit with proportion of 1:1

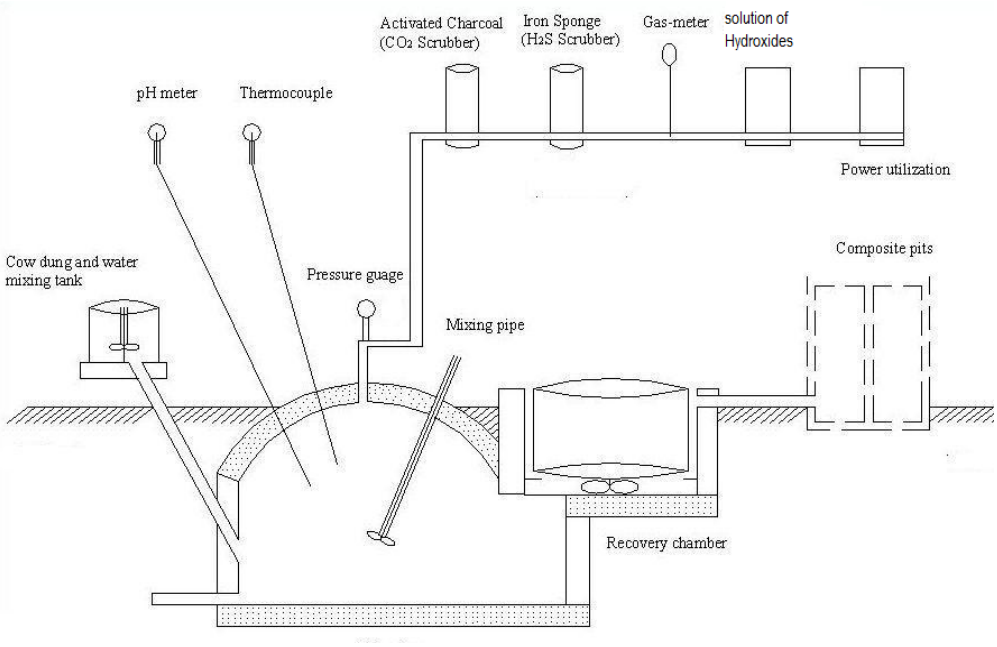

Fig. 1: Schematic Diagram of Biogas Plant KSK Campus.

3.3) Instruments Used

The ATEX Certified, Portable Gas Detector used for biogas analysis. Analyzer has two modes Standard Mode & Biogas Mode. Biogas Mode was for the detection of CH_4 and CO_2 (0-100% Volume) of a gas sample and the protection of personnel working within this environment by also measuring the background levels of oxygen and H_2S.

4) RESULTS & DISCUSSION

Fig. 2 shows the two weeks data for the quality of the biogas produced at the pilot scale plant. Current study was focused for the removal of carbon dioxide & hydrogen sulfide from biogas.

