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The road to zero waste: Anaerobic digestor

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ABSTRACT

This paper focuses on the designing and development of anaerobic digester for generation of methane gas from kitchen waste. It assesses, in particular, both technical and environmental implications of a waste pre-sorting that may affect the treatment process. The scope of the study encompassed material segregation, digestion of kitchen waste, final disposal of waste. The study showed that material recycling leads to an improvement of the working conditions with respect to digestion. The study also demonstrated that digestion approach is a useful tool for the study of technical and environmental aspects of an energy system.

Keywords: Anaerobic digester design, hydrolysis, acidogenesis, methanogenesis.

1. Introduction

The designing of the anaerobic digester, for the generation of Methane (CH4) gas with the help of kitchen waste, is an initial step to reduce the generation of solid waste in India by having proper management strategies. This is one of the conventional methods for the reduction of waste at source. Laboratory scale experiments are performed to check the feasibility of the digester for the better generation of gas by this digester. The anaerobic condition is a natural phenomenon and the biological anaerobic conditions are self generating, these are developed under the air tight container of the digester.

The construction and design of the anaerobic digester for the generation of methane gas by processing kitchen waste is very much similar to the design of portable floating dome type bio-gas plant . The digester is the apparatus which is used for the decomposition of waste in a effective manner.

In India the waste generation rate is increasing by 1.33 times per year as per calculated by recent studies. Up to 2047 India will produce around 260 million tonnes of solid waste and for the disposal of this waste the total land area around 1400 hectare km square is required. It is really impossible to reduce the rate of generation of waste and to provide such a big land area for its disposal. In India for solid waste management approx. Rs.1500 Crore is issued for its overall management.

In collection process around 20 – 25% of the given amount is spend, and 60 – 70% on the transportation process, for the final disposal process we are only having less than 5% of the total budget which is not sufficient and result in ineffective disposal of waste. The anaerobic digester for the generation of methane gas by kitchen waste is the apparatus which can be used for the effective disposal of solid waste from kitchen. By using this process we can maintain the budget of waste management as well as the production of energy also takes place (Chynoweth D. and Isaacson R., 1987). As in the working of the digester, the complete decomposition of waste takes place, this decomposition results in the generation of methane gas as the main product. The most important design parameter of an anaerobic sludge digester is the operational temperature. Consequently, this paper provides a synthesis of the key issues and analyses concerning the design of a high-performance anaerobic digester.

2. Anaerobic digestion process

Anaerobic digestion consists of a complex series of reaction, which are catalyzed by a consortium of bacteria and accomplish the conversion of organic compounds to the terminal products methane and carbon dioxide. Anaerobic biodegradation of organic material proceeds in the absence of oxygen and the presence of anaerobic microorganisms. It is the consequence of a series of metabolic interactions among various groups of microorganisms. It occurs in three stages, hydrolysis/liquefaction, acidogenesis and methanogenesis. The first group of microorganism secretes enzymes, which hydrolyses polymeric materials to monomers such as glucose and amino acids. These are subsequently converted by second group i.e. acetogenic bacteria to higher volatile fatty acids, H2 and acetic acid. Finally, the third group of bacteria, methanogenic, convert H_2, CO_2, and acetate, to CH_4. These stages are described in detail below. Anaerobic Digestion is carried out in large digesters that are maintained at temperatures ranging from 30°C - 65°C.

2.1 Use of generated methane

The generation of methane gas results in the form of energy which can be stored and used for several domestic purposes (Gray, 2010).

