Institutional Organic Waste Management for Bioenergy Production from Anaerobic Digestion Process

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Abstract Energy is one of the most important factors for human development and to global prosperity. Present study deals with recovery of energy from aerobically digested biomass resources such as cattle dung and hostel kitchen organic waste. In this regard anaerobic digester at lab level is fabricated to utilize the institutes canteen waste for producing biogas. Biogas production is a Clean, low carbon technology, useful for the efficient management and conversion of organic waste into clean renewable biogas and organic manure/fertilizers. It will give extensive knowledge of Design aspects of Biogas reactor and maintenance of reactor during the process. It has the potential for leveraging sustainable livelihood development as well as tackling local and global land, air and water pollution. Also decomposed slurry/waste used as manure for gardening purposes. The amount of methane present in biogas is found to be 65%. To segregate methane from other gases such as H_2S and Co_2 purification by lime treatment is adopted. Further from the experimental work it was observed that bio methane as best alternative compared to LPG in respect of calorific value biogas and emission study. The present work will be worthy for academicians and people dealing with bioenergy, environmental pollution.

Keywords* —*Anaerobic Digestion, biomass.

I. INTRODUCTION

The dependence on fossil fuels as primary energy source has led to global climate change, environmental degradation, and human health problems. 80% of the world's energy consumption still originates from combusting fossil fuels. Yet the reserves are limited means do not match with the fast population growth and their burning substantially increases the greenhouse gas (GHG) concentrations that contributed for global warming and climate change. So, bioenergy (energy production from biomass) can be seen as one of the key options.

Anaerobic digestion (AD) is a technology widely used for treatment of organic waste for biogas production. Anaerobic digestion that utilizes manure for biogas production is one of the most promising uses of biomass wastes because it provides a source of energy while simultaneously resolving ecological and agrochemical issues.

Biogas comprises of 60-65% methane (CH_4), 35-40% carbon dioxide (CO_2), 0.5-1% hydrogen sulfhide (H_2S), and the rest is water vapor etc. it is almost 20% lighter than air.

II. MATERIALS AND METHODOLOGY

Anaerobic digestion technologies

Anaerobic composition is a putrefactive breakdown of the organic matter by reduction with the absence of oxygen, leading to the production of methane (CH_4) and carbon dioxide (CO_2).

Process Microbiology

In the anaerobic composting of wastes, number of anaerobic organisms work together to bring about the conversion of organic portions of the wastes to a stable end product. One group of organisms responsible for hydrolyzing organic polymers and lipids to basic structural building blocks such as fatty acids, monosaccharide, amino acids, and related compounds. A second group of anaerobic bacterial ferments the break down products from the first group to breakdown organic acids, the most common of which in anaerobic composting is acetic acid. This second group of microorganisms (called as non-methanogens) consists of facultative and obligate anaerobic bacteria and are called ACIDOGENS or ACID FORMERS.

A third group of micro-organisms converts the hydrogen and acetic acid formers by the

acid formers to methane gas and CO_2. The bacteria

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responsible for this conversion are strict anaerobes called methanogenic and are called METHANOGENS or methane formers.

Typical energy yielding conversion reaction involving their compounds are as given in below equation

$4H_2 + CO_2 \longrightarrow CH_4 + 2H_2O$
2. $4\,HCOOH \longrightarrow CH_4 + 2H_2O + 3CO_2$
3. $CH_3COOH \longrightarrow CH_4 + CO_2$
4. $4(CH_3)_3N + 6H_2O \longrightarrow 9CH_4 + 3CO_2 + 4NH_3$
5. $4CO + 2H_2O \longrightarrow CH_4 + 3CO_2$

Biodigesters

The biodigester is a physical structure, commonly known as the biogas plant. Since various chemical and microbiological reactions take place in the biodigester, it is also known as a bioreactor or anaerobic reactor. The main function of this structure is to provide anaerobic condition within it.

Material of Digester and Drum:

The digester is made with M.S steel material. The gas drum normally consists of 2.5 mm steel sheets for the sides and 2 mm sheets for the top. It has welded-in braces which break up surface scum when the drum rotates. The drum is protected against corrosion.

