POTENTIALS FOR ANAEROBIC DIGESTION OF SEWAGE FOR ENERGY PRODUCTION AND ENVIRONMENTAL PROTECTION IN SECONDARY SCHOOLS OF KAKAMEGA COUNTY, KENYA

IBRAHIM BARASA OLUNGA

A Thesis Submitted in Partial Fulfilment of the Requirements for the Award of the Degree of Doctor of Philosophy in Disaster Management and Humanitarian Assistance of Masinde Muliro University of Science and Technology

November, 2017

DECLARATION

This is my original work and has not been submitted elsewhere for a degree or any other examination paper and award in another university.

Sign: .... Date: 14/11/2017

Ibrahim Barasa Olunga

CDM/H/14/11

CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance of Masinde Muliro University of Science and Technology a thesis entitled **"Potentials for Anaerobic Digestion of Sewage for Energy Production and Environmental Protection in Secondary Schools of Kakamega County, Kenya"**.

Sign: .... Date 15/11/2017

Prof. Jacob W. Wakhungu

Department of Disaster Management and Sustainable Development,

Masinde Muliro University of Science and Technology.

Sign: .... Date: 15/11/2017

Prof. Donald N. Siamba

Department of Biological Science,

Kibabii University

COPYRIGHT

DEDICATION

This work is dedicated to my beloved wife Fairuz, my sons Rashid, Shaban, Ramadhan, daughter Firdhaus, my brothers, sisters and late parentsfor their advice and great pillar of education.

ACKNOWLEDGEMENT

I acknowledge all the people who contributed in their respective capacities towards this work. Most specifically, I wish to extend my sincere gratitude to my supervisors Prof.Jacob W. Wakhunguand Prof. Donald N. Siamba for their untiring guidance and invaluable advice.My sincere gratitude goes to all my lecturers at Centre for Disaster Management and Humanitarian Assistancefor their invaluable support and Dr. Masibayi for generating Kakamega County map. Thanks also go to Mr. Omondi Were of National Environmental Management Authority, Mr. F. Amudavi (Public Health Officer-Kakamega Central sub-county), Mrs. C. Busuru of Kenya Forest Service, Mr. Bush of Lake Victoria North Water Services Board, Mr. S. Stingo of the Ministry of Energy (Bukura Agricultural Institute),Mr.R.Makokha (Board of Management Chairman, Namirama Girls High School) and Mr. Andati (Deputy Principal Kakamega National School) for availing the pertinent literature during the Focused Group Discussion.

I am indebted to all the teachers and students who spared some time to respond to the questions and interview. I wish to extend my gratitude to officers from Water Resources Management Authorityfor technical support in laboratory analysis and pertinent literature: D. Muiruri& J.Kavala (Water Quality and Pollution Control);P.Achieng(Laboratory Services Assistant);Nanyokia Victor (ICT); K. Koreje (Assistant Technical Catchment Manager-Water Quality and Pollution Control); C. Siganga-Water Resources Technology and Management.Finally, to Mr. P. Nyongesa, the chief technician, Department of Biological Sciences, Masinde Muliro University of Science and Technology and staff of Bora Biotech Laboratories (Nairobi), thank you so much.

