FABRICATION AND DESIGN OF SELF PRESSURISED PORTABLE BIOGAS PLANT FOR KITCHEN WASTE

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Abstract
The energy demand is increasing day by day, it is important to pay attention to fulfil this energy demand. Nowadays country like India is looking for renewable energy resources.Biogas is a good option in this regard. Most of the Indian populations are depended on wood and LPG gas for heating solution. But due to the insufficient source of natural gas resource in India, government import large scale of LPG from other countries to fulfil that demand which will affect the country economy. Use of wood for cooking purpose is not safe for the environment and human beings. This project represent a portable biogas plant to cater this gap and for providing clean cooking fuel. In this design, we are using 50 litres tank used for the digestion process. Kitchen waste is fed into the digester through feed hopper with same ratio of water. A gas storage system has also used in such a manner so that pressurised gas supply could be maintained. For the storage system two tanks of 50 litres and 30 litres have used. In pre-stages the result was very positive and availability of cheap and clean cooking fuel ensure by such design at a very small scale. It is also reducing the size of the biodegradable waste at root source. Liquid residuum obtained through this process is very useful for agricultural purposes.

Introduction

A. The problem of "FUTURE"

With the increasing industrialization, urbanization and alteration within the pattern of life, that accompany the method of economic process, bring about to generation of sky rocketing quantities wastes leading to increased threats to the environment[1]. This can be perceived from below given figure 01 which showing how the waste concentration is increasing along with population. The waste is just not only a single problem which the world is facing but declining of conventional fuels with the increasing of population is a matter of concern as well. In a course of time the concentration of waste and demand of fuel will keep increasing. Therefore, it becomes important to take healthy action to get rid of both the problems. Otherwise there will not be any place left which is not covered by waste. In India, waste generation rate ranges between (0.2-0.8) kg /day depending upon the region lifestyle and the size of the city (swanindia). The percapita waste generation is increasing by 1.3%approx per year in India[2]. Having said that close 62MT waste is generated on annual basis, which will increase by 2 times by 2030[3].

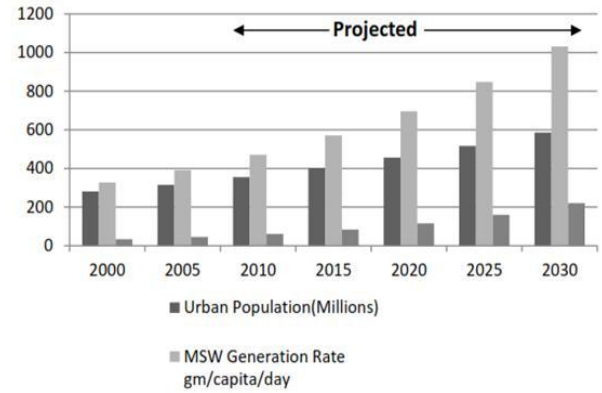


Figure 01: Parallel growth of both waste and population [4]

From the figure01, it can be seen how waste and population is increasing drastically and poses a serious threat. It can attract attention of anyone and make to think so that decisive can be taken in order to deal with both menace. It is required to go parallelly with waste and population to tackle both.

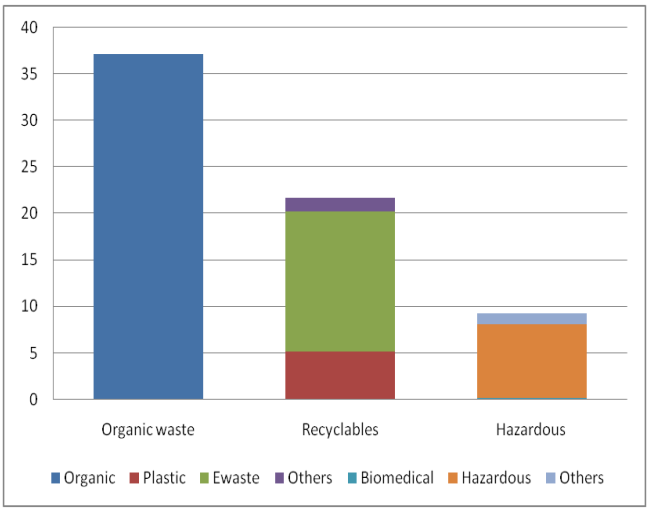


Figure 02: Different types of waste included in MSW[5]

