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Upgradation Of Biogas Using Combined Method Of Alkaline Water Scrubbing And Adsoption Through Carbon Molecular Sieve

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Abstract: Over the past decade there is increasing demand of energy in rural, urban areas of India. This has led to the depletion of natural resources like coal, wood and kerosene. These sources are inefficient and harmful to the environment. Thus there is an imminent need to replace them with clean, eco-friendly and efficient source of energy.

Biogas is an inexhaustible energy source which is clean efficient and environmental friendly, but its efficiency needs to be improved. We have opted the water scrubbing technique along with use of adsorbent such as molecular sieve for the purification of biogas. Water (alkaline) scrubbing removes carbon di oxide, hydrogen sulphide more efficiently than normal water scrubbing and enhances the concentration of methane which promotes easy packing, carriage and storage of biogas thereby enhancing its utility as a fuel.
Keywords: Biogas, Combined Method, Alkaline Water Scrubbing, Adsoption Through Carbon Molecular Sieve,

Introduction:

The renewable sources of energy are on the verge of being depleted.The present use of fossil fuels is rapidly depleting the natural reserves of coal and natural gas. The formation of fossil fuels naturally is however a very slow process which takes hundreds and thousands of years. Therefore, a lot of research is being going on to find renewable fuels nowadays to replace fossil fuels. A renewable fuel keeps environmental balance and contribute to a lesser contribution to the greenhouse effect.The energy crisis in rural areas is increasing. Moreover, the energy demand is growingevery day and the oil prices are increasing every day. Due to above facts there is need to look for decentralized energy options in rural areas[7].

Energy from Biomass is one of the most widely used options. With the advancement in new technologies there are various means to convert biomass into energy efficiently. Biogas consists mainly of methane and carbon dioxide and it can be utilized as a renewable energy as a substitute for natural gas. It is produced during anaerobic digestion of organic substrates, such as manure, sewage sludge, the organic wastes of household and industries, and agriculture.

Generation and upgradation of biogas has several environmental advantages such as:

• It is a renewable energy source.

• It can be used as a substitute for fossil fuels for e.g. in cooking.

• It reduces the release of methane to the atmosphere much less than traditional method such as landfills or manure management.

Biogas reduces indoor air pollution because it burns with more blue (i.e. clean) flame. By which women do not have to breathe wood smoke, which is a major cause of respiratory and eye disease and responsible for an estimated 1.6 million deaths each year[1].

The high quality digestate from biogas plants makes a good fertiliser with minimal smell. The fertiliser value can be improved by composting the residue with crop waste, and feeding the compost to earthworms for additional processing (vermicomposting).

The normal composition of biogas is:

Gases	**Percentage %**
Methane CH_4	52-70
Carbon dioxide CO_2	34-45
Hydrogen sulphide H_2S	11-16mg/Nm3
Water H_2O	5-7
Nitrogen N_2	Trace

However, the incombustible part of biogas, CO_2, lowers its calorific value. On average, the calorific value of biogas is 21.5 MJ/m3 whereas that of natural gas is 35.8 MJ/m3. By removing CO_2 from the biogas the calorific value is increased. Stripping CO_2 and H_2S from biogas is the so called upgrading of biogas. By upgrading biogas to natural gas quality, containing approximately88% CH_4, it is suitable for more advanced applications in which the heat is not wasted, resulting in a higher efficiency.

The process of upgrading biogas generates new possibilities for its use since it can then replace natural gas. However, upgrading adds to the costs of biogas production. It is therefore, important to have an optimized upgrading process in terms of low energy consumption and high efficiency giving high methane content in the upgradedgas. The energy content of biogas is in direct proportion to the methane concentration and by removing carbon dioxide in the upgrading process the energy content of the gas is increased.

