Bioenergy from Filter Cake in Indian Sugar Industry

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Abstract— The most important environmental challenge faced by the world is the waste management which is generated from various agro processing industries and sugar industry is no exception. Thus emphasis is being given on minimization of waste and on increasing revenue generation through utilization of by-products in an innovative manner. With the depleting natural resources, increasing demand for green and clean energy in place of conventional system using from fossil fuel, there is indeed a need to explore alternatives that maintain the ecosystem balance and also the requirements of the society without affecting the natural resources. One such rational approach towards economic and environmental sustainability is adoption of bio-energy systems with a vision to save fossil energy. Converting a conventional sugar mill into a bio-energy process plant would contribute to fossil energy savings via renewable electricity, bio-gas/bio-CNG and ethanol substituting for fossil electricity and gasoline, respectively. One of the advantages of using bio-energy system is their low greenhouse gas (GHG) emissions compared to fossil-energy ones. The present work examines the possibilities of utilizing filter cake from sugar factories for production of bio-gas, compressed bio-gas/bio-CNG, thereby addressing the environmental issues and successful transformation for value addition.

Keywords: Greenhouse gas (GHG) emissions, filter cake, bio-energy, value-addition, bio-gas

I. Introduction

Since industrialization, use of fossil fuels has inflated the rate of carbon emissions into the atmosphere. This increased level of carbon footprint in the environment is hard to be quickly assimilated by nature and hence their accumulation results in global warming and other climatic changes. The concentration level of CO_2 in the atmosphere is now at a critical stage and required measures are to be taken by all to reduce the trend in which the level of CO_2 is increasing in the atmosphere. Indian sugar industry is the second largest agro-based industries in the country which generates various solid wastes such as sugarcane trash, bagasse, filter cake and bagasse fly ash. These by-products of the sugar industry can either be considered as waste, affecting the environment, or can be looked upon as a resource when put to proper use through implementation of appropriate valorization technology. Production of green energy through use of bagasse for power generation, utilization of cane juice and molasses for production of bio-ethanol for blending in petrol has already gained favour in the sugar industry. However, there are various other alternatives that can be adopted for developing green energy and among them; bio-gas/bio-CNG seems to be one of the most promising and best alternatives to the present fossil fuels [1]. There are number of countries which have different bio-gas plant set-ups in their vicinity and are in the process of installing more e.g. Italy has doubled the bio-gas plants in 2013 and they are being increased further. Biogas is an eco-friendly fuel which is produced by the anaerobic digestion of different organic and inorganic wastes. In our day to day life we come across different forms of waste such as municipal solid waste, food waste, industrial waste, sewage sludge, animal manure and agricultural residue having the potential to be converted in to bio-gas [2].The use of bio-gas or compressed biogas/bio CNG will not only help to preserve the non-renewable energy resources but will also decrease dependence on scarce fossil resources and will also lead to decrease in green house emission and earning additional revenue in case of sugar factories.

India sugar factories crushed about 300.0 million MT of sugarcane during the crushing season 2018-19. Considering filter cake % cane been about 3.5 and limited option available for its gainful commercial exploitation, this by-product keeping in view the presence of organic material can be used for production of bio-gas, compressed biogas/ bio-CNG. The filter cake obtained from sugarcane based sugar factories usually consists of 72-75 % moisture, 8-10% ash and 20% of volatile solids along with 74-75% of organic matter on solids.

The basic principle involved in the production and optimization of biogas is anaerobic digestion i.e. decomposition taking place in the absence of oxygen [3]. The percentage of the gas produced from anaerobic process depends upon various factors like pH, temperature, organic matter and efficiency of scrubbing etc. The residue which is left after decomposition can be used as fertilizer. After the anaerobic digestion, from the residue separation of solid and liquid residue may be carried out to obtain solid and liquid fertilizer as required [4]. The main output is a gas which has the properties similar to LPG and can be used for cooking purpose or it can be converted into bio-methane or bio-CNG for use as vehicular fuel after required purification.

II. Compressed Bio Gas (CBG) Sources in India

The graphical presentation at Fig. 1 gives an idea of total compressed bio-gas potential in the country which is estimated to be about 62 million metric tonnes per annum. Out of it, spent wash obtained from molasses based distilleries and filter cake (press mud) from sugar factories can contribute to the extent of about 2 million metric tonnes per annum.

