 UNIVERSITY OF NAIROBI

SCHOOL OF ENGINEERING

DEPARTMENT OF ENVIRONMENTAL AND BIOSYSTEMS ENGINEERING

FEB 540 : ENGINEERING DESIGN PROJECT

PROJECT TITLE:

DESIGN OF AN ANAEROBIC DIGESTER FOR WASTE MANAGEMENT AND COOKING FUEL GENERATION FOR MBITA HIGHSCHOOL, HOMABAY COUNTY

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REGISTRATION NUMBER: F21/2285/2016

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**A report submitted in partial fulfillment for the requirements of the degree of bachelor of science in Environmental and Biosystems Engineering , of the university of Nairobi**

**DECLARATION**

This design project is my original work and has not been submitted in any University or institution for award of honors or for any other purpose. I therefore submit it for evaluation and consequent award of Bsc in Environmental and Biosystems Engineering.

OKIKI LINDAH AOKO

Signature…………………………………………………………………………….

Date……………………………………………………………………………………

This design project has been submitted for examination with approval of my supervisor

Signature……………………………………………………………………………..

Date………………………………………………………………………………………..

Mr P.kimani

University of Nairobi

**DEDICATION**

I give thanks to Almighty God who gave me wisdom and opportunity to write out this project research finding

The project is especially dedicated to my parents, classmates and loved ones for giving me the parliamentary support and encouragement during the research period.

**ACKNOWLEDGEMENT**

I thank God for the gift of life for the last years since I joined the department as a student and for enabling me undertake the project successfully.

The project is entirely based on the concepts of energy and design of systems and I therefore thank my lectures for their effort towards impacting knowledge.

I would also like to thank my supervisor Mr p. Kimani for taking his time to ensure the project comes to a conclusion.

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**LIST OF ACRONYMS**

AD Anaerobic digestion

MHS Mbita High School

BOD Biological oxygen demand

COD Chemical oxygen demand

OLR Organic loading rate

HRT Hydraulic retention time

SRT Solids retention time

GPR Gas production rate

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**ABSTRACT**

Anaerobic digestion is a process where biogas is generated from organic substance in the absence of oxygen. The most common application of the anaerobic digestion technology in developing countries is small-scale household digesters producing biogas for cooking purposes. This study is aimed at developing an anaerobic digestion system, optimized for economic manufacture and suited to the climate conditions in the country, which can efficiently produce biogas for cooking purposes.

Anaerobic Digestion reduces the amount of waste and generates valuable products such as biogas and nutrient rich digestate. It also plays a negligible role as a treatment option for organic kitchen waste and market waste in developing countries.

 The various digester models are ;fixed-dome digester, floating-drum digester and rubber-balloon digester. The said biogas systems contribute to self-sustainability of energy production, improve waste management and mitigate deforestation and health problems caused by poor waste management and usage of traditional cooking fuels such as firewood and charcoal.

 The purpose of the anaerobic digester (AD) is to serve for educational purposes and to produce cooking fuel for the staff, non-teaching staff and students as a whole.

The parameters studied were: biogas production from various types of organic material, the levels of acidity and dry matter of the organic material affect the temperature within the container, along with an evaluation of the time scale and rate of gas production.

 Key words: Anaerobic digestion, Biogas

**CHAPTER ONE**

# INTRODUCTION

## BACKGROUND INFORMATION

It is difficult to find clean ,economically feasible energy. Alternatives for fossil fuels has become a major concern for nations, municipalities and households all over the world. Energy demand and consumption are one of the main reasons for climate change and resource exploitation, at the same time contributing to economic prosperity and quality of life as well as restricting the living standards of humans. (Rajendran et al., 2012) One of the alternative energy solutions is biogas technology which converts organic substances to methane as fuel and valuable fertilizer from locally available resources that otherwise would go unused (Da Costa Gomez,2013) In the developing countries biogas is a substitute for firewood and charcoal that can meet the energy needs of the urban, peri-urban and rural areas. Cooking stands for 90% of the energy consumption in the households of developing countries and access to electricity outside the urbanizations is limited. (Rajendran et al. 2012)