ABSTRACT

Sewage biogas is one of the renewable green energy that is being developed in many countries of the world using anaerobic digestion. However, its utilisation in Kenya may be facing various challenges such as socio-economic, cultural and religious believes. It is strongly believed that secondary schools can generate energy from sewage to supplement biomass energy while protecting the environment. Sewage poses health risks due to poor disposal methods. It is against this background that this study assessed potentials for anaerobic digestion of sewage for energy production and environmental protection in secondary schools of Kakamega County, Kenya. The study was guided by four objectives: determine the quantity of sewage generated in secondary schools for potential energy generation in Kakamega County, Kenya; examine the potential environmental impact of chemical and microbial characteristics of the sewage generated; determine the economic and environmental benefits of anaerobic digestion of sewage for energy generation and evaluate the enhancement strategies in secondary schools for anaerobic digestion of sewage for energy generation and environmental protection. The study adopted four research designs: cross-section survey, experimental, correlational and evaluative to achieve its objectives. Focused Group Discussions, Key informants, interviews, questionnairesand observation check lists were used to collect data. Data were analyzed both descriptively and inferentially by using Graph Pad Prism 5, Excel and SAS and subjecting them to Chi-square and t-test, cross tabulation and evaluation. It was established that secondary schools in Kakamega County generate 17,662.3 tons of human waste per school academic year of 273 days with an energy equivalent of 43,273.6gj. The chemical characteristics in the sewage generated are: Total Kjeldal Nitrogen (TKN) 8.30 mg/l with a Standard Error (SE) of 0.45; pH 5.75 with SE of 0.13; Total Phosphate (P_2O_5)1.15mg/l with SE of 0.46; Cd 0.0249 mg/l; Pb 0.0046 mg/l; Dry Matter(DM) 13.80% with SE of 0.66. The microbial characteristics in the sewage generated are: *E.coli* 390 MPN/100mls and faecal coliforms 450 MPN/100 mls. The anaerobically digested effluent increased its concentration of TKN and P_2O_5 by 8.2% and 1.7% respectively. Its pH also increased by 26.1%. However, the DM, *E.coli* and faecal coliforms reduced by 61.8%, 74.4% and 88.89% respectively. The traceable quantities of heavy metals remained unchanged in the effluent after the Anaerobic Digestion (AD) process. The infrastructure, concerted efforts of all stakeholders and socio-economic factors are of paramount importance in realizing the anaerobic digestion of sewage in secondary schools for bioenergy production. Key players in this respect were the school sponsors. Majority of these sponsors accepted the use of sewage for energy generation in their schools. The students who are the direct beneficiaries of sewage energy generation are also in support of the idea. The study established that there is a substantial quantity of sewage generated in secondary schools of Kakamega County for sewage energy generation. If everything is held constant 21% ofwood fuel would be replaced by sewage energy. The microbial characteristics of the sewage generated in secondary schools impact negatively on the environment by causing pollution of the soils and water. Economically, AD of sewage will supplement the wood fuel used by schools for their cooking and heating needs. Environmentally, the process reduces the *E.coli* and faecal coliforms concentrations in the effluent to harmless trace levels. The decrease in DM means that less space will be required hence reduced rate of refilling. A decrease in *E. coli* and faecal coliforms meant that some important biological process was going on in the environment. The increase in P_2O_5 and TKN is beneficial to soils as bio nutrients. Generally, the use of sewage bioenergy will help reduce the effect of methane on the biosphere. There is adequate support from the stakeholders for the use of sewage in secondary schools to generate energy.

TABLE OF CONTENTS

LIST OF TABLES

TABLE **TITLE** **PAGE**

LIST OF FIGURES

FIGURE **TITLE** **PAGE**

LIST OF PLATES

PLATE **TITLE** **PAGE**

LIST OF APPENDICES

APPENDIX **TITLE** **PAGE**

ACRONYMS AND ABBREVIATIONS

AD	Anaerobic Digestion
AGECC	Advisory Group on Energy and Climate Change
BOD	Biological Oxygen Demand
BOM	Board of Management
CARE	Clean, Affordable, Reliable and Efficient
CBA	Cost Benefit Analysis
CBO	Community-Based Organisation
CDMHA	Centre for Disaster Management and Humanitarian Assistance
CEO	County Education Office
CH_4	Methane gas
CO_2	Carbon dioxide
COD	Chemical Oxygen Demand
CV	Coefficient of Variation
CVA	Community Vulnerability Assessment
DCA	Document Content Analysis
DRR	Disaster Risk Reduction
FGD	Focus Group Discussion
GHG	Green House Gases
GVEP	Global Village Energy Partnership
IPCC	Inter-Governmental Panel on Climate Change
ISAT	Implementation Information and Advisory Service on Appropriate Technology
KALRO	Kenya Agricultural and Livestock Research Organisation
KIFCON	Kenya Indigenous Forest Conservation Programme
KIPPRA	Kenya Institute of Public Policy Research and Analysis

MDGs	Millennium Development Goals
MMUST	Masinde Muliro University of Science and Technology
NBPG	Nepal Biogas Promotion Group
NEMA	National Environment Management Authority
NGO	Non-Governmental Organisation
OCHA	Office for the Coordination of Humanitarian Affairs
OCLs	Observational Check Lists
PTA	Parents and Teachers Association
REN	Renewable Energy Investment
SESEA	Sustainable Energy Solutions in East Africa
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organisation
WRMA	Water Resource Management Authority

OPERATIONALIZATION OF CONCEPTS

CARE Energy: Clean, Affordable, Reliable and Efficient energy.

Disaster: Serious disruption of the functioning of a community or society that involves Widespread human, material, economic, or environmental losses and impacts. It exceeds the ability of the affected community or society to cope using its own resources.

Disaster Management: Structural and non-structural measures undertaken to limit the adverse impact of natural hazards.

Disaster Response: Provision of emergency services and public assistance during and immediately after a disaster to save lives, reduce health impacts, ensure public safety and meet basic subsistence needs of the people affected.