The above figure02 is showing the MSW is consists of different types of waste, in which the amount of organic waste is more in compare to recyclable waste and hazardous waste. Frequent rise in fuel prices and advanced methods of refining conventional fuels from crude oils pose a threat to the environment and calls for a search to find cost effective and environmentally cautious methods of finding alternative fuels[6]. The fuel is an important entity which supports in growth of the nation. 80% of the world's energy consumption still originates from conventional fuels[7]. The dependence on fossil fuel as primary energy source has led to the global warming, climatic change, environment degradation and health problems[7]. The rate of consumption of fuel is more than the generation of fuel and it takes very long time to reproduce again.

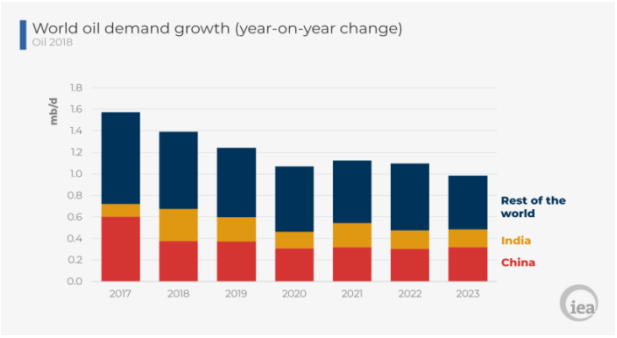


Figure 03: India's oil demand year-per-year[8]

B. A way to get back safe environment

It is needed a green, eco-friendly, and renewable type of energy. The development of renewable energy technologies and in particular biogas technology can help reduce the dependence on non-renewable resource, minimize the social impacts and environment degradation problems associated with fossil fuel[9]. Although the government agencies are making considerable effort in tackling waste related problems, there are still major gaps to be filled speciallyin the solid waste management[6]. Several support schemes namely Natural Biogas and Manure Management Program (NBMMP), off-grid biogas power generation program, waste to energy program have been started by the government for the biogas development in India[10]. One of the solution for these problems is Biogas.

Feed stock	Gas Yield m^3/kg
Cattle dung (from dairy milking or feed lot cow)	0.045
Piggery waste (from piggery farm)	0.045
Poultry dropping (From poultry farms)	0.060
Human excreta (big or small town)	0.050
Fruit waste (Fruit processing Factories)	0.055
Press mud (From sugar factories)	0.10
Banana peeling (banana food processing factories)	0.043
Cauliflower waste (from farm or vegetable markets	0.042
Food waste(from food processing Industries)	0.080

Figure 04: Yield biogas of different feedstock[11]

The potential of biogas production, an important source of energy stands in second position, next to the solar energy[12]. Biogas is produced by microbial activity with degradation of organic matter in anaerobic environment. The generated waste can be treated with anaerobic digestion. Anaerobic digestion also function as a waste disposal system particularly for human waste and therefore prevent potential source of environment contamination and the spread of pathogens[13]. For the disposal waste different disposal methods are available and there is need to select eco-friendly option to save the environment and natural resource[14]. The leading concepts nowadays are: single phase digestion, two phase digestion, dry fermentation and co-digestion[15]. Food waste

