A CASE STUDY ON IN-SITU ANAEROBIC DECOMPOSITION OF FOOD WASTE FOR EFFECTIVE BIOGAS PRODUCTION

A PROJECT REPORT

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BONAFIDE CERTIFICATE

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ABSTRACT

Conservation of energy is an important ideal today. Today's world focuses on producing energy economically and efficiently. One of the effective ways to produce energy is anaerobic decomposition of food wastes. It is also seen that food is wasted in large amount each day. Therefore, both these shortcomings are overcome by detailed analysis on usage of food wastes for energy production. The aim of the project 'A case study on Anaerobic decomposition of food wastes for effective Biogas Production' is to analyse and design a anaerobic digestion chamber using food wastes that helps to increase the amount of biogas produced, which fosters the creativity, designing skills, data interpretation skills and academic excellence. The project focuses on analysis of data on the amount of food wasted and the scope of its usage in anaerobic digestion, interpretation of its governing factors. It also includes the study on addition of new materials that tend to increase the efficiency of the digestion process. Finally, it deals with the comparison of Biogas produced with respect to conventional methods and the design of suitable digestion chamber to carry out the efficient anaerobic digestion process. The project concerns with a case study on the materials needed for effective digestion process and also oversees with an experimental small scale trial studies in comparing the efficiencies of digesters with conventionally used materials and digesters with materials that improve the anaerobic process.

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SYMBOL		DESCRIPTION
AD	-	Anaerobic Decomposition
NPK	-	Nitrogen, Phosphorous, Potassium
LPG	-	Liquified Petroleum Gas
ppm	-	Parts per million
VS	-	Volatile Solids
TS	-	Total Solids
COD	-	Chemical oxygen demand
C/N	-	Carbon nitrogen ratio
HRT	-	Hydraulic Retention Time
V_c	-	Volume of gas collecting chamber
V_{gs}	-	Volume of gas storage chamber
V_f	-	Volume of fermentation chamber
V_H	-	Volume of hydraulic chamber
V_S	-	Volume of sludge layer
D_h	-	Diameter of hydraulic chamber
P_h	-	Test pressure inside cylinder
D_o	-	Outer diameter of the cylinder
J	-	Weld joint factor
R_e	-	Yield strength of mild steel
t	-	Thickness of the chamber

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO FOOD WASTE MANAGEMENT

Natural resources are now becoming the primary focus in the field of activities related to energy generation and utilization. Production of conventional, alternative and renewable sources of energy is the major activity included, and for the recovery and reuse of energy that would otherwise be wasted. Demand for energy development, energy conservation and efficiency measures are reduced and can have benefits to society with improvements to environmental issues.

The use of energy in the society includes transportation, manufacturing, illumination, heating and air conditioning, and communication, for industrial, commercial, and domestic purposes. The resources of energy may be classified as primary resources, where the resource can be used in substantially its original form, or as secondary resources, where the energy source must be converted into a more conveniently usable form. Significant depletion of non-renewable resources of energy by human use has lead to the need for renewable sources whereas renewable resources are produced by ongoing processes that can sustain indefinite human exploitation.

The petroleum industry, the natural gas industry, the electrical power industry and the nuclear industry are included in the conventional industry. Renewable energy industries are included in the newer energy industries, comprising alternative and sustainable manufacture, distribution, and sale of alternative fuels.

The alarming problem in developing countries like India is deforestation; most of the part depends on charcoal and fuel-wood for fuel supply which requires felling of trees. This rate of deforestation leads to decrease in the fertility of land by soil erosion. Use of alternatives like dung, firewood as energy is also harmful for the health of the masses due to the smoke arising from them causing air pollution. This shows the need for an eco-friendly substitute for energy. Thus biogas energy from organic waste captured through anaerobic digestion can also be burned to produce electricity and heat (co-generation).

Restaurants, hotels and households left-over produce organic matter in the form of kitchen waste. Lots of kitchen wastes are generated daily in densely populated areas. According to Food and Agriculture organization (FAO) of the UN, approximately one third of the food produced for the human consumption, which amounts to 1.3 billion tones, gets lost or wasted. Kitchen generated wastes that enters the mixed-municipal waste system are hard to process by common means, such as incineration, due to the high moisture content. Furthermore, organic matter can be transformed into useful fertilizer and bio fuel. New removal methods that are both environmentally and economically better are being developed which rely on various forms of microbial decomposition.

Generally, four processes occur in anaerobic digestion that includes hydrolysis, acid fermentation, acetogenesis, and methanogenesis. In the step of hydrolysis, complex molecules like polysaccharides and proteins are split down into monomers like monosaccharides and amino acids by extracellular enzymes. The hydrolytic step can be facilitated by adding artificial enzymes. In acid fermentation, lactic acid bacteria ferment the monosaccharide present and produce lactic acid, which can be used industrially to make various commercial products such as plastic. Moreover, acid-resistant bacteria can be utilized to ferment sugar to produce ethanol that is thought to be an encouraging new energy source. Acetogenic bacteria can use simple sugars and produce acetate or it can act as hydrogen consumer and help fermenting processes of other bacteria. Methanogens employ products from the above acid fermentation step such as hydrogen and carbon dioxide to produce methane which can be used as energy. Consequently, organic nitrogen is changed to ammonia that can be used more easily by plants as fertilizers.

Existing anaerobic biodegradation processes including collecting organic wastes like wastes of kitchen into chambers that have environment that is controlled, allowing anaerobic bacteria to work on the organic wastes, and collecting the biogas produced like methane to use as energy supplement. It is a cleaner and more efficient alternative to aerobic composting, as anaerobic digestion is generally an energy producing process, whereas composting is largely energy consuming. Additionally, methane got from composting is released into environment where methane produced in anaerobic digester is used as fuels.

Mankind can solve this threat successfully with the aid of methane, however we have not been benefited till now, because of lack of knowledge of basic sciences – like results of work is dependent on energy that is available for doing the work. This fact can be seen in current practices using low calorific inputs like cattle dung, distillery effluent, municipal solid waste (MSW) or sewage, in biogas plants, making methane generation highly inefficient. We can convert this system to be extremely efficient by using kitchen waste/food wastes. This plant helps in reduction of pollution through integrated waste management.

There are usual waste removal problems in almost all institutions like hostels, hospitals, convents, old age-homes, etc. where majority of peoples are staying together. Consequently, the fuel consumption used in cooking in these Institutions is also immense. Fairly huge capacity of firewood and other fuels used for cooking are consumed for routine cooking purposes.

Biogas preparation solves two problems at once: It reduces waste production and produces energy. Additionally, the left over from the digestion procedures can be utilized as high quality fertilizer. This closes the nutrient cycle. By understanding the today's need of saving of energy, MIT Group of Institutions has taken an initiative & sets up Bio-Gas plant to process canteen waste.

In an example worth emulating, the Maharashtra Academy of Engineering and Educational Research (MAEER)'s Maharashtra Institute of Technology (MIT) College, Kothrud, has installed a biogas plant, commissioned by Thermax Ltd that has a capacity to generate energy equivalent to around 1.5 commercial LPG cylinders by decomposing waste from the students' canteen. Plant is set up over nearly 1,000 square ft. The plant has been installed at a cost of around Rs. 14 lakh.

The canteen caters to more than 5,000 students daily and generates over 150 kg of solid and semi-solid waste, in the form of left-over food and remains of vegetables and fruits. It was a tedious task to pack the huge amount of waste in polythene bags and hand them over to the civic body almost daily. It is now easy to dump this waste & processed at the biogas plant after some segregation. From it, MIT is getting nearly 50 kg of biogas and it is also clean and efficient.

The biogas plant aims at addressing the issue of disposal of waste from the canteen and other parts of the campus in an eco-friendly manner. M. M. Unnikrishnan, MD and CEO of Thermax, who was present during the commissioning of the biogas plant, has appealed to large educational institutes having a sizeable presence of on-campus students to opt for renewable energy methods for a safe and secure environment. Indian Express has also taken the note of this initiative &gives exposure to it.

Anaerobic digestion is a combination of procedures in which microorganisms break down biodegradable content in the absence of oxygen. The same process is utilized for industrial or domestic practices to manage waste or to produce fuels from it. Much steps of the fermentation is utilized industrially to produce food and drink products, and also home fermentation products employing the process of anaerobic digestion.

Anaerobic digestion happens naturally in certain soils and in lake and oceanic basin sediments, where it is normally referred to as "anaerobic activity". This is the result of gas methane of marshes as discovered by Alessandro Volta in 1776.

The digestion process starts with hydrolysis of bacteria in the input materials and insoluble organic polymers, like carbohydrates, are split down to soluble compounds that become ready for other bacteria. Acidogenic bacteria subsequently change the sugars and amino acids into carbon dioxide, hydrogen, ammonia, and organic acids. These bacteria change these produced organic acids into acetic acid, also with additional ammonia, hydrogen, and carbon dioxide. Finally, methanogens changes these products to methane and carbon dioxide. The methanogenic archaea capacity plays an important role in wastewater treatments anaerobically.

Anaerobic digestion is employed as part of the procedures to treat biodegradable waste and sludge produced from sewage. As a result of this integrated waste management system, anaerobic digestion restricts the release of landfill gas into the atmosphere. Energy crops such as maize are purposefully grown to be fed in the anaerobic digester.

Anaerobic decomposition is commonly used as a supply of energy which can be renewed. The process gives biogas, containing methane, carbon dioxide, and small amount of other ‘contaminant’ gases. This biogas can be employed directly as fuel, in heat and power gas engines or upgraded to natural gas-quality bio methane. The digestate rich in nutrients can also be used as a fertilizer.

Operating costs of larger facilities can be reduced, per unit; to the level that, in the present economical framework, very huge Anaerobic Decomposition systems can be fruitful whereas small ones are not. If the cost of energy continues to hike and the need for local waste treatment and fertilizers escalates, this framework may vary.

1.2 INTRODUCTION TO BIOGAS:

Biogas means a blend of various gases generated when the organic matter breaks down in the absence of oxygen. Biogas can be generated from crude materials like agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste. Biogas is a renewable energy source.

Biogas is generated by the anaerobic decomposition employing methanogen or anaerobic organisms, which breaks down the materials inside a closed system, or fermentation of biodegradable substances. This closed system is referred to as a bio digester, anaerobic digester or a bioreactor.