One of the main environmental problems of today’s society is the continuously increasing production of organic wastes. In many countries waste management, as well as waste prevention and reduction, have become major political priorities, as these are seen as representing an important share of the common efforts to reduce pollution and greenhouse gas emissions, and so the mitigation of global climate change . Production of biogas through anaerobic digestion (AD) of animal manure and slurries, as well as of a wide range of other organic wastes, is seen as one good option for reduction of greenhouse gas emissions. This is because the putrescible material, instead of just breaking down into freely emitted greenhouse gases, is converted into a renewable energy carrier in the form of biogas, and the digestate residue produced is a natural fertilizer for agriculture and home gardens. Biogas is also a major source of renewable energy in the developed countries. The development of anaerobic digesters is being adopted by the developing countries given the fact that it is not so common in these areas.

Kenya as a country has a high potential for production of biogas as an energy source. It shares some significant common factors with many other countries which have developed a significant energy production using biogas from anaerobic digestion. These common factors include: the high volume of wastes produced by different communities and industries, the daily struggle of women and children to collect wood for cooking, the large numbers of rural villages which are not connected to the main electricity grid, the high deforestation rate due to cutting wood for fuel, and the thousands of graduates who could be gainfully employed in developing this option, and who presently do not have jobs or who are working in menial jobs paying low income.

The objective of this study is to design an efficient and cost-effective anaerobic digestion system

for MHS.

The study included a number of specific objectives: to assess the biogas production potential of a number of common likely feedstocks, and to study the effects of the main

process parameters of anaerobic digester

1.

## MEASURES

Biogas us combustible and explosive. A number of safety measures just be taken into consideration. The safety factors include:

* Regular inspection of gas appliances
* Installation of safety stop valves and venting valves
* Good ventilation of rooms containing gas appliances
* The piping systems should be protected and clear

Educational factors

* Users must be aware of the dangerous nature of biogas
* Quick detection of gas leakages by watching for the conspicuous odour
* Close the generator safety valves over night when the gen is uninstalle

#  CONCLUSION AND RECOMMENDATION

Proper operation and maintenance (O&M) of the different technical components of the biogas plant is important to achieve and maintain high levels of gas production and to ensure efficient and long-term performance. A well designed biogas unit should be easy to operate and should only require minimum daily care (Sasse, 1991). It is also important that the labourers and/or plant manager responsible for the operation and maintenance of the plant are provided with proper training and clear instructions so that there is a good understanding of the required tasks and their importance. It is useful to develop and implement a maintenance strategy that includes clear allocation of responsibilities, a task schedule, and control mechanisms to check if duties have been conducted properly. The plant must be fed regularly in order to provide a stable gas production and because the bacteria prefer constant feeding. The feedstock needs to be pre-treated consistently, i.e. particle size of all feedstock must be reduced to 3–5 cm in length and mixed with water or effluent from the biogas plant. Impurities (e.g. inorganic materials such as glass, metals, plastics etc.) should be removed before pre-treatment. The amount of daily feedstock should be measured using a scale or using selected containers where the required filling level is indicated. If the biogas is to be used as cooking fuel, the biogas stoves need to be cleaned regularly. Food particles and dust have to be removed to avoid clogging of the air intake holes. Grease should be applied to all movable parts and the air flow intake readjusted. Gas pipes, joints and stove need to be checked to ensure they are still gastight when valves are closed. This can be easily detected either by smell, as biogas contains small amounts of hydrogen sulphide which smells like rotten eggs, or by smearing some liquid detergent onto the place where leakages could be expected. If leaks are present, bubbles will be observed at those locations. Leakages need to be repaired immediately to avoid hazards to the kitchen staff. Condensed water in the pipes should be removed on a weekly to monthly basis to ensure that the biogas can pass through the gas pipe easily. The appearance and odour of the digested slurry needs to be checked on a regular basis. If well digested, the effluent should not have an acidic odour (this would be an indication of overload or imbalanced microorganism population). Checking the pH of the digested slurry by means of litmus paper or a pH-meter can help to examine biological activity.

