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A PROJECT REPORT

ON

“BIO GAS FROM KITCHEN WASTE”

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In partial fulfillment for the award of the Degree

Of

BACHELOR OF ENGINEERING

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UNDER THE GUIDANCE

Of

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To the Kalsekar Technical Campus, New Panvel is a record of bonafide work carried out by him under our supervision and guidance, for partial fulfillment of the requirements for the award of the Degree of Bachelor of Engineering in Mechanical Engineering as prescribed by **University Of Mumbai**, is approved.

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APPROVAL OF DISSERTATION

This is to certify that the thesis entitled
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DECLARATION

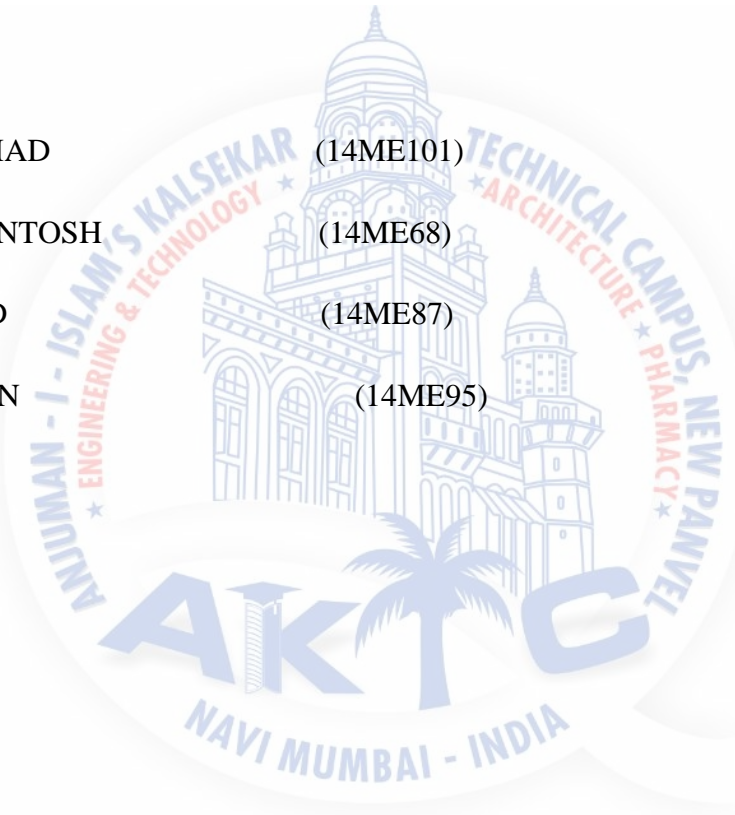
We declare that this written submission represents our ideas in our words and where other's or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

India's economic growth is contributing to a massive increase in the generation of solid waste. Approximately 55 million tones of Municipal Solid Waste is generated annually by urban areas in India. Over 59% of homes in urban India use Liquified Petroleum Gas (LPG) supplied in portable cylinders for their cooking needs.

However, due to our country's dwindling petroleum reserves and increased costly imports of petroleum, non conventional energy resources are slowly gaining importance. The use of biogas using kitchen waste as feedstock can help solve the problem of energy deficit and at the same time, allow the safe disposal of kitchen waste which is often unscientifically dumped or discarded.

Our institute canteen (AIKTC) utilize several LPG cylinders and also generates large amounts of kitchen waste. The kitchen waste generated has high calorific value and moisture content; hence it can be anaerobically digested. The biogas produced can be used to supplement the fuel requirements of the campus kitchens that generate the kitchen waste. This study consists of carrying out survey, characterization of kitchen waste and exploring it's potential to be used for biogas production.

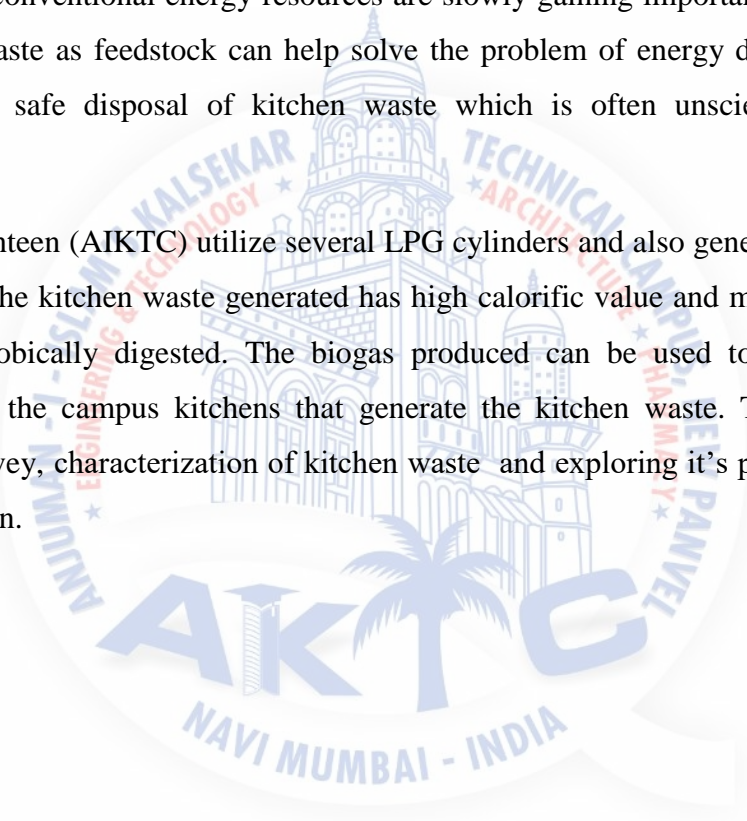


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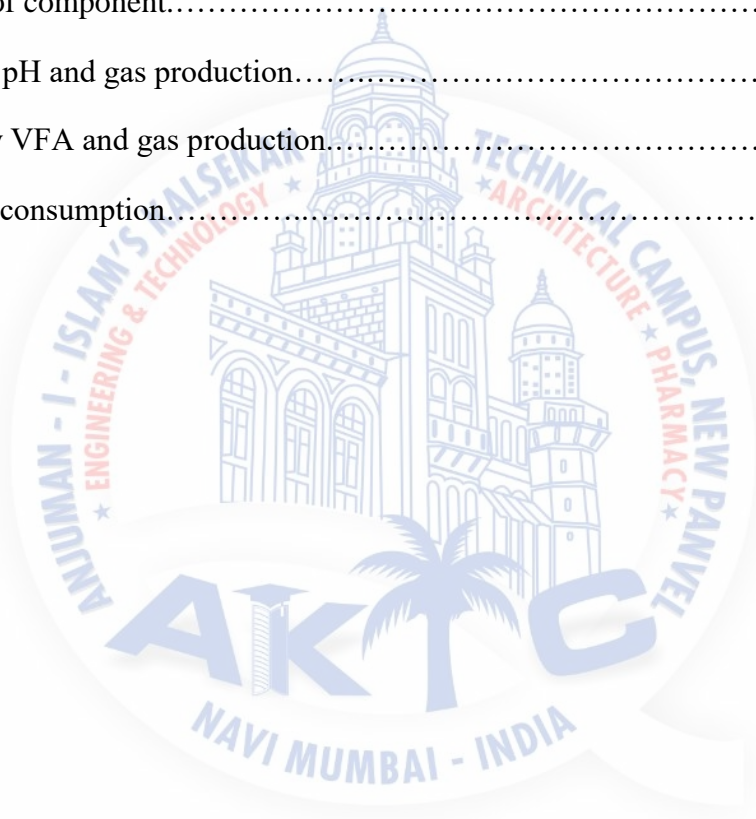
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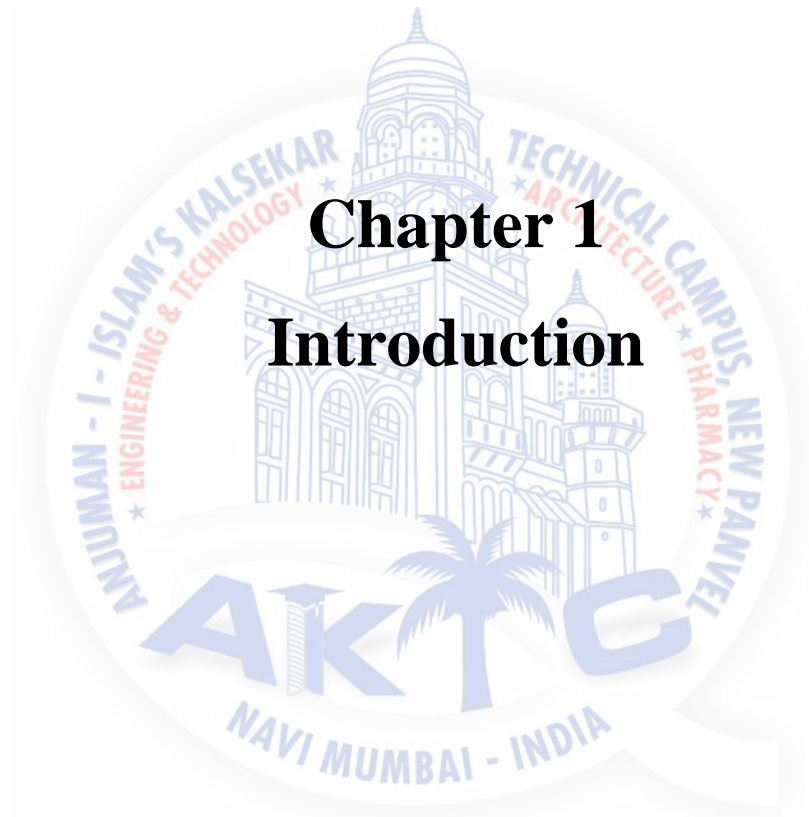
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Chapter 1

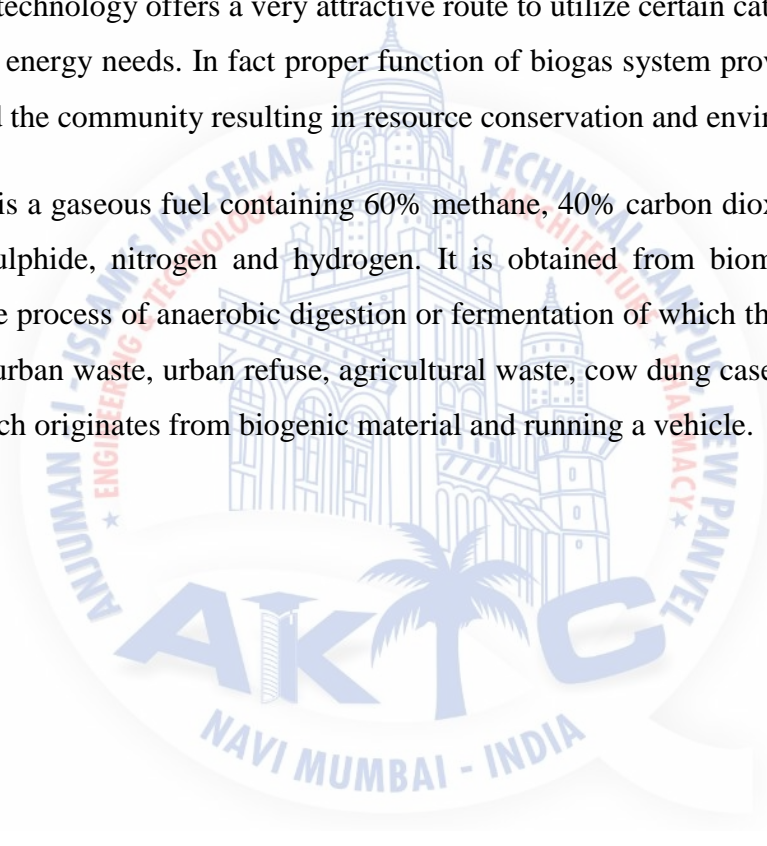
Introduction

1.1 INTRODUCTION

In today's energy demanding life style, need for exploring and exploiting new sources of energy which are renewable as well as eco-friendly is must. In rural areas of developing countries cellulosic biomass (cattle dung, agricultural residues, kitchen wastes, etc) are available in plenty which have very good potential to cater to the energy demand in India alone. Approximately 55 million tones of Municipal Solid Waste is generated annually by urban areas in India. Over 59% of homes in urban India use Liquefied Petroleum Gas (LPG) supplied in portable cylinders for their cooking needs.

Biogas technology offers a very attractive route to utilize certain categories of biomass for meeting partial energy needs. In fact proper function of biogas system provides multiple benefits to the users and the community resulting in resource conservation and environmental protection.

Biogas is a gaseous fuel containing 60% methane, 40% carbon dioxide and small amount of hydrogen sulphide, nitrogen and hydrogen. It is obtained from biomass plant and animal materials by the process of anaerobic digestion or fermentation of which the in-feed to the biogas plant includes urban waste, urban refuse, agricultural waste, cow dung case study. Biogas is used as biofuels which originates from biogenic material and running a vehicle.

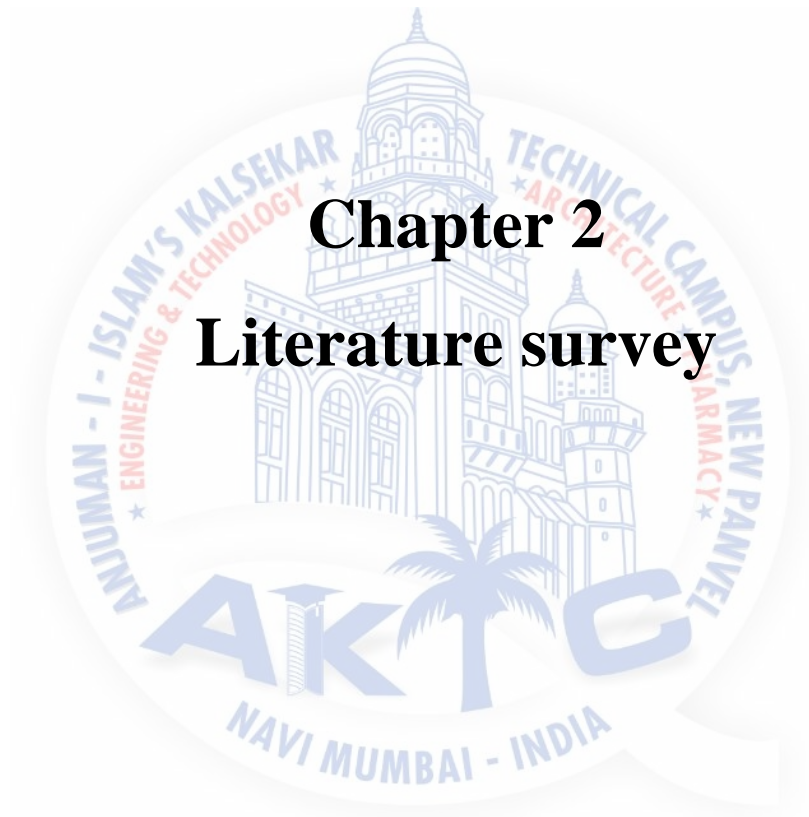


1.2 Aim And Objectives

The aim of this research project is to design, fabricate and test run a bench scale bioreactor for the production of biogas and objective of research are:

1. Design and fabricate feed preparatory using available and non expensive material.
2. Test run a bio-reactor using kitchen waste to obtain biogas as a biofuel to be recommended as a substrate for the non-renewable and expensive domestic fuel.
3. To calculate and record the cumulative volume of biogas being produced after the anaerobic digestion.