Experimental/Methodology:

Generation of Biogas:

A simple biogas plant consists of a digester, collection tank and gas storage tank. The biomass is fed into collection tank which is mainly in the form of *Butea monosperma* (Common name Palash), animal dung, vegetable wastes from homes, leftover food, sewage and manure. From the collection tank the biomass is decomposed anaerobically in the digestate by various microorganisms and bacteria, which feed upon it to release various gases known as biogas. In order to produce biogas efficiently, it is required to maintain the temperature of microbes at 37 degree centigrade in the digesting slurry tank. For this purpose the water is heated through a simple solar water heater and circulated in the drum through copper tubes.

Here, in this project we are using food waste as slurry as it breaks down and produces gas more quickly than dung, so the slurry does not need to be held for a long period, and food waste plants are therefore smaller and more suitable for urban homes. A family or community using just their own food waste can replace between 25% and 50% of their cooking fuel. However, small amount of cattle dung is used as a starter since it contains suitable bacteria responsible for producing biogas.

Our Approach Towards Upgradation Of Biogas:

To increase the efficiency of the biogas plant whether big or small, it is hence necessary to remove the undesired gases like CO2, H2S and H2O.

A variety of processes are being used for removing CO_2 from natural gas in petrochemical industries. Several basic mechanisms are involved to achieve selective separation of gas constituents. These may include physical or chemical absorption, adsorption on a solid surface, membrane separation, cryogenic separation and chemical conversion.

Our upgradation technique involves passage of the compressed gas through a cylindrical pipe of about 2 meter long. The pipe is compacted with nut bolts to obtain air tight conditions. The gas is injected at the bottom of the pipe whereas water is jetted at the top. Our set up consists of 4 cylindrical pipes. In the first two pipes we scrub the biogas with alkaline water. The scrubbed biogas which is now highly enriched in methane with minute traces of other gases is then passed into the third pipe. The pipe is packed with carbon molecular sieves. To enrich methane from biogas the molecular sieve is applied which is 10ppm water and methane content of 88% or more. In the second column the pressure of 6 bars is first released to approx. 3 bars by pressure communication with column 4. The released gas flows back to the digester in order to recover the methane[2]. Hence we are able to purify our biogas using two methods simultaneously i.e. alkaline water scrubbing method as well as adsorption through molecular sieve.

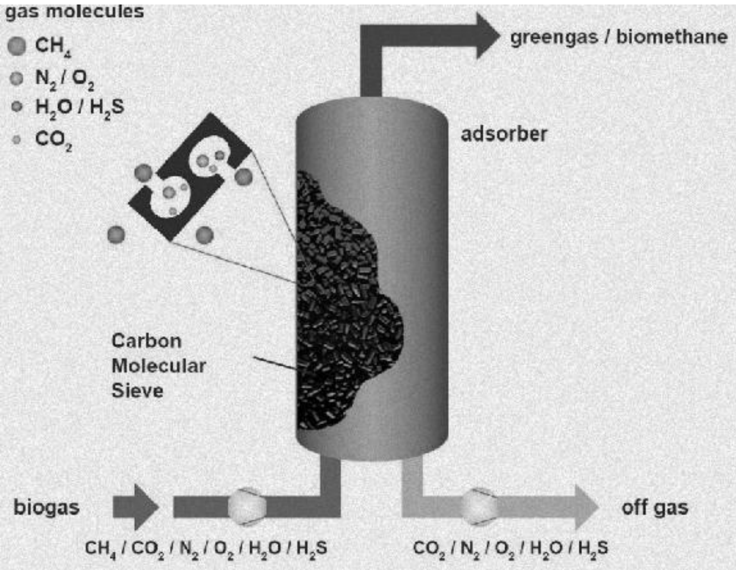

Fig: Setup Of How A Molecular Sieve Works[4]

Fig: Setup For Biogas Purification Using Scrubbing An Adsorption Method.

Results

The composition of the inlet biogas was around 58-60% of methane and about 35-38% carbon dioxide. The operation involves removal the content of carbon dioxide from the biogas. In the scrubbing technique which was employed by us, the raw biogas was fed from biogas plant into the bottom of the pipe. Biogas is fed to a column where it is “washed” with counter-current water that is sprayed from the top of the column.