Biogas fundamentally has methane (CH_4) and carbon dioxide (CO_2) and may have traces of hydrogen sulphide (H_2S), moisture and siloxanes. Methane, Hydrogen, and Carbon monoxide(CO), which are present as gas can be oxidized or combusted with oxygen. This energy discharge allows biogas to be employed as a fuel; it can be utilized for any heating processes, like cooking. Gas engines also use biogas to convert the energy in the gas into electricity and heat.

1.2.1 COMPOSITION OF BIOGAS:

Table 1.1 – 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 %

1.2.2 CHARACTERISTICS OF BIOGAS:

Composition of biogas depends upon feed material also. Biogas is approximately 20% less dense than air has an ignition temperature in range of 650 to 750 °C and is odorless & colorless gas which ignites with blue flame like LPG gas. Its caloric value is 20 Mega Joules (MJ)/m3 and it usually burns with 60 %

efficiency in a conventional biogas stove. One cubic meter of biogas is equivalent to 1.613 liters of kerosene or 2.309 kg of LPG or 0.213 kW of electricity.

Biogas decomposer systems give a residual organic sludge, after its anaerobic decomposition (AD) process that has advantageous 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 specifically valuable in agricultural residual treatment of animal excreta and kitchen refuse (residuals).

1.2.3 FACTORS AFFECTING YIELD AND PRODUCTION OF BIOGAS:

Various factors influencing the fermentation process of the organic substances under anaerobic condition are,

- The quantity and nature of organic matter
- The temperature
- Effect of C : N ratio
- Retention time
- Acidity and alkalinity (pH value) of substrate
- Effect of agitation

1.2.4 GENERAL FEATURES OF BIOGAS:

Energy content	-	6 – 6.5 kWh/m3
Fuel equivalent	-	0.6 – 0.65 l oil/m3 biogas
Explosion limits	-	6 – 12 % biogas in air

Ignition temperature	-	650 – 750 °C
Critical pressure	-	75 – 89 bar
Critical temperature	-	-82.5 °C
Normal density	-	1.2 kg/m3
Smell	-	Rotten eggs

1.3 BENEFITS OF BIOGAS TECHNOLOGY:

Well-functioning biogas systems can yield a whole range of benefits for their users, the society and the environment in general:

- Production of energy (heat, light, electricity).
- Conversion of organic waste into high quality fertilizer.
- Concession of volume of disposed waste products.
- Minimization of workload, primarily for women, in firewood collection and cooking.
- Environmental leverage through conservation of soil, water, air and woody vegetation.
- Micro-economic advantages through energy and fertilizer supplementation, additional income sources and rising yields of animal husbandry and agriculture.
- Macro-economic benefits through decentralized energy generation, import substitution and environmental protection.

Thus, biogas technology can extensively contribute to conservation and development, if the favorable conditions are concrete. However, the high investment capital needed and other drawbacks of biogas technology should be thoroughly considered.

CHAPTER 2

BIO-GAS: A GENERAL DESCRIPTION

2.1 PRODUCTION PROCESS

A biogas plant typically consists of the following segments:

(1) Manure collection

(2) Anaerobic digester

(3) Effluent storage

(4) Gas collection

(5) Gas use

Biogas is a renewable form of energy. Methanogens (bacteria that produce methane) are the final link in a series of microorganisms that decompose organic substance and give back the products of degradation to the environment.

2.2 PRINCIPLES FOR PRODUCTION OF BIOGAS

Organic materials are present in wide array from living beings to dead organisms. Organic substances are made up of Carbon (C), along with elements like Hydrogen (H), Oxygen (O), Nitrogen (N), Sulphur (S) to produce a range of organic compounds such as carbohydrates, proteins & lipids. Naturally microorganisms break the complex carbon into smaller substances through digestion process.

There are 2 types of digestion process:

- Aerobic digestion.
- Anaerobic digestion

The process of digestion happens in the presence of Oxygen called as Aerobic digestion and generates mixtures of gases containing carbon dioxide (CO2), one of the main “greenhouse gases” accountable for global warming.

The digestion process which happens in the absence of oxygen is called anaerobic digestion which also generates a combination of gases. The gas produced primarily consists of methane which produces 5200-5800 KJ/m^3 when burned at normal room temperature and provides a viable eco-friendly energy supply to replace non-renewable sources like fossil fuels.

Aerobic and anaerobic digestion processes together are being utilized in current designs for the treatment of biological sludge; there are pros and cons to both systems. Before a certain decision can be made, characteristics of wastes, general climatic conditions, type of sludge handling equipment, and the capacity of the facility must be considered. In huge facilities, it may be plausible or desirable to digest primary sludge in anaerobic manner and secondary sludge in aerobic manner. Aerobic decomposition is the biochemical oxidative stabilization of wastewater sludge in tanks, open or closed, that are independent from the liquid process system. This digestion method has the characteristics of handling waste activated, trickling filter, or primary sludge as well as mixtures of the same. The aerobic decomposer performs on the same objectives as the activated sludge process. As food is depleted, the microbes enter the endogenous phase and the cell tissue is aerobically oxidized to CO_2, H_2O, NH_4, NO_2, and NO_3.

2.3 TYPES OF BIOGAS PLANT:

Classification of biogas plant depends upon the plant design and the mode of working. One common way to classify them is

- Batch type plant
- Continuous type plant
- Moveable drum type plant

Batch type biogas plant:

Batch type biogas plants are convenient where daily sources of fresh waste materials are challenging to be obtained. A digester which is loaded in batches is filled to full capacity, sealed and given enough retention time in the digester. After the digestion is completed, the residue is unfilled and filled again. Gas production is irregular because bacterial decomposition begins slowly, spikes and then recedes with increasing consumption of volatile solids.

This difficulty can be overthrown by having least to digester so that at minimal one is always operated. This complication can also be downplayed by connecting batch loaded digester in series and fed at different times so that the adequate biogas is available for daily use. The noticing features of batch-fed kind of biogas plants are,

- Gas production in gas type is uneven.
- Batch type systems may have several decomposers for consistent gas supply
- Several digesters occupy more space.
- This type of plant require large volume of digester, therefore, initial cost becomes high.
- This plant needs addition of fermented slurry to start the digestion process.

Continuous type biogas plant:

In biogas plant which is of continuous type, the gas supply is consistent and the decomposers are fed with substrate regularly. Continuous biogas plants consist of single stage, double stage or multiple stages. Single stage process consists of decomposition of waste materials in a simple chamber or digester. Multi stage process consists of decomposition in two or more chambers. Acidogenic and methanogenic stages are physically separated in two chambers in double stage process. Thus, in the first stage, in one of the two chambers acid production is carried out and only diluted acids are fed into the second chamber to carry out bio methanation process.

Single chamber is used to carry out acidogenic and methanogenic stages without barrier in single stage process which are economic, simple and easy to operate. These plants are preferable for small and medium size biogas plants. However, the two stage biogas plants are costlier, difficult to operate and maintain but volume of gas generated is more. Hence, these plants are preferred for larger biogas plant system. The salient features of biogas plants of continuous type are:

- Gas production is continuous.
- Retention problem is less.
- Fewer problems are compared to batch type.
- Small digestion chambers area required.

Movable drum type plants:

This is also known as floating dome type biogas plants. The conventional movable drum type consists of a digester made of masonry with an inlet on one side for feeding slurry and an outlet on the other side for removing digested slurry. The gas collects in a steel gasholder which is inverted over the slurry and moves up and down depending upon accumulation and discharge of gas guided by a central guide pipe. This movable holder is made of steel.

The gas holder is painted by the anticorrosive painting at least once in a year. This plant helps to maintain consistent pressure which can be regulated by changing weight. The main disadvantage of movable drum type is that cost of metal is large and cost of maintenance is also high. To tackle this problem the scientists have created high density polyethylene. The important feature of movable drum type biogas plants are:

- Constant gas pressure.
- No problem of gas leakage.
- Higher gas production.
- Scum problem is less.

CHAPTER 3

ANAEROBIC DIGESTION: PROCESS

3.1 ANAEROBIC DIGESTION

Anaerobic digestion is a biological process that is done to degrade organic matter by producing biogas that can be used as renewable energy source and also produces sludge, used as fertilizer. The biogas production is happening in the environment in a natural way (e.g. marsh gas - decomposition of vegetable and animal matter in which the formation of bubbles at water surface can be seen). In the absence of oxygen (anaerobic), the organic matter is degraded partially by the combined action of several types of micro-organisms. A conclusion of biological reactions (see diagram) led to the creation of biogas and sludge. The bacteria does this process exist in natural form in the liquid manure and the anaerobic ecosystems; it is not needed to add more, they generate naturally in oxygen less medium.

3.2 ANAEROBIC PROCESS PLANTS

Anaerobic process plants give the conditions that help the natural breakdown of organic content by bacteria without air. The process generates three main products:

- Biogas - a combination of carbon dioxide (CO_2) and methane (CH_4), that can be used to generate heat and/or electricity
- Fiber - can be used as a nutrient-rich soil conditioner, and
- Liquor - can be used as liquid fertilizer.

The process proceeds in a digester that is a warm, sealed container without entry for air. The tank used for digestion is warmed and mixed thoroughly to create the perfect conditions for conversion of biogas.

During the functioning of the digestion process 30 - 60% of the organic content is changed to biogas which can be then be burned in a conventional gas boiler for heat liberation. The digestate is stored and can be applied straight to land or it can be separated to produce fiber and liquor.

3.3 REDUCTION OF POLLUTION THROUGH INTEGRATED WASTE MANAGEMENT

- The products of AD produce fewer odors when compared to farm slurry.
- Can reduce pollution of water courses by reducing run-off. Run-off is the liquid slurry which is sprayed onto farmland, but then drains into surface water. It can carry sediment substances and pollutants into the waters that can receive.
- AD can reduce the hazards of the communication of disease and contamination by killing bacteria, viruses and weed seeds.
- Proper AD can reduce methane (CH_4) release more efficiently than usual waste management, because the methane is converted into carbon dioxide (CO_2), a less harmful greenhouse gas.
- The usage of AD can help industry to organize organic waste in a way that is not detrimental to the surrounding area and will necessitate awareness of environmental regulations.