Chapter 2

Literature survey

2.1 LITERATURE REVIEW

“Biogas Production from Domestic Waste and its Purification with Charcoal”

Felix Chinedu Akubuenyi, and Lucky Obukowho Odokuma,

The production of biogas from domestic wastes was achieved by anaerobic digestion. The rate of production was measured using displacement method over a retention period of 30 days. The efficacy of charcoal as a purifying agent of biogas was determined by passing the gas through a charcoal medium and its components and quantity were analyzed using gas chromatography. Result shows that 0.50m³ of biogas was produced on Day. The gas became flammable from Day 12, with a production of 1.10m³ biogas. The flammability improved with time.

The gas chromatogram of the biogas conducted on Day 10 of digestion when carbon dioxide (CO₂) (a component of biogas, but does not contribute to its flammability) production was expected to be high revealed that the quantity of carbon dioxide reduced from 53.94% to 12.00% after passing it through a charcoal medium and leads to the enhancement of the methane (the flammable component of biogas) content from 0.03% to 0.05%. This indicates that charcoal can enhance the quality of biogas by adsorbing and reducing its carbon dioxide component

Biogas production which was determined by water displacement method shows production of 0.05m³ biogas on Day 1. The daily biogas production over a 30 day period is shown on Table 1. Result shows that the gas was flammable in a Bunsen burner from the Day 12 of anaerobic digestion of the substrate, with a biogas production of 1.10m³. The result of the effect of charcoal on biogas using Gas chromatography is presented on Figures 2 and 3. The values of the different components of the biogas are displayed on Tables 2 and 3.

The analysis was carried out after 10 days when CO₂ production was expected to be high. Result shows that 53.94% of CO₂ that was generated reduced to 12.00% after it was passed through a charcoal medium. Though methane production was still minimal as the digester was not yet fully anaerobic-a condition that favors the growth of methane-producing methanogenic bacteria, but the process improved the quantity of produced methane from 0.03% to 0.05%

Days	Biogas Production (m ³)
1	0.05
2	0.12
3	0.20
4	0.27
5	0.40
6	0.48
7	0.61
8	0.80
9	0.71
10	0.86
11	0.90
12	1.10
13	1.00
14	1.05
15	1.12
16	1.00
17	0.90
18	0.95
19	0.80
20	0.86
21	0.70
22	0.67
23	0.60
24	0.70
25	0.65
26	0.50
27	0.60
28	0.60
29	0.50
30	0.50

Table 2.1: Rate of Daily Biogas Production over a period of 30 Days.

Biogas production (0.05m³) was observed on Day 1. This indicates that the slurry contained microorganisms that have the enzymatic capacity to initiate fermentation. The presence of these organisms could be attributed to the introduction of digested slurry from spent anaerobic digester, which introduced additional and the necessary bacteria required for biogas production.

Research has shown that recycling digested slurry along with filtrate helps to conserve water and increase biogas production. This corroborates that finding of Kanwar and Guleri (1994), who reported that about 60–65% more biogas production can be obtained by simply recycling the digested slurry in 1m^3 plug flow type pilot plants.

Composition	Quantity	% Content
Methane	66.7680	0.03
Nitrogen	101412.0000	45.43
Oxygen	1335.9858	0.60
Carbon dioxide	120425.3672	53.94
Total	223249.7538	100

Table 2.2: Composition of Biogas before passing it through a Charcoal Medium.

Composition	Quantity	% Content
Methane	65.5387	0.05
Nitrogen	103958	85.16
Oxygen	3402.58	2.79
Carbon dioxide	14646.9	12.00
Total	122073.0259	100

Table 2.3:Composition of Biogas after passing it through a Charcoal Medium.

It also agrees with the study of Malik and Tauro (1995), who observed an increase of up to 18.8% in gas production ($\text{CH}_4 = 80\%$) when predigested slurry was used along with 10% effluent slurry recycling in a 1m^3 daily fed floating drum biogas digester. A ten-fold and three-fold increase in the degradation rate of mannitol and lactic acid respectively was observed when liquid

recirculation was initiated in a silage-fed two-phase biogas plant (Jarvis et al.,1995). The number of hydrogenotrophic methanogens increased ten-fold while there was an increase in nine-fold in activities.

The quick production of biogas could also be related to the pre-treatment (shredding) of the substrate before digestion. Large particles results in the clogging of the digester, making it difficult for microbes to carry out digestive functions. Smaller particles on the hand would provide large surface area for adsorbing the substrate that would result in increased microbial activities and consequent gas production. The positive effect of pre-treatment in biogas production has been reported by researchers (Luste et al., 2009; Mendes et al., 2006). Sharma et al. (1988) found that out of five particle sizes (0.088, 0.40, 1.0, 6.0 and 30.0mm), maximum quantity of biogas was produced from raw material of 0.088 and 0.40mm particle sizes.

Though biogas was produced on Day 1, but it did not flame. The inability of the gas to flame may be attributed to high concentration of CO₂. Biogas becomes flammable when its methane content is at least 45% ([Http:file://A:/Design-Tutor.htm](http://file://A:/Design-Tutor.htm),2003). Result shows that the gas was flammable from Day 12 in a Bunsen burner which indicates that the gas could be used for laboratory purposes. The flammability may also be as a result of high volatile solids (the biodegradable portion of the waste) in the substrate. The early onset of flammability may be traced to the presence of cow dung. This agrees the finding of Uzodinma and Ofoefule (2009) that addition of rabbit or cow dung enhances the onset of flammability. Sharma (2002) reported that cow dung acts as buffer and takes care of acid accumulation during anaerobic digestion, thereby enhancing biogas production.

The reduction in the quantity of CO₄ from 53.94%-12.00% after passing it through a charcoal medium as revealed in the gas chromatogram.. The reduction in CO₄ improves the quality of the biogas by increasing the content of methane, thereby making the biogas more flammable. This research indicates that charcoal can be used to upgrade biogas by reducing the CO₄ content and increasing the quantity of CO₄ thereby enhancing the caloric value of gas.

“Biogas production from kitchen waste”

National Institute of Technology, Rourkela 2010-2011

In our institute we have seven hostels and all having their own individual mess, where daily a large amount of kitchen waste is obtained which can be utilized for better purposes. Biogas production requires Anaerobic digestion. Project was to Create an Organic Processing Facility to create biogas which will be more cost effective, eco-friendly, cut down on landfill waste, generate a high-quality renewable fuel, and reduce carbon dioxide & methane emissions. Overall by creating a biogas reactors on campus in the backyard of our hostels will be beneficial. Kitchen (food waste) was collected from different hostels of National Institute of Technology, Rourkela's Mess as feedstock for our reactor which works as anaerobic digester system to produce biogas energy. The anaerobic digestion of kitchen waste produces biogas, a valuable energy resource Anaerobic digestion is a microbial process for production of biogas, which consist of Primarily methane (CH₄) & carbon dioxide (CO₂). Biogas can be used as energy source and also for numerous purposes. But, any possible applications requires knowledge & information about the composition and quantity of constituents in the biogas produced. The continuously-fed digester requires addition of sodium hydroxide (NaOH) to maintain the alkalinity and pH to 7. For this reactor we have prepared our Inoculum than we installed batch reactors, to which inoculum of previous cow dung slurry along with the kitchen waste was added to develop our own Inoculum. A combination of these mixed inoculum was used for biogas production at 37°C in laboratory (small scale) reactor (20L capacity) In our study, the production of biogas and methane is done from the starch-rich and sugary material and is determined at laboratory scale using the simple digesters.

From the result it has been seen that in set2 which contain kitchen waste produces more gas, compare to other two set. In set2 with kitchen waste produces average 250.69% more gas than set 1 (with 200gm cow dung) and 67.5% more gas than set 3 (with 400gm cow dung). Means kitchen waste produces more gas than cow dung as kitchen waste contains more nutrient than dung. So use of kitchen waste provide more efficient method of biogas production.

From results it has been seen that pH reduces as the process going on as the bacteria produces fatty acids. Here methanogens bacteria which utilize the fatty acids, is slow reaction compare to other so it is rate limiting step in reaction. In set2 which contains kitchen waste pH decreases highly means reaction is fast, means hydrolysis and acidogenesis reaction is fast as organism utilize the waste more speedily than dung. And total solid decreases more in set2.

Graph Analysis- It can be seen from the graph that gas production increases first upto day 3 but then it starts decreasing as acid concentration increases in the bottles and pH decreases below 7 after 4-5 days water was added to dilute which increases the pH, gas production again starts increasing. Therefore, we can infer that acid concentration greatly affects the biogas production. Biogas quality upgrade by simultaneous removal of CO₂ and H₂S in a packed column reactor. N. Tippayawong*, P. Thanompongchart Department of Mechanical Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai 50200, Thailand abstract Biogas from anaerobic digestion of biological wastes is a renewable energy resource. It has been used to provide heat, shaft power and electricity. Typical biogas contains 50-65% methane (CH₄), 30-45% carbon dioxide (CO₂), moisture and traces of hydrogen sulphide (H₂S). Presence of CO₂ and H₂S in biogas affects engine performance adversely. Reducing CO₂ and H₂S content will significantly improve quality of biogas. In this work, a method for biogas scrubbing and CH₄ enrichment is presented. Chemical absorption of CO₂ and H₂S by aqueous solutions in a packed column was experimentally investigated. The aqueous solutions employed were sodium hydroxide (NaOH), calcium hydroxide (Ca(OH)₂) and mono-ethanolamine (MEA). Liquid solvents were circulated through the column, contacting the biogas in countercurrent flow. Absorption characteristics were examined. Test results revealed that the aqueous solutions used were effective in reacting with CO₂ in biogas (over 90% removal efficiency), creating CH₄ enriched fuel. H₂S was removed to below the detection limit. Absorption capability was transient in nature. Saturation was reached in about 50 min for Ca(OH)₂, and 100 min for NaOH and MEA, respectively. With regular replacement or regeneration of used solutions, upgraded biogas can be maintained. This technique proved to be promising in upgrading biogas quality.

Aqueous solutions of NaOH, Ca(OH)₂, and MEA were used as chemical solvents to demonstrate the experimental apparatus function and ability to absorb CO₂ and H₂S. The packed column reactor was observed to simultaneously remove high proportion of CO₂ and H₂S (over 90% removal efficiency), resulting in CH₄ enriched biogas. However, this was a time dependent process. These gaseous concentrations were found to decrease with time. This effect will be discussed later in the section. Initially, the liquid solvents reacted rapidly with, and almost completely absorbed CO₂ and H₂S. Their concentrations at the outlet stream were practically very small compared to their original values. As the absorption process proceeded with time, the CO₂ and H₂S were continuously accumulated in the solvents. Due to its much higher concentration in comparison with H₂S, the CO₂ started to evolve in the outlet stream after a

certain time. The end of each run was determined when the liquid solvent became completely saturated or neutralized (pH 7e8). The corresponding breakthrough curves obtained are presented in Fig. 3, showing variation of the dimensionless CO₂ concentration and changes in pH level with time. It was found that NaOH, Ca(OH)₂ and MEA showed similar patterns. NaOH and MEA were found to become saturated in about 100 min. However, rate of Ca(OH)₂ saturation appeared to be much faster than for the other two. This was observed after around 50 min, compared with about 100 min observed for NaOH and MEA. It should be noted that MEA possessed lower basicity than NaOH and Ca(OH)₂ but its rate of change in pH level was also slower. The relatively fast saturation time realised in this investigation may be attributed to the fact that biogas used here contained very high concentration (47%) of CO₂. It should be noted that each data presented was an average value. Their coefficient of variations, defined as a ratio between standard deviation and mean value were found to be within about 10%. Plots of absorption time against dimensionless biogas concentration for CO₂ absorption by NaOH, Ca(OH)₂ and MEA. These curves may be approximated by straight lines. These linear relationships were obtained within a different range of operation times for different solutions used. The ranges were 100, 50, and 110 min for NaOH, Ca(OH)₂ and MEA, respectively. For NaOH and Ca(OH)₂, R² values of greater than 0.96 were obtained, showing good linear relationships. However, an R² value of only 0.84 was obtained for MEA. It appeared that the MEA curve was not exactly linear. A single linear relationship may not be sufficient to describe the behaviour of MEA. This observation was in line with the previous reported work on absorption with primary and tertiary amines, where two line sections were proposed. The reasons for the observed characteristics of MEA as well as for the difference from NaOH and Ca(OH)₂ are not yet known. From the reaction kinetic parameters of NaOH and linearly approximated MEA, they were found to be similar. The saturation time of the solutions in the packed column was predicted to be 2s. While saturation time for Ca(OH)₂ observed from the experiment was closely predicted by the theoretical model, significant theoretical underestimations of saturation time were observed for NaOH and MEA. With respect to absorption capacity of the solvents. Error bars show standard deviations of each case. It was observed that the total amounts of CO₂ absorbed were in the range between 0.18 and 0.22 kg/kg, with highest loadings occurring for NaOH solution. The better loading for NaOH over MEA did not imply that NaOH was a better absorbent for CO₂ removal. Other properties such as cost, ability to regenerate, chemical stability, etc. must be taken into account. It can be seen that most studies were undertaken at relatively low CO₂ concentrations of about 15% or less, compared to that found in typical biogas

(>40%). Various chemicals used include NaOH, NH₃, MEA and MDEA (methyl-diethanolamine). Results obtained from this work appeared to be in similar range to those in the literature. With respect to MEA, our results were observed to be lower than those from Lin and Shyu and Aroonwilas et al. results. This may be attributable to the fact that they used higher MEA concentrations, 0.1 M in our case compared to 1.8 M and 3 M for Lin and Shyu and Aroonwilas et al. cases, respectively. Published data for NaOH and Ca(OH)₂ was rather scarce. However, with regards to NaOH, we obtained higher absorption than that reported by Georgiou et al. Attempts were made to generate high quality CH₄ enriched gas for a prolonged period. This was conducted by replacing used NaOH and Ca(OH)₂ solutions with fresh ones at about 20% of total volume to maintain basicity level above pH 11.9. However, preliminary testing revealed that the addition had to be done in the first 15 min. And after 30 min, addition of fresh solutions was not able to produce greater than 80% purity of CH₄ enriched gas. Therefore, spent solutions had to be replaced in a 30-min interval. For MEA, a similar procedure was also performed. Replacement of a 20% volume fraction of used MEA solution with clean solution was carried out at regular intervals of 15 min. This was done to mimic partial regeneration of the spent MEA solution. Within the operation time considered, the basicity level of recirculated MEA was found to reduce only slightly from its original value prior to when the first mixing commenced. It was clear that all solutions used may be operated in such a way that purity of greater than 80% CH₄ enriched biogas could be obtained over a period of time. In terms of practical applications, these chemicals proved to be potentially suitable absorbents. However, it should be pointed out that although high concentrations of CH₄ were obtained after a short time these high concentrations were found to decrease rapidly. To maintain high absorption rate, a substantial fraction of original volume of the solution needed to be replaced or regenerated. Frequent replacement would lead to a fluctuation in concentrations. One of the limitations of biogas upgrading lies in economics of the bulk separation of CO₂. The main disadvantage of using alkaline solvents was that they are very difficult or impossible to regenerate for reuse. Even though they are relatively low cost materials, large amount of chemicals would be required to satisfy purity requirements of CH₄ enriched gas. Use of MEA has the advantage of being able to be regenerated. However, for a small scale biogas production as considered in this study, initial investment cost for constructing the set up, as well as energy requirement may be excessive and outweigh the benefit of using high purity biogas. Further work may thus be required.

