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Harnessing Maximum Energy From Biomass and Generation of Biogas

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Abstract- *This paper represents how to harness the maximum energy from biomass and the production of biogas. Biogas Production requires anaerobic digestion. The anaerobic digestion of kitchen wastes produces biogas, a valuable energy resource. In Yeshwantrao Chavan College of Engineering, there are two canteens, and both having their own individual mess, where daily amount of kitchen waste is obtained which can be utilized for better purposes. In the campus of YCCE biogas plant for the production of biogas has been installed. For harnessing the maximum energy pre-digester tank in which any type of kitchen waste, manure etc. get fermented has been installed. So that the process of anaerobic digestion gets faster in digester tank. To maintain the temperature of biogas plant the solar water heater fully home made using copper coil and glass has also been used. This project is to create an Organic Processing Facility to create biogas which will be more cost effective, eco-friendly, generate high quality renewable fuel, and reduce carbon dioxide and methane emission..*
Keywords—*Biogas; Digeste Tankr; Predigester Tank; Kitchen Waste; Solar water Heater; Anaerobic Digestion*

I. Introduction

Day to day increase in population increases the generation of waste in the universe. Dumping of waste without proper treatment leads to ecological imbalance. Accumulation of waste also creates severe long term environmental problems like climatic change, global warming etc. So, it is need to go for wireless waste management system and utilization of renewable energy sources. The biogas is most convenient and easy form to get energy from biomass resources. It can be used for domestic purpose, electricity production and as a fuel for vehicles.

Efficiency of biogas plant depends on various parameters such as internal temperature, pH value, type of feed stock etc. pH value has to be maintained from 6.5 to 7.5 otherwise due to variation in pH the process of formation of gas gets affected and efficiency gets reduced. Also changes in temperature will affect efficiency.

Out of 1.8 million biogas plants installed throughout India, 24501 plants were studied and the status is compared with other studies. It reveals that about 60% plants are functional. With the center focusing more on developing alternative fuel economy, India will soon stop importing petroleum products, Union Minister, Nitin Gadkari said Biogas is a renewable source of energy, whose consumption amount to 19% (at 2011) of Global Energy consumption. Biomass currently accounts for 2/3rd of renewable energy in Europe and Bio-energy will play a key role in achieving the ambitious targets approved by the renewable energy directives. Germany has a leading role in Europe with almost 4000 biogas plants, most of them on farms for co-generation.

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II. Need Of Renewable Energy Sources

The need of the energy for the development of country is one of the major reasons to move for the renewable energy sources. The energy requirement of the growing population is increasing day by day, and in coming future it will be a big question standing in front of the world how to manage the energy supply with such non- renewable sources.

The non-renewable sources pollute the environment to the great extent. The petrol, diesel release gases like carbon-mono-oxide (CO) which are harmful for environment. Thermal power plants meet 80% need of the energy throughout India. The thermal power plants pollute the environment as the large quantity of the gases is being released from the chimney. They use coal as raw material for the generation of the electricity. The coal will get exhaust in coming future. According to the survey the coal from the India will get exhaust till the end of the year 2050. The hydro power plants occupy large area. It create the many social and economic problems. The nuclear power plant uses uranium as the raw material. The waste from this plant is also very harmful for the plants and living being around it. Hence careful disposal of this waste is also important. Plus all this three power plants require large space as compared to the biogas plant. And the capital, operating cost of this plant is much higher than the capital and operational cost of biogas plant.

The solar, wind, tidal and biomass are major sources of renewable energy. The solar energy is widely used but due to its cost it is not possible and feasible for everyone to use this energy.

The wind and tidal energy also contribute but at very lower proportion due to the lots of restrictions and conditions over implementation of the plants for this energy sources. Hence the organic biomass is an important source of the energy. It is a clean source of energy. It requires much less cost and space for the installment and running of the plant. The slurry from these plants can be the best fertilizer which can be used for optimizing the production at fields.

