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FULL LENGTH ARTICLE

Design of Small Scale Anaerobic Digester Using Kitchen Waste In Rural Development Countries

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ABSTRACT

This paper deals with the design and fabrication of a food waste based biogas generation system. An experimental setup is designed and implemented and the paper illustrates the of biogas plant compared to Liquid Petroleum Gas. Also the paper explains the method of transportation of waste food from different locations to multiple biogas plants.
Keywords: *Biogas, Food Waste, Bacteria, Chemical analysis, LPG*

INTRODUCTION

Most of the families in India depend on L P G for cooking and the demand is increasing day by day. We have to spend a large amount of foreign exchange for importing crude oil. Also, in a densely populated nation like India, disposal of waste food, creates the problem of environmental decay and hence needed to be handled properly. Gobar gas plants developed in 80's were not effective because they could be implemented in villages. In addition, gobar gas plants are not effective due to less heat generation [1]. Biogas plant can be easily implemented in urban or rural areas where waste food with high starch content is available which can be used to produce methane gas and remaining slurry can be used as manure [2]. If 20 % of L P G is replaced by waste food based bio gas plant, it will lead to a saving of substantial amount of foreign exchange and improve

The economy of the nation. Also atmospheric degradation can be minimized.

Why bio gas?

Domestic biogas installation reduce greenhouse gasses by three ways-

1) Emission reduction by change in manure management method depends on the method used before the biogas installation .Each manure management system is characterised by the Methane Conversion Factor. The MCF defines the portion of methane production potential. In general in anaerobic conditions the MFC is higher than in aerobic system with all its intermediary levels.
2) The substitution of fossil fuels(so called "fuel-switch") for cooking with biogas reduces the GHG emission from fossil fuel consumption or electricity produced from fossil fuels. The amount of emission reduction depends on the amount of fossil fuels replaced, and the type of fossil fuel replaced.
3) Substitution of chemical fertilizer with bio-slurry. Bio-slurry is the by—product of biogas production and is a solid and fluid product of substrate decomposition in the fermenter. It can be applied as organic fertilizer and thus replace mineral fertilizer. The substitution of mineral fertilizer entails an emission reduction, but due to complicated monitoring this component is usually not taken into account in household biogas projects.

Principles of Biogas Production

Organic substances exist in wide variety from living beings to dead organisms. Organic matters are composed of Carbon (C), combined with elements such as Hydrogen (H), Oxygen (O), Nitrogen (N), and Sulphur (S) to form variety of organic compounds such as carbohydrates, proteins and lipids. In nature MOs (microorganisms), through digestion process breaks the complex carbon into smaller substances. There are 2 types of digestion process:

i. Aerobic digestion.

ii. Anaerobic digestion.

AEROBIC DIGESTION

The digestion process occurring in presence of Oxygen is called Aerobic digestion and produces mixtures of gases having carbon dioxide (CO2), one of the main "green houses" responsible for global warming. The digestion process occurring without (absence) oxygen is called An `aerobic digestion which generates mixtures of gases. The gas produced which is mainly methane produces 5200-5800 KJ/m3 which when burned at normal room temperature and presents a viable environmentally friendly energy source to replace fossil fuels (non-renewable).

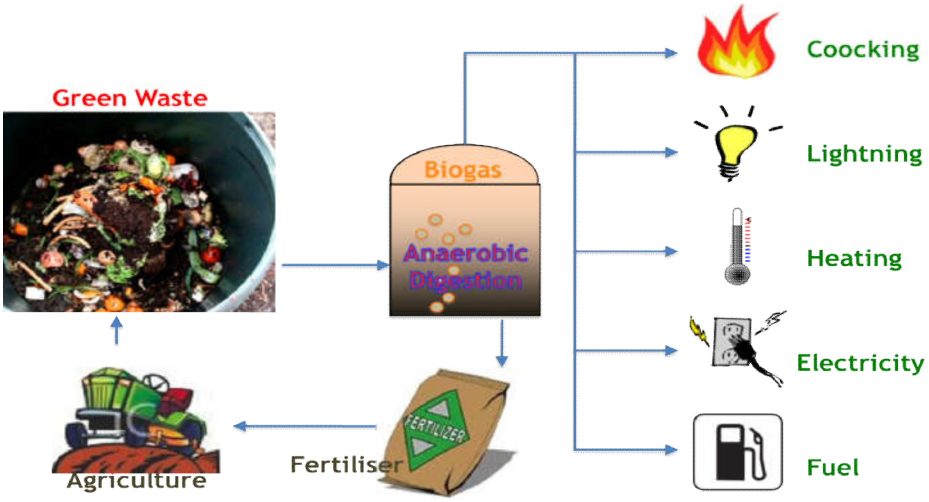
composition of biogas component	**Concentration (by volume)**
Methane (CH_4)	55- 60%
Carbon dioxide(co_2)	35-40%
Water (H_2O)	2- 7%
Hydrogen Sulphide(H_2S)	(2%)
Ammonia (NH_3)	0- 0.05%
Nitrogen (N)	0- 2%
Oxygen (O_2)	0- 2%
Hydrogen (H)	0- 1%