Removal of CO₂ and H₂S from biogas by aqueous solutions in a packed column was investigated. NaOH, Ca(OH)₂ and MEA were employed in the present study and their absorption characteristics were examined. A simple empirical model was also adopted for CO₂ absorption rate prediction. Test results indicated similar absorption patterns between the chemical solvents used. Chemical absorption by solvents in a packed column was an effective technique for removing CO₂ and H₂S over a short operation time, but their absorption capability declined rapidly with time. Ca(OH)₂ appeared to become saturated more rapidly than the other solvents. The CO₂ loading ranged between 0.18 and 0.22 kg CO₂ per kg chemicals used. Chemical absorption by alkali aqueous solutions did not appear to be promising for biogas quality upgrade due to the nonregenerable nature, requirement of large liquid solvents volume and the environmental impact. However, amine solutions may be worth exploring further, due to the regeneration capability. Additional experimental results are required to provide the basis for system selection and design, as well as subsequent up-scaling. The next phase of experimental work will involve setting up a regeneration system for amine absorbent, evaluating its long term performance, and undertaking cost analysis of the system, as well as a possible scale up study and field test in a biogas farm.

“Sizing of an Anaerobic Biodigester for the Organic Fraction of Municipal Solid Waste”

AUTHOR: R. Kigozi, A. O. Aboyade Member, IAENG, and E. Muzenda, Member, IAE

The anaerobic digestion (AD) of the organic fraction of municipal solid waste (OFMSW) for biogas production is a potential solution to the growing challenges associated with municipal solid waste (MSW) management while simultaneously providing an alternative clean energy source. Biogas is produced by the anaerobic digestion (AD) of biomass using microorganisms in specifically designed plants called biogas digesters under controlled conditions or naturally in marshes and landfills. It is a rather clean and versatile fuel as opposed to fossil fuels. To design an efficient AD system, a proper understanding of the quality and quantity of available feedstock must be made as well as prevailing operating conditions. This paper represents steps that were taken to come up with an optimal size of biodigester to treat OFMSW produced at the University of Johannesburg's Doornfontein Campus in downtown Johannesburg. The campus generates 232.2kg of OFMSW per day which required 30m³ of bio digester capacity.

The study presents methods and results from a case study to size a suitable anaerobic biodigester to handle OFMSW generated at the University of Johannesburg's Doornfontein Campus. The plant was scaled based on reliable estimates of waste quantification and characterisation studies conducted at the study area. Of the 378kg of solid waste generated daily at the school campus, 231.22kg is the biodegradable portion which will be handled by the proposed biogas digester consisting of food waste and compostable garden waste. This this will require 30m³ of bio digester capacity. A Puxin digester model a Chinese technology supplied locally by BiogasSA will be the preferred model which is present in standard sizes of 10 and 6m³. Therefore, the project will require three (3) 10m³ plants.

“Biogas prediction and design of a food waste to energy system for the urban environment”

AUTHOR: Nathan Curry, Pragasen Pillay P.D. Ziogas Power Electronics Laboratory.

Anaerobic digestion applied to the organic waste produced in urban environments could provide a critical solution to growing garbage problems while simultaneously reducing external energy requirements. As landfills across Canada and the rest of the world are filled to their limits, a carbonneutral process which can locally generate electricity and heat while providing up to 50% volatile solid reduction is something to be seriously considered. This paper investigates the feasibility of urban anaerobic digestion, presents four techniques for biogas estimation e ultimate analysis, yield from molecular formula analysis, a novel computer simulation technique using Anaerobic Digestion Model #1 (ADM1), and a literature review of experimentally determined biogas yields. In addition, a case study for 11small-scale anaerobic digestion system design is presented for an urban building.

This paper argues for the use of small-scale anaerobic digestion in the urban buildings to deal with the organic waste produced on site as a way to save on transportation costs and reducing the amount of waste that is sent to landfills. Several techniques were presented to estimate biogas production from food waste. A design technique for sizing an anaerobic digestion system was also presented. A case study of a system design was presented for dealing with 165 tonnes of food waste in a building in downtown Montreal, Canada, including estimated energy consumption and production. This technology could be integrated into pre-standing urban

buildings or designed and integrated into new buildings for a paradigm shift toward a more renewable, sustainable future.

“Optimization of anaerobic fermentation of kitchen waste”

AUTHOR: Dlabaja T., Malat'ák J., 2013.

Anaerobic fermentation is a suitable method of energetic and material utilisation of waste coming from restaurants and canteens. Laboratory experiments of wet anaerobic fermentation were performed in a continuous reactor and in batch reactors under mesophilic conditions. Effects of hydraulic retention time, organic loading rate, period of feeding and recirculation of digestate were examined in the continuous reactor. Effects of substrate pre-treatment (crushing, heating, freezing) were examined in the batch reactors. Degree of substrate degradation ranged between 83–85% within hydraulic retention time of 2–30 days. Appropriate organic loading rate was found in the range 2–3 kg of volatile solids per m³/day. Recirculation of digestate (both an inoculum for fresh substrate and replacement of fresh water supply) caused an increase in ammonia concentration and led to immediate inhibition of the process. The results further showed a positive effect of substrate pre-treatment in the initial phase of fermentation. However, degree of degradation did not show a significant increase for the period of 20 days of fermentation.

The results of this investigation indicate that kitchen waste coming from catering services is a suitable raw material for wet mesophilic anaerobic fermentation. This material is easily biodegradable even without the application of pre-treatments (83–85% degree of degradation after 20 days of fermentation) and the biogas yield after 15 days of fermentation reaches a min. 95% of the total yield. This reduces the need of the reactor size and hydraulic retention time. The organic loading rate can be maintained at higher values of the recommended range 2–3 kg of VS/m³/day. The biogas yield confirms the reported literature values of 0.25 to 0.55 m³/kg of VS with methane share of 57–67% (Pastorek et al. 2004; Li et al. 2010). The proportion of methane decreases with shorter hydraulic retention time and higher organic loading rate which was as expected. For the purpose of individual fermentation of kitchen waste, it is recommended to further examine the thermophilic dry anaerobic fermentation technology with one continuous reactor.

“Biogas production by two-stage thermophilic and mesophilic biodigestion of kitchen waste”

National Institute of Technology, Rourkela. 2013-2014

The present research work focuses on the biogas production from kitchen waste generated at the NIT hostels and to investigate the effects of the key process parameters like pH and temperature, by operating a pilot scale setup in two stage thermophilic and mesophilic digestion conditions. In 1st experimental setup, a comparison of the digestion of food wastes in small scale was done. In this experiment three setups were operated in mesophilic, thermophilic and two stage mesophilic and thermophilic conditions respectively. The comparison of kitchen waste digestion in case of two stage setup was found to be 30% faster than mesophilic setup in terms of total solids and carbohydrates degradation over the operation period of 20 days. The biogas production initially was found to be 40% faster in case of two stage setup than the mesophilic setup.

In 2nd experimental setup the pilot scale setup was based on two stage thermophilic and mesophilic digestion process and operated as a batch reactor. In batch condition, maximum of 7.45 Liters biogas was produced from the digestion of 6 kg of food wastes in 25 days. The initial total solid content of the waste slurry was measured to be 10.27% which was reduced to 5.51% on 25th day. The initial total carbohydrate and volatile fatty acid concentration was 61.2 g/L and 2475.5 mg/L respectively. After 24 days of digestion, the total carbohydrate concentration was decreased to 22.3 g/L, whereas volatile fatty acid concentration was increased to 4954 mg/L. The project work signifies that the kitchen waste can be used as a potential source for biogas production using two stage digestion process and thus effective waste management can be achieved.

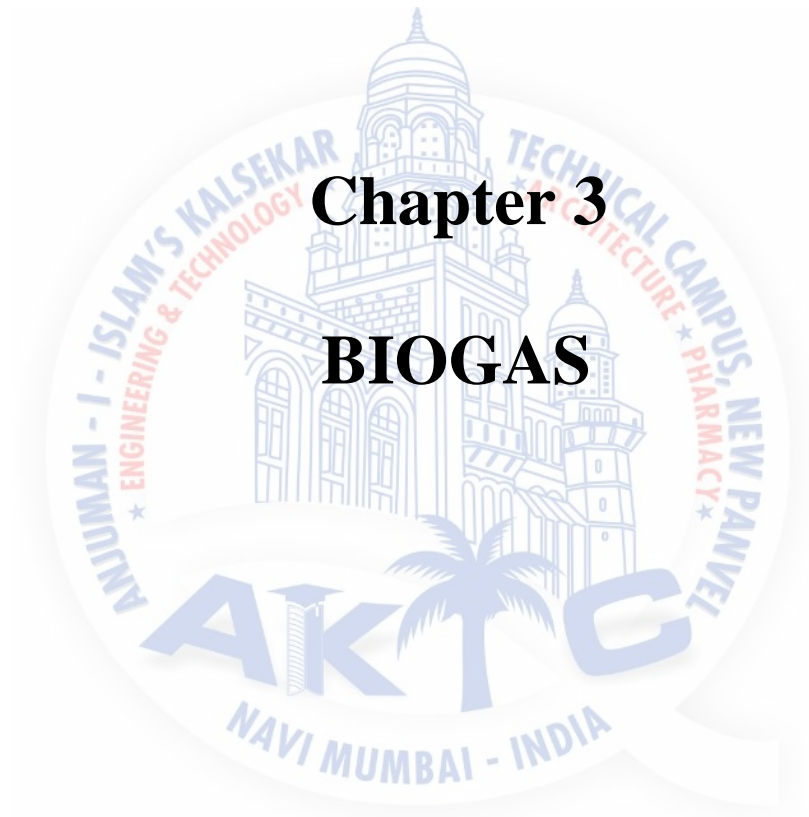
The Biogas setup based on kitchen wastes was implemented on small scale setups to find the effects of the process parameters on the biogas production. It was found that the pH and temperature conditions had huge influence on the working of the biogas plant. In 1st experimental setup a comparison of the digestion of food wastes in small scale was done. In this experiment three setups were compared under mesophilic, thermophilic and two stage mesophilic and thermophilic conditions. The kitchen waste digestion in case of two stage thermophilic and mesophilic setup was found to be 30% faster than mesophilic setup. This difference was observed with respect to total solids and carbohydrates change over the operation period. The gas production initially was found to be 40% faster in case of two stage setup than the mesophilic setup.

The pilot scale plant was based on two stage thermophilic and mesophilic digestion process and operated as a batch reactor under controlled conditions of pH and temperature. A constant rate of gas production was achieved but accumulation of volatile fatty acids was also observed. In batch condition, it was observed that a maximum of 7.45 Liters biogas was produced from the digestion of 6 kg of food wastes in 25 days. Initially the total solids of the waste slurry was measured to be 10.27% on the day of starting the reactor and 5.51% on 25th day. The total carbohydrates degradation was measured to be 61.2 g/L on the day of starting the reactor and 22.3 g/L on 24th day. The volatile fatty acid concentration was measured as 2475.5 mg/L on the day of starting the reactor and 4954 mg/L on 24th day.

The gas analysis results were not satisfactory. It was expected that in batch conditions the digestion of one batch of feed substrate should have completed within 15 days. It was observed from the analysis of various characteristics that the digestion in the reactor was much slower than expected. The gas analysis data showed only 18.66 % methane gas concentration on 25th day. The possible reason for the low amount of methane gas formation may be due to accumulation of volatile fatty acids. Hence it is suggested the reactor should be operated for more than 3 months in continuous mode to obtain better results.

The future prospect of the project can be the improvement of biogas production from kitchen wastes by incorporating additives and optimization of other process parameters in the two stage anaerobic digestion process.

The survey of the NIT hostels for the data of the food wastes generated showed large amount of food wastes produced at our hostels that can be treated by setting up a large scale two stage biogas plant, for production of biogas, taking into view the successful implementation of such biogas plant at Bhabha Atomic Research Center (BARC) premises.



Chapter 3

BIOGAS

BIOGAS

Biogas is produced by bacteria through the bio-degradation of organic material under anaerobic conditions. Natural generation of biogas is an important part of bio-geochemical carbon cycle. It can be used both in rural and urban areas.

Component	Concentration (by volume)
Methane (CH ₄)	55-60 %
Carbon dioxide (CO ₂)	35-40 %
Water (H ₂ O)	2-7 %
Hydrogen sulphide (H ₂ S)	20-20,000 ppm (2%)
Ammonia (NH ₃)	0-0.05 %
Nitrogen (N)	0-2 %
Oxygen (O ₂)	0-2 %
Hydrogen (H)	0-1 %

Table-3.1. Composition of biogas.

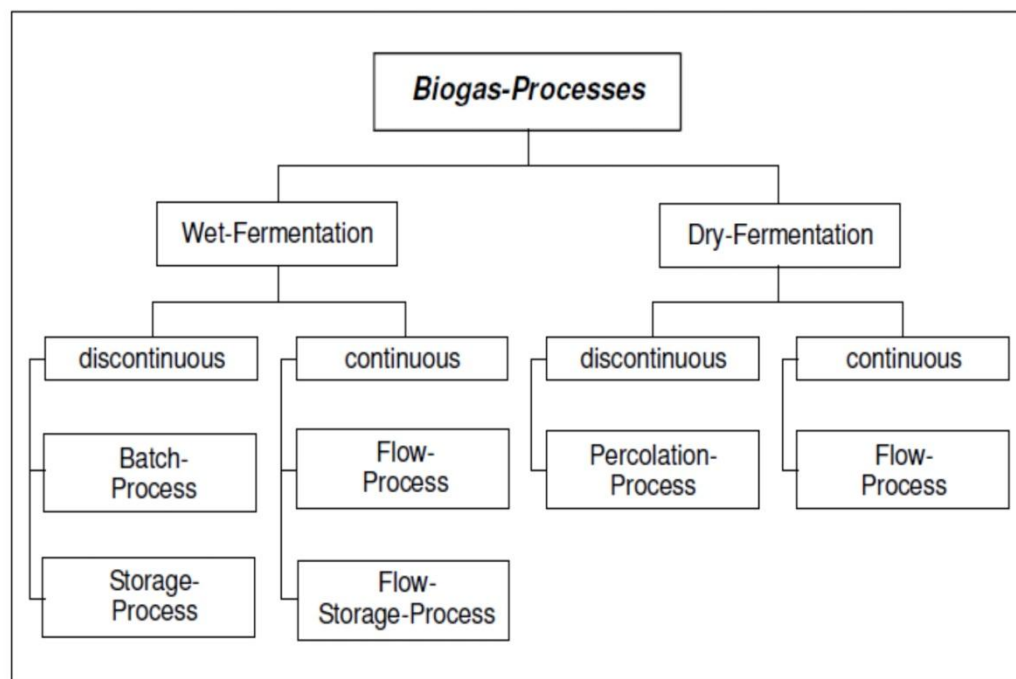


Fig 3.1: Biogas Processes

CHARACTERISTICS OF BIOGAS

Biogas has methane as its main constituent that is produced by the anaerobic biodegradation of the organic material of the wastes by microorganisms in anaerobic conditions. It results in residual waste which is of superior nutrient quality as a fertilizer.