Anaerobic digestion involves conversion of food waste by decomposition into a mixture of gases known as BIOGAS. For this process, an anaerobic digester was developed. This model is chosen to produce biogas because it is safe, economical and can store biogas effectively. This model consists of two cylinders. Outer cylinder of 500 liters capacity and inner cylinder 300 liters capacity.

The inner cylinder rotates and rises as a centrally fixed in the outer cylinder. When the inner cylinder rises over the pipe it indicates the accumulation of biogas by storing the volume of gas collected. The outlet cylinder is provided with an inlet and an outlet. An inlet is for introducing food waste. Outlet is for cleaning the cylinder and as the sludge increases it can find its way out through this point. It is fitted with a pressure gauge to know the existing pressure of the biogas. A valve is fitted for collection of biogases produced and stored.

III. DESIGN DETAILS OF THE ANAEROBIC DIGESTER FABRICATED FOR DECOMPOSITION OF FOOD WASTE

The model was fabricated out of mild steel as it is safe for storing gas which is highly inflammable. It consists of several inbuilt parts which are firmly welded. It was painted to ensure that it avoids rusting as food waste is introduced.

The outer cylinder was fabricated to a height of 1300mm. It has an inlet for introducing the food into the cylinder. An outlet is provided for the decomposed matter to get discharged from the cylinder for disposal as compost to greeneries. The central pipe connected was at a height of 1200mm which is useful in indicating the

Cooked Waste		**Uncooked Waste**	
Easily Degradable	Not Easily Degradable	Easily Degradable	Not Easily Degradable
Rice, Dhal Etc.	Chapati Etc.	Vegetables, Fruits, Damaged Vegetables Etc.	Vegetable Leaves, peels (the part of vegetable has Lignin component)

Table-1: types of waste

Collection of Food Waste:

The food waste collected from the institute hostel mess was segregated. The institute medical hospital canteen, boys' hostel and girls' hostel, waste was segregated from food rise of the inner cylinder over the pipe. An inlet was introduced to the outer cylinder. Outlet was fixed at the required height from the bottom of the cylinder. At the bottom of the outer cylinder a valve is provided for the purpose of cleaning and maintaining the equipment.

The outer cylinder handles were provided all around for easy handling of the equipment.

Inner cylinder is provided with a nozzle for extraction of gases. It was also provided with a valve for measuring the pressure of the biogas collected within the inner cylinder. The other end of the cylinder is kept open so that it provides entry for the gases. This cylinder is also provided with a central pipe which has a diameter slightly larger than that of the pipe which is fixed in the outer cylinder. This helps noting down the height of rising of the inner cylinder with the collection of gases.

Testing of the pilot model: In order to make sure the model was leak proof, it was completely filled with water and left for 48 hours noting the initial height of the inner cylinder on the central pipe. After 48 hours it was noted that there was no drop in the rise of the inner cylinder. This ensured us that the tank was leak proof for water or air. waste according to the cooked, uncooked and biodegradable food waste. Mess timetable:

According to the easily digested forms are classified into classified the waste

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Table2: classification of food waste

Food	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
Breakfast	Y	Y	Y	Y	Y	Y	Y
Lunch	Y	Y	Y	Y	Y	Y	Y
Snacks	Y	N	Y	N	Y	N	Y
Dinner	Y	Y	Y	Y	Y	Y	N

Y =available, N=Not available PROCESS MICROBIOLOGY:

The outer cylinder in which the food waste and the cow dung will allow for decomposition process. Initially food waste of 30 mm size introduced were getting reduced in size during the decomposition process. The waste was introduced for 7 days continuously and each day the waste consisting of carbohydrates, fats and proteins was getting converted into sugar, fatty acids and amino acids in the process of hydrolysis. In converting these acids into carbonic acids, alcohols, hydrogen, CO2, and ammonia acidogens or acid farmers play a vital role. A third group of microorganisms known as methane farmers convert hydrogen, acetic acid, and CO2 into CH4, H2S, CO2.