3.4 BIOLOGICAL PROCESS (MICROBIOLOGY)

- Hydrolysis
- Acidogenesis
- Acetogenesis
- Methanogenesis

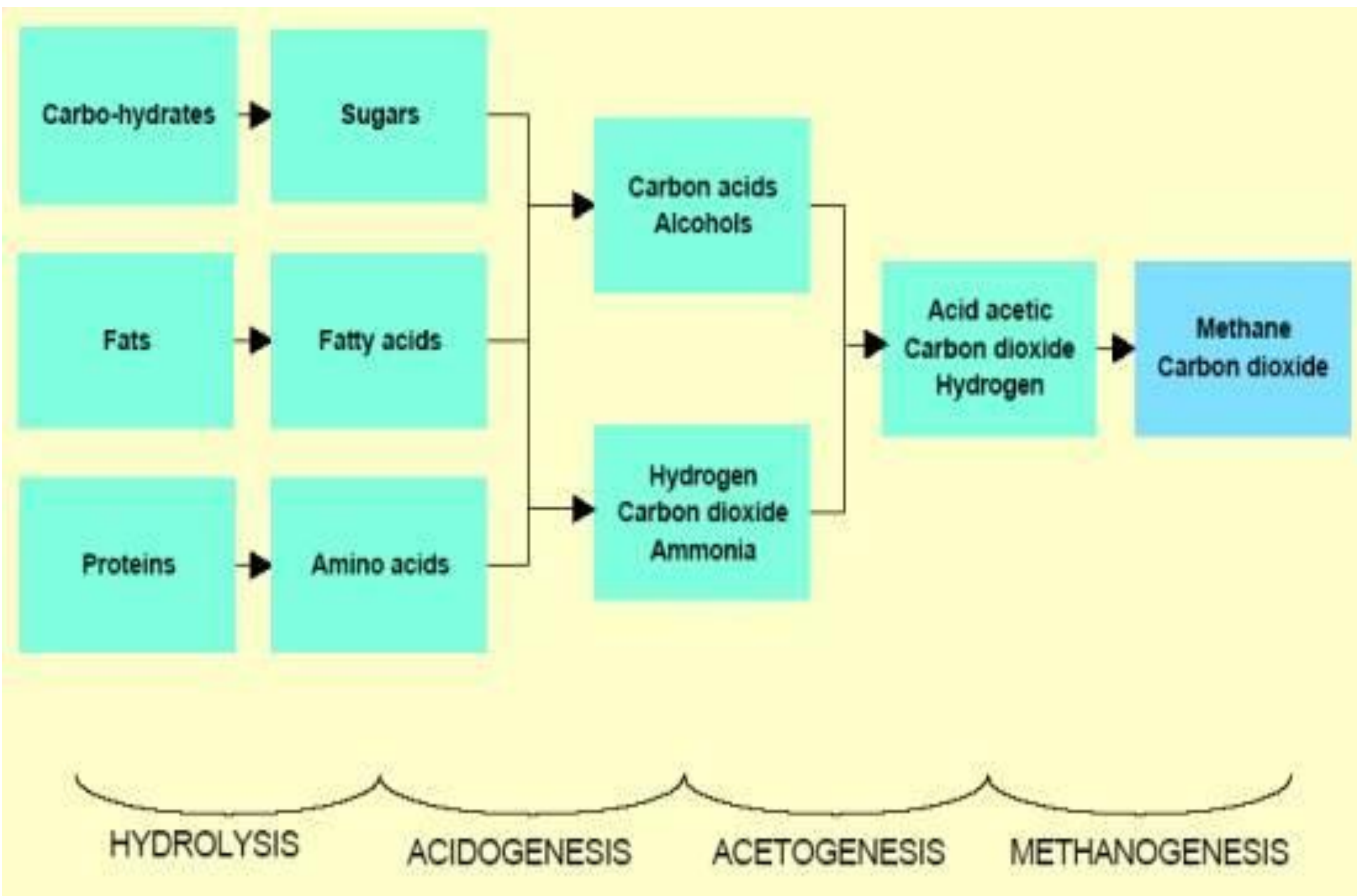


Fig 3.1 – Steps involved in the formation of biogas

Hydrolysis:

The first step of the anaerobic degradation is the hydrolysis of complex organic materials like carbohydrates, proteins, & lipids to its basic monomers such as amino acids, fatty acids, and simple sugars by the hydrolytic enzymes. While few of the outcomes of hydrolysis, including hydrogen and acetate, can be used by methanogens later in the anaerobic digestion process, the majority of the molecules, which are still relatively big, must be split down in the process of acidogenesis so that they can be used to produce methane. Hydrolysis is a relatively slow step and it can limit the rate of the overall anaerobic digestion process, especially when using solid waste as the substrate.

Acidogenesis:

Acidogenesis is the next step of anaerobic digestion in which acidogenic microorganisms further break down the biomass products after hydrolysis. These fermentative bacteria produce an acidic environment in the digester. During the process of acidogenesis, monomer compounds that are soluble are split into small organic compounds, such as ammonia, H_2, CO_2, H_2S short chain (volatile) acids, ketones (glycerol, acetone), and alcohols (ethanol, methanol). While acidogenic bacteria further splits the organic content, it is still too big and unusable for the ultimate goal of methane production, so the biomass must next undergo the process of acetogenesis.

Acetogenesis:

Generally, acetogenesis is the formation of acetate, a product of acetic acid, from carbon and energy sources by acetogens. Acetogens catabolize most of the end products produced in acidogenesis into acetic acid, CO_2 and H_2 that are used by methanogens to produce methane.

Methanogenesis:

The last phase of anaerobic digestion is the methanogenesis phase in which methanogens create methane from the final products of acetogenesis as well as from some of the intermediate products from hydrolysis and acidogenesis. There are two general pathways involving the use of acetic acid and carbon dioxide, the two main products of the first three steps of anaerobic digestion, to create methane in methanogenesis. While CO_2 can be transformed into methane and water by the reaction, the main step to create methane in methanogenesis is the way that involves acetic acid. This process produces methane and CO_2, the two main componenets of anaerobic digestion.

CHAPTER 4

LITERATURE REVIEW

Md. Abdullah Hil Baky (2014) undertook the anaerobic digestion and the process simulation of food wastes and the experimental results showed that an average specific gas production of 14.4 kg-mol/hr will be obtained for 0.05 kg-mol/hr loading rate of starch. From of the simulated results, the production of gas was found as 19.82 kg-mol/hr for the same loading rate of starch. The percentage of methane and CO2 got from the biogas plant was 69% and 29% respectively.

Rajesh Ghosh (2013) concluded that Biogas is one of the future fuel, but it difficult to obtain when compared to the other most efficient fossil fuel today. But if we apply the ideas and modern technology to produce biogas from waste, we can increase the methane yield and hence the efficiency. It is proven that one ton of municipal waste can produce up to 250kg‘s of biogas. If we utilize the waste produced in the urban cities to produce biogas it is possible to eliminate the energy crisis which we are facing today. For example, if we utilize the waste produced in the Bangalore, which is about 2000 tons per day, we can produce up to 5lakh kg of biogas daily, from which we can light up about 1000 houses.

The report of **Michael K. Sternstrom** discusses the results of a two-year investigation to determine the suitability of Los Angeles area municipal solid waste for producing digester gas. An experimental study was conducted using four 50 gallon pilot-scale digesters. The digesters were operated at organic loading rates ranging from 0.10 lb VS/ft3day to 0.25 lb VS/ft3 day and over hydraulic retention times ranging from 15 to 30 days. Feed solids concentration ranged from 3.1 to 10.1% VS. In all cases the municipal solid waste was blended with raw, primary sludge obtained from the Hyperion Treatment Plant in a ratio of 80% waste to 20%

sludge, on a volatile solids mass basis. The results of the experimental investigation show that a medium BTU gas (55-60% methane) can be produced at a rate of 6.5 to 7.5 ft3 gas/lb VS applied. The highest gas productions were obtained at the lowest loading rate. At higher loading rates reduced gas productions were observed, and this reduction is attributed to the inability to adequately mix the digesters.

Hilkiah Igoni (2008) observed the Effect of Total Solids Concentration of Municipal Solid Waste on the Biogas Produced in an Anaerobic Continuous Digester. The amount of total solids (TS) in the waste content influences the pH, temperature and effectiveness of the microorganisms in the decomposition process. Investigation on various concentrations of the TS of MSW in an anaerobic tank reactor where stirring was done continuously and the corresponding amounts of biogas produced, in order to determine conditions for optimum gas production was done. The results obtained indicate that when the percentage total solids (PTS) of municipal solid waste in a continuous anaerobic digestion process elevates, there is also a corresponding geometric increase for the amount of biogas produced. The percentage of total solids concentration states that the former is a power function of the latter, showing that at some point in the increase of the TS, no additional rise in the volumetric amount of the biogas would be observed.

Chen Ru Chen (1984) gave his thesis on Nutrient recovery. A lot of laboratory tests and field demonstrations have shown that the NPK recovery through anaerobic digestion is better than that through traditional compost. Thus, the anaerobic digestion technology can now compete with aerobic process for waste treatment. The rapid expansion of rural biogas digesters is convincing evidence. A rapid development of dry fermentation and rapid anaerobic reactors is expected soon.

A Tilche (1981) studied the anaerobic digestion of high strength molasses wastewater (molasses alcohol spillage and raw molasses) in a hybrid anaerobic baffled reactor. At an organic loading rate of 20 kg COD/m^3-day, the reactor performed effectively achieving total and soluble COD removals in excess of 70%. Granulation of biomass was seen in the reactor and the granules grew over time as the experiment went on. The most important methanogens similar to *Methanothrix* and *Methanosarcina* species were noticed in the granules. Nitrogen and phosphorous were supplemented whenever needed. Biomass retention inside the reactor was very good. Gas production was 5 v/v of the reactor per day.

Lissens (2004) finished a study on an operation of biogas to increase the total yield of biogas from 50% availability to 90% using several treatments including: a mesophilic laboratory scale tank reactor that undergoes continuous stirring, an up-flow bio film reactor, a fiber liquefaction reactor that releases the bacteria *Fibrobacter succinogenes* and a system that injects water during the process. These methods were adequate in delivering about large increments to the total production; however, the study was under a very controlled method, which leaves room for error when used under varying conditions. However, Bouallagui (2004) determined that the smaller influxes in temperature do not acutely impact the in-situ anaerobic digestion for biogas production.