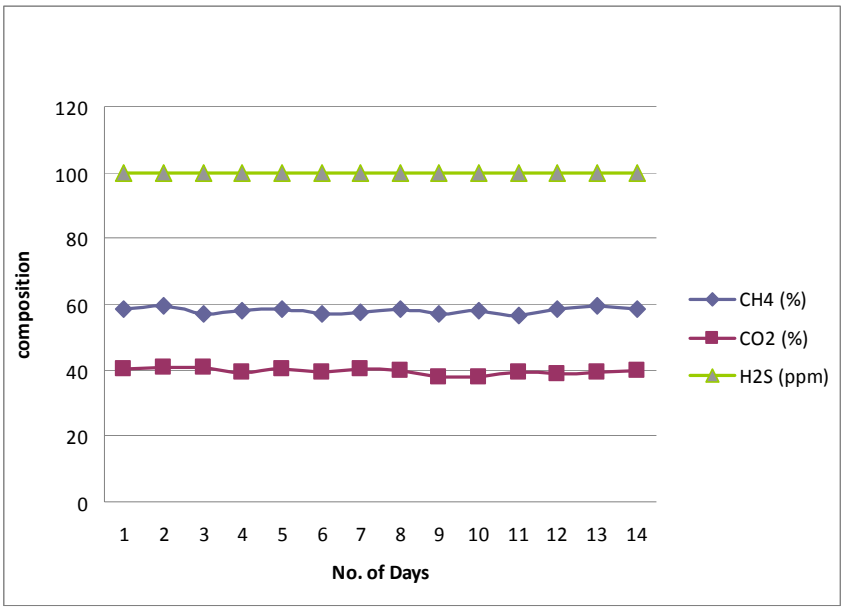

Fig. 2: Raw Biogas Data

Fig. 3 compares the percentage of methane before and after the up gradation through chemical absorption method. It is clear from the figure that the sodium hydroxide solution upgraded more than that the other hydroxides. This is due to the fact that Sodium hydroxide is the principal strong base than the other hydroxides. The OH−, a highly nucleophilic anion present in the solution attacks polar bonds in both inorganic and organic materials.

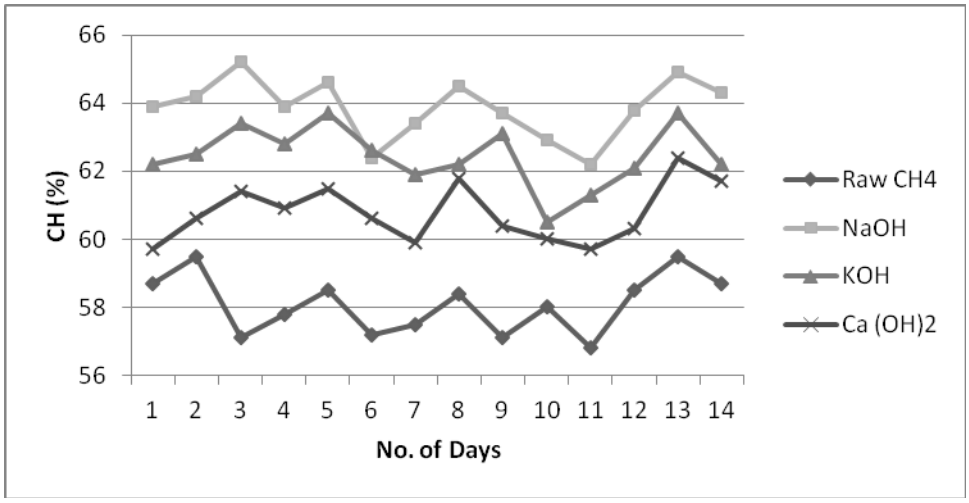

Fig. 3: Up gradation of Methane

In this method the CO_2 is also absorbed and transferred into aqueous 1M solutions of hydroxides. Fig. 4 shows the removal of carbon dioxide, when reacted with the solution of hydroxides of sodium, potassium & calcium. 4-5% removal in the carbon dioxide was noted during the experimentation.