The usual composition of biogas is:

Methane	(50% - 70%)
Carbon dioxide	(30% - 40%)
Hydrogen	(5% - 10%)
Nitrogen	(1% - 2%)
Water vapor	(0.3%)
Hydrogen sulfide	(traces)

Composition of biogas depends upon feed material also. Biogas is about 20% lighter than air has an ignition temperature in range of 650 to 750 °C. An odorless & colourless gas that burns with blue flame similar to LPG gas. Its calorific value is 20 Mega Joules (MJ) /m³ and it usually burns with 60 % efficiency in a conventional biogas stove.

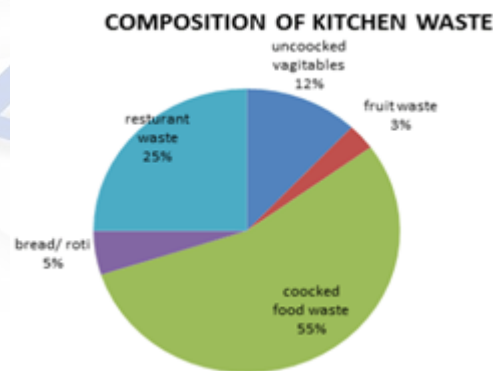


Fig 3.2: Composition of kitchen waste

This gas is useful as fuel to substitute firewood, cow-dung, petrol, LPG, diesel, & electricity, depending on the nature of the task, and local supply conditions and constraints.

Biogas digester systems provide a residue organic waste, after its anaerobic digestion (AD) that has superior 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 particularly valuable in agricultural residual treatment of animal excreta and kitchen refuse(residuals).

PROPERTIES OF BIOGAS

1. Change in volume as a function of temperature and pressure.
2. Change in calorific value as function of temperature ,pressure and water vapour content.
3. Change in water vapour as a function of temperature and pressure.

FACTORS AFFECTING YIELD AND PRODUCTION OF BIOGAS

Many factors affecting the fermentation process of organic substances under anaerobic condition are,

- The quantity and nature of organic matter
- The temperature
- Acidity and alkalinity (PH value) of substrate
- The flow and dilution of material

Energy Content	6-6.5 kWh/m ³
Fuel Equivalent	0.6-0.65 l oil/m ³ 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/m ³
Smell	Bad eggs

TABLE 3.2:- GENERAL FEATURES OF BIOGAS

BENEFITS OF BIOGAS TECHNOLOGY:

Composting is one of the important components of solid waste management (SWM). It is a form of source reduction or waste prevention, as the materials are completely diverted from the disposal facilities and require no management or transportation. Community-yard trimming composting programme, source-separated organic composting and mixed municipal solid waste (MSW) composting constitute the various recycling processes. A major portion of municipal solid wastes in India contain up to 70% by weight of organic materials.

In addition, certain industrial by-products – those from food processing, agricultural and paper industries – are mostly composed of organic materials.

Composting, being an organic material, can significantly reduce waste stream volume. Diverting such materials from the waste stream frees up landfill space needed for materials that cannot be composted. Composting owes its current popularity to several factors, including increased landfill tipping fees, shortage of landfill capacity and increasingly restrictive measures imposed by regulatory agencies. In addition, recycling mandates indirectly encourage composting, as they consider it an acceptable strategy for achieving mandatory goals.

Composting may also offer an attractive economic advantage for communities where the costs of using other options are high. However, it is considered a viable option only when the compost can be marketed. In some cases, nevertheless, the benefits of reducing disposal needs through composting may be adequate to justify choosing this option, even if the compost is only used as a landfill cover. Compost, because of its high organic matter content, makes a valuable soil amendment and is used to provide nutrients for plants. When mixed with soil, compost promotes a proper balance between air and water in the resulting mixture, helps reduce soil erosion and serves as a slow-release fertilizer.

- Production of energy.
- Transformation of organic wastes to very high quality fertilizer.
- Improvement of hygienic conditions through reduction of pathogens.
- Environmental advantages through protection of soil, water, air etc.
- Micro-economical benefits by energy and fertilizer substitutes.

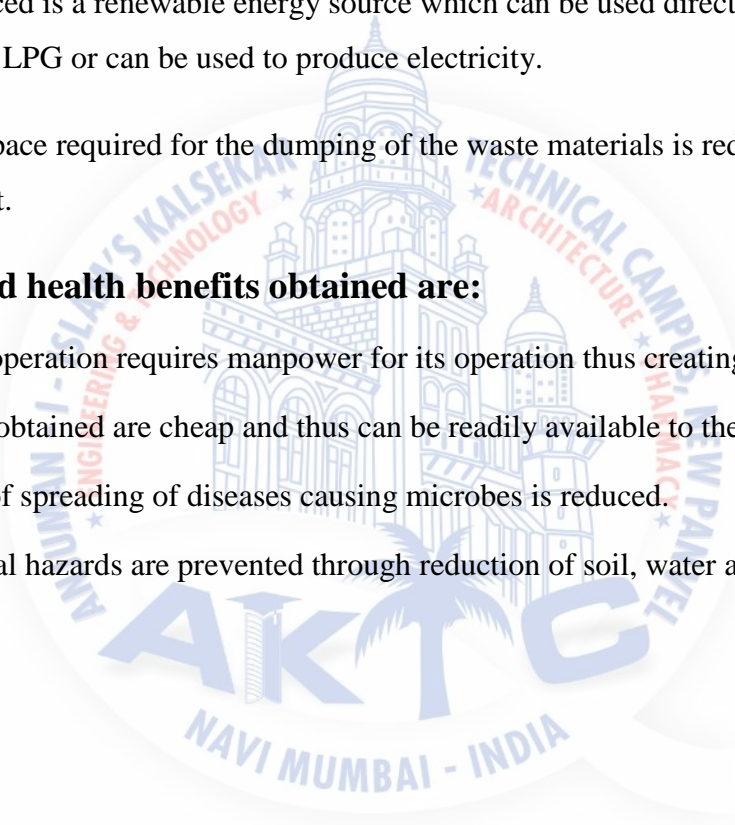
- Macro-economical benefits through decentralizes energy generation and environmental protection.

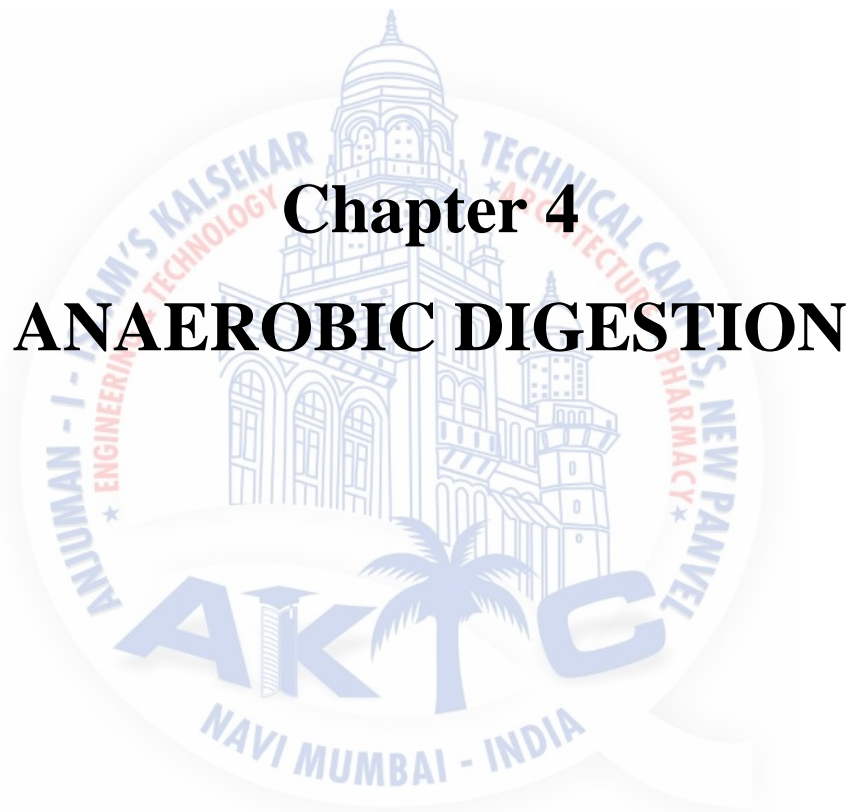
The economic benefits obtained are:

1. The waste materials are treated at without becoming a problem to the environment in the form of air and water pollution.
2. Fertilizer is obtained as a byproduct of the process which are rich in nutrients and can be directly used as manure in farms to improve soil fertility.
3. Biogas produced is a renewable energy source which can be used directly in cooking stones as an alternative of LPG or can be used to produce electricity.
4. The landfill space required for the dumping of the waste materials is reduced thus reducing the land requirement.

The social and health benefits obtained are:

1. Biogas plant operation requires manpower for its operation thus creating job opportunities.
2. The fertilizer obtained are cheap and thus can be readily available to the farmers at low cost.
3. The chances of spreading of diseases causing microbes is reduced.
4. Environmental hazards are prevented through reduction of soil, water and air pollution.





Chapter 4

ANAEROBIC DIGESTION

4.1 Anaerobic digestion

Anaerobic digestion is a collection of processes by which microorganisms break down biodegradable material in the absence of oxygen. The process is used for industrial or domestic purposes to manage waste or to produce fuels. Much of the fermentation used industrially to produce food and drink products, as well as home fermentation, uses anaerobic digestion. Anaerobic digestion occurs naturally in some soils and in lake and oceanic basin sediments, where it is usually referred to as "anaerobic activity".

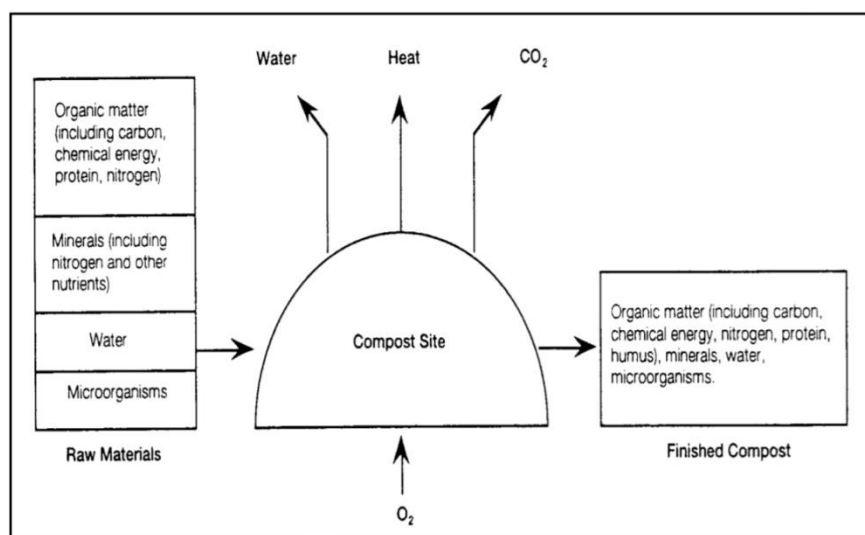


Fig 4.1 composition of gas

The digestion process begins with bacterial hydrolysis of the input materials. Insoluble organic polymers, such as carbohydrates, are broken down to soluble derivatives that become available for other bacteria. Acidogenic bacteria then convert the sugars and amino acids into carbon dioxide, hydrogen, ammonia, and organic acids. These bacteria convert these resulting organic acids into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide. Finally, methanogens convert these products to methane and carbon dioxide. The methanogenic archaea populations play an indispensable role in anaerobic wastewater treatments. Anaerobic digestion is widely used as a source of renewable energy. The process produces a biogas, consisting of methane, carbon dioxide and traces of other 'contaminant' gases. This biogas can be used directly as fuel, in combined heat and power gas engines or upgraded to natural gas-quality biomethane. The nutrient-rich digestate also produced can be used

as fertilizer. With the re-use of waste as a resource and new technological approaches that have lowered capital costs, anaerobic digestion has in recent years received increased attention among governments in a number of countries, among these the United Kingdom (201) Germany and Denmark (2011).

4.1.1 Process

Many microorganisms affect anaerobic digestion, including acetic acid-forming bacteria (acetogens) and methane-forming archaea (methanogens). These organisms promote a number of chemical processes in converting the biomass to biogas. Gaseous oxygen is excluded from the reactions by physical containment. Anaerobes utilize electron acceptors from sources other than oxygen gas. These acceptors can be the organic material itself or may be supplied by inorganic oxides from within the input material. When the oxygen source in an anaerobic system is derived from the organic material itself, the 'intermediate' end products are primarily alcohols, aldehydes, and organic acids, plus carbon dioxide. In the presence of specialised methanogens, the intermediates are converted to the 'final' end products of methane, carbon dioxide, and trace levels of hydrogen sulfide. In an anaerobic system, the majority of the chemical energy contained within the starting material is released by methanogenic bacteria as methane.

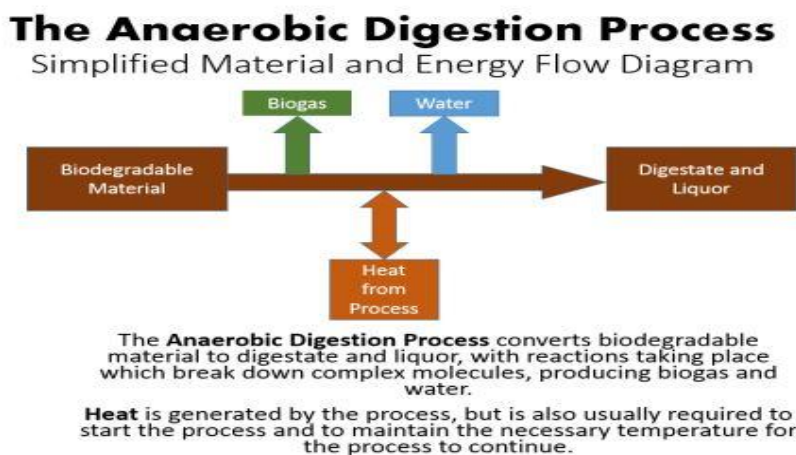
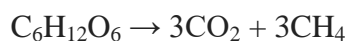


Fig 4.2: Anaerobic digestion process

4.1.2 Process stage

The four key stages of anaerobic digestion involve hydrolysis, acidogenesis, acetogenesis and methanogenesis. The overall process can be described by the chemical reaction, where organic material such as glucose is biochemically digested into carbon dioxide (CO₂) and methane (CH₄) by the anaerobic microorganisms.