Jong Won Kang (2010) studied the On-site Removal of H_2S from Biogas Produced by Food Waste using an Aerobic Sludge Bio-filter for Steam Reforming Processing. They show that a bio-filter containing immobilized aerobic sludge was successfully adapted for the removal of H_2S and CO_2 from the biogas produced using food waste. The bio-filter efficiently removed 99% of 1,058 ppm H_2S from biogas produced by food waste treatment system at a retention time of 400 sec. The observed maximum rate of removal was 359 g-$H_2S/m^3/h$ with a normal mass loading rate of 14.7 g-$H_2S/m^3/h$ for the bio-filter in large-scale. The large-scale bio-filter using a culture system that is mixed proved better H_2S removal capacity than bio-filters using certain bacteria strains. In the kinetic analysis, the highest H_2S removal rate (Vm) and half saturation constant (Ks) were interpreted to be 842.6 g-$H_2S/m^3/h$ and 2.2 mg/L, respectively. Syngas was developed by the catalytic steam reformation of the biogas purified, which indicates the possibility of high efficiency electricity generation by SOFCs and methanol manufacturing.

Joseph Prousek (2012) suggested that Wood-decaying mushrooms can be applied for the pretreatment of lignocellulosic substrates such as leaves, hay and straw. The use of the fungus Auricularia auricula-judae that decays wood for the decomposition of sweet chestnuts (Castanea sativa) leaves and hay is discussed. Such substrate that are pretreated were used in the anaerobic processes for production of biogas. Comparison between pretreated and non-pretreated substrate showed that an elevation of 15 % in the production of biogas can be attained using the pretreated substrate. Composition of organic compounds in the sludge during the anaerobic process was identified by HPLC. The obtained results show that the utilization of pretreated leaves and hay leads to a gradual increase of the concentration of formic, acetic, and volatile fatty acids as well as to the formation of some aldehydes, ketones, and alcohols.

Beatrice M Smith (2013) suggested that Energy efficiencies varied between 8% and 54% for electricity generation; 16% and 83% for heat; 18% and 90% for electricity and heat; and 4% and 18% for transport. Direct usage of biogas has the maximum efficiencies, but the application of this fuel is restricted to sites co-located with the anaerobic digestion facility, restricting available markets and functions. Liquid fuels have the dominance of versatility, but the conclusions show low efficiencies constantly across all ways and applications. The energy efficiency of bio-methane routes competes well with biogas and comes with the advantage that it is more easily transported and used in a wide variety of applications. The conclusion were also compared with fossil fuels and analyzed in the framework of national policies. This research produced a development of a versatile framework for comparing the efficiencies of energy which can provide the platform for further examination on optimizing the feasibility of biogas-to-energy systems across a range of signals.

Murphy, McKeog, and Kiely (2004) completed a study in Ireland analyzing the usages of biogas and bio fuels. This study gives a detailed summary of comparisons with other fuel sources with respect to its consequence on the environment, economical dependence, and performance of the plant. One of the results the study found was a greater financial advantage in making use of bio-fuels for transport rather than production of power; however, power generation was more constant and less maintenance requirements.

P Patricio (2013) introduced that a biomass supply chain optimization model, including current costs and new incentives for biogas exploitation. The model is used to explore the impact of Italian energy policies on the profitability of alternative biogas utilization pathways in two regional cases studies, characterized by different penetration of CNG refueling stations. The effect of local factors on energy vectors share and on GHG emission reduction are investigated with factor analysis. It is found that CBM production represents the most profitable choice for entrepreneurs under current levels of bio-methane incentives, however because of the small Italian CBM market size it risks to be overly subsidized. Allocating funds to promote a further expansion of CNG would probably help CBM development and benefits more than increasing specific incentives.

Sander Brunn (2014) hinted that there are a number of advantages to small-scale biogas production on farms, including savings on firewood or fossil fuels and reductions in odor and greenhouse gas emissions. For these reasons, governments and development aid agencies have supported the installation of biogas digesters. However, biogas digesters are often poorly managed and there is a lack of proper distribution systems for biogas. This results in methane being released inadvertently through leaks in digesters and tubing, and intentionally when production exceeds demand. As methane has a global warming potential 25 times greater than that of carbon dioxide, this compromises the environmental advantages of digesters. Calculations performed in this paper indicate that the break-even point at which the released methane has as great an impact on global warming as the fuel that has been replaced occurs when between 3% and 51% of the produced biogas is released, depending on the type of fuel that has been replaced. The limited information available as regards methane leaking from small-scale biogas digesters in developing countries indicates that emissions may be as high as 40%. With the best estimates of global numbers of small-scale digesters and their biogas production, this corresponds to methane losses of 4.5 Tg yr^{-1} (total gas per year) or about 1% of global emissions or 10% as much as emissions from rice production. Further proliferation of small-scale digesters could therefore contribute significantly to global emissions of methane. It is therefore important that governments and development aid agencies place stricter requirements on digester maintenance and biogas handling before incentives are created and legislation introduced for the installation of small-scale biogas digesters.

CHAPTER 5

GOVERNING FACTORS

5.1 OBJECTIVES:

i) Optimization of gas production

ii) Comparison with conventional plants

iii) Effect of different parameters

- Temperature
- Hydraulic retention time
- pH
- Total solid concentration

5.2 SELECTION OF SUITABLE FACTORS

Temperature:

According to the studies conducted by Rameshprabu Ramaraj and Yuwalee Unpaprom on the effect of temperature on efficiency of biogas production through anaerobic decomposition, the total biogas yield was achieved 7863.69 ml/L in room temperature(27°C), 10376.59 ml/L in mesophilic temperature(35°C) and 9981.08 ml/L thermophilic temperature(55°C). Evidently the mesophilic and thermophilic temperature ranges have higher efficiency of anaerobic decomposition compared to room temperatures. However the major disadvantage of thermophilic anaerobic decomposition is the reduced dewatering properties of the decomposed sludge. Hence, the requirement of energy for heating this decomposed sludge is very large and leads to reduced stability of the heating process. At the project location, the average surrounding temperature was observed to be around 30°C. In order to achieve the mesophilic range, the designed tank would be coated with black paint. Further the tank is buried underground to maintain the elevated temperature around the digestion chamber.

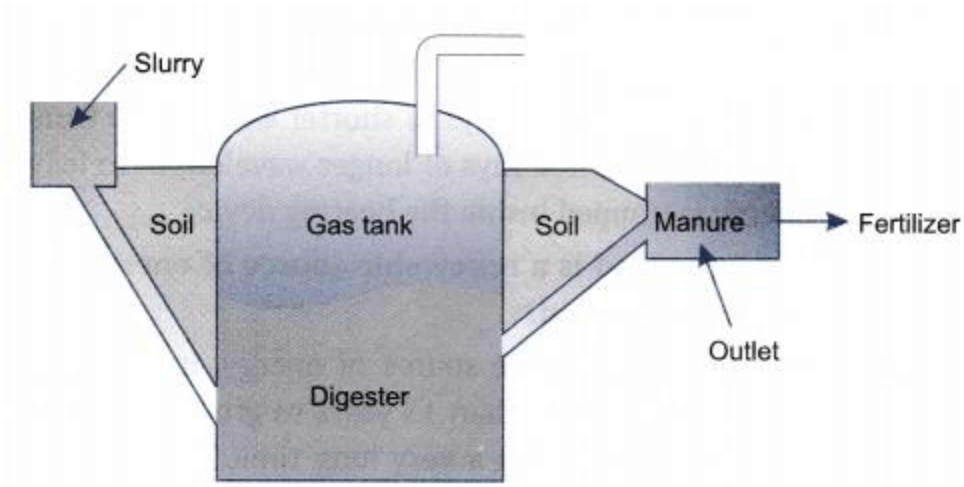


Fig 5.1:- Underground Digester Tank to maintain Mesophilic temperature

Hydraulic retention time:

Recently, a study was conducted by Dobre on the anaerobic degradation process using silkworm excreta and mulberry waste as separate samples. Both silkworm excreta and mulberry waste provided a favorable environment for the development and optimal metabolic activity of microbial bacteria involved in the anaerobic degradation process, as C/N ratio of the substrate was around the optimal values (between 15 and 35). Additionally, it does not contain inhibitory compounds such as detergents, antibiotics, antiseptics, that induce toxic environment to the bacteria. Both of the samples were decomposed within 19days, while approximately 80% of accumulated methane production was achieved in the first 10 days of the process. Mulberry waste was characterized by a higher energy potential than silkworm excrement. Thus the relatively short time of methane production helped in minimizing the Hydraulic Retention Time while increasing the calorific value of the biogas. This reduction in Hydraulic Retention Time due to the addition of mulberry waste aids to lower of the required volume of the digester tank thereby the overall dimensions of the digester.

The hydraulic retention time (HRT) is a primary key in the design of anaerobic digestion process. A short HRT can show a good rate of the raw material flux, but shows a reduction in biogas productivity. A long HRT requires a larger volume of reactor and therefore increased costs. The HRT is established depending on the digester volume and the loaded substrate volume in time unit. The anaerobic digesters which operate at high speeds can retain a prolonged Solids Retention Time (SRT) because of the immobilization of bacterial biomass or overcrowding, works with short HRT and low costs.

Total Solids Concentration:

G. Paramaguru investigated the effect of total solids (5%, 10%, 15% and 20%) on the biogas production in reactors with mesophilic temperature condition (35°C) and hydraulic retention time of 30 days. The volume of daily biogas production, cumulative biogas production, methane and carbon dioxide composition were measured using water displacement method. The experimental results revealed that the reactor with 7-10% of total solid content yielded higher biogas compared with other reactors. Another study conducted by Zhiqiang Liu and Jian Lv analyzed the effect of total solids concentration and temperature on biogas production from anaerobic digestion with dairy manure. Batch experiments were carried out for TS concentrations of 6%, 8%, and 10%, respectively, at five different temperatures (31, 34, 37, 40, and 43°C). The optimal condition for anaerobic digestion was 8% of TS concentration at the mesophilic temperature. In our case, the substrate was observed to have an average concentration of 25% total solids. In accordance with the above two studies, the substrate was diluted with water to bring down the total solids concentration to be 8%.

p^H:

Typically, the rate of biogas formation is higher when the pH range is maintained between 6.8 and 7.2 (Neutral pH value), that is, under controlled environment. An experimental proof was given by S.Sumardiono to control the pH environment by the addition of varying amounts of Vinasse to substrate. The main control element in the Vinasse is urea which helped in reducing the pH of the substrate. The control sample (without urea addition) had the least total biogas production of all samples which was 3.673 mL/g COD. A sample with COD/N ratio of 600/7 had total biogas production of 6.096 mL/g COD which was the most of all COD/N variables. Biogas production with controlled pH was greater than with the uncontrolled p^H. Thus indirectly addition of Vinasse brought down the pH value. In our case, molasses has been added to regulate the pH value.