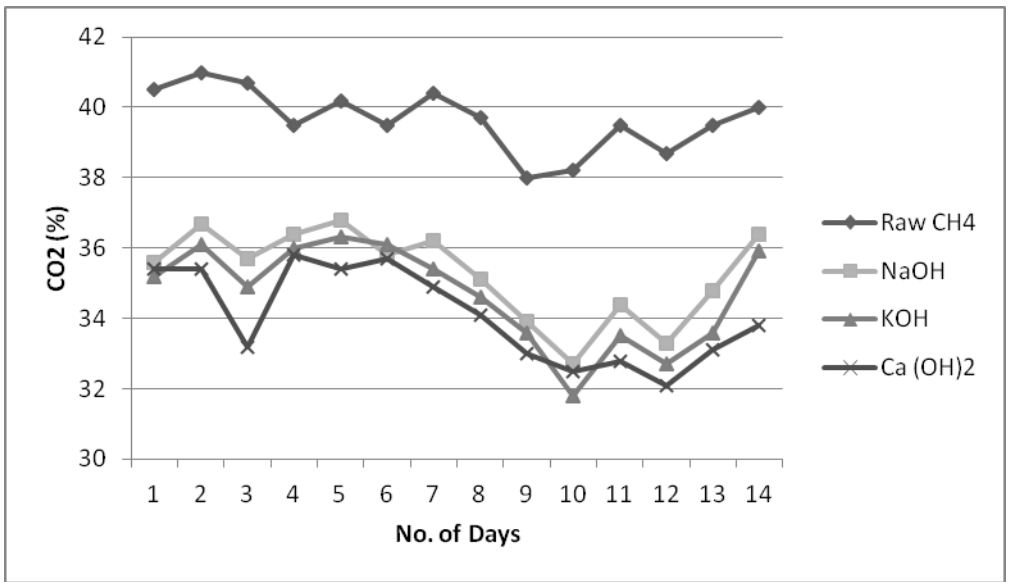

Fig. 4: Removal of Carbon Dioxide

Fig. 5 shows the level of H_2S level reduced in the biogas by passing the gas through activated carbon. Activated carbon used to remove both H_2S and CO_2. Activated carbon catalytically converts H_2S to elemental sulfur. Then the gas passed through iron sponge filter. Hydrogen sulfide then scrubbed out from biogas in hydroxides solution solutions.

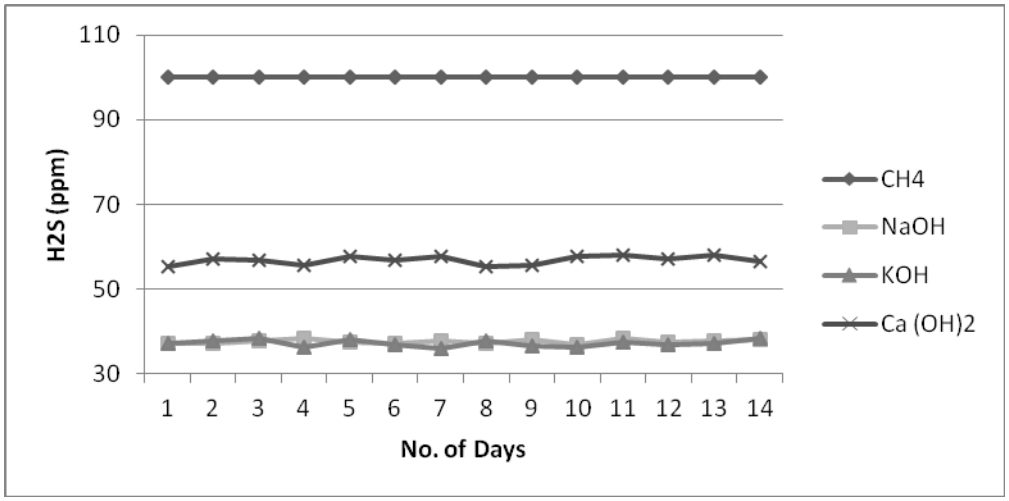

Fig. 5: Removal of Hydrogen Sulphide

The average up gradation in the biogas, when treated with the iron sponge & activated charcoal & then passing through the solutions of sodium, potassium & calcium hydroxides after the removal of the carbon dioxide & hydrogen sulfide is shown in the table (2). Table shows that carbon dioxide removed up to 4-5 % % hydrogen sulfide as 55-60 ppm. This method is locally designed & implemented at pilot plant installed at KSK campus. The system requires no energy for operation. These are the initial experimentation result for which the biogas data taken for 14 days.

Table 2: Average Up-gradation of Biogas

	Raw Biogas	**NaOH**	**KOH**	**$Ca(OH)_2$**
CH_4 (%)	58.09	63.85	62.44	60.77
CO_2 (%)	39.67	35.27	34.69	34.08
H_2S(ppm)	100	37.65	37.24	56.8

The environmental impact of the upgrading processes is an important factor that can be used to compare the different techniques. If the pollutants that are removed from biogas during upgrading are emitted in the atmosphere, the contamination of the environment will run counter to the goal of producing an environmentally-friendly fuel to replace current fossil fuels. During the upgrading process CO_2 is emitted in the atmosphere as a waste stream. The used amine solution must be replaced a few times a year and thus is also a waste. This solution can be separated

into a water phase and the amines using a membrane. The clean water phase can then be purged to a river.

