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Design and Construction of Manually Operated Biogas Plant for a Farm and Village Settlement in Nigeria

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Abstract: *The biogas generating method involves filling the digester with cow dung, and is left to ferment for days; the result of the fermentation produces biogas in the digester. The gas is then passed through a rubber pipe to the gas holding cylinder. The compositions of the gases are mainly methane and carbon dioxide. The plant is manually operated and does not require high skilled manpower .It is basically expected to be use in farm houses in village settlements. This will cut down on environmental pollution, global warming and reduce the rate of cutting down trees in rural areas.*

Key words: *Biogas, digester, fermentation, biological waste.*

I. INTRODUCTION

Biogas is a combustible mixture of gases produced by micro-organisms when livestock manure and other biological wastes are allowed to ferment in a close system.

We have had it good for many years, using and misusing fuels supplies at will for decades. In some countries particularly Nigeria, the average consumption of fuel equates from two to three gallons per day. This makes an annual consumption of over 1 to 2 billion gallons that is for a population of close to 175 million people. This is probably the most wasteful of the nation but still not extremely far ahead of the others.

At the present consumption rate it is estimated that the known reserves of refine able crude oil will be exhausted in about thirty years to come. The constant effort of our oil companies to sell more and more of the black gold make it unlikely that today's consumption will not increase in the future.

One huge source that has barely used up to now is biological gas. Millions of cubic meters of methane in the form of subsamples gas or biogas are produced every year by the decomposition of organic materials both animals and vegetables. It is almost identical to the natural gas pumped out of the ground by the oil companies and used by many for heating and cooking. In the past however, biogas has been treated as a dangerous by-product that must be removed as quickly as possible, instead of been harnessed for useful purpose. On the other hand, it requires developments of new methods of production and use as a renewable energy sources to suit the economical and geographical requirement of the country.

The recent global energy crisis has generated interest in the use of animal waste for energy as a substitute for fossil fuel. Production of fuel gas (methane) from animal waste in oxygen free atmosphere is one of the most important possible alternatives and could eventually help in prevention of indiscriminate cutting of trees as a source of energy.

II. THEORETICAL BACKGROUND

Biogas in anaerobic digestion generally regarded as the most important product. The methane (CH_4) content of the gas produced varies between 50% and 80% depending on the nature of the organic materials. From animal waste, the gas generated is in the range of 65% - 75% methane. There may be additional small amounts of Nitrogen from air with hydrogen sulphide of less than 1% and hydrogen from microbial metabolism and traces of other hydrocarbons. The gas is wet and contains ammonia traces and volatile fatty acids. These can be produced by using a sealed container by the process of anaerobic fermentation of animal, human, wastes vegetation materials such as grasses, crops residuals, house hold garbage and organic industrial waste.

To facilitate optimum efficiency of production, conditions in the plant should be favorable to the bacteria involved, since the bacterial are sensitive to environmental changes. A number of factors such as organic waste nature, temperature, PH value among others are known to affect biogas generation.
The nature of feed stocks affects the volume of gas depending on their carbon-nitrogen ratio. In many cases, various substances should be mixed together in order to ensure a favorable gas yield while stabilizing the digesting process and promote gas production. This means the time for which any portion of the feed will remain in a continuous flow digester. Some comprehensive surveys that have been conducted by young suggest that retention time is the most useful single indicator of performance. Its units are hours or day (Dioha I.J. Gulma, 1989).
Anaerobic digestion takes place in an oxygen free environment to ensure this condition linked parts of the plant should be provided with perfect sealing to favour maximum gas production. The most important part of the plant begins the gas cylinder, plastic and butyls rubber bags have been suggested but water sealing of the gas holder or floating roof digester has also the advantage of acting as a safety valve if gas pressure is increasing by failure in some other parts the system as an excess gas will bubble out through the liquid seal if the gas production exceeds storage capacity. In hot weather, there is a tendency for slurry to stay out in the angular space between the digester tank and gas cylinder, the resultant solids tend to impede the vertical motion of the gas cylinder. The remaining part of the plant can be provided with thread tape as sealing element (Dangogo S. 1986). The complete anaerobic digestion of cow-dung or manure and chicken waste takes place in about 8 weeks at normal room temperature. One third of the total biogas will be produced in the first week, another quarter in the second week which the gas emission in volume within the remaining weeks.
Gas production can be accelerated and made more consistent by continuously feeding the digester with small amount of waste daily. This will also preserve the nitrogen level in the slurry for use as fertilizer.
In hot regions it is relatively easy to simply shade the digester to keep it in the ideal range of temperature, but cold environment present more of a challenge.
The first action, is naturally to isolate the digester with strew or wood shaving. A layer about 50-100cm thick, coated with water proof covering is a good start if this still proves to be in sufficient in winter, then heating cost may have to be added to the biogas digester.
It is relatively simple to keep the digester at the ideal temperature if hot water, regulated with a thermostat is circulated through the system. Usually is sufficient to circulate the heating for a couple of hours in the morning and evening. Naturally the biogas produced by the digester can be used for this purpose. The small quantity of the gas wasted in heating the digester will more than compensate for the greatly increased biogas production.
The pure gases collected are used for various heating process e.g. water heating, building heating, lighting and cooking. It can also be used in gas burning appliances, running of internal combustion engines, power pumps and crops processing machinery. It can also be used to generate electricity when produced in large quantity.
Furthermore, other benefits include saving of fossil fuel, reduction of fuel expenditure and conservation of forest and grasses among hygienic condition of rural areas. Finally the residuals of fermentation produce an excellent organic fertilizer, soil conditioner and essential ingredient.
Sludge or slurry is the end result of anaerobic digester of the biogas plant which is rich in nitrogen. It also serves as fertilizer, since it contains nitrogen, phosphorus, and potassium. The humus material formed improved physical soil properties. Sludge serves as a source of energy and nutrient for the development of microbial population, improves the solubility and thus availability to higher plant.