Disaster Risk Reduction: The concept and practice of mitigating disaster risks through systematic efforts to analyse and manage the causes of disasters. It includes: reducingexposure to hazards, lessening vulnerability of people and property, wise management of land and the environment as well as improving preparedness for adverse events.

E. coli is a subgroup of the faecal coliform group and are found in the intestines of people and warm-bloodedanimals.

Environment: The physical, chemical, biotic and cultural conditions in which the local communities live and develop their livelihoods.

Environmental Awareness: The state of having knowledge of the environment.

Environmental Management: Measures and controls undertaken at individual, community, institutional, national and international levels to ensure that natural resources are allocated and utilized in a manner that will improve the quality of life for present and future generations.

Environmental Protection: Policies and procedures aimed at conserving the natural resources, preserving the current state of natural environment and where possible reversing its degradation.

Environmental Quality: The state of the environment in terms of standard of air, water and or land.

Faecal coliform bacteria are a sub-group of the total coliform group and are found in the intestines andfaeces of warm-blooded animals.

Hazard:A dangerous phenomenon, substance, human activity, or condition that may cause loss of life, injury or other health impacts, damage to property, loss of livelihoods and services, social and economic disruption, or environmental damage.

Human Excreta: Faeces and urine, which consist of proteins, carbohydrates, and fats.

Microbial Fuel Cells:Bio-electrochemical devices in which microorganisms (bacteria) convert organic substances in wastewater into electricity in a single step in an anaerobic environment.

Public School:A school maintained or assisted out of public funds.

Quality of Sewage: Microbial, mineral and heavy metal composition of raw sewage.

Quantity of Sewage: Volume of sewage generated per school.

Renewable Energy:Sources of energy that can be replenished or cannot be exhausted**.**

Sewage: Used water and waste substances that are produced by human bodies that arecarried away from houses and factories through sewers (special pipes).

Total coliform: Bacteria found in the environment (soil/vegetation), usually harmless.

Vulnerability: Characteristics and circumstances of a person, group, community, system, or asset that make it susceptible to the damaging effects of a hazard.

CHAPTER ONE

INTRODUCTION

1.1 Background

The Intergovernmental Panel on Climate Change report observes that about 90% of all natural disasters afflicting the world are related to severe weather and extreme climate change events (Jones, et al., 2007). This change is attributed to various causes including those related to energy production and consumption such as the Greenhouse Gases (GHGs). Current patterns of energy production and consumption are unsustainable and threaten the environment on both global and local scales.

At the global level the energy system, particularly fossil fuel, is a dominant contributor to climate variability representing around 60 % of total current Green House Gas (GHG) emissions (AGECC, 2010). There is need to undertake researches and actions aimed at eliminating or reducing these negative impacts. According to REN21 (2011), renewable energy grew strongly in 2010 to supply an estimated 16% of global final energy consumption.

People living in Sub-Sahara Africa lack access to clean, affordable, reliable and environmentally-safe energy. They rely on solid biomass especially wood fuel to meet their basic needs for cooking (Brown, 2006). Reliance on biomass such as wood fuel has serious implications on health and is associated with general environmental degradation(WHO, 2006).Biomass burning produces tons of fine particulate matter (PM), a pollutant associated with asthma, heart diseaseand cancer.It also produces hundreds of tons of nitrogen oxides (NOx) and volatile organic compounds (VOCs) two ingredients of the ground-level ozonedangerous to human respiratory health and the environment.Therefore, alternative source of Clean, Affordable, Reliable, and Efficient (CARE)energy such as biogas is being sought by the consumers to meet their energy needs. Such energy should be acceptable culturally, economically, environmentally, and socially. UNEP(2011) and WHO (2013)advocate for alternative sources of energy that can be replenished or cannot be exhausted (they are renewable), but have less environmental degradation, no adverse effect on human health and preserve many of the ecological balance of the earth.

Some of the feedstock used for anaerobic production of biogas include plants and animal byproducts such as manure, digestive tract contents, milk and milk products, eggs and egg products as well as sewage. Anaerobic extraction of biogas from sewage has additional sanitation benefits as it has been realised that sewage disposal from concentrated groups of people such as prisons reduces health hazard for both the people and the surrounding areas (KIST, 2005). Based on this, installation of large-scale biogas plants has been undertaken in Rwandan prisons to generate sewage biogas for cooking and sanitation.