5) CONCLUSIONS

Biogas cleaning experimentation was done with the help of Chemical Absorption Method at biogas plant KSK campus. The results showed the up gradation in the methane (3-4%) & decrease in the carbon dioxide (4-5%) & Hydrogen sulfide (40-45 ppm). Hydrogen sulfide reacts with iron oxides to form iron sulfide. The chemical solutions used were sodium hydroxide, potassium hydroxide and calcium hydroxide. The upgraded biogas will be utilized for cooking, heating, lightening & electricity.

In the present energy crisis, biogas utilization after up gradation can be one of the cheapest methods for the power generation applications. Biogas can be used as transportable fuel & for all other applications designed for the natural gas after the removal of these elements. By adopting the cleaning of biogas the waste manure of dung can be managed i.e. this is the best way of solid waste management as well.

6) ACKNOWLEDGMENT

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7) REFERENCES

Abdel-Hadi, M., "A simple apparatus for biogas quality determination", Misr J. Ag. Eng., Vol. 25, PP. 1055-1066.

Alonso-Vicario, A., Ochoa-Gómez, J.R., Gil-Río, S., Gómez-Jiménez Aberasturi, O., Ramírez-López, C.A., Torrecilla-Soria, J. and Dominguez, A., (2010), "Purification and upgrading of biogas by pressure swing adsorption on synthetic and natural zeolites",Microporous and Mesoporous Materials, Vol. 134, pp. 100–107.

Bhattacharya, TK., Mishra, TN. and Singh, B. (1988), "Techniques for removal of CO_2 and H_2S from biogas", in 24th annual convention of ISAE in PKV, Akola 1988.

Biswas, TD., Kartha, ARS. and Pundarikakhadu, R. (1977), "Removal of carbon dioxide from biogas", in Proceedings of national symposium on biogas technology and uses in New Delhi, IARI 1977.

Berndt, Dr. A.S. (2006), "Intelligent Utilization of Biogas-Upgrading and Adding to the Grid", Jonköping, May 2006.

Ciccoli, R., Cigolotti, V., Lo Presti, R., Massi, E., McPhail, S.J., Monteleone, G., Moreno, A., Naticchioni, V., Paoletti, C., Simonetti, E. and Zaza, F. (2010), "Molten carbonate fuel cells fed with biogas: Combating H_2S", Waste Management, Vol. 30, pp. 1018–1024.

Díaz, I., Lopes, A.C., Pérez, S.I. and Fdz-Polanco, M. (2010), "Performance evaluation of oxygen, air and nitrate for the micro aerobic removal of hydrogen sulphide in biogas from sludge digestion", Bio resource Technology, Vol. 101 pp. 7724–7730.

Khapre, UL. (1989), "Studies on biogas utilization for domestic cooking", in 25th annual convention of ISAE in CTAE, Udaipur 1989.

Ryckebosch, E., Drouillon, M. and Vervaeren, H. (2011), "Techniques for transformation of biogas to bio methane", Bio Mass and Bio Energy, Vol. 35 pp. 1633-1645.

Shannon, R. (2000), Biogas conference proceedings, available at: http://www.rosneath.com.all/ ipc6/ch08/shannon2/.

S.S. Kapdi, V.K. Vijay, S.K. Rajesh, Rajendra Prasad, (2004), "Biogas scrubbing, compression and storage: perspective and prospectus in Indian context", Centre for Rural Development and Technology, Indian Institute of Technology, New Delhi 110 016, India.

Tippayawong, N. and Thanompongchart, P. (2010), "Biogas quality upgrade by simultaneous removal of CO_2 and H_2S in a packed column reactor", Energy, Vol. 30, pp. 1-5.

Wellinger, A. and Lindeberg, A. (1999), "Biogas upgrading and utilization", Task 24: energy from biological conversion of organic wastes, PP. 1–19.