Corresponding to the above factors discussed, it is seen that the rate of gas production increases when the benign surroundings are maintained. Thereafter we planned to increase the production of biogas using mulberry waste and sugarcane molasses spent wash.

5.3 SUBSTITUENTS USED:

5.3.1 MULBERRY:

Humans have used silk to produce textiles of great value and beauty for centuries. The major domesticated insect, which has been commercially exploited, is the mulberry silkworm, accounting for the greatest share in total silk production (89%).

The breeding of insects is linked closely to the waste generated problem, like excreta and leaf waste. Small-scale farmers can produce 250–300 kg of silkworm waste, which is equivalent to 2500 kg of manure from the farm and may be used to fertilize 0.067 ha of farmland. Excreta of Silkworm have been used successfully as a great source of manure in farm, due to their content of essential nutrients for plants.

It is clear that all wastes produced from agriculture may be transformed into biogas. The pros from changing organic waste matter into biogas are enormous. The production of biogas is not only an economical gain, but also the manure is much of the same kind. It is a high quality substrate to produce biogas through an anaerobic fermentation process, since it ensures a favorable environment for the development and optimal metabolic activity of bacteria involved in the process. This substrate contains only biodegradable organic matter, its C/N ratio is around the optimal 15–35; additionally, it does not contain inhibitory compounds, e.g. detergents, antibiotics, antiseptics, which are toxic to bacteria (Dobre , 2014). However, obtaining an effective hydraulic retention time (HRT) and biogas production depend not only on the substrate composition, but also on the organic loading rate (OLR) and appropriate process temperature.

5.3.2 MOLASSES:

Molasses is a by-product got from the processed wastes of sugar cane. It is a thick, viscous, sticky substance that can be employed for sweetening as it has high concentration of sulfur dioxide got from the sugar extraction. The accurate act of extracting molasses from sugar cane includes three separate steps to its production. You can end at any one of these steps and have molasses with some consistency. The proceedings of these steps change the taste and viscosity of the molasses by extracting a certain amount of the sugar.

Molasses, either in liquid or solid state, is often employed as a vector for urea and other additive agents. It can be mixed with urea, minerals and vitamins to make solids bricks called molasses-urea blocks or multi-nutrient blocks. For example, to provide low quality diets. Production of biogas from wastes of sugarcane has immense advantage for generation of energy. The anaerobic digestion (AD) of sugarcane waste can be seen as a promising strategy, as the digestate could still be used to replace partially the mineral fertilizers on the fields of sugarcane and the biogas produced could be converted to bio methane and sold as a brand new energy product by the sugarcane manufacturing plants.

CHAPTER 6

A SURVEY ON HOSTEL DATA

6.1 HOSTEL DETAILS

The hostel site concerned is located within the PSG Institute of Technology and Applied Research, Neelambur campus over an area of 4500 sq.ft. It includes 2 sections for boys (G1) and girls (G2) separately, accommodating a total of 828 occupants. Food prepared under a common kitchen is served separately in each section. The food wasted in the kitchen and the two dining halls are the focused areas. In the dining area, the wastes end up in serving dishes and the bins. The quantity of food wasted daily is measured after each serving (breakfast, lunch and dinner). An observation was made for the total amount of food wasted in the serving areas and the waste bins of both the dining halls within the period of 16.12.2018 and 03.01.2019 and tabulated in table – 6.1. A chart has been prepared from the above observations for analysis (Chart – 6.1 & 6.2).

The quantity of food wasted does not remain constant for any day. The factors governing the amount of food wasted depends upon the number of occupants at the time of serving, the time of serving and the menu of the particular day. The data collected was done during the beginning of semester. This means both holidays and working days were included in the study and the amount was not found to deviate much. Hence an average data was used for further studies which amounted to 152.73 kg per day, with each occupant contributing 185 grams to total food waste generated.

Table 6.1 – Food waste measured daily

Date	Day	Food unserved (kg)			Food in bins-Boys Hostel (kg)			Food in bins-Girls Hostel (kg)		
		Morning	Afternoon	Night	Morning	Afternoon	Night	Morning	Afternoon	Night
16.12.2018	Sunday	24	20	22	10	30	16	12	20	14
17.12.2018	Monday	15	10	17	8	15	20	17	17	22
18.12.2018	Tuesday	24	34	60	17	14	21	16	15	17
19.12.2018	Wednesday	18	4	38	30	18	22	29	14	18
20.12.2018	Thursday	-	-	36	14	30	30	20	25	28
21.12.2018	Friday	9	12	73	15	18	18	20	16	15
22.12.2018	Saturday	24	-	35	12	24	12	13	12	9
23.12.2018	Sunday	18	24	28	7	18	8	5	12	5
24.12.2018	Monday	14	17	13	2	20	10	5	12	6
25.12.2018	Tuesday	20	39	23	5	15	12	-	10	-
26.12.2018	Wednesday	19	20	20	18	24	15	10	18	11
27.12.2018	Thursday	2	3	32	8	20	20	6	11	12
28.12.2018	Friday	-	-	9	20	25	28	22	17	25
29.12.2018	Saturday	-	-	33	26	36	15	25	17	18
30.12.2018	Sunday	10	19	41	7	25	18	5	18	15
31.12.2018	Monday	12	-	12	12	18	35	15	15	32
01.01.2019	Tuesday	22	12	10	30	18	10	27	11	10
02.01.2019	Wednesday	-	14	18	10	18	15	10	15	11
03.01.2019	Thursday	10	4	10	23	30	25	7	30	22

Table 6.2 – Quantity of food wasted

Date	Day	Food Unserved (kg)	Food In Boys Hostel Bins (kg)	Food In Girls Hostel Bins (kg)	Total Food Wasted (kg)
16.12.2018	Sunday	66	56	46	168
17.12.2018	Monday	42	43	56	141
18.12.2018	Tuesday	118	52	48	218
19.12.2018	Wednesday	60	70	61	191
20.12.2018	Thursday	36	74	73	183
21.12.2018	Friday	94	51	51	196
22.12.2018	Saturday	59	48	34	141
23.12.2018	Sunday	70	33	22	125
24.12.2018	Monday	44	32	23	99
25.12.2018	Tuesday	82	32	10	124
26.12.2018	Wednesday	59	57	39	155
27.12.2018	Thursday	37	48	29	114
28.12.2018	Friday	9	73	64	146
29.12.2018	Saturday	33	77	60	170
30.12.2018	Sunday	70	50	38	158
31.12.2018	Monday	24	65	62	151
01.01.2019	Tuesday	44	58	48	150
02.01.2019	Wednesday	32	43	36	111
03.01.2019	Thursday	24	78	59	161