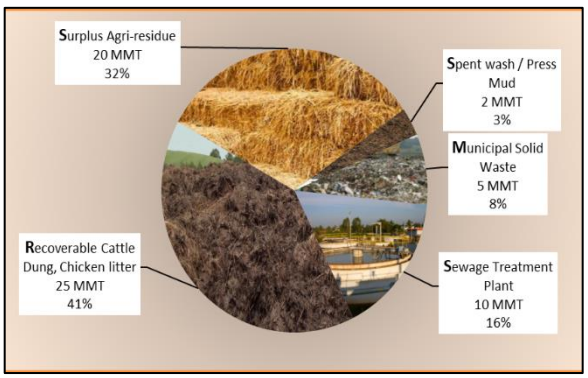

Fig. 1: Total CBG potential: 62 MMT

III. BIOGAS AND COMPRESSED BIOGAS/BIO-CNG

Biogas is formed by anaerobic digestion using bacteria formed due to biodegradation of organic waste material. Biogas formed consists of methane, carbon dioxide and small amounts of H_2S, N, CO and O_2. Methane is considered the most important one with respect to use of biogas as fuel. It is pertinent to mention here that it is the methane content in the gas which determines its quality and characterizes it as biogas or compressed bio-gas/bio-CNG. While biogas is used for domestic purposes, compressed bio-gas/bio-CNG is employed as automotive fuel necessitating higher methane content and least of other impurities.

A general composition of biogas and compressed biogas/bio-CNG is given in table 1.

Parameters	Biogas	Compressed Biogas
Methane (v/v)	55-65 %	92-98 %
CO_2 (v/v)	35-45 %	2-8%
H_2S (ppm)	500-30,000	< 20 ppm
Other Impurities	Present	Mostly removed, Not present
Calorific Value (LCV)	19500 kJ/Kg	52000 kJ/kg

Table 1: Characteristics of Biogas and Compressed-Biogas

IV. COMPOSITION OF FILTER CAKE:

The filter cake obtained from sugarcane based sugar factories usually consists of 72-75% moisture, 8-10% ash and 20 % of volatile solids along with 74-75% of organic matter on solids. However, it varies to certain extent depending upon the sugarcane quality and also on clarification process adopted by the sugar factory i.e. defecation, sulphitation and carbonation. General composition of filter cake from plantation white sugar factories adopting Double Sulphitation Process is as given in table 2.

Sr. No.	Parameter	Average Values (% w/w)
1.	Moisture	72-75
2.	Ash	8-10
3.	Volatile Solids	18-22
4.	Organic matter on solids	72-76
5.	Sugar	1.5-2.0
6.	Wax	6-7
7.	C/N ratio	13-15

Table 2: Characteristics of Filter Cake

V. PROCESS FOR COMPRESSED BIO-METHANE PRODUCTION

A typical process flow for production of compressed bio-gas/bio-methane/bio-CNG is shown in fig. 2.

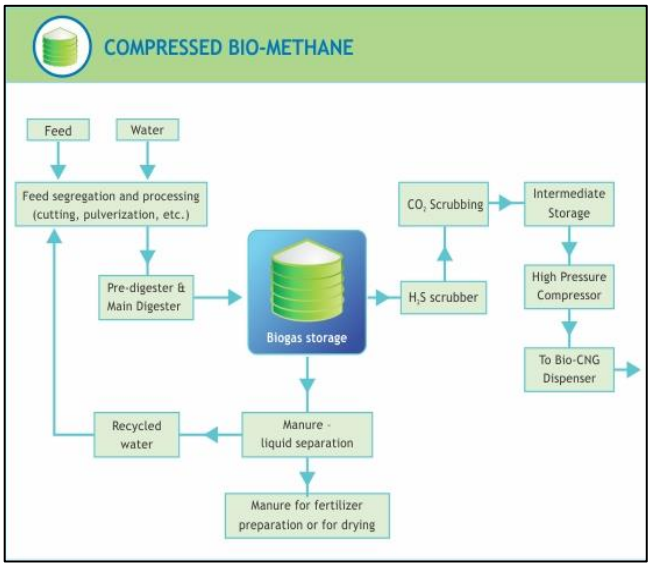

Fig. 2: Diagrammatic Representation of Compressed Bio-Methane Production

The different stages for optimization in production of compressed biogas/compressed bio-methane or bio -CNG are as shown in fig.3

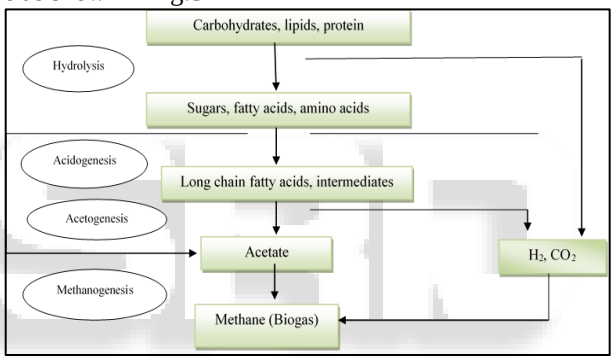

Fig. 3: Chemistry of Anaerobic digestion

The producer gas is scrubbed to eliminate the carbon di-oxide and hydrogen sulphite which are formed along with raw gas. This process is necessary because higher concentrations of H_2S gas can cause corrosion to some biogas plant parts, such as the combined heat and power units (CHP), biogas upgrading systems, and metal pipes and tanks, leading to high costs of maintenance [5]. During this process, the raw gas is absorbed then filtered and the methane content per unit volume of gas is increased which is required for bio-gas or bio-methane or as the case may be.