- **Hydrolysis**

In most cases, biomass is made up of large organic polymers. For the bacteria in anaerobic digesters to access the energy potential of the material, these chains must first be broken down into their smaller constituent parts. These constituent parts, or monomers, such as sugars, are readily available to other bacteria. The process of breaking these chains and dissolving the smaller molecules into solution is called hydrolysis. Therefore, hydrolysis of these high-molecular-weight polymeric components is the necessary first step in anaerobic digestion. Through hydrolysis the complex organic molecules are broken down into simple sugars, amino acids, and fatty acids.

- **Acidogenesis**

The biological process of acidogenesis results in further breakdown of the remaining components by acidogenic (fermentative) bacteria. Here, VFAs are created, along with ammonia, carbon dioxide, and hydrogen sulfide, as well as other byproducts. The process of acidogenesis is similar to the way milk sours.

- **Acetogenesis**

The third stage of anaerobic digestion is acetogenesis. Here, simple molecules created through the acidogenesis phase are further digested by acetogens to produce largely acetic acid, as well as carbon dioxide and hydrogen.

- **Methanogenesis**

The terminal stage of anaerobic digestion is the biological process of methanogenesis. Here, methanogens use the intermediate products of the preceding stages and convert them into methane, carbon dioxide, and water. These components make up the majority of the biogas.

emitted from the system. Methanogenesis is sensitive to both high and low pHs and occurs between pH 6.5 and pH 8. The remaining, indigestible material the microbes cannot use and any dead bacterial remains constitute the digestate.

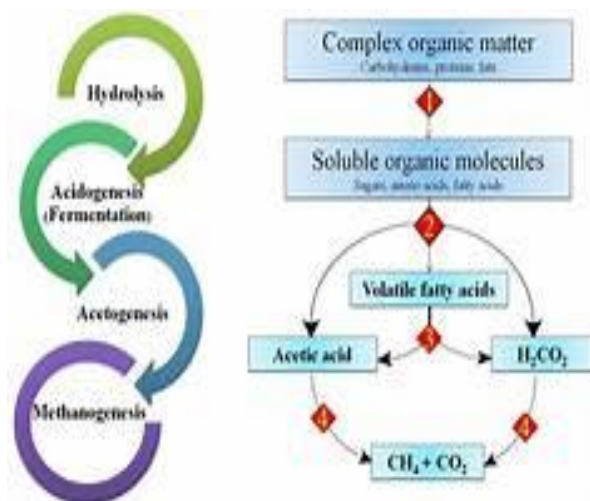


Fig 4.3: Methanogenesis process

4.1.3 Temperature

The two conventional operational temperature levels for anaerobic digesters determine the species of methanogens in the digesters:

1. Mesophilic digestion takes place optimally around 30 to 38 °C, or at ambient temperatures between 20 and 45 °C, where mesophiles are the primary microorganism present.
2. Thermophilic digestion takes place optimally around 49 to 57 °C, or at elevated temperatures up to 70 °C, where thermophiles are the primary microorganisms present.

The increased temperatures facilitate faster reaction rates, and thus faster gas yields. Operation at higher temperatures facilitates greater pathogen reduction of the digestate. In countries where legislation, such as the Animal By-Products Regulations in the European Union, requires digestate to meet certain levels of pathogen reduction there may be a benefit to using thermophilic temperatures instead of mesophilic.

4.1.4 Solids content

In a typical scenario, three different operational parameters are associated with the solids content of the feedstock to the digesters:

- High solids (dry—stackable substrate)

- High solids (wet—pumpable substrate)
- Low solids (wet—pumpable substrate)

High solids (dry) digesters are designed to process materials with a solids content between 25 and 40%. Unlike wet digesters that process pumpable slurries, high solids (dry – stackable substrate) digesters are designed to process solid substrates without the addition of water. The primary styles of dry digesters are continuous vertical plug flow and batch tunnel horizontal digesters. Continuous vertical plug flow digesters are upright, cylindrical tanks where feedstock is continuously fed into the top of the digester, and flows downward by gravity during digestion. In batch tunnel digesters, the feedstock is deposited in tunnel-like chambers with a gas-tight door. Neither approach has mixing inside the digester. The amount of pretreatment, such as contaminant removal, depends both upon the nature of the waste streams being processed and the desired quality of the digestate. Size reduction (grinding) is beneficial in continuous vertical systems, as it accelerates digestion, while batch systems avoid grinding and instead require structure (e.g. yard waste) to reduce compaction of the stacked pile. Continuous vertical dry digesters have a smaller footprint due to the shorter effective retention time and vertical design. Wet digesters can be designed to operate in either a high-solids content, with a total suspended solids (TSS) concentration greater than ~20%, or a low-solids concentration less than ~15%.

High solids (wet) digesters process a thick slurry that requires more energy input to move and process the feedstock. The thickness of the material may also lead to associated problems with abrasion. High solids digesters will typically have a lower land requirement due to the lower volumes associated with the moisture. High solids digesters also require correction of conventional performance calculations (e.g. gas production, retention time, kinetics, etc.) originally based on very dilute sewage digestion concepts, since larger fractions of the feedstock mass are potentially convertible to biogas.

4.1.5 Complexity

Digestion systems can be configured with different levels of complexity. In a single-stage digestion system (one-stage), all of the biological reactions occur within a single, sealed reactor or holding tank. Using a single stage reduces construction costs, but results in less control of the

reactions occurring within the system. Acidogenic bacteria, through the production of acids, reduce the pH of the tank. Methanogenic bacteria, as outlined earlier, operate in a strictly defined pH range. Therefore, the biological reactions of the different species in a single-stage reactor can be in direct competition with each other. Another one-stage reaction system is an anaerobic lagoon. These lagoons are pond-like, earthen basins used for the treatment and long-term storage of manures. Here the anaerobic reactions are contained within the natural anaerobic sludge contained in the pool.

In a two-stage digestion system (multistage), different digestion vessels are optimised to bring maximum control over the bacterial communities living within the digesters. Acidogenic bacteria produce organic acids and more quickly grow and reproduce than methanogenic bacteria. Methanogenic bacteria require stable pH and temperature to optimise their performance.

Under typical circumstances, hydrolysis, acetogenesis, and acidogenesis occur within the first reaction vessel. The organic material is then heated to the required operational temperature (either mesophilic or thermophilic) prior to being pumped into a methanogenic reactor. The initial hydrolysis or acidogenesis tanks prior to the methanogenic reactor can provide a buffer to the rate at which feedstock is added. Some European countries require a degree of elevated heat treatment to kill harmful bacteria in the input waste. In this instance, there may be a pasteurisation or sterilisation stage prior to digestion or between the two digestion tanks. Notably, it is not possible to completely isolate the different reaction phases, and often some biogas is produced in the hydrolysis or acidogenesis tanks.

4.1.6 Residence time

The residence time in a digester varies with the amount and type of feed material, and with the configuration of the digestion system. In a typical two-stage mesophilic digestion, residence time varies between 15 and 40 days, while for a single-stage thermophilic digestion, residence times is normally faster and takes around 14 days. The plug-flow nature of some of these systems will mean the full degradation of the material may not have been realised in this timescale. In this event, digestate exiting the system will be darker in colour and will typically have more odour. In the case of an upflow anaerobic sludge blanket digestion (UASB), hydraulic residence times can be as short as 1 hour to 1 day, and solid retention times can be up to 90 days. In this manner, a UASB system is able to separate solids and hydraulic retention times with the use of a sludge blanket. Continuous digesters have mechanical or hydraulic devices, depending

on the level of solids in the material, to mix the contents, enabling the bacteria and the food to be in contact. They also allow excess material to be continuously extracted to maintain a reasonably constant volume within the digestion tanks.

4.1.7 Feedstocks

The most important initial issue when considering the application of anaerobic digestion systems is the feedstock to the process. Almost any organic material can be processed with anaerobic digestion. However, if biogas production is the aim, the level of putrescibility is the key factor in its successful application. The more putrescible (digestible) the material, the higher the gas yields possible from the system.

Feedstocks can include biodegradable waste materials, such as waste paper, grass clippings, leftover food, sewage, and animal waste. Woody wastes are the exception, because they are largely unaffected by digestion, as most anaerobes are unable to degrade lignin. Xylophalgeous anaerobes (lignin consumers) or using high temperature pretreatment, such as pyrolysis, can be used to break down the lignin. Anaerobic digesters can also be fed with specially grown energy crops, such as silage, for dedicated biogas production.

The length of time required for anaerobic digestion depends on the chemical complexity of the material. Material rich in easily digestible sugars breaks down quickly whereas intact lignocellulosic material rich in cellulose and hemicellulose polymers can take much longer to break down. Anaerobic microorganisms are generally unable to break down lignin, the recalcitrant aromatic component of biomass.

Anaerobic digesters were originally designed for operation using sewage sludge and manures. Sewage and manure are not, however, the material with the most potential for anaerobic digestion, as the biodegradable material has already had much of the energy content taken out by the animals that produced it. Therefore, many digesters operate with codigestion of two or more types of feedstock. For example, in a farm-based digester that uses dairy manure as the primary feedstock, the gas production may be significantly increased by adding a second feedstock, e.g., grass and corn (typical on-farm feedstock), or various organic byproducts, such as slaughterhouse waste, fats, oils and grease from restaurants, organic household waste, etc.

Digesters processing dedicated energy crops can achieve high levels of degradation and biogas production. Slurry-only systems are generally cheaper, but generate far less energy than

those using crops, such as maize and grass silage; by using a modest amount of crop material (30%), an anaerobic digestion plant can increase energy output tenfold for only three times the capital cost, relative to a slurry-only system.

4.1.8 Moisture content

Second consideration related to the feedstock is moisture content. Drier, stackable substrates, such as food and yard waste, are suitable for digestion in tunnel-like chambers. Tunnel-style systems typically have near-zero wastewater discharge, as well, so this style of system has advantages where the discharge of digester liquids are a liability. The moisture content of the target feedstock will also affect what type of system is applied to its treatment. To use a high-solids anaerobic digester for dilute feedstocks, bulking agents, such as compost, should be applied to increase the solids content of the input material. Another key consideration is the carbon:nitrogen ratio of the input material. This ratio is the balance of food a microbe requires to grow; the optimal C:N ratio is 20–30:1. Excess N can lead to ammonia inhibition of digestion.

4.1.9 Applications

- **Power generation**

In developing countries, simple home and farm-based anaerobic digestion systems offer the potential for low-cost energy for cooking and lighting. From 1975, China and India have both had large, government-backed schemes for adaptation of small biogas plants for use in the household for cooking and lighting. At present, projects for anaerobic digestion in the developing world can gain financial support through the United Nations Clean Development Mechanism if they are able to show they provide reduced carbon emissions.

Methane and power produced in anaerobic digestion facilities can be used to replace energy derived from fossil fuels, and hence reduce emissions of greenhouse gases, because the carbon in biodegradable material is part of a carbon cycle. The carbon released into the atmosphere from the combustion of biogas has been removed by plants for them to grow in the recent past, usually within the last decade, but more typically within the last growing season. If the plants are regrown, taking the carbon out of the atmosphere once more, the system will be carbon

neutral. In contrast, carbon in fossil fuels has been sequestered in the earth for many millions of years, the combustion of which increases the overall levels of carbon dioxide in the atmosphere.

Biogas from sewage sludge treatment is sometimes used to run a gas engine to produce electrical power, some or all of which can be used to run the sewage works. Some waste heat from the engine is then used to heat the digester. The waste heat is, in general, enough to heat the digester to the required temperatures. The power potential from sewage works is limited – in the UK, there are about 80 MW total of such generation, with the potential to increase to 150 MW, which is insignificant compared to the average power demand in the UK of about 35,000 MW. The scope for biogas generation from nonsewage waste biological matter – energy crops, food waste, abattoir waste, etc. - is much higher, estimated to be capable of about 3,000 MW. Farm biogas plants using animal waste and energy crops are expected to contribute to reducing CO₂ emissions and strengthen the grid, while providing UK farmers with additional revenues. In Oakland, California at the East Bay Municipal Utility District's main wastewater treatment plant (EBMUD), food waste is currently codigested with primary and secondary municipal wastewater solids and other high-strength wastes. Compared to municipal wastewater solids digestion alone, food waste codigestion has many benefits. Anaerobic digestion of food waste pulp from the EBMUD food waste process provides a higher normalized energy benefit, compared to municipal wastewater solids: 730 to 1,300 kWh per dry ton of food waste applied compared to 560 to 940 kWh per dry ton of municipal wastewater solids applied.

- **Vehicle fuel**

After upgrading with the above-mentioned technologies, the biogas (transformed into biomethane) can be used as vehicle fuel in adapted vehicles. This use is very extensive in Sweden, where over 38,600 gas vehicles exist, and 60% of the vehicle gas is biomethane generated in anaerobic digestion plants.

- **Fertiliser and soil conditioner**

The solid, fibrous component of the digested material can be used as a soil conditioner to increase the organic content of soils. Digester liquor can be used as a fertiliser to supply vital nutrients to soils instead of chemical fertilisers that require large amounts of energy to produce and transport. The use of manufactured fertilisers is, therefore, more carbon-intensive than the use of anaerobic digester liquor fertiliser. In countries such as Spain, where many soils are

organically depleted, the markets for the digested solids can be equally as important as the biogas.

- **Cooking gas**

By using a bio-digester, which produces the bacteria required for decomposing, cooking gas is generated. The organic garbage like fallen leaves, kitchen waste, food waste etc. are fed into a crusher unit, where the mixture is conflated with a small amount of water. The mixture is then fed into the bio-digester, where the bacteria decomposes it to produce cooking gas. This gas is piped to kitchen stove. A 2 cubic meter bio-digester can produce 2 cubic meter of cooking gas. This is equivalent to 1 kg of LPG. The notable advantage of using a bio-digester is the sludge which is a rich organic manure.