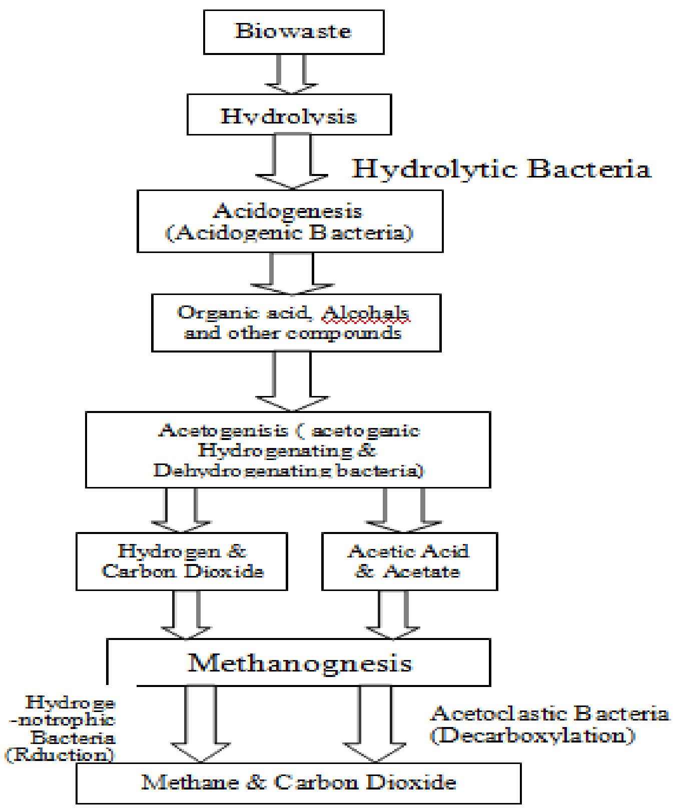

Figure 1: The mechanisation of bio waste

1. Can replace the LPG in the kitchen for cocking purpose.
2. Generated gas can be used for lightening the gas lamps.
3. In many of the biological process of water treatment plants, the urea and DAP is used as the food for the microbes because these are having high CNP ratio (Carbon: Nitrogen: Phosphorus). The expenditure on urea and DAP in the plant for the day is more than lac rupees per day. The waste received from the output of the digester after the complete decomposition may have he high CNP ratio, than this waste can be used instead of urea and DAP in the plant as the factor of cost reduction in the plant (Guangxue Wu, Mark Gerard Healy, Xinmin Zhan., 2009). By using the output waste the digester is having the 100% utilization of waste which results in optimum use waste.

3. Phases of anaerobic digestion

3.1 Hydrolysis/liquefaction

In the first stage of hydrolysis, or liquefaction, fermentative bacteria convert the insoluble complex organic matter, such as cellulose, into soluble molecules such as sugars, amino acids and fatty acids. The complex polymeric matter is hydrolyzed to monomer, e.g., cellulose to sugars or alcohols and proteins to peptides or amino acids, by hydrolytic enzymes, (lipases, proteases, celluloses, amylases, etc.) secreted by microbes (Harper and Stephen R., 1996). The hydrolytic activity is of significant importance in high organic waste and may become rate limiting. Some industrial operations overcome this limitation by the use of chemical reagents to enhance hydrolysis. The application of chemicals to enhance the first step has been found to result in a shorter digestion time and provide a higher methane yield.

3.1.1 Hydrolysis/liquefaction reactions

Lipids → Fatty Acids
Polysaccharides → Monosaccharides
Protein → Amino Acids
Nucleic Acids → Purines & Pyrimidines

3.2 Acedogenesis

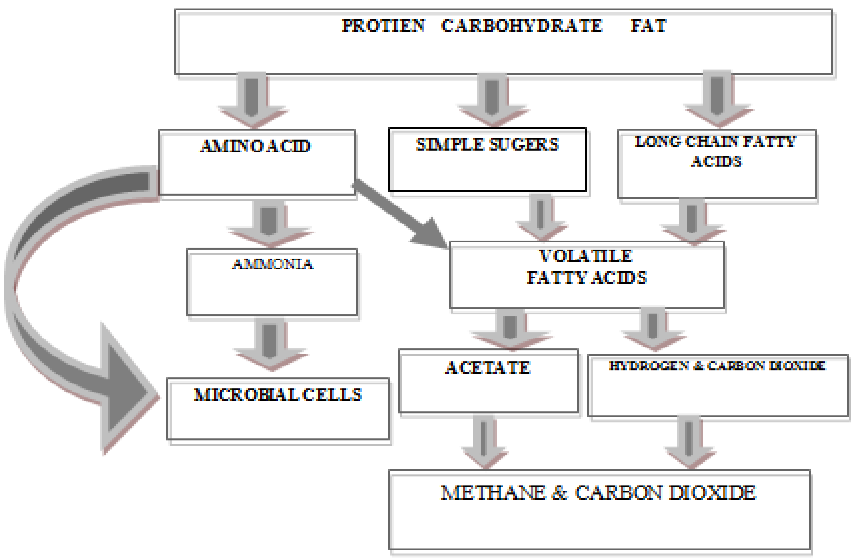

Figure 2: Simplified diagram of substrate dissimilation

The main product of this stage is acetic, lactic and propionic acids and pH falls as the levels of these compounds increase. Carbon dioxide and hydrogen also evolved as the result of the catabolism of carbohydrates, with the additional potential for the production of methanol and/or other simple alcohols. The proportion of the different by products depends on the environmental conditions, to some extent, and more largely, on the particular bacteria species present. Acedogenesis is the part for methane formation after hydrolysis process acedogenisis, in the presence of acedogenic bacteria, organic acid, alcohol and other compounds (Hilkiah Igoni at al, 2008).

3.3 Methanogenesis

Methanogenesis involves the production of methane from raw materials produced in the previous stage (John C. Kabouris, 2008). This is brought by obligate anaerobes, whose growth rate is, overall, slower than the bacteria responsible for the proceeding stages.

The methane is produced by a number acetate-degrading methanogens in two ways: either by means of cleavage of acetic acid molecules to generate carbon dioxide and methane, or by reduction of carbon dioxide with hydrogen. Methane production is higher from reduction of carbon dioxide but limited hydrogen concentration in digesters results in that the acetate reaction is the primary producer of methane. Methanogens can also be divided into two groups: acetate and H_2/CO_2 consumers. The methanogenesis reactions can be expressed as follows [9, 10]:

$CH_3COOH \rightarrow CH_4 + CO_2$
$2C_2H_5OH + CO_2 \rightarrow CH_4 + 2CH_3COOH$
$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

Mathanogenesis is pH sensitive, the requires range being mildly acidic (6.6-7.0).

