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Design of Biogas Plant for College Canteen

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Abstract: This research work concentrates on design of biogas plan for college canteen of KG Reddy College of Engineering and Technology. The plant design was to produce the biogas for cooking food to 500 students per day by the canteen food waste. The bio degradable food waste was consider for bio gas production. The one month survey was conducted to calculate the food waste generating from the canteen. The vegetables waste and food waste was weighted at end of every day and noted for one month food waste calculation. The required quantity of gas is 9lits per day (4.86m3/day) to cook the food for average of 500 students. The average generated food waste (22.8kgs/day) will generates 5.4m3 of biogas the is more than required biogas. The design parameter was shown in the conclusions.
Key Words: Bio Gas plant, LPG and Food waste.

1. INTRODUCTION:

Due to scarcity of petroleum product and coal it threatens to supply of fuel throughout the world also problem of their combustion leds to research in different corners to get access the new sources of energy, like renewable energy resources. Solar energy, wind energy, different thermal and hydro sources of energy, biogas are all renewable energy resources. But, biogas is distinct from other renewable energies because of its characterstics of using,controlling and collecting organic wastes and at the same time producing fertilizer and water for use in agricultural irrigation. Biogas does not have any geographical limitations nor does it requires advanced technology for producing energy, also it is very simple to use and apply.

Deforestation is a very big problem in developing countries like India, most of the part depends on charcoal and fuel-wood for fuel supply which requires cutting of forest. Also, due to deforestation It leads to decrease the fertility of land by soil erosion. Use of dung , firewood as energy is also harmful for the health of the masses due to the smoke arising from them causing air pollution. We need an ecofriendly substitute for energy.

Kitchen waste is organic material having the high calorific value and nutrient value to microbes, that’s why efficiency of methane production can be increased by several order of magnitude as said earlier.It means higher efficiency and size of reactor and cost of biogas production is reduced. Also in most of cities and places, kitchen waste is disposed in landfill or discarded which causes the public health hazards and diseases like malaria, choleria, typhoid,etc. Inadequate management of wastes like uncontrolled dumping bears several adverse consequences. It not only leads to polluting surface and groundwater through leachate and further promotes the breeding of flies , mosquitoes, rats and other disease bearing vectors. Also, it emits unpleasant odour & methane which is a major greenhouse gas contributing to global warming.

Mankind can tackle this problem(threat) successfully with the help of methane , however till now we have not been benifited, because of ignorance of basic sciences – like output of work is dependent on energy available for doing that work. This fact can be seen in current practices of using low calororific inputs like cattle dung, distillery effluent, municipal solid waste (MSW) or seweage, in biogas plants, making methane generation highly inefficient. We can make this system extremely efficient by using kitchen waste/food wastes.

The typical biogas is having the highest composition of Methane (50-70%) and remaining Carbon dioxide (30-50%), also small traces of some other gases, having the calorific value ranging from 21-24MJ/m^3.

The main advantage of this process is that the product can be used as a cooking, vehicle fuel or for co-generation of electricity and heat, and also leads to reductions in greenhouse gas emissions.

The installation of biogas plant in the developing countries like India and China are started in 1970s.Currently there are 4 and 22 million biogas plants are installed in India and China respectively. The installation is not only the problem with respective to biogas generation but also its maintenance concerns increased attention towards the efficient working of biogas plants as about 50% of installed plants stops working due to lack of maintenance in many countries. There remains potential for domestic plants to utilize currently underexploited biogas substrates such as kitchen waste, weeds and crop residues.

Kitchen waste is an easily biodegradable organic matter with high moisture, carbohydrate, lipid, and protein compositions. The major limitation of anaerobic digestion of kitchen waste alone is the rapid accumulation of volatile fatty acids (VFAs) followed by a pH drop in the reactor, which inhibits methanogenic bacteria.

2. LITERATURE REVIEW

Biogas is a gas produced by bacteria through the bio-degradation of organic material under anaerobic conditions. Natural generation of biogas is an important part of bio-geochemical carbon cycle as shown in below Fig 1. It can be used both in rural and urban areas.