III. Methodology

Many microorganisms affect anaerobic digestion, including acetic acid-forming bacteria (acetogens) and methane-forming archaea (methanogens). These organisms promote a number of chemical processes in converting the biomass to biogas. Gaseous oxygen is excluded from the reactions by physical containment. Anaerobes utilize electron acceptors from sources other than oxygen gas. These acceptors can be the organic material itself or may be supplied by inorganic oxides from within the input material. When the oxygen source in an anaerobic system is derived from the organic material itself, the 'intermediate' end products are primarily alcohols, aldehydes, and organic acids, plus carbon dioxide. In the presence of specialised methanogens, the intermediates are converted to the 'final' end products of methane, carbon dioxide, and trace levels of hydrogen sulphide. In an anaerobic system, the majority of the chemical energy contained within the starting material is released by methanogenic bacteria as methane

Process Stage

The four key stages of anaerobic digestion involve hydrolysis, acidogenesis, acetogenesis and methanogenesis. The overall process can be described by the chemical reaction, where organic material such as glucose is biochemically digested into carbon dioxide (CO_2) and methane (CH_4) by the anaerobic microorganisms.

$C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$

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Hydrolysis

In most cases, biomass is made up of large organic polymers. For the bacteria in anaerobic digesters to access the energy potential of the material, these chains must first be broken down into their smaller constituent parts. These constituent parts, or monomers, such as sugars, are readily available to other bacteria. The process of breaking these chains and dissolving the smaller molecules into solution is called hydrolysis. Therefore, hydrolysis of these high-molecular-weight polymeric components is the necessary first step in anaerobic digestion. Through hydrolysis the complex organic molecules are broken down into simple sugars, amino acids, and fatty acids.

$(C_6H_{10}O_5)n + n(H_2O) = n(C_6H_{12}\,O_{22)}$

Acetate and hydrogen produced in the first stages can be used directly by methanogens. Other molecules, such as volatile fatty acids (VFAs) with a chain length greater than that of acetate must first be catabolised into compounds that can be directly used by methanogens.

Acid Producing Stage

The biological process of acidogenesis results in further breakdown of the remaining components by acidogenic (fermentative) bacteria. Here, VFAs are created, along with ammonia, carbon dioxide, and hydrogen sulphide, as well as other byproducts. The process of acidogenesis is similar to the way milk sours.

$n(C_6H_{12}O_6) \rightarrow n(CH_3COOH) + CO_2 + H_2O$

Acetogenic Stage

The third stage of anaerobic digestion is acetogenesis. Here, simple molecules created through the acidogenesis phase are further digested by acetogens to produce largely acetic acid, as well as carbon dioxide and hydrogen.

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

Methanogenic Stage

The terminal stage of anaerobic digestion is the biological process of methanogenesis. Here, methanogens use the intermediate products of the preceding stages and convert them into methane, carbon dioxide, and water. These components make up the majority of the biogas emitted from the system.

Methanogenesis is sensitive to both high and low pH and occurs between pH 6.5 and pH 8. The remaining, indigestible material the microbes cannot use and any dead bacterial remains constitute the digestate.
$CH_3COOH \rightarrow CH_4 + CO_2$

IV. Factor Affecting Biodigestion Or Generation Of Biogas

The following are the factors that affect the generation of biogas:

1. pH or hydrogen ion concentration

pH of the slurry changes at the various stages of the digestion. In the initial acid formation stages in the fermentation process, the pH is around 6 or less and much of CO_2 is given off. In the latter 2-3 weeks times, the pH increases as the volatile acid and N_2 compounds are digested and CH_4 is produced. To maintain a constant supply of biogas it is necessary to maintain a suitable pH range in the digester. The digester is usually buffered if the pH is maintained between 6.5to 7.5.In this pH range micro-organisms will be very active and biodigestion will be very efficient. If the pH range is between4 and 6it is called acidic .If it is between 9to 10 it is called alkaline. The ideal pH values for digestion of sewage solids are reported to be in the range 7 to 7.5.

2. Temperature

Methane bacteria work best at a temperature of between 35°C-38^{0}C .The fall in gas production starts at 20^{0}C and stops at a temperature of 10°C.At one experiment 2.25m^3 of gas was produced from 4.25m^3 of cattle dung every day when the digester temperature was 25^{0}C.When the temperature was raised to 28.3^{0}C, the gas production increased by 50% to 3.75 m^3/day.