During this process, the inner cylinder was rising on the pipe (mounted centrally in the outer cylinder) with the accumulation of gases that was produced by the waste. This gives a found to be25-30oC for the microbial activity. Monitoring of pH, temperature and moisture content were done on a daily basis. The excess sludge produced finds its way through the outlet. Through the outlet of

Temperature (in ^{0}C)		REMARKS
Day-1	27	The temperature was within the normal range of 25 to 350C aiding efficient working of microorganisms. As the decomposition reaction starts, it leads to a slight increase in the temperature.
Day-2	26	
Day-3	27	
Day-4	25	
Day-5	28	
Day-6	27	
Day-7	26	

Table-3: Temperature survey

inner cylinder biogas was collected in a cylinder by compressing the gas from the compressor. The compressed biogas is expected to contain H2S, CH4, and CO2.

All the food waste was thoroughly mixed before being introduced into the digester. During the process of anaerobic decomposition, it was preferred to use only food waste collected from different hostels. This food waste consisted of cooked food and pulses. The amount of waste introduced was 9 -10 Kgs daily for 7 days. Initially before introducing the waste, a required amount of cow dung was added to initiate indication of collection of biogas i. During the process of decomposition, pH of the waste was ensured below 7 in order to see that the food waste is acidic. It was always found to be from 5.3-6.2. Temperature was microbial activity. Moisture content of food waste was found out and normally it was found to be around 70%. In order to have a homogeneous mixture of cow dung and food waste thorough mixing was carried out by agitation with the inner cylinder when constantly rotated.

EXPERIMENTAL SETUP:1

Feed combination for 1 experimental set up digester filled 100kg of cow dung 50 kg of food waste (2(cow dung):1(food waste)) and water added is 50litre.

pH: pH is a measure of the acidity or basicity of an aqueous solution.

PH		REMARKS
DAY-1	6.2	Initially the pH is nearer to neutral condition but gradually decreases, showing the growth of microbial activity essential for Decomposition of waste.
DAY-2	5.9	
DAY-3	5.5	
DAY-4	5.6	
DAY-5	5.35	
DAY-6	5.4	
DAY-7	5.3	

Table-4: PH Survey

Moisture content

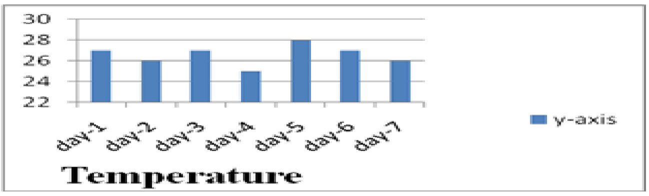
Water content or moisture content is the quantity of water contained in a material.

Moisture content = (weight of water content in a sample) / (dry weight of sample)

with a pH less than 7 are said to be acidic and solutions with a pH greater than 7 are basic or alkaline.

Graph value represents the pH value of experiment set 1
Note: X-axis represents the pH values Y-axis represents the days of the experiment

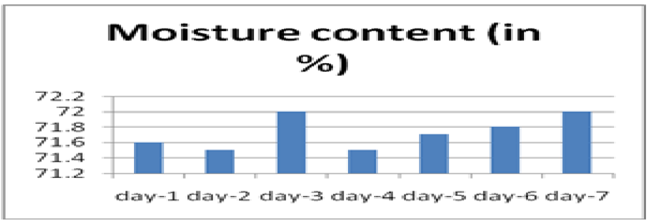
Y-axis represents the moisture content percentage and X-axis represents the day of analysis.



Graphical Representation: 2

pH:

Graph: Graph representing pH analysis for 2 set experiment



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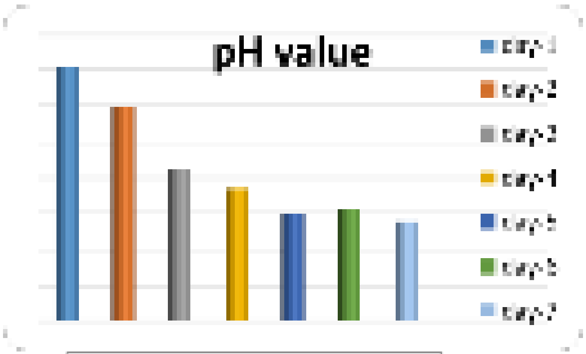
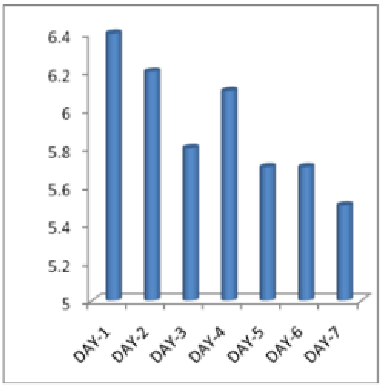
Graphical representation:1