4. Development of anaerobic digestion

Using following contents anaerobic digestion is developed for testing. Including following contents, also keep observation on temperature and retain period (Pescod, Professor M.B. Waren, 1998). Figure shows how to generate Methane gas by stirring and loading of waste and temperature maintaining. Digesters run at around 35^0C and 55^0C (mesospheric and thermophilic range of temperature). The optimum temperature may depend on the exact type of bio waste material treatment and digester used. The bio waste needs to be allowed to remain in the digester until the required level of treatment has achieved. There exist a direct relationship between temperature and retain period (Ricardo F.F. Pontes, José M. Pinto., 2009). Anaerobic Digestion is basically a wet process. The production of methane with digesters designed around a high organic loading requiring a large resident bacterial population to achieve proper through-put. Anaerobic treatment is related to several different acids with based chemical equilibrium. Anaerobic Digestion process requires a constant temperature to progress its high efficiency. The materials used for development of anaerobic digestion are given in the following section:

4.1 Material used for designing of anaerobic digester

1. Co-axial couple of Cylindrical tanks, outer tank and inner tank. Made up of 18 gauge thick GI sheet.

Figure 3: Anaerobic digester for generation of Methane Gas from kitchen waste

Figure 4: Stirring of waste

Figure 5: Loading of waste

Outer tank acts as a digester having diameter of 28.5 inches and height of 34 inches, Inner Tank acts as a floating dome for the digester having diameter of 25 inches and a height of 31 inches. Curve provided to both the tanks is 1.25 inch to 1.5 inch. Outer dome is having the holes of 1.25 inch, one at the centre of the bottom and other on the side wall.Inner tank is having the hole of 0.5 inch at its surface. The cubical tank is also used for the input of the waste having height of 21 inch, depth of 18 inch, width of 18 inch.

Other materials used are

1. 3 sockets of 1.25 inch.
2. 1 socket of 0.5 inch
3. 2 nipples of 1.25 inch
4. 2 nipples of 0.5 inch.
5. 2 check valves of 1.25 inch
6. 1 checks valves of 0.5 inch
7. 1 L-shaped connector.
8. 1 gas valve.
9. Pipe having a length of 2.16m
10. Diameter of 1.25"

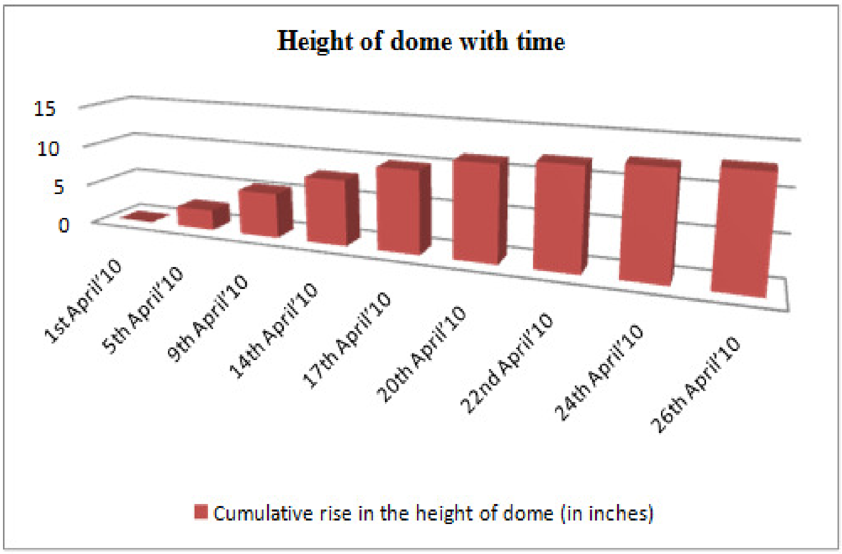

Chart 1: variance in height of dome

Table 1: Testing of different constituents held in laboratory

Organic Carbon(gm)		Phosphorus,(P) (mg/l)	Moisture Content (%)				Hardness (mg/l)		Chloride (mg/l)	Sulphate (mg/l)	Nitrogen (mg/l)
			Wet basis		Dry basis						
Input	Output		Input waste	Output waste	Input waste	Output waste	Ca	Mg			
1.58	0.790	4.5	39.8	41.62	66.3	71.30	403.7	1196.2	2.8005	7.8942	784

Source: Environmental Department Laboratory, HCST, Mathura

4. Conclusion

Consequently, this paper provides a synthesis of the key issues and analyses concerning the design of a high-performance anaerobic digester**.** Irrespective of whichever of variety of Anaerobic digestion system is used, at the end of the processing, there will be quantity of residual fibrous material to used in same way. In commercial purposes, this end use ranges from simple landfill cover, through direct land spread for agricultural purposes, to production of a high quality soil additive. Anaerobic Digestion is technically and economically feasible for a variety of community waste feedstock. This facility achieves excellent overall separation of the incoming waste. Moreover, there is increasing evidence that the use of digestive on the land has additional benefits in normal condition which has been reported previously. A great deal is known regarding the fundamental microbiology of the Anaerobic Digestion Process, although much more is to be discussed in this paper.

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