A. Material & methods:

Laboratory trials were taken up at the institute with the filter cake obtained from institute's experimental sugar factory and also from neighboring commercial sugar factories. Various combinations of filter cake with other feed stocks e.g. sewage, spent wash and farm yard manure (FYM) were tried and based on the findings of laboratory trials, the most appropriate combination was tried on pilot plant scale at the institute.

B. Laboratory Trials:

Laboratory trials with different combinations of filter cake and other feed stocks were conducted as per table no. 3 to assess potential of biogas or bio-methane generation:

S. No.	Substrate	Percentage
1	Filter Cake: FYM	80:20
2	Filter Cake: FYM	60:40
3	Filter Cake: FYM	30:70
4	Filter Cake: Sewage	50:50
5	Filter Cake: FYM : Sewage	50:25:25
6	Filter Cake: FYM : Spent Wash	50:25:25
7	Filter Cake: FYM : Spent Wash : Sewage	50:17:17:16
8	Filter Cake: FYM : Green leaves	50:40:10
9	Filter Cake : FYM : Spent Wash: Green Leaves (fine particles)	50:25:15:10
10	Filter Cake: FYM : Spent Wash: Green Leaves (chopped)	50: 25:15:10

Table 3: Combinations of filter cake and other feed stocks used

C. Pilot Plant Trials:

On the basis of the laboratory trials conducted the best combination was observed as Filter Cake: FYM (80: 20), which was taken up further for pilot plant trials at National Sugar Institute, Kanpur, India.

Filter Cake (Slurry Consistency) - Moisture Content in filter cake was about 75-78% and the total solid content in the feed stock had been about 22-25%.

Pilot Scale Plant (Batch type) comprised of:

1) Batch type Reaction tank of 500LCapacity.
2) CO_2 Scrubbing through 20% Lime Water.
3) H_2S Scrubbing through 20% Iron Oxide.
4) Compressor and a Gas Reservoir.
5) Gas Analyzer required for measuring the quantity and purity of gas formed viz. Methane, CO_2, H_2S, CO and O_2

VI. Observations

1) The batch stirred tank bioreactor operating under mesophilic conditions (temperature at about 30-35˚C) was used to investigate the Hydraulic Retention Time (HRT) on anaerobic digestion of filter cake.
2) The gas formation took place after 15-20 days (methane content 30- 45 %) and peak gas generation was observed between 20 to 40 days (methane content 60- 90%).
3) 30 Kg of filter cake gave about 1 Kg of purified biogas or bio-methane having methane content around 95%.
4) The exhausted residual slurry may be used as bio-fertilizer for which further studies are being taken up.
5) Bio-gas, bio-methane/bio-CNG produced from filter cake in combination with other feed materials as a result of anaerobic reaction with scrubbing may serve as clean energy. However, since scrubbing costs may be significant, as discussed in the subsequent paragraphs, trials of available technologies shall have to be made to ascertain the most cost effective one.
6) The bio energy may be utilized for many commercial activities viz. as a kitchen fuel to fuel for vehicles.
7) Such utilization of the filter cake may open new area for utilization of filter cake for value addition to the sugar industry.

VII. Future Plan of Action:

1) Further studies shall be taken up after scaling up the experimental set up.
2) The experiments shall be conducted with filter cake obtained from various agro climatic zones under various conditions of filter cake quality, combination of filter cake and other feed stocks to validate the data and optimize the process parameters.
3) Since quality of bio methane and bio-CNG depends largely on scrubbing efficiencies it is proposed that following methods shall be tried and most appropriate may be adopted for removing H_2S:
   - Biological Fixation
   - Iron Chloride Dosing
   - Water Scrubbing
   - Activated Carbon
   - Iron Chelating
   - Amine Scrubbing
4) Similarly following methods shall be tried for removing CO_2 and shall be adopted considering their efficiency and cost economics.
   - Pressure Swing Adsorption (PSA / VPSA)
   - Chemical Scrubbing
   - Water Scrub
   - Membrane Separation
5) To work out the cost of production of bio-gas/bio-methane, bio-CNG

VIII. Conclusion

Keeping in view the environmental concerns, the future is for green sustainable renewable energy. Using biomass can be an efficient way to reduce carbon emissions in the atmosphere and is also a good way to have a sustainable source of energy A potential market for biogas/compressed biogas or compressed bio-methane or so called bio-CNG is available in the India which needs to be harnessed.

With proper investment and planning, this untapped potential can be exploited which will also help in value addition for the sugar factories. However, more studies are required to be taken particularly with respect to cost of production, scrubbing costs and potential of biogas or compressed biogas generation during the off season due to likely hood change in the quality of stored filter cake.

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