The main emphasis is on the fact that we used alkaline water whose ph. is near about 9, water is alkalined using NaOH, because it also reacts strongly with carbon dioxide.

$$CO_2 + H_2O \rightleftharpoons 2H^+ + CO_3^{2-} \rightleftharpoons H_2CO_3.$$

1. According to Le-chatelier’s principle, if we increase the concentration of OH^- on the left side,

then the solubility of carbon dioxide will increase in water.

2. Solubility also increases on increasing pressure[2].

$$CO_2 + H2O \rightleftharpoons H_2CO_3$$

This relation can be described by Henry’s Law:

Pi = H Cmax

Cmax Saturation concentration of the component [mol=m3]

H Henry’s coefficient [Pa _ m3=mol]

Pi Partial pressure of the component [Pa]

3. The column is normally filled with some material to enhance the interface area promoting CO_2 absorption[9].

4. The solubility of CO_2 gas in water strongly increases at lower temperatures. In order to reducepumping energy, the water should be available at low temperatures. Therefore we supply cold water at to maintain the required conditions.

The solubility of carbon dioxide in water is more than the methane gas. We carry this procedure in the first two pipes[8].

In the third pipe we use adsorption technique using carbon molecular sieve. The reason for using the sieve in the last two pipes is that the biogas still contains certain amount of carbon di oxide and moisture. By using the adsorption technique the carbon di oxide gas is adsorbed and we are further able to purify the gas. The material selected should at least satisfy one of two criteria:

1. Have a higher selectivity to CO_2: this gas should be more “attached” to the surface of the material than CH_4; in most solids CO_2 can create stronger bonds with surface groups than CH_4. This kind of materials will be termed as equilibrium-based adsorbents since. Its main selectivity is due to differences of interaction forces between $CO_2$and CH_4 with and the surface[6].

2. The pores of the adsorbent can be adjusted in such a way that CO_2 (kinetic diameter of 3.4 Ǻ) can easily penetrate into their structure while larger CH_4 molecules (kinetic diameter of 3.8 Ǻ) have size limitations to diffuse through them. These materials will be termed as kinetic adsorbents since its main selectivity is due to diffusion constrains.

We have used carbon molecular sieve,this material has a clear selectivity towards CO2, but the most important property in CMS-3K is not its equilibrium selectivity, but the kinetic selectivity. In this material, CO2 adsorbs much faster than CH4.

The purified biogas contains about 80-88% of methane which enhances its efficiency. The pressure in the columns is regulated by pressure controllers.

Parameter	Biogas	Upgraded Biogas	Natural gas
Methane [vol%]	50-70	80-90	89
Other hydrocarbons [vol%]	0	0	9.4
Hydrogen [vol%]	0	0	0
Carbon dioxide [vol%]	30-50	10-15	0.67
Nitrogen [vol%]	up to 1	up to 1	0.28
Oxygen [vol%]	up to 0.5	up to 0.5	0
Hydrogen sulphide [ppmv]	0-4000	0-100	2.9
Ammonia [ppmv]	up to 100	up to 50	0

Conclusions

The high pressure water scrubbing we used is a much simple andeasier process, compared to the other techniques. It can remove both H_2S and CO_2using a water stream, and can handle different temperatures and moisture content.

[3]However, the amount of water that has to be used for this process can become very large. This is an aspect looked carefully during this research, by using slightly alkaline water the solvability of carbon dioxide and hydrogen sulphide increased and amount of water needed also decreases.

Pressure swing adsorption is used in many upgrading processes. It is a technique which results in a high CH4-enrichment, without having a lot of emissions while the needed power is relatively low. But, on the other hand, when using this process, an extra step is needed to remove the H2S.

We have solved this problem by using water scrubbing in the above process in which H_2S is already removed as H_2SO_4.

The main advantages of our process are:
- A high CH4-enrichment
- Low power demand
-Low cost of upgradation.

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