is a desirable materials to co-digest with dairy manure because of its high biodegradability[7]. The reason for food waste is easily available and gives maximum percentage of methane. By using food waste there can be reduction in the daily waste generated in houses as well as generating an alternative source of energy[7]. Animal manure and agricultural wastes are primarily used as feedstocks in household biogas digester producing biogas and bio-slurry that can be used as organic fertiliser[10]. Biogas consists of methane, carbon-dioxide, hydrogen, hydrogen-disulphide and some traces of water vapour. Biogas is distinct from other renewable energies because of its characteristics of using, controlling, and collecting organic wastes and at the same time producing fertiliser and water for use in agricultural irrigation[16]. It can also be used in modern waste management to facilities where it can be used to run any type of heat engine to generate either mechanical or electrical power[17]. The biogas obtained from AD can be purified to natural gas standard and is called bio-methane. The efficiency of methane gets increased by compressing it. Food waste produces two clean energy gases hydrogen and methane, which can be burned to produce electricity, heat or to propel vehicles. AD is a nice way to solve the problem of waste and fuel crisis.In this paper, the production of biogas by co-digestion of kitchen waste with cow-dung is carried in thermophilic condition for 30 days. This paper presents the design and working procedure to make a portable self-pressurised biogas plant at a small level. This portable biogas plant could be uses at small levels such as domestic kitchen waste, mess and canteen to mitigate the problem of biodegradable waste at root source.

Preparation of prototype

A. Setup:

This setup consists of three containers, PVC pipes and bends, gas valves, gas pipes, m-seal, silicon adhesive, drilling machine, scale and rubber seal.

Table1: Materials that are used in the prototype

S. No.	Item	Material	Capacity/Size
1	Digester Tank	HDPE	50L
2	Storage Tank	HDPE	50L
3	Collector Tank	HDPE	35L
4	Gas Pipe	PVC	2 m
5	Gas valve	Brass	¼”
6	Feedstock pipe	UPVC	110cm
7	Spring	Carbon Steel	D=3cm d=0.2cm

B. Construction:

In this prototype, three containers are of 50L, 50L and 35L. One is used as a digester and other as a water storage tank. The last container is used as the gas storage. The digester of 50 litres is drilled at two positions: one is at the top and other at curved surface of the container at a height of 420 mm from the bottom. The diameter of each hole is 5cm. The top hole is serving for feeding purpose and the other hole is for releasing the digested slurry. The 50 litre container is used for water storage. The gas storage container is uplifted position inside the water storage container. And this container is fixed to water storage container in such a way so that it can move up and down. The gas storage system consists of two drums one of 50La and other of 35L. The 35L tank is immerged upside down into the 50L tank, in which water is filled up to a certain level, making room for the gas to store under pressure. This structure is made up of wooden rectangular board on which gas storage system is placed and four wooden rods. Ends of these wooden rods are fixed in vertical position on the wooden board around the gas storage system and other ends are connected diagonally by wooden rectangular thin strip so that it makes a cross like symbol as seen from top. The centre of these cross is drilled so that 0.8cm iron rod of length 73.15cm would pass through it easily. The 8mm iron rod is connected to inverted gas tank at the centre in vertical position. This rod is passed through set of springs. The other end of rod is passedthrough the wooden cross. Here spring is used to maintain the pressure of gas. As the production of gas increases causes the pressure inside the tank also increases which results in upward movement of gas tank. Due to this rod movement, the amount by which rod rises above the wooden cross is used to measure the amount of gas produced. For transfer of gas from digester to gas storage system, there are holes made: one at digester where gas valve is fitted and two on the gas storage. Out of one is used to take gas from digester to gas storage through gas pipe. Second hole is made on gas storage system for transfer of gas from gas storage tank to purification unit. The purification unit is placed in between digester and gas storage system. The outlet pipe of digester tank is connected with the inlet of the purification unit and the outlet of purification unit is connected with the inlet of gas storage system.

