

# Production of Biogas from wastes Blended with CowDung for Electricity generation-A Case study

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**Abstract.** The country's production of solid waste generation is piling up year after year and the generation of Bio-Gas finds a fruitful solution to overcome this problem. This technology can contribute to energy conservation if the economic viability and social acceptance of this technology are favorable. Our campus has a number of hostel buildings which generates large quantum of kitchen waste and sewage per day. This research will have process of carrying out survey, characterization of kitchen waste from several kitchens & Canteens and knowing the potential for biogas production. The waste generated from kitchen and sewage from the hostels is given as feedstock to produce 600 m<sup>3</sup> of biogas per day with cow dung as byproduct. The methane gas generated from Biogas is purified and this is used for power generation. Two biogas engine generators of 30 kVA and 50 kVA were installed. This power is used for backup power for girl's hostel lighting load. From this study it is concluded that the generation of Biogas production and its usage for power production is the best option to handle these large quantum of sewage, kitchen waste generated from various buildings and also treated effluent from biogas plant and the biomass generated is a wealth for doing agriculture for any community ultimately it protects the environment.

## 1. Introduction

In further generations there will be demand for excessive energy because of fast depletion of fossil fuel deposits, fuel quality, price which is to be paid for basic materials plus their transportation cost and all the above have degradation of environment which is caused by the use of conventional energy sources. The solution lies by the use of non-conventional energy (or) renewable resources.

Renewable sources of energy can be defined as the sources of energy which are capable of being produced continuously. The renewable sources are inexhaustible and clean as they are primary sources from sun, biomass and wind, etc. Hence appropriate new technologies and policies are to be propagated, promoted, and adopted for the purpose of optimizing the use of available energy resources. Some of the sources are a) Tidal energy b) Wind energy c) Bio mass d) Solar energy e) Geo thermal energy.

Biogas (or) Biomass is defined as the gas produced by the process of breakdown of organic matter in the absence of oxygen. Organic waste includes animal material, dead plant, kitchen waste and animal feces which can be converted into a fuel called biogas. Biogas generally originates from biogenic material



which is type of biofuel.

In the process of production of biogas anaerobic digestion takes place with anaerobic bacteria (or) fermentation of biodegradable materials in the absence of oxygen. It primarily consists of carbon dioxide methane and small amounts of hydrogen sulphide, siloxanes, and moistures. The gases methane, carbon monoxide and hydrogen can be oxidized with oxygen. This energy which is released allows biogas to be used as a fuel, purpose of heating and also can be used in a gas engine for the purpose of converting the energy into electricity and heat.

The major problem is the water scarcity so recycling the waste water and effective treatment and utilization of the treated water will help in various areas like agriculture and household purposes. As the treated effluent contains potassium and phosphate reduces the quantity of manure and it increases the yield of the crops.

## **2. Research Objectives and Scope**

The primary objective of this paper is to find the amount of electricity produced, its usage and the subsequent amount of cost reduction, thereby finding the rate of electricity produced per unit load. Global warming-increasing CO<sub>2</sub> emissions are the main cause of increased sea level and subsequent global warming. Rising prices of fossil fuels-including crude oil prices thus impacting the increase in rate of petrol and diesel and by using biofuel it will have positive impact on our economy and low cost of operation. The study on each crops-regarding the type of irrigation, amount of manure required, life period etc., study on soil-type of soil, fertility index of the soil. Checking the parameters of treated effluent water and comparing it with FAO irrigation water quality standards. Suggesting the suitable type of crop for the soil when treated effluent water is supplied, to get the maximum yield.

## **3. Research Methodology**

This research applies a case-study approach with an in-depth statistical analyses of data obtained from a project. The research methodology includes

- 1) Properties of biogas.
- 2) Digestion tank.
- 3) Generation of electricity.
- 4) Composition of effluent treated water characteristics and its impacts if used directly.
- 5) Study on soil sample. Methods adopted two soil samples are collected from the field
  - a) Soil sample with the application of TEW once a day
  - b) Existing dry soil sample
- 6) Suggestions
- 7) Results and discussions
- 8) Conclusions, advantages and disadvantages of biogas and treated effluent.