Sewage is used water and waste substances that are produced by human bodiesand carried away from houses and factories through sewers (Hornby, 2010). Its disposal poses serious environmental challenges yet it is largely full of organic compounds that store usable energy in their chemical bonds. Raw sewage consists of organic and inorganic solids in dissolved and suspended form with 90-99.9% of water. Methane can be extracted from it through a natural process of anaerobic (oxygen-free) digestion or produce electricity using microbial fuel cells(Lovley, 2006; European Commission, 2013). Thesealternative waste management techniques can be used sustainably to generate sewage energy for contribution to future global energy demands andminimize its adverse environmental impact(Lovley, 2006; European Commission, 2013). Underanaerobic conditions, methanogenic bacteria convert waste into methane and carbon dioxide and the fermentation process rids waste of the pathogenic mesophiles effectively reducing the risk to the entire environment. Therefore, countries are striving to reduce pollutants and GHGs by embracing renewable energy from biomass such as the sewage.

1.2 Statement of the Problem

In Kenya, student enrolment in schools has increased due to the enactment of free primary education. This increase in student population has increased sewage generation and the demand for energy, hence, increased challenges to the environment. The Humanitarian Charter stipulates that safe disposal of human excreta creates the first barrier to excreta-related diseases, thus, reducing transmission through direct and indirect routes (Sphere Project, 2004). Safe excreta disposal is, therefore, a major priority in disaster situations that should be addressed speedily.In the recent past, Leptospirosis affected and left ten people dead in Chesamisi, in Kimilili sub county, Bungoma County. Five of these were Chesamisi High School students, three Chesamisi Primary School pupils and two members of the neighbouring community (GOK, 2005).

Sewage threatens human health yet it can be utilised to generate energy. Generation of biogas from sewage is associated with important health benefits since biological waste can be placed in a bio-digester instead of being dumped in the local area (SGP, 2012). This knowledge has led to production of biogas from sewage and residual watersin an educational institution in Ecuador. The project led to improvements in the school's sanitation, lowered the risk of disease infection, contamination of water supply and even saved the energy costs that accrue to it (SGP, 2012). In the City of Oslo, Norway, biogas generated from sewage is being used to fuel public transport buses (Johansen, 2009). In Rwanda, prisons are running on biogas using both human waste and cow dung feedstock (KIST, 2005). The 'flying toilets' in Kibera slum of Kenya have been turned into biogas production using anaerobic digestion (Dixon and Nicholas, 2012). Ramba High School in Nyanza is utilising its pit latrines to anaerobically generate biogas for cooking (personal observation). This technology can be applied in secondary schools in Kakamega County to reduce over reliance on wood fuel by utilising sewage for bioenergy generation hence, mitigate environmental health risks.

Woodfuel has remained the most important source of energy in Kenya since it meets over 70% of its total energy consumption needs(Kamfor, 2002). About 90% of Kenya'seducational institutions use wood fuel for cooking (Camp Kenya, 2011).Most institutions such as schools, hospitals and restaurants in Kajiado and Kisii regions in Kenya depended on wood fuel for energy (Musembi, et al*,* 2010). The study recommended that schools should plant their trees and generate biogas from waste to minimize dependence on fast depleting local supply of wood.Similarly, Sky link (2011), advocated for the expansion on the use of biogas in schools since Kenya's forest cover was diminishing rapidly. This was meant to help cut down on the heavy use of wood fuel and bring the benefits of renewable energy such as biogas to many people while benefiting the environment at the same time. This makes biogas an attractive alternative cooking fuel.

Methane, which is the main component of biogas is a greenhouse gas with a much higher "greenhouse potential" than CO_2 (GTZ, 2010). Converting methane to carbon dioxide through combustionis a contribution of biogas technology to the mitigation of global warming. Otherwise, biomass used for biogas generation can still undergo anaerobic decomposition and release methane to the atmosphere.These cases illustrate the important role that biogas technology can play in improving human waste management and mitigate energy and environmental challenges. It is against this back ground that this study,as one of the emergency responses essential for people's dignity, safety, health and well-being evaluated potentials for anaerobic digestion of sewage for energy production and environmental protection in secondary schools of Kakamega County.

1.3 Research Objectives

The overall objective of the study was to determine the Potential of Utilisation of Sewage for Energy Production and Environmental Protection in Secondary Schools in Kakamega County, Kenya. The study specifically sought to:

i. Determine the quantity of sewage generated in secondary schools for potential energy generationin Kakamega County, Kenya.

ii. Examine the potential environmental impact of chemical and microbial characteristics of sewage generated in secondary schoolsin Kakamega County, Kenya.

iii. Determine the potential economic and environmental benefits of anaerobic digestion of sewage for energy generation in secondary schoolsin Kakamega County, Kenya.

iv. Evaluate enhancement strategies in secondary schools for anaerobic digestion of sewage for energy generation and environmental protectionin Kakamega County, Kenya.