4.2 Flow chart of anaerobic digestion

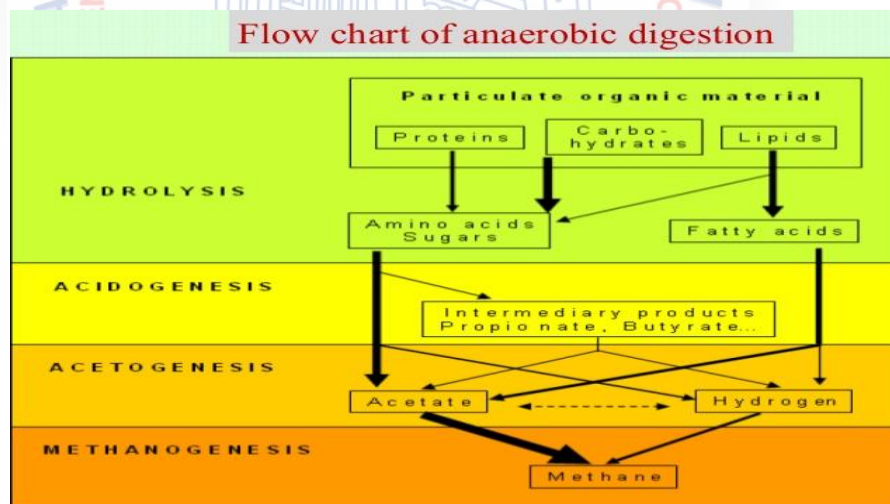


Fig 4.4:Flow chart

4.3 Principles of Biogas Production

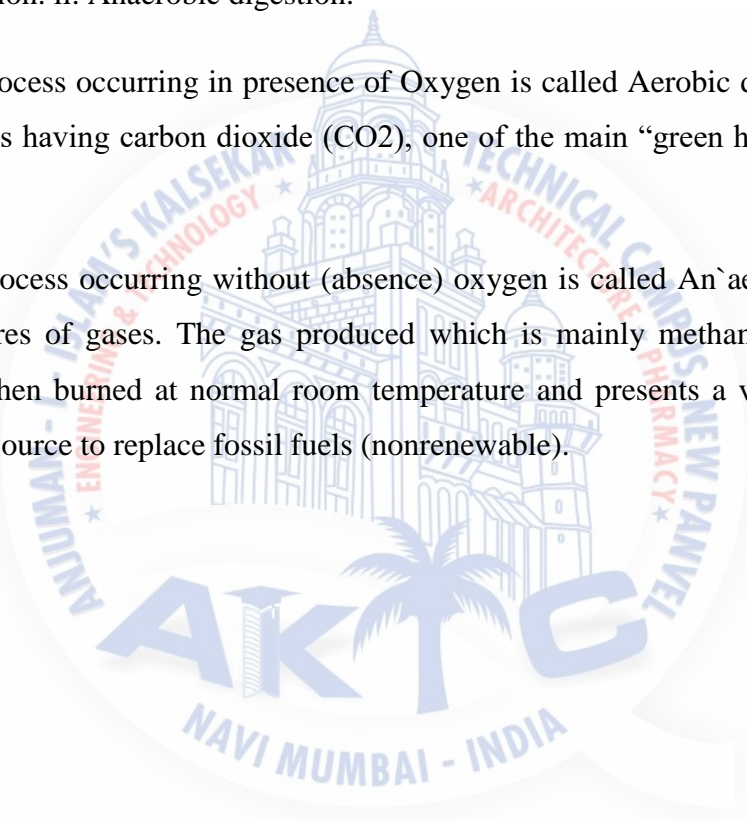
Organic substances exist in wide variety from living beings to dead organisms. Organic matters are composed of Carbon (C), combined with elements such as Hydrogen (H), Oxygen (O), Nitrogen (N), and Sulphur (S) to form variety of organic compounds such as carbohydrates, proteins and lipids. In nature MOs (microorganisms), through digestion process breaks the complex carbon into smaller substances.

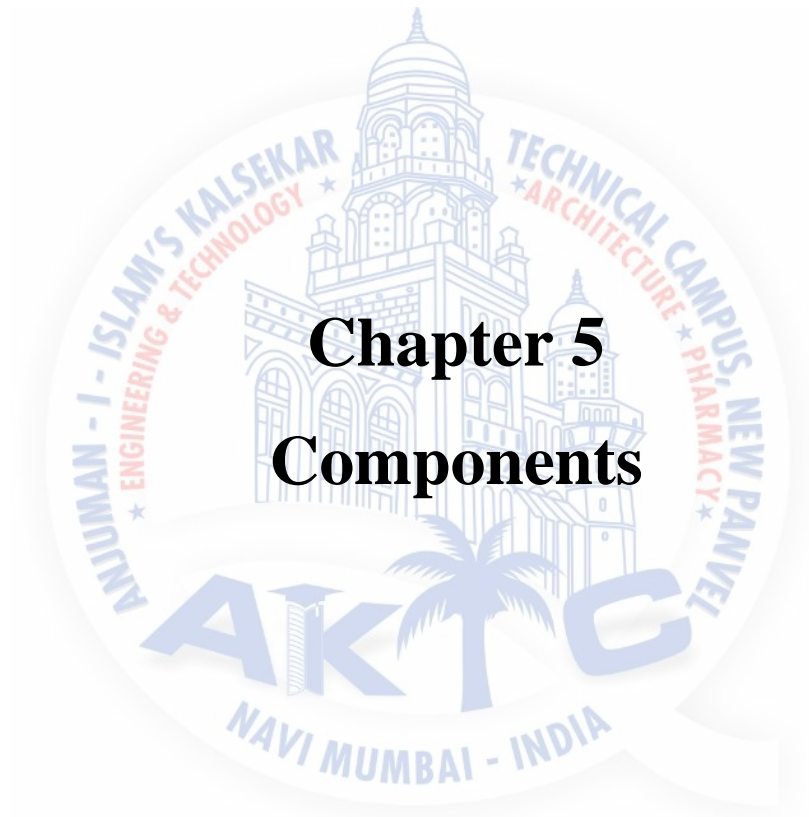
There are 2 types of digestion process:

i. Aerobic digestion. ii. Anaerobic digestion.

The digestion process occurring in presence of Oxygen is called Aerobic digestion and produces mixtures of gases having carbon dioxide (CO₂), one of the main “green houses” responsible for global warming.

The digestion process occurring without (absence) oxygen is called Anaerobic digestion which generates mixtures of gases. The gas produced which is mainly methane produces 52005800 KJ/m³ which when burned at normal room temperature and presents a viable environmentally friendly energy source to replace fossil fuels (nonrenewable).





Chapter 5 Components

5.1 Component used for bio-digester

5.1.1 Digester

There are many types of digester can be used for biogas plant. In our plant we have used 200ltr of capacity of drum. The material of drum is plastic.



Fig. 5.1: Digester

5.1.2 Gas collector

In the biogas system gas storage is very Important function. So we have used car tyre tube to store the gas.



Fig. 5.2: Gas collector

5.1.3 Pressure gauge

The range of pressure gauge is 0-2bar.



Fig. 5.3: Pressure gauge

5.1.4 Pressure relief valve



Fig. 5.4: Pressure relief valve

5.1.5 Motor

The motor is of 3 phase 1HP 1000RPM.



Fig. 5.5: Motor

5.2.5 Crusher



Fig:5.6: Crusher

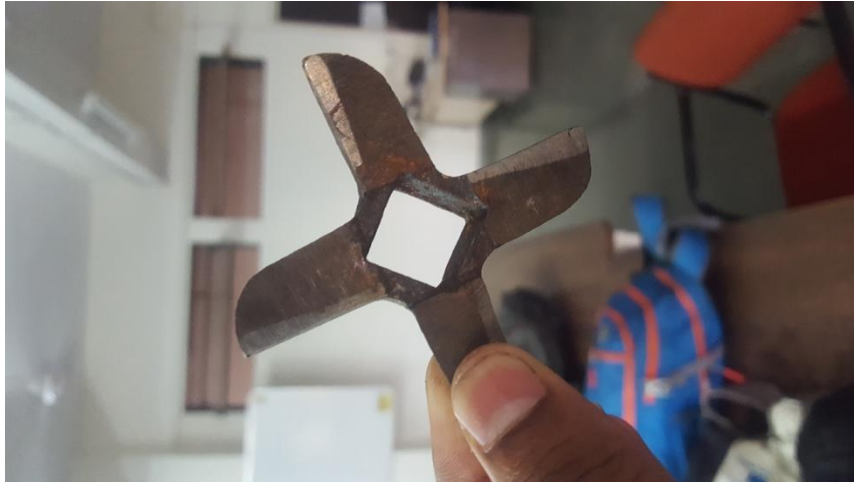
5.2.5.1 Body



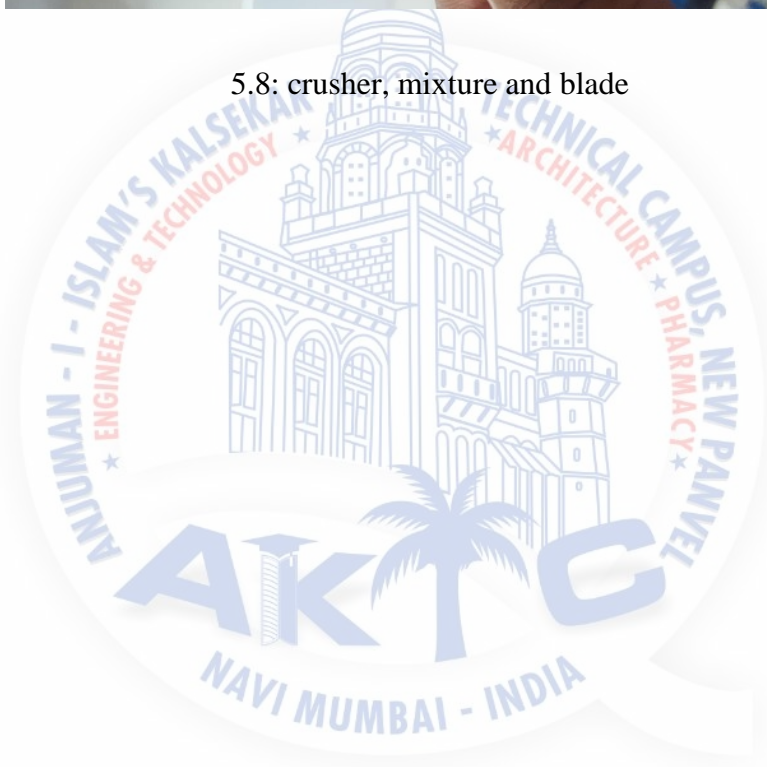
Fig 5.7: Crusher body

5.2.5.2 Crusher, mixture and blade



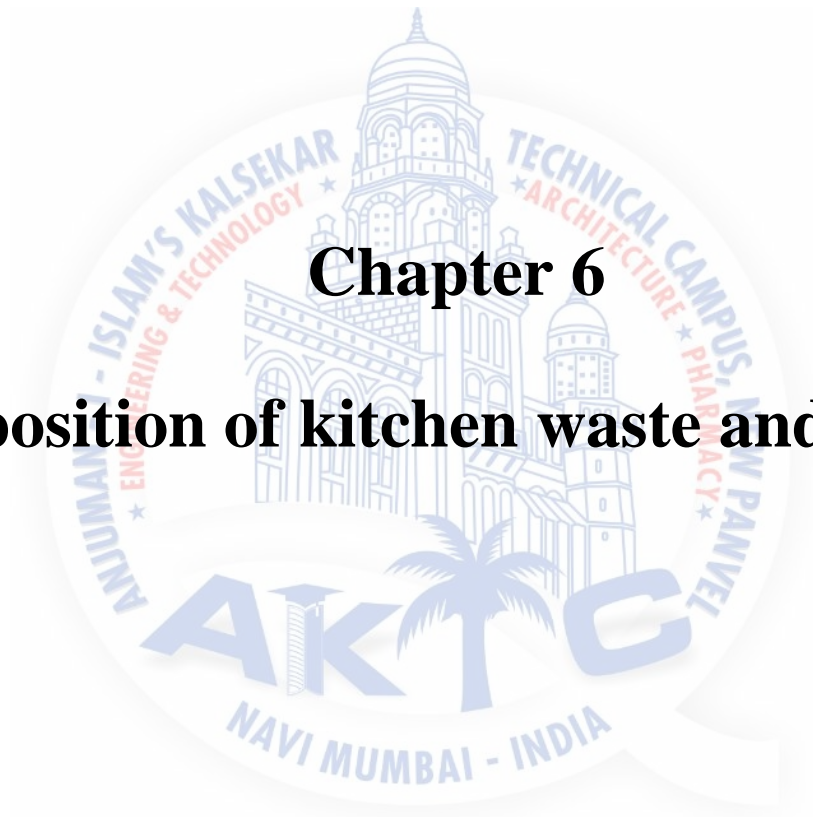


5.8: crusher, mixture and blade



Chapter 6

Composition of kitchen waste and digester



6.1 Composition of kitchen waste from AIKTC canteen

Average composition of kitchen waste was analyzed on various occasions. Over 50 % of waste was composed of uncooked vegetable & fruit waste. Eggs, raw meat, the main source of pathogens were relatively low in mass at 1.5% & 1.2% also about 15% of cooked meat was there.

(A) Uncooked fruits & vegetables (51%)

(B) Cooked meat (16%)

(C) Uncooked meat (15%)

(D) Bread (2%)

(E) Tea waste (5%)

(F) Eggs (6%)

(G) Cheese (3%)



Fig 6.1 : kitchen waste

6.2 Component list

SR NO.	COMPONENT
1.	1 HP motor (3 phase)
2.	Pulley (25cm, 12.5cm, 6.5cm)
3.	Crusher machine
4.	V-belt
5.	3-phase plug
6.	Belt cover
7.	Wood base (60*40)cm
8.	Shock absorber

Table-6.1: list of component

6.3 FEED PREPARATION:

CASE 1:

DIAMETER

LARGER PULLEY = 25cm (machine)

Small pulley = 12.5cm(motor)

SPEED (RPM)

LARGER PULLEY (MACHINE)

$N = 525 \text{ rpm}$

SMALL PULLEY

$N = 1000 \text{ rpm}$

MOTOR POWER

$P = 1 \text{ HP (HORSE POWER)}$

$P = \text{TORQUE} * \text{OMEGA}$

[$\text{OMEGA} = (2 * 3.147 * N) / (60)$]

[$\text{OMEGA} = (2 * 3.147 * 1000) / (60)$]

[$\text{OMEGA} = 104.719 \text{ radian/s}$]

$745.7 = \text{TORQUE} * 104.719$

$\text{TORQUE} = 7.1209 \text{ Nm}$

CASE 2:

DIAMETER

LARGER PULLEY = 25 cm (machine)

Small pulley = 6.5 cm (motor)

SPEED (RPM)

LARGER PULLEY (MACHINE)

$N = 260 \text{ rpm}$

SMALL PULLEY

$$N = 1000 \text{ rpm}$$

From the above calculation we find different speed for the preparation of feed from which we find different size of feed which is very helpful in Anaerobic Digestion process. Three different type of pulleys are used . The larger one is mounted on crusher machine and smaller one is mounted on 1000 rpm motor. Torque is also calculated which is 7.129 N-m



Fig 6.2 : Feed Preprating Machine

6.4 METHODS AND CALCULATIONS

6.4.1 Analytical Methods & Calculations

1) Total Solids (Ts %) - It is the amount of solid present in the sample after the water present in it is evaporised.

The sample, approximately 10 gm. is taken and poured in foil plate and dried to a constant weight at about 1050C in furnace.

$$TS \% = (\text{Final weight/Initial weight}) \dots\dots\dots (i)$$

2) Volatile Solids (Vs %) – Dried residue from Total Solid analysis weighed and heated in crucible for 2hrs at 500 0C in furnace. After cooling crucible residue weighed.

$$VS \% = [100-(V3-V1/V2-V1)] * 100 \dots\dots\dots (ii)$$

V1= Weight of crucible.

V2= Weight of dry residue & crucible.

V3= Weight of ash & crucible (after cooling)

Method 1:

Titration procedure for measurements of VFA and alkalinity .