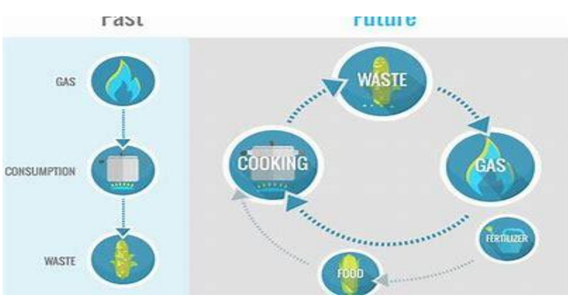

Fig1. Bio Gas Cycle

Characterstics of Bio Gas :-

Composition of biogas depends upon feed material also. Biogas is about 20% lighter than air has an ignition temperature in range of 650^o to 750^{0}C.An odorless& colourless gas that burns with blue flame similar to LPG gas. Its caloric value is 20 Mega Joules (MJ) /m^3 and it usually burns with 60 % efficiency in a conventional biogas stove.

This gas is useful as fuel to substitute firewood, cow-dung, petrol, LPG, diesel, & electricity, depending on the nature of the task, and local supply conditions and constraints. Biogas digestor systems provides a residue organic waste, after its anaerobic digestion(AD) that has superior nutrient qualities over normal organic fertilizer, as it is in the form of ammonia and can be used as manure. Anaerobic biogas digesters also function as waste disposal systems, particularly for human wastes, and can, therefore, prevent potential sources of environmental contamination and the spread of pathogens and disease causing bacteria. Biogas technology is particularly valuable in agricultural residual treatment of animal excreta and kitchen refuse. The process of biogas plant was shown in Fig. 2. and the composition of biogas was shown in Table 1.

Table 1. 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)	20-20,000 ppm (2%)
Ammonia (NH_3)	0-0.05 %
Nitrogen (N)	0-2 %
Oxygen (O_2)	0-2 %
Hydrogen (H)	0-1 %

Hilkiah Igoni [1] studied the Effect of Total Solids Concentration of Municipal Solid Waste on the Biogas Produced in an Anaerobic Continuous Digester. The total solids (TS) concentration of the waste influences the pH, temperature and effectiveness of the microorganisms in the decomposition process. They investigated various concentrations of the TS of MSW in an anaerobic Continuously Stirred Tank Reactor (CSTR) and the corresponding amounts of biogas produced, in order to determine conditions for optimum gas production. The results show that when the percentage total solids (PTS) of municipal sold waste in an anaerobic continuous digestion process increases, there is a corresponding geometric increase for biogas produced. A statistical analysis of the relationship between the volume of biogas produced and the percentage total solids concentration established that the former is a power function of the latter, indicating that at some point in the increase of the TS, no further rise in the volume of the biogas would be obtained.

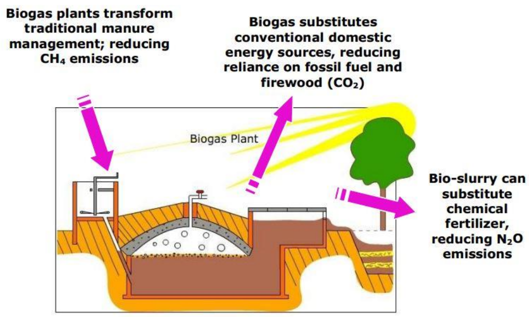

Fig 2. Schematic diagram of Biogas plant

Shalini Singh et al. [2] studied the increased in biogas production using microbial stimulants. They studied the effect of microbial stimulant aquasan and teresan on biogas yield from cattle dung and combined residue of cattle dung and kitchen waste respectively. The result shows that dual addition of aquasan to cattle dung on day 1 and day 15 increased the gas production by 55% over unamended cattle dung and addition of teresan to catteldung : kitchen waste (1:1) mixed residue 15% increased gas production.

ARTI [3] – Appropriate Rural Technology of India, Pune (2003) has developed a compact biogas plant which uses waste food rather than any cow dung as feedstock, to supply biogas for cooking. The plant is sufficiently compact to be used by urban households, and about 2000 are currently in use – both in urban and rural households in Maharashtra. The design and development of this simple, yet powerful technology for the people, has won ARTI the Ashden Award for sustainable Energy 2006 in the Food Security category. Dr. Anand Karve (ARTI) developed a compact biogas system that uses starchy or sugary feedstock (waste grain flour, spoilt grain, overripe or misshapen fruit, nonedible seeds, fruits and rhizomes, green leaves, kitchen waste, leftover food, etc). Just 2 kg of such feedstock produces about 500 g of methane, and the reaction is completed with 24 hours. The conventional biogas systems, using cattle dung, sewerage, etc. use about 40 kg feedstock to produce the same quantity of methane, and require about 40 days to complete the reaction. Thus, from the point of view of conversion of feedstock into methane, the system developed by Dr. Anand Karve .It is 20 times as efficient as the conventional system, and from the point of view of reaction time, it is 40 times as efficient. Thus, overall, the new system is 800 times as efficient as the conventional biogas system.