1.4 Research Questions

To accomplish the above objectives the study was guided by the following four research questions:

i. What is the quantity of sewage generated in secondary schools for potential energy generationin Kakamega County, Kenya?
ii. How do the chemical and microbial characteristics of sewage generated in secondary schools impact on the environmentin Kakamega County, Kenya?
iii. Is energy generation potential from anaerobic digestion of sewage significantly economical and environmentally beneficial to secondary schoolsin Kakamega County, Kenya?
iv. Which enhancement strategies are available in secondary schools for anaerobic digestion of sewage for energy generation and environmental protectionin Kakamega County, Kenya?

1.5 Significance

Sewage-related issues are some of the thematic areas that have been focused on by the UN. A response to this theme by KIST (2005) led to the installation of large-scale biogas plants in Rwandan prisons to treat toilet wastes and generate biogas for cooking. This was after a realisation that sewage disposal from concentrated groups of people such as prisons were a major health hazard in the environment. Similarly, Barnhart (2012) pointed out that there is need for research into the energy needs like biogas in places such as institutions.This study was a response to this call. Modern technology of biogas generation can be utilised to produce biogas from such waste to mitigate these challenges.

Biogas produces a clean alternative fuel, provides a use for organic waste streams that may otherwise be released into the environment, prevents the release of methane (a potent GHG) to the atmosphere, creates valuable liquid and solid fertilizers as a bio-product to enrich soils and enhance food crop production.

As the population of Kenya continues to rely on wood for fuel despite its increasing cost and CO_2 production, the country's forest cover is below the minimum10% recommended by the UN(UNEP, 2008). Kenya's forest cover is now at only 6.99 %. (KFS 2013, GoK 2014).The situation seems to be worsening as institutions continue to use wood fuel for cooking. A study to determine the potentials for anaerobic digestion of sewage for energy production in secondary schools inKakamega County is therefore justified as this will enhance sewage management in schools and enhance environmental protection.

1.6 Scope

The study was concerned with the Anaerobic Digestion of Sewage for Energy Production and Environmental Protection in Secondary Schools of Kakamega County. It was carried out between February 2014 and March 2015 in the sampled schools in the twelve Sub-counties of Kakamega County. The uniqueness of the County hinged on the assumption that its large population would lead to an increase in student enrolment in schools. Consequently, this wouldover stretch the schools' energy needsleading to environmental degradation. The study focused on secondary schools in Kakamega County. This is because Kakamega County has the highest number of

Secondary schools in Kenya (GoK, 2014). It has 408 secondary schools (383 public, 25 private) with the highest student enrolment of 116, 732 (112, 632 in public, 4,100 in private) and also the highest number of boarding schools totaling to 280.

Quantitative data was collected by computing sewage quantity in each school.Data collection covered some laboratory tests on the sewage to determine its quality by analyzing the moisture and fibre content, nitrogen, phosphorous, potassium, carbon and calcium content in the human excreta. The analysis was also done to ascertain the presence of heavy metals as well as the pathogen profile that cause infectious diseases such as cholera, hepatitis, typhoid, schistosomiasis and diarrhoea.

This study conformed to the Minimum Standards in Water, Sanitation and Hygiene Promotion which are a practical expression of the principles and rights embodied in the Humanitarian Charter (Sphere Project, 2004). Information was sourced from stakeholders and experts from the Ministry of education, Energy, Public Health, Kenya Forest Service, NEMA, Municipal Council, NGOs and local leaders as well as document analysis and relevant publications.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the literature related to sewage utilisation for energy production and environmental protection. The aim is to critically analyse the available pertinent literature and capture the gaps in knowledge. The literature reviewed focused on four pillars of the study: determine the quantity of sewage generated in secondary schools for potential energy generation, assess the potential environmental impact of the chemical and microbial characteristics of sewage, establish the potential economic and environmental benefits of anaerobic digestion of sewage for energy in secondary schools and evaluate the enhancement strategies in secondary schools for anaerobic digestion of sewage for energy generation and environmental protection. Both academic and industrial literature were sought from journal databases, government reports, the public domain, various surveys, publications and conference presentations via internet search. It further sampled methodological approaches in previous studies and ended with a conceptual framework.

2.2 Relevance of Bioenergy Production to Environmental Protection

According toSphere Project (2004),an environmentprovides the natural resources that sustain individuals and determines the quality of the surroundings in which they live. It needs protection if these essential functions are to be maintained. The minimum standards address the need to prevent over-exploitation, pollution and degradation of environmental conditions. Their proposed minimal preventive actions aim to secure the life-supporting functions of the environment and seek to introduce mechanisms that foster the adaptability of natural systems for self-recovery(Sphere Project, 2004).