Selection of feedstock

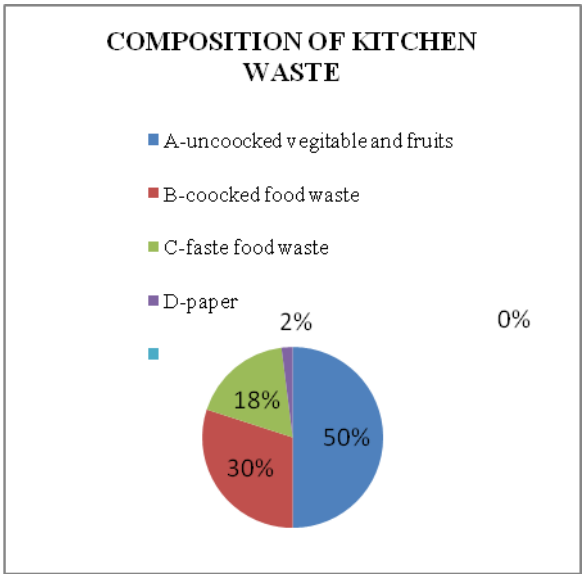
For the generation of the biogas, the variety of organic waste materials are used in an anaerobic digester as a feedstock.

A. Process of selection of kitchen waste.

In this project kitchen waste has been collecting from hostel mesh and canteen of JIMS Engineering Management Technical Campus. Feedstock consists of daal, chawal, chapatti, cooked and uncooked vegetable and different fruits.

B. Composition of kitchen wastes of jims management technical campus hostel and canteen

Average composition of kitchen waste is analyzed as approx 50% of the waste is uncooked vegetables and fruits, 30% of the waste is cooked food, 18 % of the wastes are fastfood and 2% of the wastes are paper. Generally food waste are selected such as: soyabean, paneer, pulses, carrot, banana peels, bread ,cooked food . The food waste was mixed with water used for rice washing to make fine slurry. For collecting waste a separate container of 5 liters is used in which this kitchen wastes are collected.



Preparation of feedstock

At initial stage 20 kg of digested cow dung was mixed with 20 litres of water in 1:1 ratio in 50 litres digester tank. Since it contains enough microorganisms for the anaerobic digestion process. After the inoculation digester was kept for some days and gas production was checked on regular basis. After some days kitchen waste was added for checking gas production. Before feeding into digester, the slurry was mixed by hand grinder in a separate container for few minutes and fed to the digester daily for five days. The slurry of 5 kg is prepared in the ratio of 1:1 that is 2.5 kg of selected kitchen waste and 2.5 kg of water.

Purification of biogas

Biogas can be produced from organic materials by anaerobic degradation. Biogas consists of various components like methane, carbon-dioxide, hydrogen sulphide and traces of other gas compounds[18]. Biogas can be used directly to generate power, but the large volume of carbon-dioxide reduces the heating value of the gas, increasing compression and transportation costs and limiting economic feasibility[19]. Purification allows for a wider variety of uses, either for heat and electricity or for vehicles. For using biogas as a fuel we have to purify the biogas before its actual use which will remove carbondioxide hydrogen sulphide from biogas since these gases are more soluble in water than methane. The absorption process is purely physical. The principle of separation or purify based on different solubility of various gas components in a liquid scrubbing solution. We have used water as a selective absorbent and it is also widely used in water scrubbing of biogas at an industrial scale also[20]. The best advantages of water scrubbing is that it does not require any special chemicals and removal of both carbon dioxide as well as hydrogen sulphide

In the purification method we convert raw biogas into upgraded biogas

Low Grade Fuel → High Grade fuel

Low grade fuel, which contain lower percentage of methane(CH_4 55-65% and CO_2 35-45%)

High grade fuel, which contain higher percentage of methane (CH_4>90% and <10% other gases)

In biogas purification process raw biogas stream like H_2S, CO_2 and moisture are absorbed or scrubbed off, leaving above 90% methane per unit volume of gas[21].Presence of CO_2 leads to the following problems:

i. It lowering the power output

ii. It can cause freezing problems at valves

Traces of H_2S lead to produce H_2SO_4 which corrode the internal of pipe fittings. Moisture causes corrosion and lowering the heating value of the fuel.