## **4. Properties of Biogas**

The production of biogas is done by the anaerobic digestion biodegradable materials like manure, green waste, sewage, plant material, municipal waste and crops. Biogas mainly consists of carbon dioxide methane and small amounts of hydrogen sulphide, siloxanes, and moistures.

The general composition of Biogas is

Methane gas- 55-70%

Carbon dioxide gas- 30-45%

Hydrogen Sulphide- 2-8%

The gases methane, carbon monoxide and hydrogen can be oxidized with oxygen. This energy which is released allows biogas to be used as a fuel, purpose of heating and also can be used in a gas engine for the purpose of converting the energy into electricity and heat. Biogas can be used as natural gas by compressing and the generated gas is used to power motor vehicles. Biogas is one of the renewable energy source, so it can be used for renewable energy subsidies in some parts of the world. Cleaned biogas can be upgraded to natural gas when it is changed to bio methane. Biogas is normally be produced as landfill gas (LFG) or digested gas. A biogas plant is the often named as anaerobic digester because it treats farm wastes. Anaerobic digesters are used for producing biogas.

#### *4.1 Digestion tank*

In digestion tank a series of processes takes place in which microorganisms are used for break down of biodegradable material in the absence of oxygen. It is used for managing wastes in both industrial and domestic purposes to release energy. In industries to produce food and drink products, and also home fermentation mainly anaerobic digestion is used. Anaerobic digestion produces silage.

The process of digestion begins with bacterial hydrolysis of the influent materials to break down insoluble organic polymers like carbohydrates, and it will make them available for other bacteria. Then Acidogenic bacteria converts the amino acids and sugars into hydrogen, ammonia, carbon dioxide and organic acids. Then Acetogenic bacteria converts resulting organic acids into acetic acid, and also additional amounts of ammonia, hydrogen, carbon dioxide. In the last stage methanogens convert these available products to carbon dioxide and methane. The methanogenic archaea populations plays an important role in anaerobic wastewater treatments.

Anaerobic digestion is the process widely used as a source of renewable energy process which produces a biogas consisting of methane, carbon dioxide and traces of other gases. This gases available can be used directly to replace fossil fuels.

Anaerobic digestion consists of four key biological and chemical processes:

1. hydrolysis
2. acidogenesis
3. acetogenesis
4. methanogenesis

**Hydrolysis:**

It is the process of breaking the chains and dissolving the small molecules into a solution. Therefore, the first step in anaerobic digestion is the hydrolysis of these high molecular Weight polymeric components. In hydrolysis the complex organic molecules are broken down into amino acids, simple sugars, and fatty acids.

**Acidogenesis:**

It is a biological process which results in further breakdown of the remaining components by bacteria called acidogenic. Here, VFAs are created, along with carbon dioxide, ammonia, and hydrogen sulphide, and also some other by products. The acidogenesis process is similar to the way milk sours.

**Acetogenesis:**

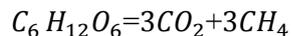
In anaerobic digestion the third stage is acetogenesis. In this process simple molecules created in the acidogenesis phase are further digested by acetogens for producing large amount of acetic acid, hydrogen and carbon dioxide.

Methanogenesis:

In anaerobic digestion the terminal stage is the biological process of methanogenesis. In this process methanogens use intermediate products from the previous stages and convert them into water, methane and carbon dioxide. In this process majority of the biogas is emitted.

For this process PH plays an important role it should be between PH 6.5 and PH 8.

A simplified chemical equation for the overall processes of anaerobic digestion is as follows:



The standardization for the volume of dry biogas is done via a simple mathematic algorithm. The volume of water vapor will be the function of biogas temperature correction of measured gas volume for both water vapor content and thermal expansion.

Biogas contains siloxanes formed from anaerobic decomposition of materials which are commonly found in detergents and soaps. During the process of decomposition of materials containing siloxanes silicon is released which combines with free oxygen and also some other elements in the combustion gas. In this process deposits are formed containing mostly silica, silicates and small amounts of calcium, zinc, phosphorous.