However, it is worth noting that the pH value of the digestate only indicates instability of the anaerobic process when the substrate-specific buffer capacity has already been consumed (Eder & Schulz, 2006). If the pH is below 5.5, feeding has to be stopped and only started again with a gradually increasing feeding rate once the pH has stabilised. The gas pipes above ground, valves, fittings, appliances and gas storage balloons need to be checked for leaks. The section on ‘Annual monitoring activities’provides methods on how to examine gas tightness.

Maintaining the biodigester contents within a relatively narrow temperature range is important, and this is ideally around 35-38 degrees Celsius.

It is critical for a continuous-feed anaerobic digestion system that the feedstock be consistent and with only very minor changes in composition over time (the moisture or dry matter content changes are not so critical). Of greatest importance is the total exclusion of oxygen from the interior of the digester once the digester is initially filled and producing biogas. The reason that the batch digesters in the lab experiments were not filled totally with the feedstock at the start was to allow a small space above the

fermenting mix for biogas to build up, and so to present any digestate being carried out along the biogas tube. While initially this space would contain a few liters of air mixture including oxygen this would not measurably affect the overall result.

# REFERENCES

1. (Eder & Schulz, 2006). (Sasse, 1991). (Chen, Cheng & Creamer 2008).( Rajendran et al., 2012)(Ahlgren&Gustafsson, 2015)( Bischofsberger et al., 2005; Bekker, 2007).
2. Biolley L. and Diggelmann R. (2011). Biogas from Solid Waste - Development and FurtherEngineering of Dry Fermentation Technology in Kumasi, Ghana. BSc Thesis. University of Applied Sciences (ZHAW) and Swiss Federal Institute of Aquatic Scienceand Technology (Eawag). Dübendorf, Switzerland.
3. Bischofsberger W. et al. (2005). Anaerobtechnik. 2. Auflage. Heidelberg. Germany. ISBN 978-3-540-06850-1
4. BSP-N Biogas Sector Partnership-Nepal (2008). Assessment, construction and monitoring ofbiogas plants in Kaski, Chitwan and Kanchanpur District Jails. Final completion report,January 2008. Unpublished.
5. Buffiere P., Loisel D., Bernet N., Delgenes J-P. (2006). Towards new indicators for theprediction of solid waste anaerobic digestion properties. Water Science &Technology,Vol 53, No 8, 233–241.
6. Buysman E. (2009). Anaerobic Digestion for Developing Countries with Cold Climates
7. Burri M. and Martius G. (2011). Biogas from Solid Waste –Conception and Construction of aDry Fermentation Pilot Plant for Developing Countries. MSc Thesis. Swiss Federal
8. Institute of Technology (ETH) and Swiss Federal Institute of Aquatic Science and Technology (Eawag). Dübendorf, Switzerland

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# AUTOCAD DRAWINGS

 

# APPENDICES

A list of tables showing the rate of production and the contents of commonly used substrates

|  |  |  |
| --- | --- | --- |
| **Materials** | **Medium temperature (35c)** | **Ordinary temperature** **(8-25c)** |
| Pig manure | 0.45 | 0.25-0.30 |
| Cattle dung | 0.30 | 0.20-0.25 |
| Human waste  | 0.43 | 0.25 -0.30 |
| Rice straw | 0.40 | 0.20 -0.25 |
| Wheat straw | 0.45 | 0.20 -0.25 |
| Green grass | 0.44 | 0.20 – 0.25 |

Table rate of production of biogas for different materials m³/kg

|  |  |  |
| --- | --- | --- |
| **Materials** | **Dry matter content** | **Water content** |
| Dry rice straw |  83 | 17 |
| Dry wheat straw |  82 | 18 |
| Corn stalks |  80 | 20 |
| Green grass |  24  | 76 |
| Human excrement |  20 | 80 |
| Pig excrement |  18 | 82 |
| Cattle excrement |  17 | 83 |
| Human urine |  0.4 | 99.6 |
| Pig urine | 0.4 | 99.6 |
| Cattle urine | 0.6 | 99.4 |