ANAEROBIC DIGESTION

It is also referred to as biomethanization, is a natural process that takes place in absence of air (oxygen). It involves biochemical decomposition of complex organic material by various biochemical processes with release of energy rich biogas and production of nutrious effluents. The three important biological process (microbiology) are, **Hydrolysis**In the first step the organic matter is enzymolysed externally by extracellular enzymes, cellulose, amylase, protease & lipase, of microorganisms. Bacteria decompose long chains of complex carbohydrates, proteins, & lipids into small chains. For example, Polysaccharides are converted into monosaccharide. Proteins are split into peptides and amino acids. **Acidification** Acid-producing bacteria involved in this step, convert the intermediates of fermenting bacteria into acetic acid, hydrogen and carbon dioxide. These bacteria are anaerobic and can grow under acidic conditions. To produce acetic acid, they need oxygen and carbon. For this, they use dissolved O2 or bounded-oxygen. Hereby, the acid-producing bacterium creates anaerobic condition which is essential for the methane producing microorganisms. Also, they reduce the compounds with low molecular weights into alcohols, organic acids, amino acids, carbon dioxide, hydrogen sulphide and traces of methane. From a chemical point, this process is partially endergonic (i.e. only possible with energy input), since bacteria alone are not capable of sustaining that type of reaction. **Methanogenesis**(Methane formation) Methane-producing bacteria, which were involved in the third step, decompose compounds having low molecular weight. They utilize hydrogen, carbon dioxide and acetic acid to form methane and carbon dioxide. Under natural conditions, CH4 producing microorganisms occur to the extent that anaerobic conditions are provided, e.g. under water (for example in marine sediments), and in marshes. They are basically anaerobic and very sensitive to environmental changes, if any occurs. The methanogenic bacterium belongs to the archaebacter genus,[3]i.e. to a group of bacteria with heterogeneous morphology and lot of common biochemical and molecular-biological properties that distinguishes them from other bacteria. The main difference lies in the makeup of the bacteria’s cell walls.

Process of Producing Biogas

The process of producing biogas involves anaerobic digestion. In this process, acetic acid forming bacteria (acetogens) and methane forming archea (methanogens) are fed to the digester. The oxygen source in an anaerobic system is derived from the organic material itself. In the presence of specialized methanogens, the intermediates are converted to the 'final' end products of methane, carbon dioxide, and trace levels of hydrogen sulfide. In an anaerobic system, the majority of the chemical energy contained within the starting material is released by methanogenic bacteria as methane. Populations of anaerobic microorganisms typically take a significant period of time to establish themselves to be fully effective. Therefore, common practice is to introduce anaerobic microorganisms from materials with existing populations, a process known as seeding the digesters, typically accomplished with the addition of sewage sludge or cattle slurry.



Design

The dimension of biogas plant depends on the thermal energy to be produced. Since it is intended to replace a part of L P G gas, the energy equivalent for 1 cylinder of LPG is calculated. [4]

Equivalence with LPG
Calorific value of LPG = 50 MJ/kg
One cylinder weighs 14.2 kg
Therefore, net energy in 1 cylinder = 14.2 x 50 MJ
The net energy in 1 cylinder = 710 MJ
The energy available in 1m3 plant in one month.
Biogas contains about 60% methane.
Calorific Value of methane = 55 MJ/kg Density of Methane at NTP = 0.668 kg/m3
Therefore, Calorific value of methane = 55 x 0.668 = 36.74 MJ/m3
Methane being the only major source of heat,
Calorific value of biogas = 0.6 x 36.74 MJ/m3 = 22.044 MJ/m3
A plant of 1 m3 capacity produces 0.7 m3 of gas per day.
Net energy in 0.7 m3 of biogas = 0.7 x 22 MJ
Net energy in 0.7 m3 of biogas = 15.4 MJ
Assuming that the efficiency of a biogas stove and LPG stove is the same
Energy provided per month = 15.4 x 30
Energy provided per month = 462 MJ
Therefore a biogas plant of 1 m3 capacity is equivalent to 65% of an LPG cylinder per month.