Consequently, there will be environmental protection. This requires consideration of climate variability.

Climate variability is attributed to various causes such as energy production and consumption (AGECC, 2010). This report observed that energy system is a dominant contributor to climate variability representing around 60 % of total current GHG emissions at the global level. Increased biogasproduction for substituting fossil fuel is one possibility to counteract global warming.

According to OCHA (2010), energy is integral to all aspects of human welfare, including security, food production, water, health, education, and shelter. This implied that energy-related issues were the concerns of humanitarian affairs to avert any disasters that would arise. Human excreta pose various health risks yet it is one of the alternatives being sought to solve energy issues in the world. Institutions such as schools were not an exception in this respect since they had an increasing student population that could lead to a significant amount of sewage at their disposal. This posed untold or unreported challenges to these institutions and neighbouring communitiesOCHA (2010).Such environmental health risks require assessment for appropriate environmental protection measures.

2.3 Relevance of Environmental Protection to the Concept of Disaster Risk Reduction

Environmental protection has become a matter of international concern. This is as a result of references being made to environmental matters in international human rights instruments.This has culminated into the formulation and inclusion of the rights to life and to health in reference to environmental issues. For instance, the International Covenant on Economic, Social and Cultural Rights (1966),guarantees the right to safe and healthy working conditions (Art. 7 b) and the right of children and young persons to be free from work harmful to their health (art. 10-3). The right to health contained in article 12 of the Covenant expressly calls on state parties to take steps for the improvement of all aspects of environmental and industrial hygiene and the prevention, treatment and control of epidemic, endemic, occupational, and other diseases (Shelton, 2002). According to the UN (2007),one of thestrategies for disaster reductionis through systematic efforts to analyze and manage the causal factors of disasters, includingimproved preparedness for adverse events, reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment.

This study focused on risksassociated with poor environmental health or unsafe water that are related to sewage management.Disaster Risk Reduction (DRR) is about supporting local civil society, communities, households and individuals to become less vulnerable and strengthen their capacity to anticipate, resist, cope with and recover from natural hazards.

2.4 Health Policy and the Constitution of Kenya

The Constitution (GOK, 2010),provides an overarching conducive legal framework for ensuring a more comprehensive and people driven health services delivery. It seeks to ensure that a rights-based approach to health is adopted and applied in the delivery of health services. The Constitutionprovides that every person has the right to the highest attainable standard of health. It also guarantees the underlying determinants of the right to health, such as adequate housing, food, clean safe water, social security and educaton. The health Policy therefore seeks to make the realizaton of the right to health by all Kenyans a reality. This study sought to help realise this health right.

2.5 Global, Regional, and National Health

Globalization, political instability and the emerging regional and national macroeconomic challenges have adversely impacted on health (GOK, 2012). These challenges have been triggered by the global economic downturn and climate change. In addition, the increased cross-border movements of goods, services and people as well as international rules and institutions have had a considerable influence on national health risks and priorities. A number of regional and global initiatives focusing on health have been undertaken to respond to these challenges. These include major reforms within the United Nations and international and regional declarations and commitments. This Policy has been developed at a tme when other global initiatives such as those targeting non communicable diseases, social determinants of health, managing emerging and re-emerging health threats are gaining momentum. This study aimed at helping to resolve the re-emerging health threats in the environment.

2.6 Orientation of Health Policy to adequate Health information for evidence based Decision making

According to the Kenya Health Policy 2012-2030 (GOK, 2012), health orientation targets consumers, health managers, policy makers and all other actors in the health sector with a view to guide their decision making processes. This has to be attained through focusing on implementation of the following strategies:

i. Harmonizaton of data collection, analysis, and dissemination mechanisms of state and non state actors through a legal framework,
ii. Continued strengthening of accuracy, timeliness, completeness of health information from population and health facilities,
iii. Comprehensive analysis of health information to inform decision making;
iv. Strengthening mechanisms for health information dissemination to ensure information is available where and when needed,
v. Establishing mechanisms to promote, coordinate, regulate and ensure sustainability of health research and development,
vi. Puting in place health surveillance and response mechanisms.

This study endeavoured to create new knowledge so as to contribute to the existing one in a bid to help policy makers in decision making.

2.7 Relevance of Sewage Biogas Utilisation to Climate Variability

According to Green Africa (2011), Kenya relies 9% on electricity, 22 % on petrol, 1% on renewable energy sources and 68 % on wood fuel as sources of energy. With the country's forest cover standing at 1.7 % against the global requirement of about 10 %, there is need to seek for alternative sources of energy which can help protect the diminishing carbon sinks.These alternative sources of energy have to be green energies that are environment friendly. Such sources are biogas from organic waste.