3. Total solid Content

The cow dung is mixed usually in the proportion of 1:1(by weight) in order to bring the total solid content to 8-10%. The adjustment of total solid content helps in bio digesting the material at the faster rate, and also in deciding the mixing of the various crops residues weeds plants etc. as feed stocks in biogas digester.

4. Loading Rate

Loading rate is defined as the amount of raw material (usually kg of volatile solids) fed to the digester per day per unit volume. If the digester is loaded with too much raw material at a time, acids will accumulate and fermentation will stop. The main advantage of higher rate is that by stuffing a lot into a little space, the size and therefore the cost of digester can be reduced. Most municipal sewage treatment plants operate at a loading rate of 0.5 to 1.6 kg of volatile solids per m^3 per day.

5. Seeding

Although the bacteria required for acid fermentation and methane formatiobn are present in the cow dung, their numbers are not large. It would be advantageous to increase the number of methane formers. But beyond a certain seed concentration, the gas production will decrease, due to reduction of raw cow dung solids fed to the digester.

6. Uniform Feeding

One of the prerequisite of good digestion is the uniform feeding of the digester so that the micro-organism are kept in a relatively constant organic solids concentration at all times. Therefore the digester must be fed at a same time every day with a balanced feed of the same quality and quantity.

7. Carbon to Nitrogen ratio

The elements of carbon and nitrogen are the main food of anaerobic bacteria. Carbon is used for energy and nitrogen for building the cell structure. The bacteria use up about 30 times faster than they use up nitrogen. Carbon and nitrogen should be present in the proper proportion. Other condition being favourable, a carbon nitrogen ratio of 30 will permit digestion to proceed at an optimum rate.

8. Diameter to Depth ratio

Research investigations reveal that gas production per unit volume of digester capacity was maximum when the diameter to depth ratio was in the range of 0.66 to 1.00. But report from the field do not confirm this. Digester of 16 feet depth and 4 feet to 5 feet diameter were reported to be working satisfactory.

9. Nutrients

The major nutrients required by the bacteria in the digester are C, H_2, O_2, N_2, P and S of these nutrients N_2 and P are always in short supply and therefore to maintain proper balance of nutrients an extra raw materials rich in phosphorus and chopped leguminous plants should be added along with the cow dung to obtain maximum production of gas.

10. Mixing or stirring or agitation of the content of the digester
Since bacteria in the digester have very limited reach to their food it is necessary that slurry is properly mixed and bacteria get their proper supply. It is found that slight mixing improves fermentation process.

11. Retention time or rate of feeding
The period of retention of the material for biogas generation inside the digester is known as the retention period. This period will depend on the type of feed stocks and the temperature. Normal value of the retention period is between 30 and 45 days and in some cases 60 days. By regulating the daily feed volume, the retention time can be controlled.
Periods for different materials to get well fermentation are:

- Cow and buffalo dung 50 days
- Pig-dung 20 days
- Poultry droppings 20 days
- Night soil 30 days

As mentioned this period will also depends on the ambient temperature, in tropical regions it can be even 30 days.

12. Types of feed stocks
When the feedstock is woody or contains more of lignin, then bio digestion becomes difficult. This cow and buffalo dung, human excreta, poultry dropping, pig dung, waste materials of plants, cobs, etc. can all be used as a feed stock. To obtain an efficient bio digestion, these feed stocks are combined in proportion. Pre-digestion and finely chopping will be helpful in the case of some materials. Plant wastes do not need pre-digestion. Excessive plant materials may choke the digester.

13. Toxicity
The digested slurry, if allowed to remain in the digester beyond a certain time, becomes toxic to the micro-organisms and might cause fall in the fermentation rate. Biological system needs some trace elements like calcium, magnesium, potassium etc. Production of biogas is reduced when these elements are presents in higher concentrations. Synthetic materials are toxic to methanogenic bacteria. Pesticides and disinfectants from farms can kill bacteria.

14. Pressure
Some work conducted at National Environmental, Engineering Research Institute (NEERI) Nagpur and other places indicated that the pressure on the surface of slurry also affects the fermentation. It has been reported to be better at lower pressures.