As mentioned earlier, biogas consists of 55-75% methane gas, 30-45% carbon dioxide gas, 2- 8% water vapour and traces of hydrogen. Comparing this with natural gas, which contains 75 to 90% methane gas. The energy content of the energy source mainly depends on the content of methane gas. High methane content would be more desirable. A presence of carbon dioxide and water vapour content is unavoidable, but content of sulphur must be minimized particularly when used in engines. The average calorific value of biogas is about 22-24.5 MJ/m<sup>3</sup>, so that 1 m<sup>3</sup> of biogas corresponds to 0.55-0.65 diesel fuel which is about 6 kWh.

## 5. Generation of electricity

In most of the cases in combustion engines biogas can be used as a fuel, in which mechanical energy is converted into electrical energy using electric generator to produce electricity. Appropriate electric generators are available in all countries with different outputs and sizes. This technology is well known and maintenance for this type of engines is simple. In most case 3-phase electric motors can also be used for generation of electricity.

Far more challenging is the first stage of the generator set that is the combustion engine using the biogas as fuel. In all types of combustion engines biogas can be used as fuel. Combustion engine includes diesel engines, gas engines (Otto motor) and Sterling motors etc. Gas turbines are mostly used as biogas engines, especially in the US because they are very small and can have strict exhaust emissions requirements. Small biogas turbines with outputs of 35-75 KW are available in the market. But this can be used for small-scale applications in developing countries because of speeds and the high operating temperature they are expensive. Further manufacturing of gas turbines is challenging and maintenance require specific skills due to spinning at very high speeds and the high operating temperatures. Sterling motors have the advantage of being tolerant of fuel composition and quality because they are external combustion engines and they are low efficient. Due to the low efficiency used for small applications. Internal combustion motors have become the standard technology either as gas or diesel motors in most commercially run biogas power plants.

## 6. Appropriate combustion engines

Diesel engines operate with biogas only in dual fuel mode. For the process of facilitating the ignition of the biogas, a small amount of ignition gas should be used often diesel fuel is injected together with the biogas. Modern pilot injection gas engines ("Zundstrahlmotoren") need about 2-3% additional ignition oil. Almost diesel engine can be converted into a pilot injection gas engine. The advantage is that motors running in dual fuel mode can use gas of low heating value, in such cases they consume a considerable amount of diesel. The engine sizes of around 200kW, pilot injection engines seem will have more advantage over gas motors due to their slighter higher efficiency (4-5% higher) and lower investment costs.

Gas motors with spark ignition (Otto system) can be operated only with biogas. In practice, a little amount of petrol (gasoline) is often be used to start the engine. Normally this technology will be used for very small generator sets (0.5-10 kW) as well as for large power plants. Especially in Germany, these engines are more advantageous as these do not require additional fossil fuels.

For use in gas or diesel engines, the gas must have certain requirements:

- The methane content plays an important role and it should be as high as possible as this is the main combustible part of the gas;
- The carbon dioxide and water vapour content should be kept low as possible, mainly because they causes low calorific value for the gas;
- The sulphur content mainly in form of Hydrogen sulphide, must be low, as it is converted to corrosion causing acids by condensation and combustion. The water vapor content can be reduced in the process by condensation in the gas storage or on the way to the engine. The reduction of the hydrogen sulphidecontent in the biogas can be done by various technical methods. These can be classified as biological, chemical and physical and divided into internal and external methods. In the last two decades experimentation has been carried,however, as complete elimination is unnecessary for use in robust engines.The following simple methods are generally established themselves as standard:
  - To produce gas of homogeneous quality an optimized steady fermentation process with continuous availability of appropriate feedstock or influent is important.
  - The injection of a small amount of oxygen (air) into the storage fermenter headspace leads to oxidation of Hydrogen sulphide by microorganisms and hence the elimination sulphur from the gaseous phase can be done. This is the most commonly used method for desulphurization. It is cheap and can eliminate up to 90-95% of the sulphur content in the biogas. However, the challenging is the right proportioning of air.
- Another option is filtration that is external chemical treatment. The active material may be:
  - Activated carbon: Certain companies provide activated carbon filters as a component in their gensets.
  - Iron-hydroxide: In this process filter can be regenerated by adding oxygen and it is reversible Adsorption material is iron rich soils, waste material from aluminumorsteel production;