Organic waste produces methane when it decomposes.According to US EPA (2012b), methaneemissions from wastewater contributedto approximately 7 per cent of total globalmethane emissions in 2010 and they were expected to grow byapproximately 19 per cent between 2010and 2030, with Africa, the Middle East, Asia, Central and South America projectedto have the greatest increases.Methane is a greenhouse gas

(GHG) more than 25 times as potent as carbon dioxide (Anderson et al., 2016).This means that improved sanitation and sewage management can make an importantcontribution to climate mitigation, reducingemissions of several key GHGs, primarilyCO_2, methane, and nitrous oxide.Methane is released more efficiently from sewage during anaerobic digestion process.Thus, generating biogasfrom wastewater and excreta can be an efficient way to produce renewable energy and also an effective climate mitigation measure (UNEP, 2006).

In the light of the foregoing, there is need to seek for potentials alternative sources of energy to counter the negative impact caused by wood fuel consumption on the environment. It has been demonstrated that carbon sinks may be diminishing. An increase in student enrolment in schools implies that there is an increase in human waste production hence, an increase in the challenges of its disposal. This scenario forms a trio of issues: the issue of wood fuel consumption and its impact on the environment; the issue of sewage disposal and its implications on public health and the potentialsforanaerobic digestion of sewage for energy production to mitigate the health hazard in the environment being created by these two issues. There is no sufficient literature on this body of knowledge in Kakamega County. This study therefore endevoured to fill this gap by assessing the potentials for anaerobic digestion of sewage for energy generation and environmental protection. The quantity and quality of sewage generated in the secondary schools for this purpose was, therefore, sought.

2.8 Quantity of Sewage Generated in schools for Potential Energy Production

Anaerobic digestion enables generation of a renewable source of energy which has an important climatic twin effect. First, the use of renewable energy reduces the CO_2-

emissions through a reduction of the demand for fossil fuels. Secondly, at the same time, by capturing uncontrolled methane emissions, the second most important greenhouse gas is reduced (Equation. 2.1).

$1 m^3$ cattle manure = 22.5 m^3 biogas = 146 kWh gross = 36 kg CO_2- Emissions: ***(Equation. 2.1)***

Smaller agricultural units can additionally reduce the use of forest resources for household energy purposes and thus slow down deforestation (about 1 ha of forest per rural biogas plant per year), soil degradation and resulting natural catastrophes like flooding or desertification as described in equation 2.2 and 2.3.

1 m^3 biogas (up to 65% CH_4) = 0.5 litre fuel oil = 1.6 kg CO_2 ***(Equation 2.2)***

1 m^3 biogas = 5.5 kg wood fuel= 11 kg CO_2 ***(Equation 2.3)***

The anaerobic decomposition of human excreta produces methane gas, which can be harnessed by biogas plants to produce energy (Gustavsson, 2000). The ambient temperature in most locations in Africa is sufficient to maintain the decomposition process due to the generally prevailing warm climate. As such, no artificial heating is required. Biogas installations are generally based on psychrophilic (<20°C) or mesophilic (30-42°C) anaerobic digestion. Digesters for biogas generation available in Sub-Saharan Africa are of 3 main types: flexible balloon, floating drum, and fixed dome (Figures 2.1 to 2.4). The choice of the design of the digester is a key determinant in the success of the implementation.

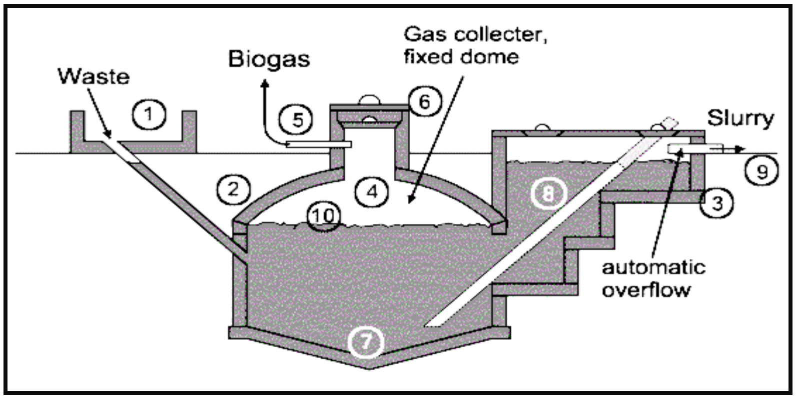


Figure 2. 1: Fixed dome plant-Nicarao design:*Source:* GTZ (2009)

[1. Mixing tank with inlet pipe and sand trap. 2. Digester. 3. Compensation and removal tank. 4. Gasholder. 5. Gas pipe. 6. Entry hatch, with gastight seal. 7. Accumulation of thick sludge. 8. Outlet pipe. 9. Reference level. 10. Supernatant scum, broken up by varying level].