Table 2: General features and characteristics of biogas, (Source: Engineering ToolBox, (2008)

Boiling point	111.51K
Fuel equivalent	0.6-.65 l oil/m^3 biogas
Explosion limits	6-12% biogas in air
Auto-ignition temperature	810K
Critical pressure	45-50bar
Critical temperature	190K
Normal density	0.65-.70 Kg/m^3

Needs of biogas compression energy density of high grade biogas is comparatively low at low pressure so it must be compressed at high pressure (200-250 bar)[22]. Compressed biogas leads to

i. Reduce storage space required
ii. Increases energy concentration
iii. Overcome resistance to gas flow

Water Scrubbing Process Involves the physical absorption of CO_2 and H_2S in water at high pressure Only use pressurized water as an absorbent so it is cheapest as well as easiest[23]. The dissolved CO_2,H_2S in water are collected at the bottom part of water scrubbing tank .For moisture removing we use the concept of selective adsorption of moisture at outer surface of adsorbent like silica gel , activated alumina, zeolite molecular etc.

In this project, plastic bottle of volume 2L is taken for the purification. Atthe top of bottle 2 holes are made diagonally of 5mm diameter and thetransparent rubber pipe of 5mm diameter is used. Digester outlet valve is connected to the inlet of purification unit through pipe.The outlet of the purification unit is connected to the inlet of gas storage tank through pipe. The bottle is filled with water containing 75% of its volume. Measuring scale is also provided on the top of the gas storage system in order to calculate the volume of gas produced.

Characteristics of Biogas

Characteristics of biogas is depends on the concentration of methane (CH_4) present in it. Biogas production from organic waste is affected by the temperature where anaerobic digestion take place, generally at very low or at high temperature so it is essential to maintain optimum temperature (37°C)[24]. Biogas is about 20% lighter than air has an ignition temperature in range of 650 to 750 °C.It is an odourless and colourless gas which is burn withblue flame like LPG gas. Its calorific value is 20 Mega joules (MJ)/m^3 and its burning efficiency is 60% in a stove[16].

Result and Discussion

In our college JEMTEC, there are two canteens and one hostel which produce enough food waste and kitchen waste. It is earlier, kept and awaited for a days for dumping vehicle to come and disposed-off on an open dumping by conventional method of disposal and also promote the breeding of mosquitoes with bad smell. This waste can be used to generate biogas by Anaerobic Digester. The Anaerobic Digester has been fabricated of floating type. On the basis, of lab scale experiment, the cow-dung and water is taken in the ratio 1:1, the Kitchen waste and cow dung is taken in the ratio 2:1 which will produce more gas.

The experiment has been closely monitored and changes in position of spring rod which is fixed on above the storage tank, due to gas production have been noted. Initially sudden production of gas taken 10 to 15 days of time,after that every 5 days reading of gas have been taken

Table 3: Gas production of the sample

Days	Values (in m^3)
1	0
15	0.01
20	0.018
25	0.024
30	0.030
35	0.036

Conclusion

Thus, it has been concluded that the digester of kitchen waste produced good amount of biogas with 67% methane content. The research has provided, that after 10 -15 days of setting the feed to the digester, a considerable amount of gas is produced, which may be due to the cultivation of the bacteria into the digester chamber. The total biogas production has been estimated to be around 0.04 m^3. The slurry tends to have neutrality (pH of 6.6-7.0), which provide a good source of natural fertilizer. Use of biogas is an important source of fuel which reduces the green-house gas emission and reduces the environment pollution.

Future Scope

Researchers are encouraged to proceed with further experiment to upgrade the biogas generated from kitchen waste. And also it hinders the applicability of biogas in S.I engine fuel application.

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