- i) Before analysis, the sample needs to be filtered through a 0.45µm membrane filter.
- ii) Filtered sample (20-50ml) is put into a titration vessel, the size of which is determined by the basic requirement to guarantee that the tip of the pH electrode is always below the liquid surface.
- iii) Initial pH is recorded
- iv) The sample is titrated slowly with 0.1N sulphuric acid until pH 5.0 is reached. The added volume A1 [ml] of the titrant is recorded.

v) More acid is slowly added until pH 4.3 is reached. The volume A2 [ml] of the added titrant is again recorded.

vi) The latter step is repeated until pH 4.0 is reached, and the volume A3 [ml] of added titrant recorded once more.

vii) A constant mixing of sample and added titrant is required right from the start to minimize exchange with the atmosphere during titration.

viii) Calculation scheme :

$$\text{Alk} = A * N * 1000 / \text{SV} \quad \dots\dots \text{(iv)}$$

Alk = Alkalinity [mmol/l], also referred to as TIC (Total Inorganic Carbon).

A = Consumption of Sulphuric acid (H₂SO₄, 0.1N) to titrate from initial pH to pH 4.3 [ml]. A = A1 + A2 [ml].

N = Normality [mmol/l].

SV = Initial sample volume [ml].

$$\text{VFA} = (131340 * N * B / 20) - (3.08 * \text{Alk}) - 10.09$$

VFA = Volatile fatty acids [mg/l acetic acid equivalents].

N = Normality [mmol/l]

B = Consumption of sulphuric acid (H₂SO₄, 0.1N) to titrate sample from pH 5.0

to pH 4.0 [ml], due to HCO₃/CO₂ buffer. B = A2 + A3 [ml]

SV = Initial sample volume [ml]

Alk = Alkalinity [mmol/l]

4) A/TIC-ratio

The A/TIC-method was developed at the Federal Research Institute for Agriculture (FAL) in Braunschweig, Germany. Used as an indicator of the process stability inside the digester, it expresses the ratio between Volatile Fatty Acids and buffer capacity (alkalinity), or in other words the amount of Acids (A) compared to Total Inorganic Carbon (TIC).

$$A \text{ [mg/ l]} = \text{VFA [mg/ l]} / \text{TIC [mg/l]} = \text{Alkalinity [mg/ l]}$$

5) Organic Content – Organic dry matter weigh the sample and weigh remaining ashes
Organic content = {Mass of TS - Mass of ashes }/Mass of TS



Fig 6.3: Final setup of digester

6.5 PROCEDURE AND START UP

6.5.1 Experiment 1

Fresh cow dung was collected and mixed with water thoroughly by hand and poured into 20 lit. digester. Content of previous experiment was used as inoculum. As it contains the required microorganism for anaerobic digestion. After the inoculation digester was kept for some days and

gas production was checked. After some days kitchen waste was added for checking gas production.

6.5.2 Experiment 2

This digester contains the following composition.

20lit digester.

Cow dung + inoculum + water added.

Cow dung – 2.5 lit

Inoculum - 3.8 lit

Water – 13.5lit

PH – 5.02

6.6 RESULTS

Day	PH(O)	PH(N)	GAS(O)ml	GAS(N)ml
1	7.5	5.6	-	-
2	7.52	6.82	800	-
3	7.25	6.33	1280	-
4	7.02	6.57	1800	400
5	6.33	6.66	1550	300
6	6.5	6.5	1700	550
7	6.55	6.8	1850	3200
8	6.4	7.03	2000	6500
9	6.9	7.2	1800	6500
10	6.7	7.16	2300	8500

Table-6.2: Daily PH And Gas Production

DAYS	VFA(O)mg/l	VFA(N)mg/l	GAS(O)ml	GAS(N)ml
1	1968	3762.5	-	-
2	1837.5	6562	800	-
3	1750	5337	1280	-
4	2012.5	3939	1800	400
5	2187.5	6125	1550	300
6	2800	6387	1700	550
7	2537.5	5687	1850	3200
8	2231.5	4287.5	2000	6500
9	2187.5	5512.5	1800	6500
10	2275	4285	2300	8500

Table-6.3: daily VFA and gas production



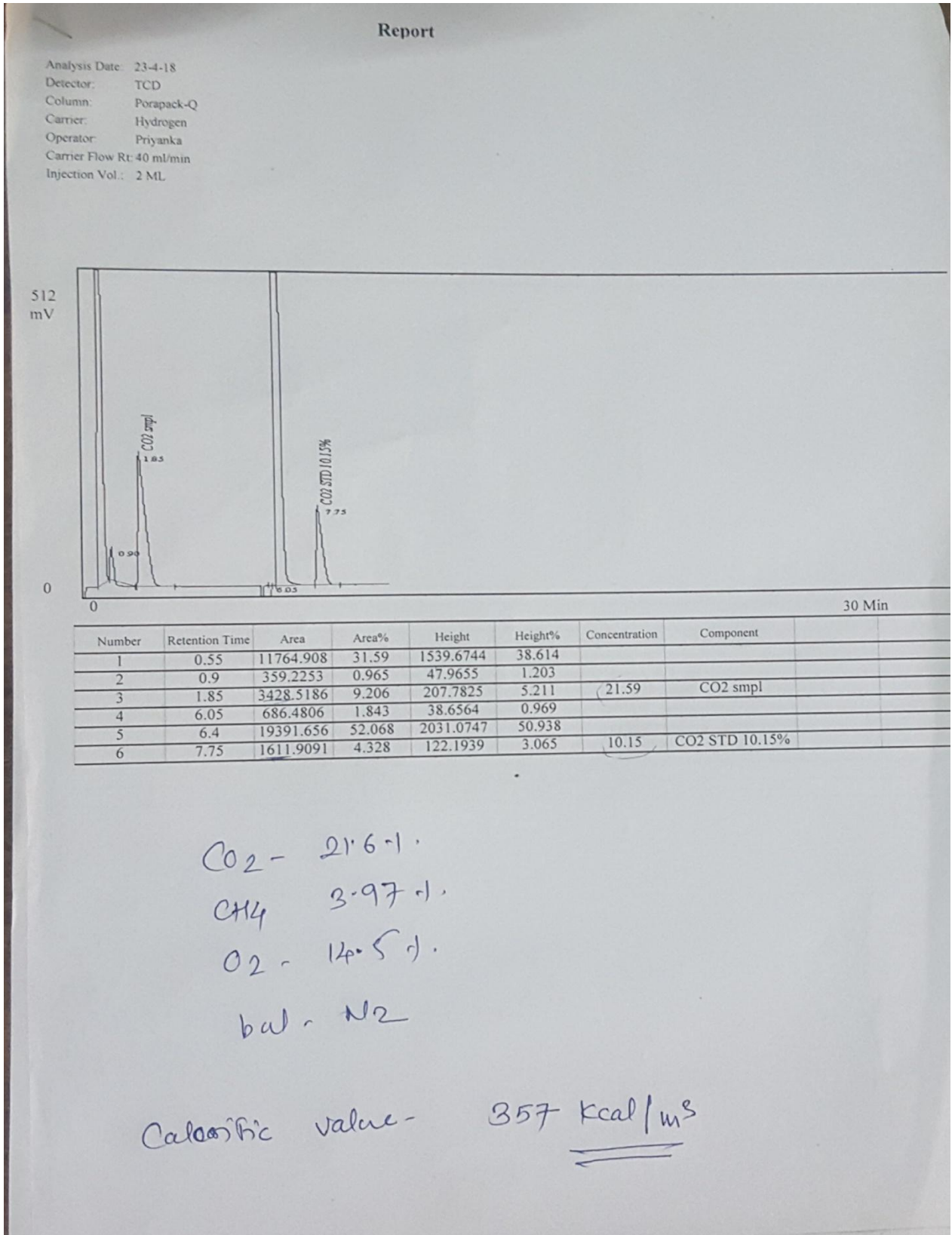


Fig. 6.4: CO2 analysis report

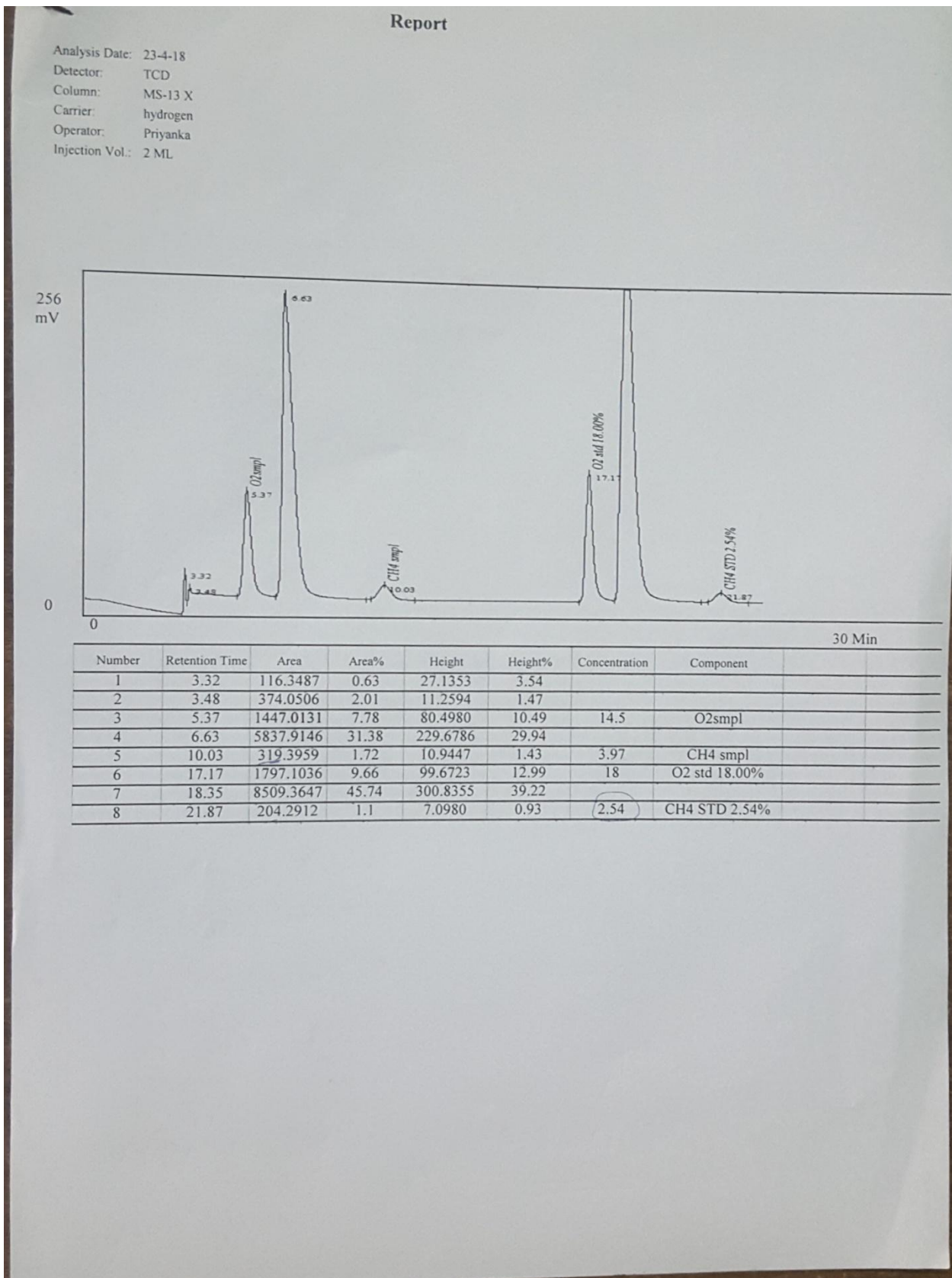
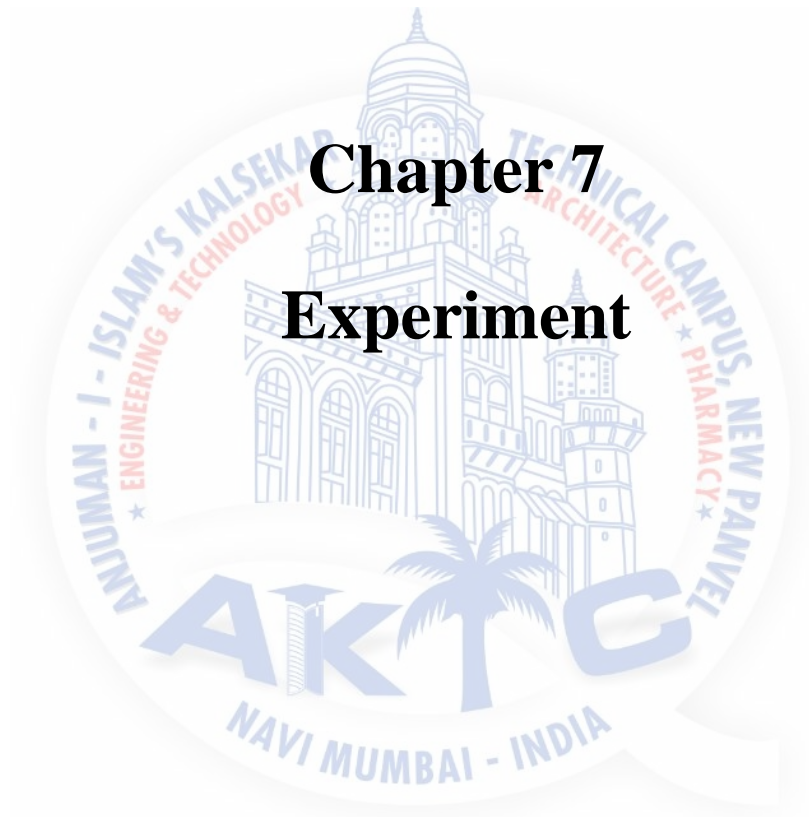


Fig. 6.5: METHANE analysis report



Chapter 7

Experiment

7.1 Experiment

A 2 liter bottle

50 gm kitchen waste + cow dung

Rest water (1.5 liter)

Result- Gas production was found but not measured.



Fig 7.1: Experiment

7.2 Experiment

Different sets of 1 litre & 2 litres bottles.

3 different sets with different composition are installed as below.