Temperature:

Temperature is a physical property of matter that quantitatively expresses the common notions of hot and cold. Quantitatively, temperature is measured with thermometers Seven days the temperature analysis was carried

EXPERIMENTAL SET NO:2

In the second set up samples were filled to digest about 100kg of cow dung, 100 kg of food waste (1(cow dung):1(food waste)) and water added is 100litre. slight lift in gas cylinder, methane observed

Table-5: Moisture Content Survey

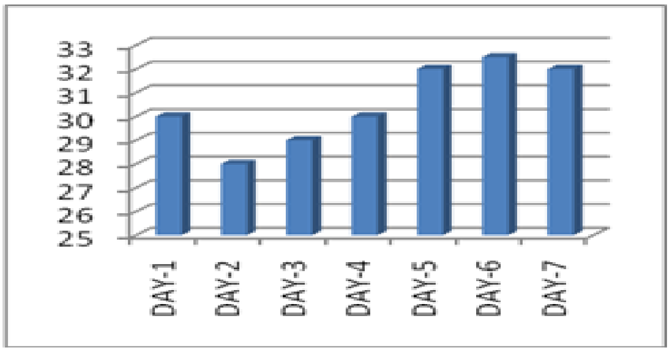
MOISTURE CONTENT (in %)		REMARKS
DAY-1	71.6	It is maintained for the survival of micro- organisms
DAY-2	71.5	
DAY-3	72	
DAY-4	71.5	
DAY-5	71.7	
DAY-6	71.8	
DAY-7	72	

Graphical Representation: 3,4

Moisture content:

Table-6: PH survey

PH		REMARKS
DAY-1	6.4	Initially the pH is nearer to neutral condition (slightly acidic) but gradually decreases, showing the growth of microbial activity essential for Decomposition of waste
DAY-2	6.2	
DAY-3	5.8	
DAY-4	6.1	
DAY-5	5.7	
DAY-6	5.7	
DAY-7	5.5	

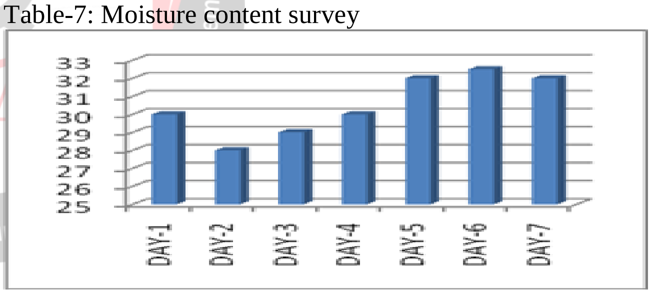


Graphical representation:4

Y-axis represents the moisture content percentage and X- axis represents the day of analysis

MOISTURE CONTENT (in %)		REMARKS
DAY-1	74	It is maintained for the survival of microorganisms. Initially Moisture content was increasing by some extent and then starts decrease this clear indication of microbial activity started
DAY-2	72	
DAY-3	75	
DAY-4	74.4	
DAY-5	73	
DAY-6	72.5	
DAY-7	72	

Table-7: Moisture content survey



Graphical representation:5

X-axis represents the days of experiment analysis and Y- axis represents the temperature which is centigrade

TEMPERATUR		REMARKS
DAY-1	29	The temperature was within the normal range of 25 to 35^{0}C aiding efficient working of microorganisms.
DAY-2	27	
DAY-3	28	
DAY-4	26	
DAY-5	27	
DAY-6	28	
DAY-7	30	

Table-8: temperature survey

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Result:

We observed light lift in gas cylinder, methane observed around 50 – 55 %. but we observed the lighting of a molten lamps. we are unable to light up the stove.

EXPERIMENTAL SET 3

pH: In the third set up samples were filled to digest about 100kg of cow dung, 225 kg of food waste (1(cow dung):2(food waste)) and water added is 150litre (not at once daily 10litre with food waste).