V. Construction Of Floating Doam Type Biogas Plant

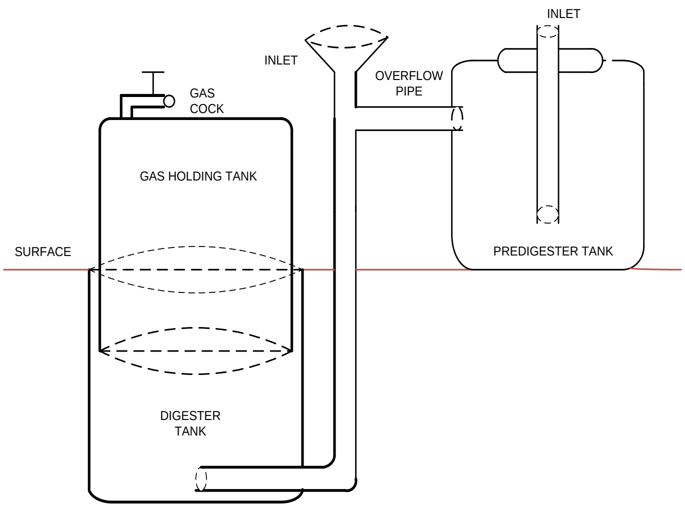


Fig.1 Front view of Biogas Plant

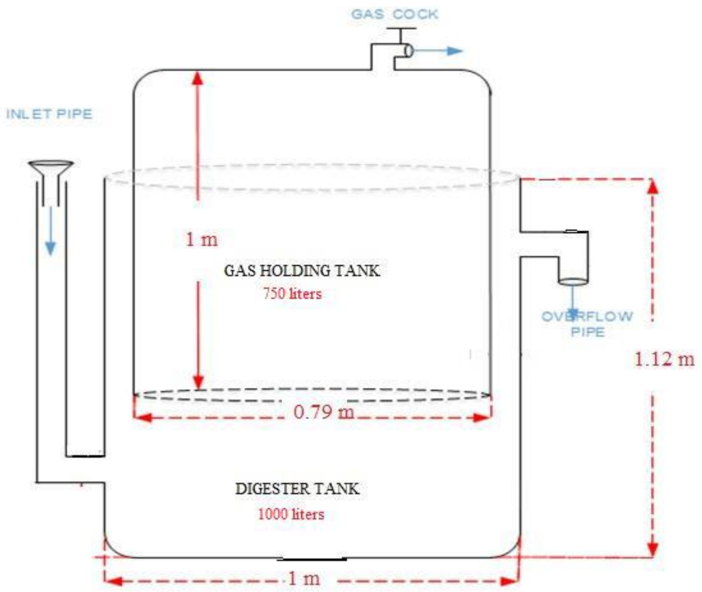
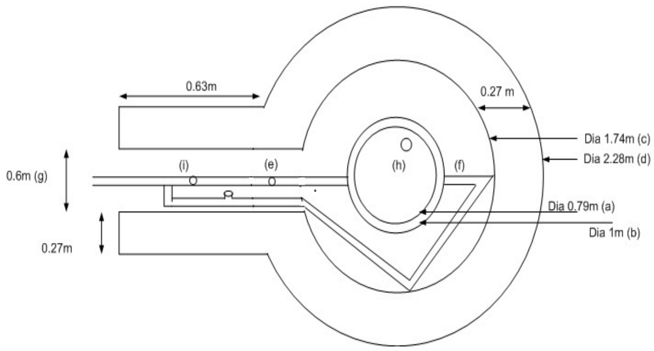


Fig.2 Floating Dome Type Biogas Plant

The overall dimensional view of biogas plant is as shown in following figure 1.2. There are total three openings in our biogas plant as inlet pipe, outlet pipe and one opening at gas holder for gas collection. Inlet pipe opening is for introduction of feedstock. Outlet pipe opening is for removal of spent slurry. In this type inverted plastic tank is used as a gas holder. The floating gas holder type of biogas plant has the following chambers/ sections



a. Gas holder Tank
b. Digester Tank
c. Inner face of Wall
d. Outer face of Wall
e. Feedstock Pipe
f. Sludge Pipe
g. Outlet Pipe
h. Biogas Outlet
i. Chamber Valve