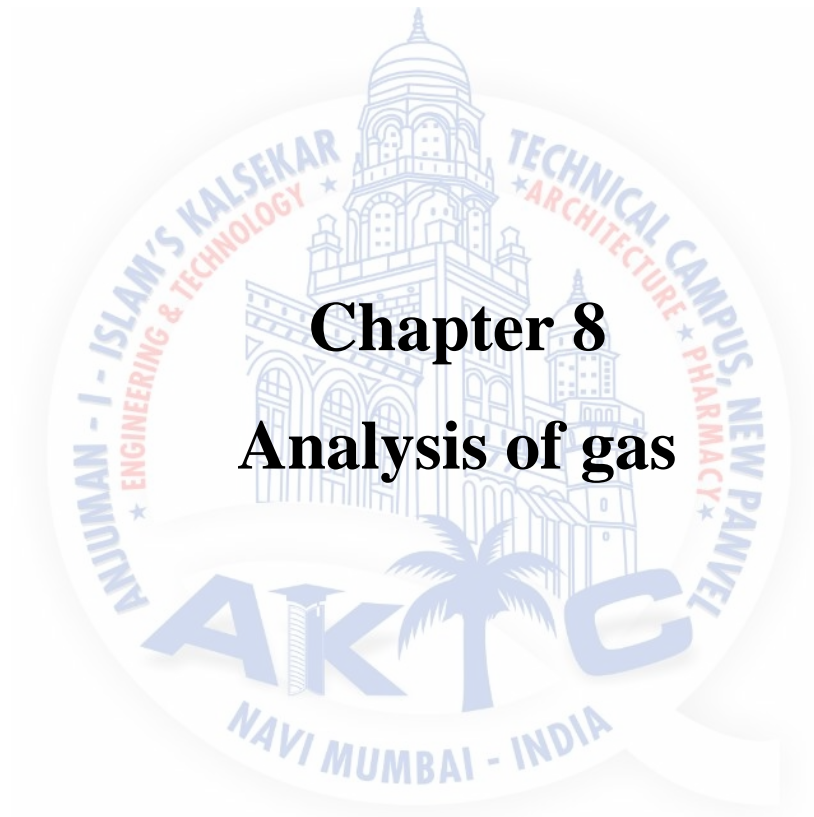
1. 200gm cow dung was mixed with water to make 1lit slurry which is poured in 1lit bottle.

2. 50gm grinded kitchen was mixed with 150gm cow dung and water is added to make 1lit solution which is poured in 1lit bottle.
3. 400gm cow dung was mixed with water to make 2lit slurry which is poured in 2lit bottle.

Results:

In all of the 3 sets gas production occurs and gas burned with blue flame. process continues, volatile fatty acids(VFA) are produced which causes the decrease in PH of solution.





Chapter 8

Analysis of gas

8.1 ANALYSIS OF GAS PRODUCED

Anaerobic digestion process is a long and time consuming process for the production of biogas. We have taken the reading of gas produced for 10 days. Various observation has been observed of the gas produced such as calorific value, pH value, temperature, methane content, carbon dioxide content.

- Calorific value = 3.7 kWh/m³
- methane content = 40%
- carbon dioxide content = 16.8%

8.2 CASE STUDY

SR NO	CANTEEN	LPG consumption/month
1	Canteen 1	1413 kg
2	Canteen 2	1460.1 kg

Table -8.1: LPG Consumption

8.2.1 ANALYSIS

Calorific value of Biogas = 6 kWh/m³

Calorific value of LPG = 26.1 kWh/m³

Let us assume we need to boil water sample of 100 gm

We have Energy required to boil 100 gm water = 259.59 Kj

Hence, we need Biogas to boil 100 gm water = 12.018 lit

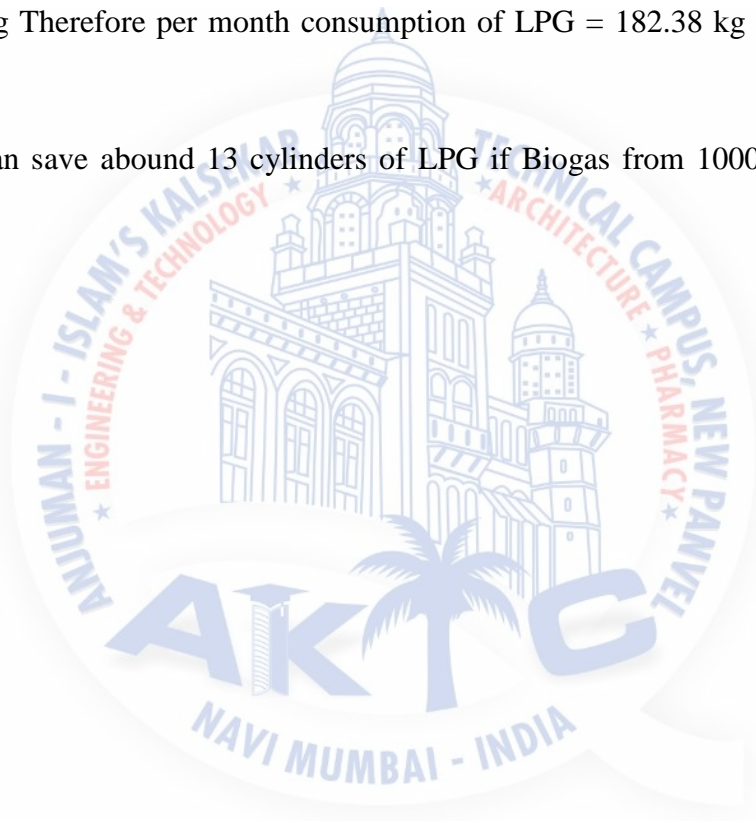
And, we need LPG to boil 100 gm water = 2.76 lit.

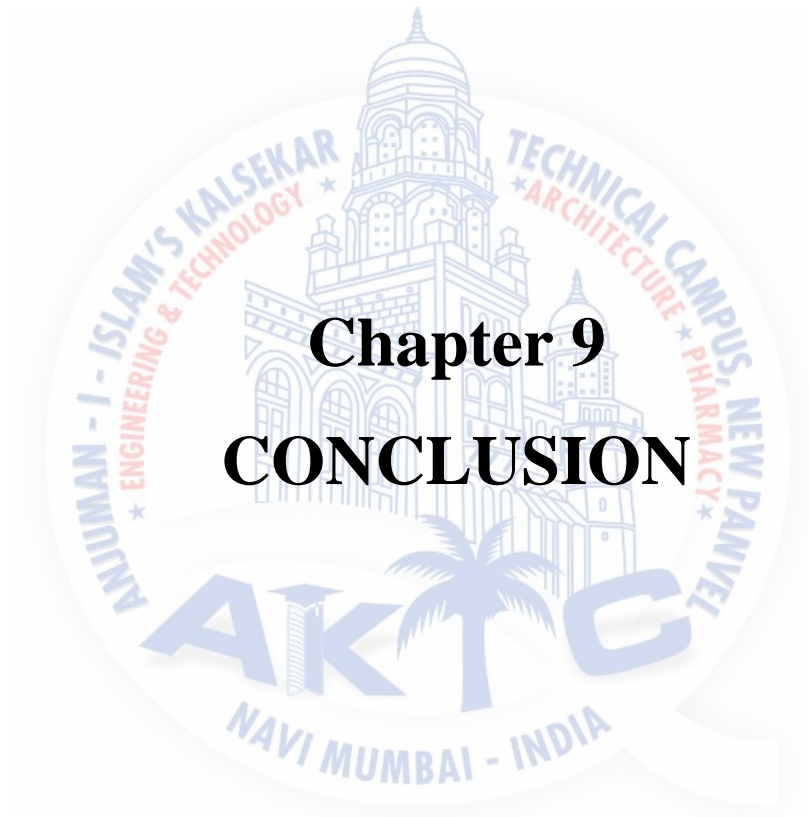
Therefore, amount of water which can be boiled using this much Biogas = 5.408 lit/day Now, amount of LPG required to boil 5.408 lit of water per day = 149.26 lit So We can save up to 10 cylinders of LPG per day.

8.2.2 ANALYSIS 2

Let us use the Biogas produced in our plant for Breakfast & evening snacks (1 hr in morning and 1 hr in the evening) 650 lit if used for 2 hrs gives = $66.46 * 103 \text{ J/day}$ Let V be the amount of LPG used to produce same amount of energy Hence, we get, $V = 2827.56 \text{ lit}$ i.e. Mass (m) of LPG = 6.079 kg Therefore per month consumption of LPG = 182.38 kg which is equivalent to 12.84 cylinders

Result: - We can save around 13 cylinders of LPG if Biogas from 1000 lit tank is used for 2 hours daily.



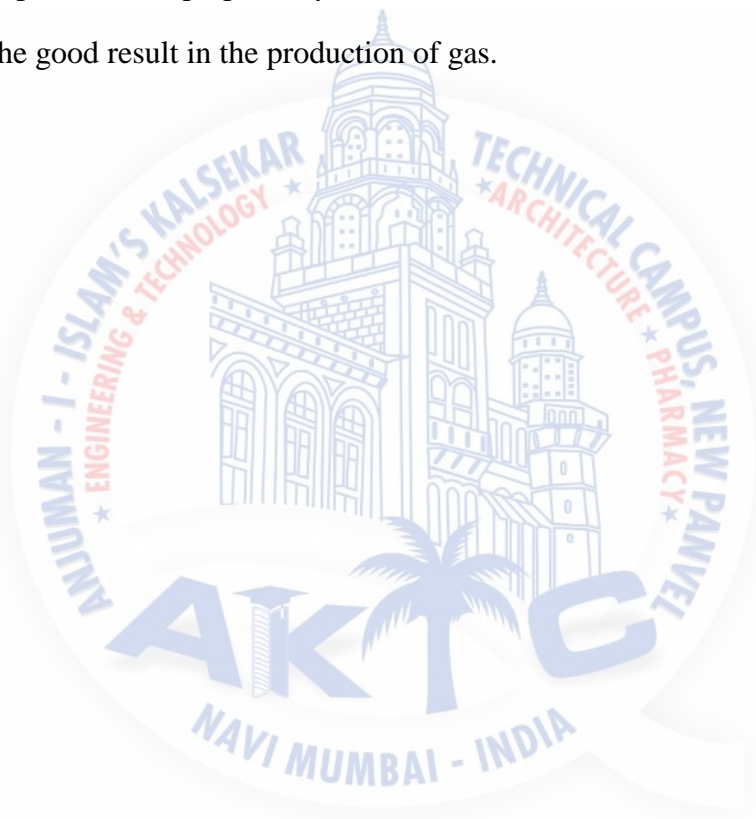


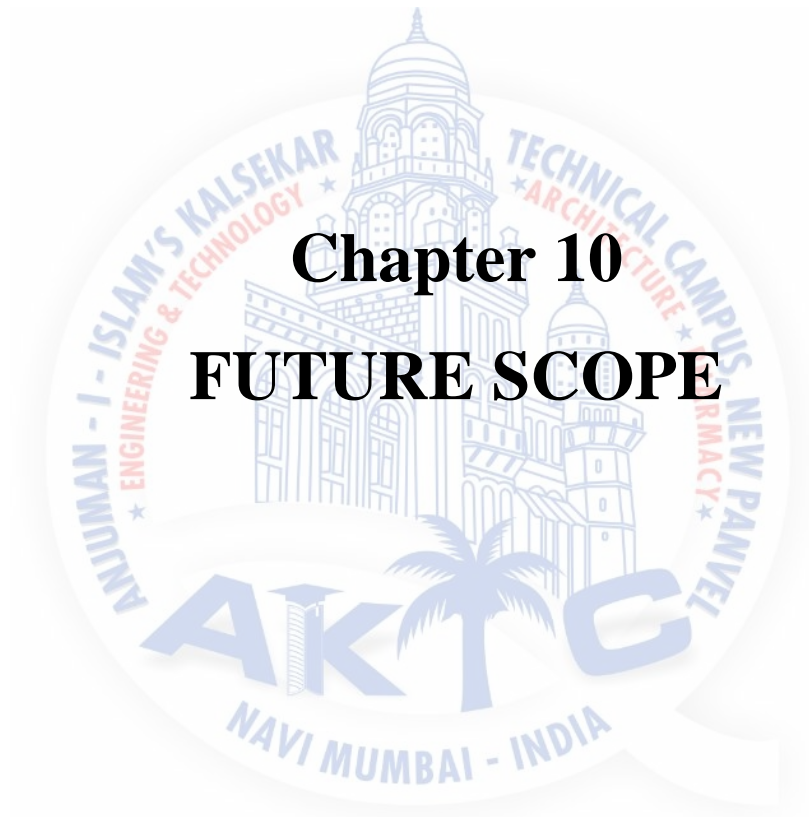
Chapter 9 CONCLUSION

During our survey, we have found that the biogas plant mostly have problem of feed preparation. They use 7.5-10 HP mixture for feed preparation. The instructions to the operator are to load the mixture with 50% water and 50% feed and prepare slurry by running the mixture for 10 minute. No arrangement is there to change the rpm or impeller. This leads to non uniform slurry with many agglomerated lumps. These lumps choke the inlet and outlet of digester. So the plant doesn't run effectively.

In our study, we mainly concentrate on the preparations of feed. We make the feed of uniform size due to which digestion process was very fast. The gas production was also very fast. For the feed preparation we use 1HP (3-PHASE) motor on which different size of pulleys was mounted. This control the speed of feed preparatory machine.

Hence we find the good result in the production of gas.



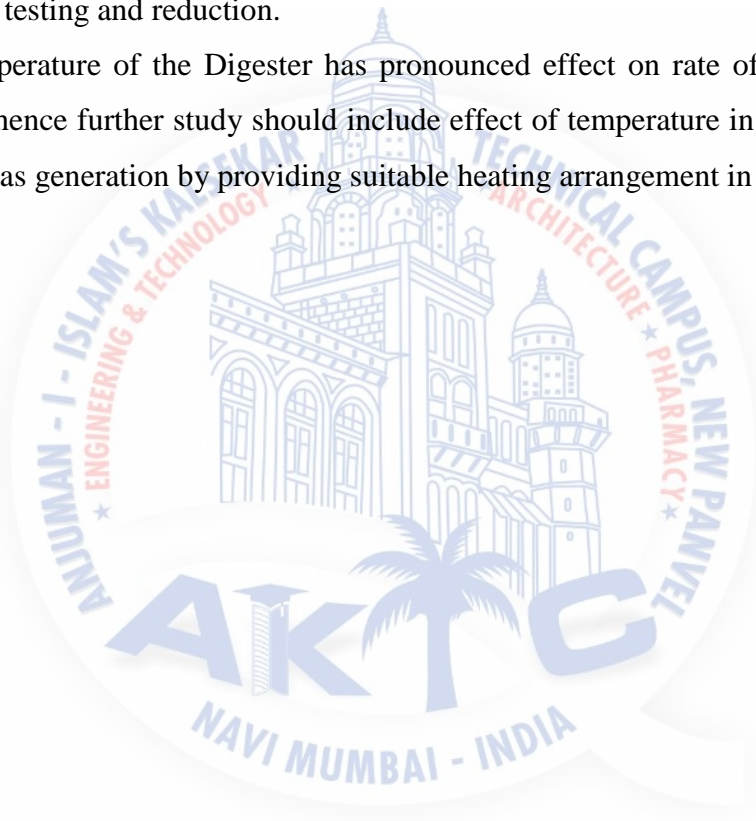


Chapter 10

FUTURE SCOPE

FUTURE SCOPE

- 1) In most cases acidogenic and methanogenic process take place in same digester. In future these both process can be done in separate digester. Carrying out these two processes in separate vessels increases the yield of gas per ton of kitchen waste charged as reported in the literature
- 2) The remaining digestate should be tested for the presence of Salmonella pathogen and methods to reduce their population to be developed. European Union Codes insist on such testing and reduction.
- 3) Temperature of the Digester has pronounced effect on rate of generation of Biogas and hence further study should include effect of temperature in the digester on rate of Biogas generation by providing suitable heating arrangement in the Digester



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