## 7. Composition of effluent treated water characteristics and its impacts if used directly

The composition of sewage water various depending upon the source, collection type and treatment provided. Large proportions of these sewage waters is organic in nature and it contains essential plant nutrients. The sewage water contains more than 90% water. The solid portion contains 25-40% inert materials, 35-50% organics, 10-15% bio-resistant organics and 5-8% miscellaneous substances on oven dry weight basis. The chemical composition of sewage waters is tested and it has found many in

pH, suspended solids, electrical conductivity, organic C, CO, Mg<sup>++</sup>, Ca<sup>++</sup> and other essential and toxic elements in the sewage water. The pH of the sewage water ranged from 7.2 to 8.3 and it was within normal range and irrigation standards. These waters doesn't have any significant change in the soil pH due to high buffering capacity of the soils. The EC of sewage waters collected from various villages varied from 0.1 to 0.4 ds ml and their continuous use in the agricultural fields may have a significant increase in salinity of the soils and ultimately restricting the plant growth. The BOD values vary from 50 to 135mg/l. BOD value above 100mg/l is actually not suitable for irrigation, thus we have to reduce it below 100mg/l by sedimentation and filtration process. Apart from these properties, the sewage waters contains amount of N, P and K. The amounts of N, P and K in sewage waters ranges from 9 to 105, 4.3 to 54 and 20 to 2600 mg/L respectively. Moreover due to several factors the composition of sewage water is not constant and changes within the year. The extent of the contaminants will be less during the rainy seasons. so on consolidation the waste water has the following constituents

- Nutrients (Nitrogen, Phosphorus, Potassium)
- Organic matter
- Inorganic matter (dissolved minerals)
- Pathogens
- Toxic chemicals

The wastewater constituents, parameters, and possible impacts are given explained below Plant food nutrients like N, P, K etc. creates following impact

-Excess N: It has a potential to cause nitrogen injury, delayed growing season, excessive vegetative growth and maturity, and potential to cause economic loss to farmer

-Excessive amounts of N and P will cause excessive growth of undesirable species (eutrophication).

-Nitrogen leaching will cause groundwater pollution with adverse effect to health and environmental impacts.

-Lack of nitrogen will cause Yellowing of younger leaves (attains a state of chlorotic) poor plant growth.

-Lack of phosphorus will cause change in colour of leaves, stunted growth, small sized fruit, purple veins in the leaves of the plant and reduced blooms of fruits.

Biodegradable organics parameters like BOD, COD causes depletion of dissolved oxygen in surface water - development of septic conditions unsuitable for the workers to work in brings very bad odour.

Hydrogen ion pH concentration causes - possible adverse impact on plant growth due to acidity or alkalinity impact sometimes beneficial on soil flora and fauna.

## **8. Impacts**

### *8.1. Agriculture*

Some of the potential impacts of wastewater use in agriculture in discussed below. If the waste water is directly used for agriculture it will have some pathogenic microorganisms such as bacteria, viruses and parasites, which are responsible to cause diseases. Human parasites like protozoa and helminthes eggs will have special importance in this regard as it is more difficult to remove if not treated properly and will cause a large number of infectious gastrointestinal diseases. However, in the process of evaluating health impacts it must be remembered that the actual risk that make people fall ill must be quantified and not the whether the pathogens are present in water.

### *8.2. Crops*

Wastewater treated and untreated is extensively used in agriculture because it consists of nutrients and provides the moisture necessary for crop growth. By the use of wastewater irrigation crops gives more yields which reduces the use for chemical fertilizers providing net cost savings to farmers. If the total

nitrogen delivered to the crop through wastewater irrigation is more than the recommended nitrogen dose for optimal yields, it may but delay ripening and maturity, stimulate vegetative growth and in extreme circumstances, cause yield losses. Scientists have made attempts to quantify the effects of treated and untreated Wastewater on a number of qualities and parameters.

Wastewater can be used for producing better quality crops with higher yield.

Following benefits can be obtained by Proper agronomic and water management practices:

- 1) Value of fertilizer saved.
- 2) Higher yields
- 3) Additional water for irrigation, and

Alternatively, yields may negatively be affected if plant food nutrients delivered through wastewater irrigation may result in nutrient over supply.