Characters	Bigger size biogas Plant	Smaller size biogas Plant
Size	1m^{3}digester	0.5 m^3 digester
Capacity	upto 2 kg itchen waste	upto 1 kg kitchen waste
Quantity of gas produced	upto 1 kg biogas,capable of replacing 250 gm of LPG.	upto 0.5 kg biogas, capable of replacing 100 gm of LPG.
Uses under cooking purposes	either breakfast or one meal can be cooked entirely on biogas.	about 15-20 min of cooking (tea,snakes, etc.) can be done.

How to start the process?

The system is first loaded with slurry of about 15 litters of kitchen wastes, green waste and water. The bacteria present in the intestine and consequently in the dung of the cattle are the bacteria that will break down the organic material into methane and carbon dioxide. After a waiting time of about 2 weeks, the gas should start to be emitted and the upper tank will rise. Test the gas by burning it: if it is combustible, you can start adding high calorie material.

Feedstock: daily 0.5kg to 1 kg mashed feedstock mixed with 10 litres water in the morning and the same in the evening. The feed can be waste flour, vegetable residues, waste food, waste oil, fruit peelings and rotten fruit. Oil cake, left over from oil-pressing, is another useful feedstock. Even rhizomes of banana, canna, nutgrass, non-edible seeds (e.g. Leucaena, Sesbania, tamarind, mango kernels) and spoilt grain serve as excellent feedstock material. Feedstock with large lumps (more than 20 mm) should be broken up with a food blender[5].Hand and pedal powered food blenders are being developed, for when electricity is not available. The digester should provides a steady supply of gas, typically 250 g of gas per day from 1 kg (dry matter) of feed.

What kind of problems can occure?

A biogas plant can become acidicand fail if it is over-fed, and this is a particular challenge with a plant using highly digestible organic materials. If this happens, the plant can be recovered by ceasing feeding and then building up the feed rate slowly. This problem was more common with the early smaller systems (0.5 or 0.75 m3) than with the later, larger systems.

Safety

there are important safety rules to consider: Like water, electricity, automobiles and most of life biogas is not completely safe, but by being aware of the dangers involved you are well on the way to a safe and happy digestion experience.

FIRE/EXPLOSION

Methane, which is makes up from 0% to 80% of biogas, forms explosive mixtures in air! The lower explosive limit being 5% methane and the upper limit 15% methane. Biogas mixtures containing more than 50 % methane are combustible, while lower percentages may support, or fuel, combustion. With this in mind no naked flames should be used in the vicinity of a digester and electrical equipment must be of suitable quality, normally "explosion proof". Other sources of sparks are any iron or steel tools or other items, power tools (particularly comutators and brushes), normal electrical switches, mobile phones and static electricity.

If conducting a flamability test take a small sample well away from the main digester, or incorporate a flame trap in the supply line, which must be of suitable length (minimum 20 m). As biogas displaces air it reduces the oxygen level, restricting respiration, so any digester area needs to be well ventilated to minimize the risks of fire/explosion and asphyxiation [6].

DISEASE

As Anaerobic Digestion relys on a mixed population of bacteria of largely unknown origin, but often including animal wastes, to carry out the waste treatment process care should be taken to avoid contact with the digester contents and to wash thoroughly after working around the digester (and particularly before eating or drinking). This also helps to minimise the spread odours which may accompany the digestion process. The digestion process does reduce the number of pathogenic (disease causing) bacteria, particularly at higher operating temperatures, but the biological nature of the process needs to be kept in mind.

ASPHYXIATION

Biogas consists mainly of CH_4 and CO_2, with low levels of H_2S and other gases. Each of these components has its own problems, as well as displacing oxygen.

CH_4–lighter than air (will collect in roof spaces etc.), explosive.

CO_2 - heavier than air (will collect in sumps etc.), slightly elevated levels affect respiration rate, higher levels displace oxygen as well.

H_2S - (rotten egg gas) destroys all factory (smelling) tissues and lungs, becomes odourless as the level increases to dangerous and fatal.

CONCLUSIONS

Biogas is a very good substitute for LPG gas because India is self-reliant in food production and crude oil is imported.

A regular feeding of biogas plant with proper amount will ensure consistent release of biogas and ensures uninterrupted production of gas.

Even if the plant is not fed for one or two days, (Saturday and Sundayin work place), the efficiency of the plant is not affected.

Crushed and blended food improves the liberation of biogas as digestion becomes easy.

Actually we are working on project of design of small scale anaerobic digester use mixture of kitchen waste, green waste & cow dung.

Hence affordable in our T.K.I.E.T college, warananagar and our canteens.

The local distribution system in our small location between plants and college canteen, mess ensures continuous supply of food waste with an added advantage of reduction in environmental hazards within our college campus .Food provided under meal in canteen and mess is simple and mostly rice so a simple single stage digestion process is sufficient and effective. College have complete support in the plants hence we are more responsible for its working as was seen in household level plants.

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