Fig 3 Top view of Biogas Plant

A. Digester Tank/ Pre Digester Tank

It is a plastic tank of capacity 1000 liters. The digester tank is fed with the feedstock material can be cow dung, food waste , used tea powder etc. The feed stock in digester tank goes under the process of anaerobic digestion process for production of methane gas

B. Gas Holder Tank

It is a plastic tank of capacity 750 liter. The gasholder floats directly on the fermented slurry. The gas produced is collected in the gas drum, which rises on production of gas.

C. Locking System

Locking System is provided to avoid tilting of gas holder tank. It holds the gas holder tank firmly above the digester tank and allows to move up and down smoothly.

D **.** Food Crusher

It is used for mixing and crushing the feedstock so that it is finely chopped and blockage in pipes can be avoided.

E. Pressure Gauge

To measure the pressure of gas produced, an analog pressure gauge (meter) is connected at the gas outlet.

E. Filter

A filter is connected near the gas valve. It absorbs the dust and moisture contents present in the produced gas. Thus it gives a clean gas.

F**.** Pressure Regulator

A pressure regulator is connected before the Twin Gas Burner. It is used for regulating the pressure of gas according to requirement.

G. Solar Water Heater:

It is a purely homemade water heater consisting of copper tube which carries cold water and gets heated by the sun's heat trapped by glass fitted over it.

VI. Working Of The Plant

The process of generation of biogas starts with the proper selection of the manure which will generate maximum methane and minimum carbon di oxide and oxygen. So for this we have selected cow dung as the best manure. Along with it the kitchen wastes that includes tea powder, vegetable wastes and manure consisting of sugar like fruits wastes, etc.

For the fast fermentation process we have constructed a pre-digestor tank in which cow dung slurry, tea powder and fruit wastes dried and crushed in the crusher to the fine form are inserted besides putting cow dung in the main tank. This predigested manure is then allowed to overflow in the main tank which already consist of fermented cow dung. So by this way, the fermentation gets completed in less time giving us the maximum methane production.

The micro-organisms formed in the fermentation process require specific temperature for their growth. Exceeding this and also lesser than this temperature can disturb their growth. To have a check on this we have installed a solar water heater which will maintain the temperature inside at a set temperature besides also will main the moisture inside.

The daily feeding of the manure in the pre digester ensures the daily output to the gas installed at some distant place from the plant which is used for the cooking and other applications.

Fig1.4. Main Digester Tank Installed At YCCE

Fig1.5. Overview of the complete Plant

Fig1.6. Final Output

VII. Summary

The gas we get from the biogas can be used for the various purposes like to produce electricity, as a fuel. But for the electricity generation and for using as a fuel, large quantity of the gas is required. For generating the large quantity of biogas, the efficient generation is required. For efficient generation the constructional design, environmental conditions, feedstock type, feeding rate all this parameters are responsible. The analysis of feedstock is the major contribution to this research. The nutrient value in the feedstock decides the amount of gas and quality of the gas, Hence it is an essential theory to give the analysis of the feedstock. The biogas plants are treated and fed with the different types of the feedstock for the analysis. The bacteria generation time and retention time are being noted and the effect on the biogas generation has been studied through different conditions. The purification method of the biogas has been studied in this project.

VIII. Conclusion

It can be concluded that the biogas is one the most convenient, efficient source of the energy. The output of the feedstock having the low fixed solids gives the best gas output. We used the different feedstock among that cow dung and extracted tea powder gives the best output of the gas production. The rotten fruits and vegetables come after that respectively. So overall we used canteen waste as a feedstock. Use of food crusher helps in reducing the bigger size solid contents in the feedstock, which makes the anaerobic digestion process faster, resulting in increase in output of gas. The biogas generation process is highly depends upon the C/N ratio of the feedstock. Higher the C/N ratio, higher will be the production. The temperature affects in large extent to the gas production. It is found that the production of gas is faster in summer days as compared to winter days.

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