### 8.3. Groundwater Resources

The quality of groundwater resources are affected by the wastewater application by the excess salts and nutrients which are found in wastewater leaching below the roots of plants. The impact on the groundwater depends on various factors which includes water table depth, groundwater quality, drainage of soil and quality of wastewater irrigation. The quality of groundwater can be determined by the impact and magnitude from leaching of nitrates. The brackish groundwater indicates the leaching of nitrates would be of little concern. The wastewater also effect on potable water supplies such as tube wells and also the evaluation is done based on the groundwater pollution. The above are to be considered before using the treated effluent water.

## 9. RESULTS

- TEW improves the soil fertility by reducing the salinity content of the soil
- It increases the potassium and phosphate content of the soil thus reduces the quantity of manure used.
- Nitrogen content of the soil though slightly reduced is still within optimum limits.
- Farmers spend nearly 5 lakh for installation and maintenance of bore wells which seems to be really difficult for some peasants.
- So the use of TEW minimizes their expenses to some extent.

The major disadvantage is the bad odour of the treated waste water, which could be reduced by the following methods:

- Tanks must be rinsed properly and it must be cleaned from any stagnant solids at the bottom so as to prevent the growth of bacteria.
- Sulphate in the water, or a carryover of sulphur from oils, can act as a source for bacteria growth producing a sulphide odour.
- When high total suspended solids occur in the treated waste water, bacteria grow and give off the hydrogen gas odour.
- This odour creates uncomfortable environment for the workers to work in.

Odour can be controlled by one of the following:

- 1) Neutralization of the offending odour.
- 2) Masking of the odour.
- 3) Switching the oxygen source that contributes to the growth of bacteria.

## 10. Recommendations

### AQUA PUCKS:

- Aqua pucks are used to reduce odours caused by anaerobic conditions.
- These contain oxygenating technology with bio-degradable bacteria to eliminate noxious odours.
- Aqua pucks also breakdown fats and oils. The action generated from aqua pucks purges water from odours and gases.

## 11. Further Conclusions

By using biogas we have economic, agronomic, environmental advantages:

Economic advantages include:

- Income can be increased.
- Increase in the cost of fossil fuels which can be reduced by use biogas
- Manure cost can be reduced by use of effluent outlet as a manure.

Agronomic advantages include:

- Liquid manure can be transformed into manure and which can be used as a fertilizer.
- Organic waste processing for competitive prices.

Environmental advantages include:

- Sustainable management of organic waste.
- Reduction of pollution due to nitrogen stripping.
- Biogas is a renewable energy which replaces fossil fuels.

Waste disposal, improper sewerage and drainage are the major environmental concern because of high levels of water pollution in an urbanizing India. The sewage contains essential nutrients and possesses properties which are easily utilized for the purpose of irrigating the field crops. This project highlights the present and future water supply demand.

The large amount of wastewater collected in the effluent treatment plant will be diverted into nearby villages for their agricultural purposes after the treatment is completed. Remedial measures need to be taken for improving the wastewater reuse pattern.

## References

- [1] Ghimire P C 2013 SNV supported domestic biogas programmes in Asia and Africa. *Renewable Energ.* **49** 90-4.
- [2] Deublein D and Steinhauser A 2010 Biogas from waste and renewable resources. 2<sup>nd</sup> Edition. *Wiley*.
- [3] Abatzoglou N and Boivin S 2008 A Review of biogas purification processes. *Biofuels, Bioproducts and Biorefining* **3**(1) 42-71. doi:10.1002/bbb.117. ISSN1932-104X
- [4] Huertas J I Giraldo N and Izquierdo S 2011 Removal of H<sub>2</sub>S and CO<sub>2</sub> from Biogas by amine absorption. *Mass Transfer in Chem. Eng. Process.* **7** 133-50.
- [5] Overview of greenhouse gases, Methane emissions. Climate change, United States environmental protection agency, 11 December 2015
- [6] Biomass Energy: Manure for fuel 2009 State energy conservation office. State of Texas.
- [7] Hanjra M A 2012 Wastewater irrigation and environmental health: Implications for water governance and public policy. *Int. J. Hyg. Environ. Health* **215**(3) 255-69.