III. DESIGN AND CONSTRUCTION REQUIREMENT

The need to make continuously supply of 45kg of fresh dung per day is necessary which facilitates the installation of a 1.7m^3 gas daily. The daily dropping from a medium size cow, buffalo or bullock is about 10kg. Therefore, a famer should have at least five heads of cattle to install a biogas plant. He should have adequate space on the farm yard for the gas installation and space for output slurry pots, which are connected to the plant by means of channels. A sufficient quantity of water should be available since dung must be mixed with water before feeding into the plant. The mixture of waste material and water is in the ration of 1:16 feed into the digester to produce a certain amount of gas. The plant comprises of a digester for fermentation of cow dung, vegetables and other organic matters. A gas cylinder is assembled to the digester by means of a flexible hose to collect and direct the gas produced into the kitchen or where it is desired to be used of correct pressure. The out sherry can be waste and finely used as manure.

Design calculations.

$\pi = 3.142$

$h = height$

$d = diameter$

V_d=Volume of digester

V_f=Volume occupied by fluid

W = Quantity of waste
M_w = Amount of water
T_r = retention time
C = gas yield per unit day of whole input
V_b = Volume of Biogas
The volume of the digestion is given as
$V_d = \pi \frac{d^2}{4} h$ …………………………………….. (1)
Where:

$$\pi = 3.142$$
$$h = 560mm$$
$$d = 290.1mm$$

V_d = 37.02 m^3

$V_f = \frac{2}{3} x V_d$ ……………………………………… (2)

V_f=24.68 m^3

The quantity of waste needed for initial feeding (w)and the feeding ratio 1:¼ water to waste.

$$W = \frac{V_f \times f.ratio}{2.25}$$
$$W = 13.71m^3$$

Therefore, the amount of water required:

$$M_w = \frac{V_f}{2.25}$$
$$M_w = 10.97m^3$$

The retention time 'T_r' when 24.68m^3sludge is feed daily is

$$T_r = \frac{V_d}{V_f} - - - - - - - - - - - - - - - (3)$$
$$T_r = \frac{37.02}{24.68}$$
$$T_r = 1.5\ days$$
$$T_r = 36\ hours$$

The volume of the gas produced on daily basis (μb). Biogas yield per unit day of whole input (c).

$$C = \frac{0.35m^3}{kg}$$
$$Vb = c \times w$$
$$Vb = 0.35 \times 13.71$$
$$Vb = \frac{4.7985m^3}{day}$$
$$Vb = 4.8m^3/day$$

Biogas Digester

This is essentially a stainless steel circular drum with hemispherical shapes at the top and bottom of the cylinder made from stainless steel. The drum is 560mm high, and 290.1mm in diameter with thickness 1mm.

A pipe is welded at the side of the drum for the attachment of the hoses for collection of the gas, the drum has a cover that is made from the same material and hemispherical in shape which has two holes, one at the middle is for the stirrer and the other side hole is for the slurry inlet which is attach with a funnel for the easy entrance of slurry.

Gas Cylinder

The gas cylinder is also of stainless steel drum, which is connected to the digester through a flexible hose. The cylinder has a height of 500mm and diameter of 290mm.The gas produced in 'the digester rises through the slurry and is collected in the cylinder. The accumulated gas flows through the gas pipe to the kitchen or wherever it is desired to be used.

IV. MATERIAL SELECTION

The selection of material form an integral part of any design process. There are numerous metals, alloys and non-metals available for use as engineering materials, hence the materials selected where base on its ability to withstand hash environmental and weather condition.

Mild Steel Bars

MS bars are used to construct the covers of outlet tank and water drain chamber. For plants of 4, 6 and 8 cum, MS rods of 8 mm diameters are used and for plant of 10 cum capacity 10 mm diameter is recommended.

Main Gas Pipe

Gas stored in the gas cylinder is conveyed to the pipeline through this pipe which is placed in the topmost portion of the dome. The joint of reduction elbow with this pipe should be perfect and air tight to avoid gas leakage. The gas pipe should be properly galvanised and must be of sound quality. This pipe should be made up of light quality iron and MS rod welded at one end to embed it with the concrete during installation. The length of this pipe should be at least 60 cm.

Main gas valve

It controls the flow of biogas in the pipeline from the gas cylinder. It is opened when gas is to be used and closed after each use. If substandard quality of main gas valve is used there is always risk of gas leakage. This valve should be of high quality and approved by the concerned quality control authorities.

Pipes Fittings

The pipeconveying gas from gas cylinder to the point of application should conform to quality specification as per the standard of Pakistan. Light quality Galvanised Iron pipe is best suited for this purpose; however, high quality, PVC pipe could also be used. The pipe should be of at least half inch diameter. For pipe with more than 60 m length or (30 m if two burners are to be used at a time) %" diameter pipe has to be used. If GI pipe is to be used, a six meter pipe should weigh at least 6 kg. The fittings used in the pipeline of a biogas plants are socket, elbow, tee and nipples. These fitting should meet the required quality standard.

V. CONCLUSION

An obvious obstacle to the large scale production of biogas technology is the fact that the majority of the rural populace cannot afford the exorbitant cost of investment requirement without government involvement, hence the need for manually operated and low cost design and construction of a potable biogas plant.The ease of operation and availability of raw materials couple with minimal maintenance skill required makes it adaptable to the rural dwellers. Similarly as an alternative and renewable energy source it serves as a control of greenhouse effect by minimizing deforestation which is commonly found within the rural area in Northern part of Nigeria.

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