PH		REMARKS
DAY 1	76	It is maintained for the survival of microorganisms. Initially Moisture content was increasing some extent and then starts decrease this clear indication of microbial activity started.
DAY 2	75	
DAY 3	74.5	
DAY 4	74	
DAY 5	73	

Table-9

PH		REMARKS
DAY 1	7.4	Initially the pH is above neutral condition, slightly alkaline condition, at day 2 to 3 day it is nearer to neutral condition but gradually decreases, showing the growth of microbial activity essential for Decomposition of waste.
DAY 2	7.2	
DAY 3	6.8	
DAY 4	6.4	
DAY 5	6.2	
DAY-6	5.9	
DAY-7	5.5	

Table-10

Moisture content:

TEMPERATURE:

TEMPERATURE (in ^{0}C)		REMARKS
DAY-1	30	The temperature was within the normal range of 25 to 35^{0}C aiding efficient working of microorganisms. As decomposition reaction started leads to slightly.
DAY-2	28	
DAY-3	29	
DAY-4	30	
DAY-5	32	
DAY-6	32.5	
DAY-7	32	

Table-10: Temperature Survey

Result:

We observed good lift in the gas cylinder, methane observed around 60 – 65 %. we light up the molten lamp and stove. Compressed using compressor and then

IV. PROCEDURE

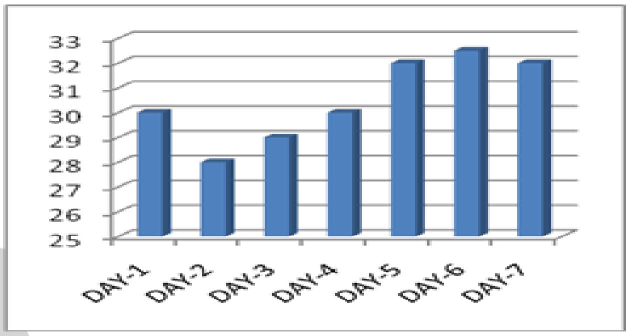
Experimental setup 1

Initially the digester filled 100kg of cow dung 5o kg of food waste (2(cow dung):1(food waste)) and water added was 50litre. We observed light lift in the gas cylinder, methane observed around 40 – 50 %. we are unable to light up the molten lamp and stove

Experimental setup 2

In the second set up samples were filled to digest about 100kg of cow dung, 100 kg of food waste (1(cow dung):1(food waste)) and water added is 100litre. We observed light lift in the gas cylinder, methane observed around 50 – 55 %. but we observed the lighting of a molten lamp. we are unable to light up the stove

Ratio of water and waste is 1:1.



Graphical representation-6

Experimental setup 3

In the third set up samples were filled to digest about 100kg of cow dung, 225 kg of food waste (1(cow dung):2(food waste)) and water added is 150litre (not at once daily 10litre with food waste). we observed good lift in gas cylinder, methane observed around 60 – 65 %. we light up the molten lamp and stove. compressed using a compressor and then purified by using lime solution.

Decomposed slurry collected in the bucket and that was used for manure purposes.

a. Indication of biogas in cylinder:

Fig-1

Increase in volume in the anaerobic digestion showing production of biogas

It was witnessed that sunlight and temperature shown effective in increase in gas production noticed by the inner cylinder of the reactor was rising by the light

Maximum height achieved:

b. Maximum height achieved:

outlet was open to atmosphere to ensure all the gas has

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been disposed off for both experiments 1 and 2:

Segregation of lime in biogas.

Biogas is made up mainly of methane (CH4) and carbon dioxide (CO2). It also contains traces of hydrogen sulfide (H2S).

The main purpose of the lime treatment is reducing the Co2 and Moisture content that in terms increase the

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$$

calorific values of the Biogas.

Procedure

This mixture of biogas was passed over lime solution in order to dissolve CO2 and H2S. The addition of carbon dioxide gas to lime water, Ca (OH)2, first results in the precipitation of CaCO3. Additional CO2, however, dissolve the precipitate. The reaction can be reversed to give the CaCO3 precipitate once again either by boiling the solution or bubbling air through it.

1. Initially the produced biogas is passed over lime solution present in the designed apparatus as shown in figure.

2. The biogas is allowed sufficiently to react with the lime solution.

3. Then the biogas is pumped out from the apparatus and is collected in the cylinder for testing.

4. The biogas collected in the cylinder is tested using Gas chromatography in the lab.

The main objective of this project is to separate methane from the mixture of gases and the process carried out for this purpose is explained below using equipment given below.