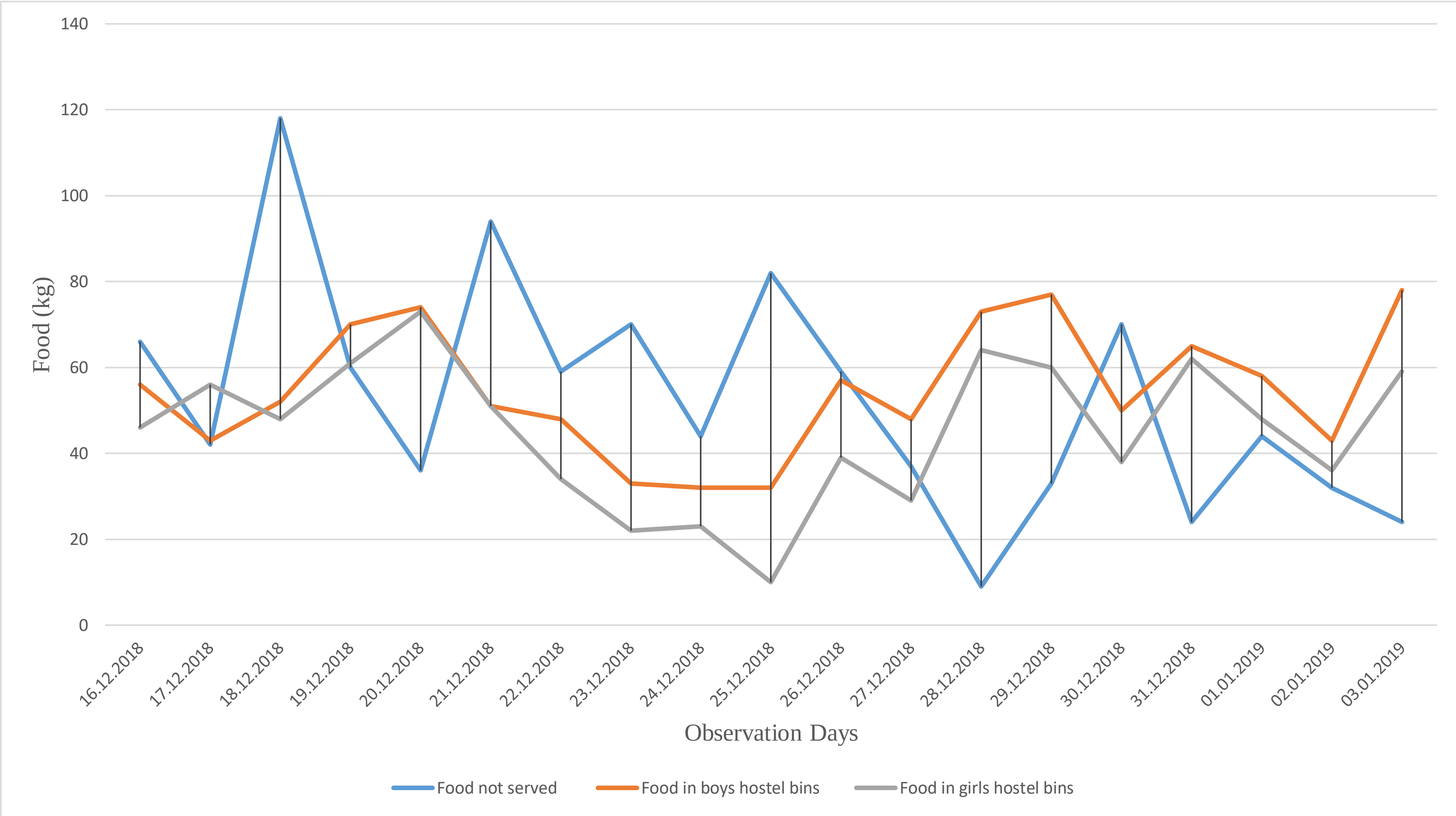


Chart 6.1 - Food wastes from different sources

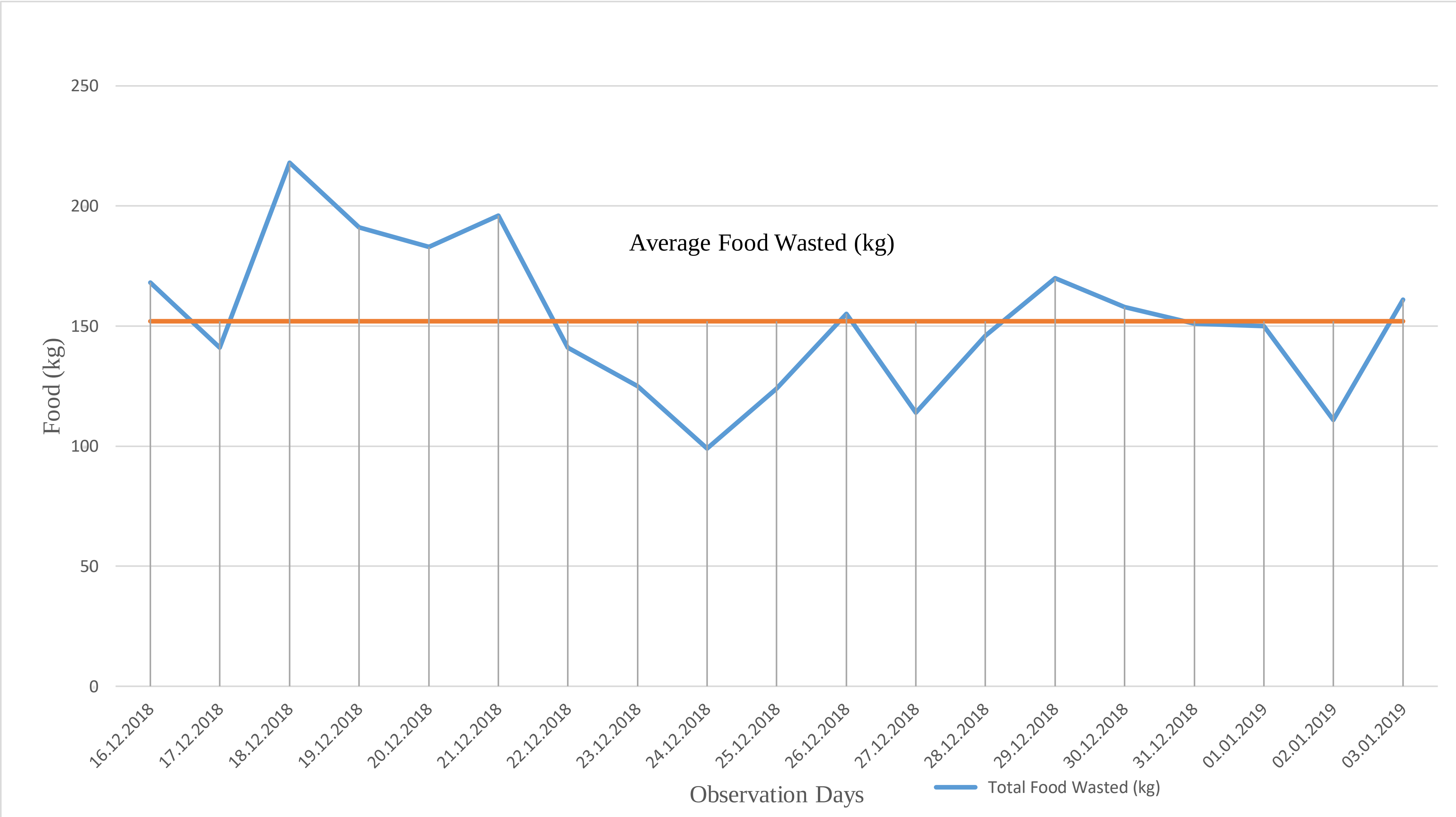


Chart 6.2 – Fluctuations in food wasted

6.2 PRECAUTIONS WHILE COLLECTING SAMPLE:

1. The edible vegetable wastes were only collected for the digester tank which contained food samples such as rice, idli, dosa, egg, and mushroom.
2. The mulberry waste was collected from a farm carefully.
3. The sugarcane extract were taken from the sugarcane residue and care is taken that it is not exposed to heat as volumetric expansion can occur.

6.3 DETERMINATION OF TOTAL SOLIDS:

Total solids are the amount of solids present in the sample after the water present in it is evaporated. Total solids include both the total dissolved solids and total suspended solids. Here, only the amount of total solids present in the given food waste sample is measured. For this, the following steps were carried out.

- A china dish is washed and cleaned of any impurities, kept in the oven for 5 minutes at 105 °C.
- The empty weight of the china dish is noted as W_1.
- Approximately 5 gram of the substrate sample is taken in the china dish and then placed in the oven until all the water present in the sample has evaporated.
- Then the sample is taken out and kept in the desiccators to cool.
- Now the weight of the china dish is noted as W_2.

The percentage of total solids can be calculated from the following formula,

% Total Solid of the sample, TS = (Final weight/Initial weight) * 100

Calculation of percentage of Total Solids:

Amount of the food sample taken = 5 gram

Sample 1:

Empty weight of the dish, W_1 = 76.313 g

Weight of the sample after evaporation, W_2 = 77.653 g

% TS of sample 1 = $((W_2 – W_1) / 5) \times 100$

= ((77.653 – 76.313) / 5) x 100

TS_1 = 26.81 %

Sample 2:

Empty weight of the dish, W_1 = 75.734 g

Weight of the sample after evaporation, W_2 = 76.924 g

% TS of sample 1 = $((W_2 – W_1) / 5) \times 100$

= ((76.924 – 75.734) / 5) x 100

TS_2 = 23.79 %

Average Total Solids %, TS	= 25.30 %

Fig 6.3 – Food sample before placing in oven

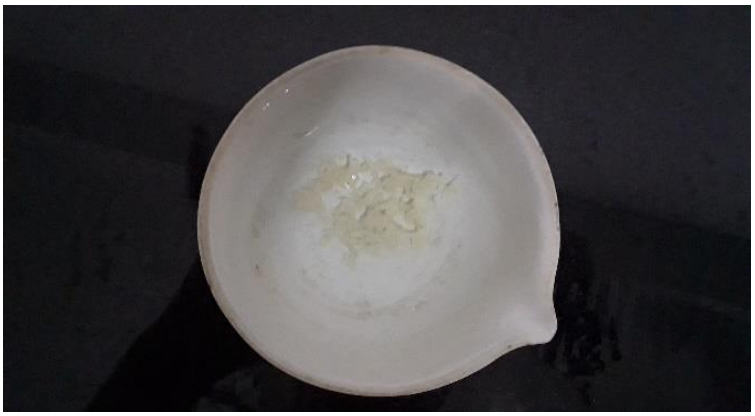


Fig 6.4 – Food sample after placing in oven

Fig 6.5 - Oven

CHAPTER 7

BIOGAS DIGESTER SETUP

7.1 WORK PLAN

This work is conducted in two phases,

1. Trial experiment for investigating whether the additives will play any role in increasing the production of biogas.
2. Experimental verification for increased efficiency by additives in laboratory scale.
3. Design of the large scale biogas plant in accordance with the results of laboratory scale model.

7.2 INSTALLATIONS:

The important aspect in smoother running of plant is by avoiding the choking of the plant. This occurs due to thick biological waste that does not reach the microorganisms to digest. The convenient solution to this problem is to convert solid wastes into liquid slurry. Mixer can also be used to convert solid into slurry.

7.3 SETUP 1:

An experiment was conducted on two samples with different combinations of substrate. The first mixture was the control sample which had only food waste as digestate. The second mixture of food wastes had additives such as molasses, mulberry waste and silkworm excreta that helped in regulating the factors to attain the favorable conditions. The mixtures were tested in a 20 liters container.

Fig 7.1 – Substrate mixtures to be poured in test container

(Left: mixture 1 – cow dung + food waste + water

Right: mixture 2 – cow dung + food waste + mulberry waste + molasses + water)

Fig 7.2 – Setup 1

The materials were collected and mixed thoroughly with water and poured into the digester. The digesters were fixed with a tube to collect the gas and a setup for measuring the gas volume by water displacement method was installed. In water displacement method, the gas produced from the waste sample is led into a tube filled with water at atmospheric pressure. As the gas gets collected in the tube, the pressure of the gas in the digester increases beyond the atmospheric pressure. This causes the gas in the tube to rise above the water in the tube itself. Cow dung was used as inoculums as it contains the necessary microorganisms for the anaerobic digestion to take place. The digesters were kept under close observation such that it was continuously exposed to the sunlight. After one day, the digester with the second sample was found to have produced more gas and the container seemed to be pressurized (bulged). As the gas produced from the digester seemed to be increasing at an alarming rate, we dismantled the setup for both the samples as a precautionary measure. While dismantling it was seen that due to the high pressure inside the digester tank, the substrate came rushing out through the opening.

7.4 SETUP 2:

From the results of first setup, we can infer that the container was not able to account for the extreme changes in volume and pressure produced by the former substrate. This lead to a change in the usage of container from a rigid brittle material to plastic material so that the extreme changes in volume and pressure can be accounted for and the gas produced stays within without any leakage. Hence, a tractor tire-tube was used as the digester tank for the modified substrate as the rubber material has enough extensibility, rebound resilience, tensile strength and tear resistivity. The following were the steps followed. The radial tube was first cleaned thoroughly and then checked for any punctures by immersing the tube into a water tub and pumping through the nozzle. Formation of air bubbles inside the water tub indicates the presence of punctures, in which case it has to be fixed. Then the substrate mixture containing the substituent was prepared with the following volume ratio and poured into the tube.

Table 7.1 – Ratio of substituent in mixture

Substituent	Parts
Molasses	1.5
Mulberry waste	1.5
Food waste	2.5
Cow dung	1.5
Water	3.0

Fig 7.3 – Setup 2

The tube was then sealed at both ends with the help of clamps and again checked for any leakage by immersing the sealed tube into water tub. As no leakages were observed, the setup was left alone at the mesophilic temperature range so that anaerobic decomposition may take place. The setup was left undisturbed for the whole Hydraulic Retention Period (HRT) of 20 days at mesophilic temperature. The setup was monitored throughout the period to check if there was any uncontrollable bulging. At the end of 20^{th} day, the gas produced from the setup was collected and analysed.