Kumar et al. [4] investigated the reactivity of methane. They concluded that it has more than 20 times the global warming potential of carbon dioxide and that the concentration of it in the atmosphere is increasing with one to two per cent per year. The article continues by highlighting that about 3 to 19% of anthropogenic sources of methane originate from landfills.

Lissens et al. [5] completed a study on a biogas operation to increase the total biogas yield from 50% available biogas to 90% using several treatments including: a mesophilic laboratory scale continuously stirred tank reactor, an up flow biofilm reactor, a fiber liquefaction reactor releasing the bacteria Fibrobacter succinogenes and a system that adds water during the process. These methods were sufficient in bringing about large increases to the total yield; however, the study was under a very controlled method, which leaves room for error when used under varying conditions.

Ranjeet Singh et al. [6] completed a study in Ireland analyzing the usages of biogas and biofuels. This study provides a detailed summary of comparisons with other fuel sources with regards to its effect on the environment, finical dependence, and functioning of the plant. One of the conclusions the study found was a greater economic advantage with utilizing biofuels for transport rather than power production; however, power generation was more permanent and has less maintenance demands.

Thomsen et al. [7] found that increasing oxygen pressure during wet oxidation on the digested biowaste increased the total amount of methane yield. Specifically, the yield which is normally 50 to 60% increased by 35 to 40% demonstrating the increased ability to retrieve methane to produce economic benefits.

Kale and Mehele [8] studied the feasibility for dairy cow waste to be used in anaerobic digestive systems. Because the animal’s wastes are more reactive than other cow wastes, the study suggests dairy cow wastes should be chosen over other animal wastes .

Jantsch and Mattiasson [9] discuss how anaerobic digestion is a suitable method for the treatment of wastewater and organic wastes, yielding biogas as a useful by-product. However, due to instabilities in start-up and operation it is often not considered. A common way of preventing instability problems and avoiding acidification in anaerobic digesters is to keep the organic load of the digester far below its maximum capacity. There are a large number of factors which affect biogas production efficiency including: environmental conditions such as pH, temperature, type and quality of substrate; mixing; high organic loading; formation of high volatile fatty acids; and inadequate alkalinity.

Karve Jantsch and Mattiasson [10] discuss how anaerobic digestion is a suitable method for the treatment of wastewater and organic wastes, yielding biogas as a useful by-product. However, due to instabilities in start-up and operation it is often not considered. A common way of preventing instability problems and avoiding acidification in anaerobic digesters is to keep the organic load of the digester far below its maximum capacity. There are a large number of factors which affect biogas production efficiency including: environmental conditions such as pH, temperature, type and quality of substrate; mixing; high organic loading; formation of high volatile fatty acids; and inadequate alkalinity.

3. DESIGN

3.1 Design Calculations:

a) Gas production rate (G): One kg of kitchen waste (undiluted) if digested well, yields about $0.24 m^3$ of gas. The gas production rate G for the available waste thus given as Eq. (1).

$$G = 0.24W \quad (1)$$

Where, W = 22.8kg/day

$G = 0.24 \times 22.5 = 5.4 \ m^3/day$

b) Active slurry volume (V_s): The active slurry volume in the digester is directly related to the HRT chosen and is given by Eq. (2).

$$V_s = HRT \times \frac{2W}{1000} \quad (2)$$

Where, Taking HRT = 30days

$$Vs = 30 \times \frac{2\times 22.5}{1000} = 1.35 \ m^3$$

c) Calculation of H and (D): There is no strict rule for the relative values of H and D, but usually a D/H ratio 2.0 is used in practice. Knowing the active slurry volume from above calculation, H can be calculated from Eq. (3).