Lime reaction with CO2:

$$CaOS + H_2O \longrightarrow Ca(OH)_2$$

Lime reaction with H2

$$H_2S + CaO \longrightarrow CaS + H_2O$$

calcium sulphate precipitate formed at lime solution bottle which can regenerate also or else we replace with new solution lime is cheap material

The presence of other gases is expected to be very negligible. Hence it was not accounted. The gas collected over lime was expected as methane (CH4). To verify the presence of CH4, the below mentioned test was conducted. Picture showing the segregation of gases in progress:

Fig 2: lime solution preparation

Fig 3: photo showing the collection of the Biogas at test tube for Biogas analysis

Compressor

As the pressure which was delivered by the pilot model was not sufficient for the gas to be utilized in various applications. The gas needed to be compressed in order to develop a better pressure. A manually operated pressure pump which was used. The compressing had a capacity of 0.150 ft3 for every cycle. The pilot model delivered a pressure of 8 to 10 Kg/cm2 whereas when the gas had been compressed into a gas cylinder a pressure of 15 kg/cm2 was obtained.

Table-11: calorific values

	Unit	Exp-1	Exp-2	Exp-3
Calorific values of gaseous	MJ/m3	13.52	15.59	20.12

The pressure devolved within the reactor during experiments 1,2 & 3 conducted for different composition cow dung and food waste

In experiment no 1: we observed pressure 3 to 4 kg \cm2 In experiment no 2: we observed pressure 5 to 6 kg\cm2 In experiment no 3: we observed pressure 8 to 10 kg \cm2

Flame test:

A flame test is a procedure used to detect the presence of certain metal ions, based on each element's characteristic emission spectrum

. The color of flames in general also depends on temperature; see flame color. The procedure is simple. Turn on a gas appliance and watch as the gas flame burns. Look for blue colors.

That's methane gas burning. If there are yellow, orange, green, purple or red colors in the flame- that isn't just methane gas burning. Such colors indicate that something else is burning with methane.

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illumination of Mantle lamp:

The methane after segregation was filled in a mantle lamp and was successfully illuminated. Thus, it shows the presence of methane.

calorific value the gaseous:

The heating value/energy value /calorific value of a substance, usually fuel or food, is the amount of heat released during the

combustion of a specified amount of it. The energy value is a characteristic for each substance. It is measured in units of energy per unit of the substance, usually mass, such as: kJ/kg, kJ/mol, kcal/kg, Btu/lb.

Heating value is commonly determined by use of a bomb calorimeter.

Heating value unit conversions:

- kcal/kg = MJ/kg * 238.846
- Btu/lb.= MJ/kg * 429.923
- Btu/lb.= kcals * 1.8

	Unit	Exp-1	Exp-2	Exp-3
Methane content	Vol %	40 – 50	50 – 55	60 – 65
Carbon dioxide	Vol %	50-58	40-48	30-38
Calorific value	MJ/m3	13.52	15.59	20.12
Pressure	Kg/cm3	3 - 4	5 – 6	8 – 10
Moisture content (avg)	Vol %	71.72	73.27	74.14
pH (avg)		5.760	5.914	6.48
Temperature (avg)	C	26.5714	27.85	30.5

Table-12: Results

V. RESULTS

- Production of biogas from the food waste.
- Flame test was conducted to confirm the presence of methane.
- Methane gas was segregated from the biogas mixture.
- Mantle lamp was illuminated

Conclusion:

College canteen waste such as peelings of raw and cooked vegetables, rotten vegetables etc. is usually dumped along with other waste produced in the community. But this vegetable waste can be effectively used for generation of biogas, which can be used as an alternative to the depleting conventional energy sources. In this project methane produced from college canteen waste was used for several applications such as cooking, illumination of mantle lamps, running of automobiles. The biogas slurry obtained after final decomposition could be best used as an organic fertilizer which helps in improving the soil fertility and crop production.

Purification of bio-gas for methane for maximum yield of methane by segregation of other gases such as H2S and CO2 which helps in running of automobiles with effective reduction of moisture content.

Biogas is a potential renewable energy source for India and other countries for energy security and capturing carbon emission

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