7.5 ANALYSIS OF GAS PRODUCED:

7.5.1 SYRINGE METHOD:

Syringe method is used for the measurement of amount of methane and carbon dioxide in the gas produced. A syringe fitted with flexible tube and dilute sodium hydroxide (NaOH) solution was used for carbon dioxide percentage estimation, since NaOH absorbs CO_2 but does not absorb methane.

Procedure followed:

(1) Prepare 100 ml of dilute (2N) sodium hydroxide solution by dissolving 80 grams NaOH granules in about 100 ml of water.

(2) Take 20-30 ml sample of the produced biogas of the experiment into the syringe (fill the syringe with H_2O to reduce air contamination initially) and insert the end of the tube into the solution of NaOH , then discard the excess gas to get a 20 ml gas sample.

(3) Now take approximately 30 ml of solution and keep the end of the tube submerged in the NaOH solution while shaking syringe for 30 seconds.

(4) Point it downwards and push the excess liquid out, so that syringe plunger level reaches 30 ml. Now read the volume of liquid, which should be 6-8 ml indicating about 30-40% of gas absorbed so we can say the balance of 65-60% is methane.

(5) If the flame produced does not ignite properly and if you get over 50% methane (a reading which is less than 5 ml of liquid) you must have nitrogen or other gas present.

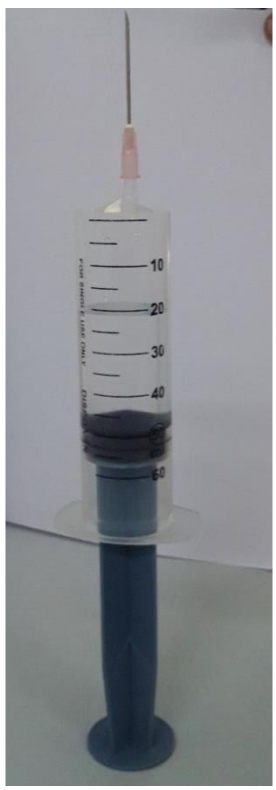
7.5.2 RESULTS OBTAINED:

Table 7.2 - Composition of Biogas produced

Methane	-	(45 - 60%)
Carbon Dioxide	-	(35 - 45%)
Nitrogen	-	(2 - 3%)
Water Vapor	-	(0.5%)
Carbon Monoxide	-	Traces
Oxygen	-	Traces

A) Getting gas sample

B) 20 ml gas sample



C) 20 ml gas sample + 30 ml NaOH

D) After CO_2 is dissolved

Fig 7.4 – INJECTION METHOD

7.6 DESIGN OF THE DIGESTER TANK

The efficiency of a digestion tank depends on the amount of food wastes it can hold, the pressure that it can withstand and the duration for which the materials stay in it. It also depends upon the material of construction and the temperature it is subjected. Considering all this, the important parameters that have to be found are the volume of the digester tank, volume of hydraulic chamber (the chamber which stores the excess amount of gas or food wastes that are produced), and thickness of the digestion chamber. Apart from these, certain factors like contamination problems, moisture content and leakage problems have to be thoroughly checked.

7.6.1 VOLUME DESIGN OF DIGESTER TANK:

The first step in the design of the digester tank is to find the geometric configuration for each portions of the tank. Care should be taken that the volume designed is not too small for holding the substrate and the gas and not too big that the pressure inside the tank is not enough for collection and usage.

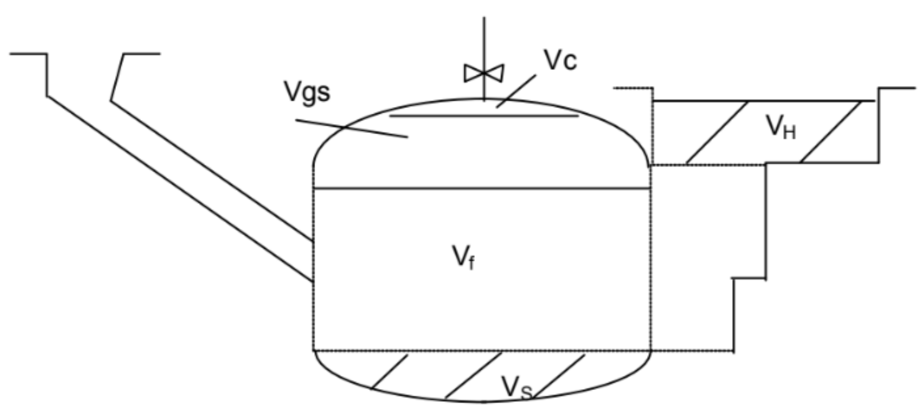


Fig 7.5- Cross section of the digester

Cross section of the digester:

a) Volume of gas collecting chamber = V_c
b) Volume of gas storage chamber = V_{gs}
c) Volume of fermentation chamber = V_f
d) Volume of hydraulic chamber = V_H
e) Volume of sludge layer = V_S

Total volume of digester, $V = V_c + V_{gs} + V_f + V_S$

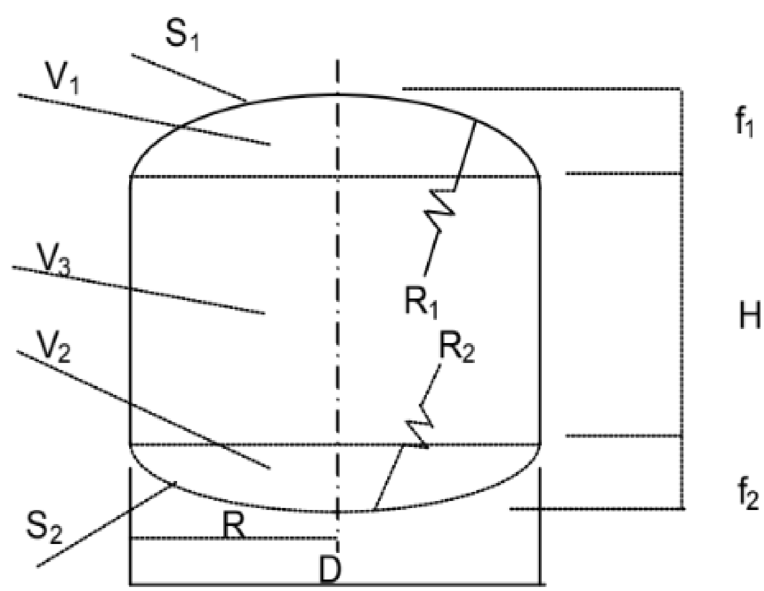


Fig 7.6 – Geometrical dimensions of cylinder

Assumptions:

For Volume,

$V_c \leq 5\%V$

$V_S \leq 15\%V$

$V_{gs} + V_f = 80\%V$

$V_{gs} = V_H$

$V_{gs} = 0.5\ (V_{gs} + V_f + V_S)\ K$

where K = Gas production rate per m^3 digester volume per day.

For Geometrical dimensions,

$D = 1.3078\ V^{1/3}$

$V_1 = 0.0827\ D^3$

$V_2 = 0.05011D^3$

$V_3 = 0.3142D^3$

$R_1 = 0.725D$

$R_2 = 1.0625D$

$f_1 = D/5$

$f_2 = D/8$

$S_1 = 0.911D^2$

$S_2 = 0.8345D^2$

Volume calculation of digester and hydraulic chamber:

a) **Volume calculation of digester chamber:**

Total amount of food waste collected = 152 kg/day

Average Temperature = 30° C

Design:

Let HRT = 20 days (for temperature of 30° C)

Total discharge = 152 kg/day

Total Solids (TS) of fresh discharge = 152 x 0.25 = 38 kg/day

In 8% concentration of TS (To make favorable condition)

8 kg solid = 100 kg of influent

1 kg solid = 100/8 kg of influent

38kg solid = 475 kg of influent

Therefore total influent required = 475 kg

Water that has to be added to prepare the discharge 8% concentration of TS

= 475 – 152 = 323 kg

Working volume of digester = $V_{gs} + V_f$

$V_{gs} + V_f$ = Q x HRT

= 475 x 20 = 9500 kg

= 9.5 m^3

For geometrical assumptions:

$V_{gs} + V_f = 0.8V$

Or V = 9.5 / 0.8 = 11.875 m^3. (Putting $V_{gs} + V_f = 9.5$ m^3)

$D = 1.3078\ V^{1/3} = 2.98$ m ~ 3m.

$V_3 = \pi D^2 \times H/4$

And we assume that $V_3 = 0.3142\ D^3$

Therefore H =1.21 m ~ 1.3 m

Now we find from the assumptions as we know the values of H & D:

$f1 = D/5 = 0.6$ m

$f2 = D/8 = 0.375$ m

$R1 = 0.725$ D $=2.175$ m

$R2 = 1.0625$ D $= 3.1875$ m

$V1 = 0.0827$ D3 $= 2.2329$ m^3

Vc = 0.05 V = 0.59375 m^3

Now the dimensions of the digester chamber are known and drawn below:

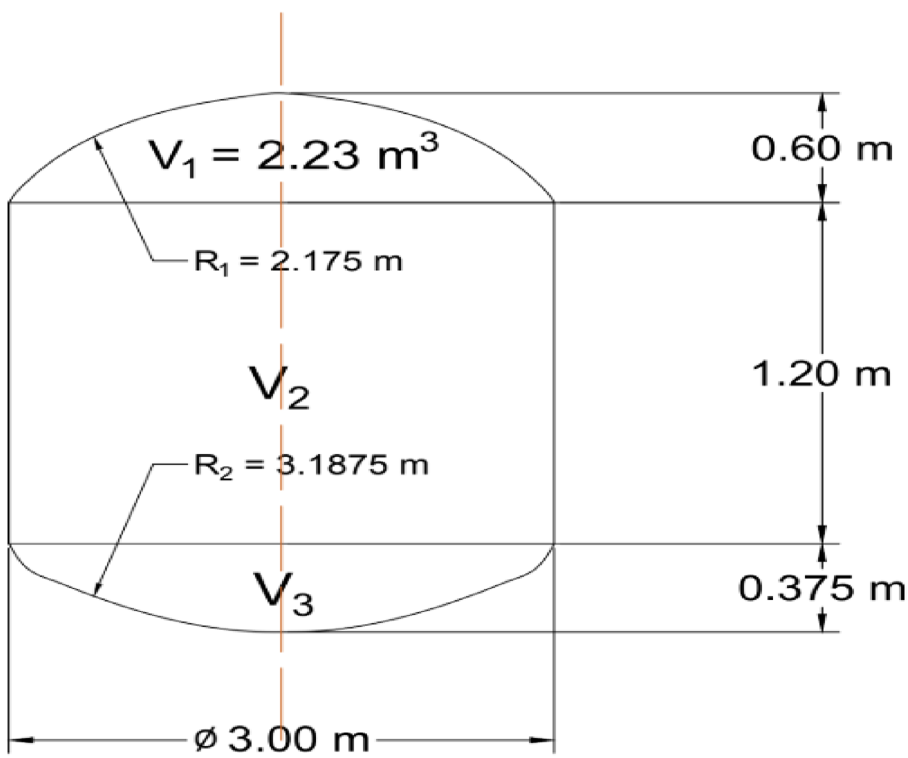


Fig 7.7: Dimensions of Digestion Chamber

b) **Volume calculation of hydraulic chamber:**

From assumptions:

$V_c = 0.05\ V = 0.59375\ m^3$

$V_{gs} = 0.5\ (V_{gs} + V_f + V_S)\ K$

(where K = gas production rate per m^3 volume digestate per day = 0.4)

Therefore, $V_{gs} = 200\ m^3$ ⟶ (A)

Again, V_{gs} = 50% daily gas yield

= 0.5 x TS x gas producing rate per kg of TS

(where gas producing rate per kg of TS = 0.28 kg per m^3)

= 0.5 x 38 x 0.28

= $5.32\ m^3$ ⟶ (B)

From A & B, we get $V_{gs} = 200\ m^3$

$V_c + V_{gs} = 200.594\ m^3$

again, $V_1 = [(V_c + V_{gs}) - (\pi D^2 \times H_1/4)]$

Or, $H_1 = 28.07655$ m

We have fixed h=1200 mm water volume (1 mm = 10 N/ m^2)

$h = h_3 + f_1 + H_1$

or, $h_3 = -27.47$ m

Again, we know that $V_{gs} = V_H$

or, $1.344\ m^3 = 3.14 \times (D_H)^2 \times h^3 / 4$

From this, $D_h = 2.85$ m

7.6.2 DETERMINATION OF THICKNESS OF DIGESTER:

IS 3196 Part 2 (welded low carbon steel cylinders exceeding 5 liter capacity for low pressure liquefiable gases) was followed to determine the thickness of the steel digester chamber. The design of the digestion chamber is divided into two portions namely, cylinder and semi-ellipsoidal dome at both ends. The permissible pressure inside the chamber is limited to 2 bars above which the anaerobic digestion is not favored. The dimensions from the above volume calculation are used below. The material used for the fabrication of tank is Mild Steel. The cylinder and the semi-ellipsoidal portions are joined together with the help of Weld. Here the Weld joint factor is taken as 0.7.

Test Pressure inside cylinder, P_h	=	2bars	(2.03943 kgf/cm^2)
Outer Diameter of the cylinder, D_o	=	3m	(3000 mm)
Weld Joint Factor, J	=	0.7	(no unit)
Yield Strength of Mild Steel, R_e	=	240 N/mm2	(24.473 kgf/mm^2)

From Clause 6.2.1; the agreed finished thickness shall not be lower than that calculated from the following formulae.

(a) For cylindrical portion, greater of the following two:

1. $$t = \frac{P_h D_o}{200*0.8\, J\, R_e + P_h} \longrightarrow \text{1.A}$$

$$= \frac{P_h D_o}{200*0.8\, J\, R_e - P_h} \longrightarrow \text{1.B}$$

2. $t = 0.136 \times \sqrt{D_o}$

From 1.A, $t = \frac{2.039 * 3000}{200 * 0.8 * 0.7 * 24.473 + 2.039}$

$= \frac{6118.29}{2743.015}$

$= 2.2305$ mm

From 1.B, $t = \frac{2.039 * 3000}{200 * 0.8 * 0.7 * 24.473 - 2.039}$

$= \frac{6118.29}{2738.936}$

$= 2.2338$ mm

From 2, $t = 0.136 \times \sqrt{3000}$

$= 7.450$ mm

(b) For semi-ellipsoidal portion (Fig)

$$t_e = \frac{P_h D_o}{200 * 0.8\ J\ R_e + P_h} \times \frac{K\ (0.65 + 0.1K)}{4}$$

where, $K = D_0 / h_o$ ($h_o / D_o \geq 0.192$)

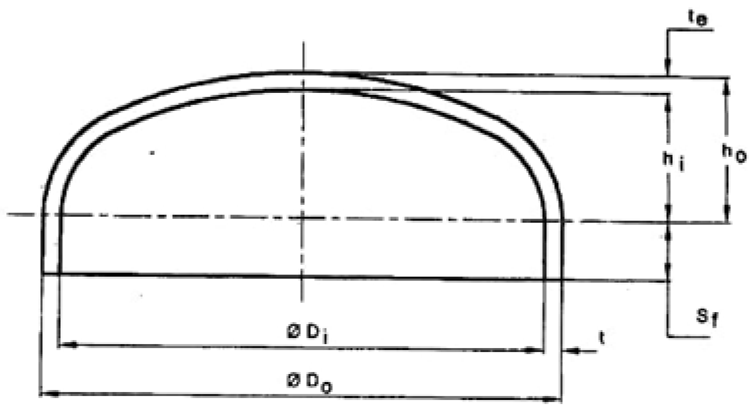


Fig: 7.8 – Semi Ellipsoidal Dome

D_o = 3000 mm

h_o = 2100 mm

K = 1.428 (0.7 > 0.192)

From (b), $t_e = \frac{2.039 * 3000}{200*0.8*0.7*24.473+2.039} \text{ x } \frac{1.428\ (0.65+0.1*1.428)}{4}$

$= 2.2305 \text{ x } 0.283$

$= 0.632$ mm

Hence the thickness of the digestion chamber is taken as 7.5 mm.

CHAPTER 8

COMPARISON OF BIOGAS WITH LPG

The amount of heat generated by burning one kilogram of a specific substance is the calorific of that substance. The unit followed is J/kg. Here, the calorific value of the biogas produced is compared with that of conventional industrial LPG cylinders. The analysis is as shown below,

Calorific value of bio gas = 6 kWh/m^3 (21600kJ/m^3)

Calorific value of LPG = 26.1kWh/m^3 (93960kJ/m^3)

For 100 g sample,

Energy required to boil 100 g of water = 259.59 kJ

Biogas required to boil 100 g of water = 0.01201805556 m^3

LPG required to boil 100 g of water = 0.002762771392 m^3

Biogas generated per day = 1.965217391 m^3

Total volume of water boiled by biogas per month = 490566.2273g
= 490.5662273kg

LPG required to boil 16.35kg of water = 13.55322339 m^3

Conventionally, the quantity of LPG is expressed in kg. Hence the above result is to be converted from m^3 to kg using the following conversion table.

kg	Litres (Liquid)	Mega Joules (MJ)	Kilowatt Hours (kWh)	Gas Volume (m^3)	Diameter* (mm)	Height* (mm)	Tare Weight* (kg)
0.51	1	25	6.9	0.27	na	na	na
1	1.96	49	13.6	0.54	na	na	na
3.7	7.25	181	50	2.0	265	340	5.5
8.5	16.6	417	116	4.6	310	460	9
15**	29	735	204	8	305	734	10
18	35	882	245	10	310	826	18
45	88	2205	612	24	375	1250	33
90	176	4410	1225	48	510	1380	65
210	411	10290	2858	113	760	1450	140

*Dimensions and tare weights can vary by cylinder manufacturer
**Data for aluminium forklift cylinder
NOTE: Some numbers have been rounded

Table 8.1: Biogas Conversion Chart

Reference: ELGAS

Amount of LPG replaced = 24.86 kg

No of LPG cylinders replaced = 1.714482759 Nos.

CHAPTER 9

RESULTS AND CONCLUSIONS

Kitchen waste is defined as the left over organic matter from restaurants, hotels and households. As a substitute to landfill, waste generated from kitchens can be composted to produces oil and fertilizer, fed to animals, or used to produce energy or fuel. Prevailing anaerobic biodegradation method requires gathering organic wastes (kitchen wastes) into chambers with controlled environment, allowing anaerobic bacteria to work on the organic wastes, and collecting the biogas such as methane produced to use as energy.

The concerned site is PSG iTech hostels accommodating 828 occupants at present, produces an average food waste of 152 kg per day. Anaerobic decomposition is suggested as a best method to manage this food waste effectively as the biogas produced can be utilized as fuel. In order to increase the efficiency of the production of biogas, additives like sugarcane molasses, silkworm excreta and mulberry waste were planned to be included in the substrate. A three stage study was done for this purpose.

SETUP – 1:

The first setup was made by introducing the control and trial mixtures inside separate 20 liters plastic water container. The control mixture had only cow dung and food wastes, while the trial mixture had additives mixed with the control mixture. An accelerated gas production could be observed, but the plastic container was not found to be sufficient to handle the pressure due to increase in volume.

SETUP – 2:

To overcome the set back in the first setup, rubber tire tube was used as the digestion chamber and the trial mixture is poured and sealed. The gas produced was collected for analysis after 20 days. Injection method using NaOH for absorbing the carbon dioxide was employed to determine the quantity of methane present in the collected gas sample. Approximately 45% to 60% of the gas volume was found to be methane, the rest being carbon dioxide and residual presence of nitrogen, water vapor, carbon monoxide and oxygen.

DESIGN OF THE LARGE SCALE DIGESTION CHAMBER:

The results from the above analysis were adopted for the design of the large scale digestion chamber capable of daily intake of 152 kg of food waste. The hydraulic retention time (HRT) was decided to be 20 days with the process temperature as 30°C. The total solid concentration was moderated to 8% to maximize the production of biogas. The working volume of the digester is found to be 9.5 m^3. The cylindrical part where the digestion process occurs has a diameter of 3m and a height of 1.4m. The gas collection chamber which is considered to a semi-ellipsoidal shaped dome had a height of 0.6m. The thickness of the whole digester shell is 7.5mm when the working pressure inside the chamber is limited to 2 bars.

On comparing the volume of the biogas produced with that of the LPG it is found that 1.7 cylinders worth of LPG can be produced monthly.

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