$$\left(\frac{\pi}{4} \times D^2\right) H = V_s, \quad (3)$$

Where, D=2H

$$\left(\frac{\pi}{4} \times (2H)^2\right) H = 1.35; \quad H = 0.76m$$

d) Slurry displacement inside digester (d) :- The selection of a suitable value of 'd' depends upon gas usage pattern. If the total cooking time is about 3 hours, the variable gas storage volume V_{sd} is obtained from Eq. (4).

$$\left(\frac{3}{24}\right) G + V_{sd} = 0.5G \quad (4)$$

This after simplification leads to $V_{sd} = 0.4G$

'd' is then obtained as

$$\left(\frac{\pi}{4}\right) \times D^2 \times d = V_{sd} = 0.4G \quad (5)$$

$$D = \left(\frac{H}{2.5}\right) \times 0.4 \quad (6)$$

e) Slurry displacement in the inlet and outlet tanks (h): The maximum pressure attained by the gas is equal to the pressure of the water (slurry) column above the lowest slurry level in the inlet/outlet tanks. The pressure usually selected to be 0.85 m water gauge as a safe limit for brick. h+d= 0.85

f) Length and breadth b of the inlet and outlet tanks : Usually a rectangular shape with is selected. If the inlet and outlet cross sectional areas are selected to be identicalwe get.

$$2 \times l \times b \times h = V_{sd} = 0.4 \quad (7)$$

Substituting $l = 1.5b$,

$$b = \left(\frac{0.2G}{1.5h}\right)^{0.5} \quad (8)$$

g) Calculation of the dome height (d_h): The volume of the sphere (dome) is given by Eq. (9)

$$V_d = \frac{\pi}{6} d_h \left[3\left(\frac{D}{2}\right)^2 + {d_h}^2\right] \quad (9)$$

The total volume of the gas space, as mentioned earlier is taken as equal to G. As the slurry or gas volume is already fixed as 0.4G, the remaining gas space volume, which is the volume of some, will be equal to (G= 0.4G).

$$0.6G = = \frac{\pi}{6} d_h \left[3\left(\frac{D}{2}\right)^2 + {d_h}^2\right] \quad (10)$$

'd_h' can be obtained by solving the above Eq. (10)

h) Radius of dome (r): The radius is obtained by the Eq. (11).

$$r = \frac{\left(\frac{D}{2}\right)^2 + {d_h}^2}{2d_h} \quad (11)$$

i) Calculation for H^1 for curved bottom digester: For digester with curved bottom, the bottom portion is identical to the dome. H^1 is then obtained from the Eq. (12).

$$G \times \frac{\pi}{4} \times D^2 \times H^1 + 0.6G$$

$$\text{(or) } H^1 = \frac{H}{2.5} \times 1.9 \quad (12)$$

j) Other dimension: The size of the inlet and outlet openings (also called boxes) in the register normally (0.6m × 0.6m) for digester of any capacity. This size is selected so that man can go inside during the construction period. The digester wall is 230mm thick and the walls of the inlet and outlet boxes are 115mm thick is provided. For curved bottoms, two brick layers are provided, the lower layer being 115 mm thick and upper layer 75 mm thick. Concreting, whether lain or reinforced should be 100mm thick.

4. CONCLUSIONS

The design parameter of biogas plant for KGRCET college canteen is shown in Table No. 2 and detailed plant diagram was shown in Fig. 3.

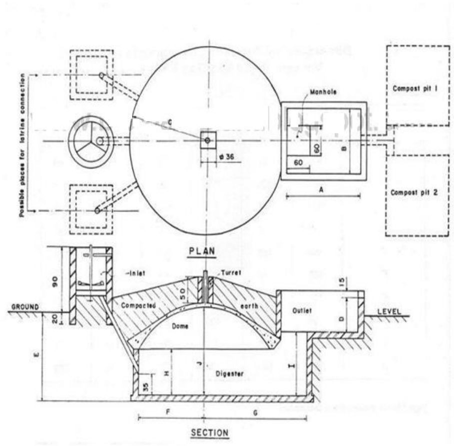

Fig 3. Biogas plant layout

TABLE 2 :- DESIGN PARAMETERS

Parameter	**Value**	**Parameter**	**Value**
G	5.472 m^3/day	*h*	0.57m
V_s	13.68m^3	*B*	1.57m
H	1.63m	*L*	2.35m
D	3.26m	d_h	0.74m
d	0.26m	*r*	2.165 m
H^1	1.23m		

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