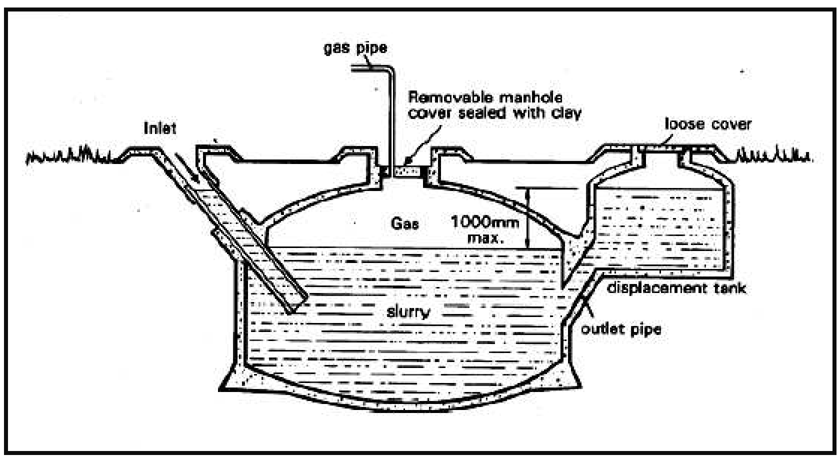


Figure 2. 2: Design of biogas plant-Fixed dome

Source: Cited in Smith et al (2011)

According to Bhol et al (2011), the cost of fixed-dome biogas plants is relativelylow. It is simple as no moving parts exist. There are also no rusting steel parts and hence a long life of the plant (20 years or more) can be expected. The plant is constructed underground, protecting it from physical damage and saving space. While the underground digester is protected from low temperatures at night and during cold seasons, sunshine and warm seasons take longer to heat up the digester. No day/night fluctuations of temperature in the digester positively influence the bacteriological processes. The construction of fixed dome plants is labor-intensive, thus creating local employment. Fixed-dome plants are not easy to build. They should only be built where construction can be supervised by experienced biogas technicians. Otherwise plants may not be gas-tight (porosity and cracks). A fixed dome plant comprises of a closed, dome-shaped digester with an immovable, rigid gas-holder and a displacement pit, also named 'compensation tank'. The gas is stored in the upper part of the digester. When gas production commences, the slurry isdisplaced into the compensating tank. Gas pressure increaseswith the volume of gas stored, i.e. with the height differencebetween the two slurry levels. If there is little gas in the gasholder,the gas pressure is low.

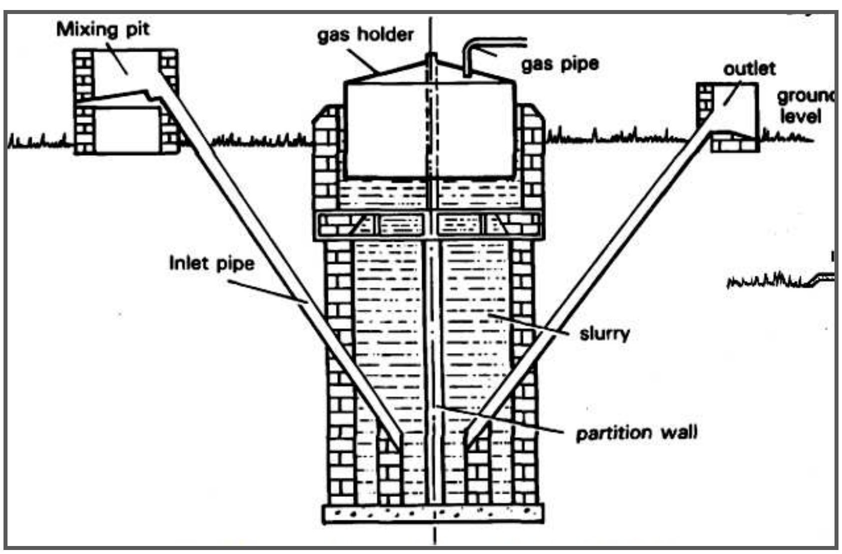


Figure 2. 3: Design of biogas plant-Floating drum

Source: Cited in Smith et al (2011)

A floating-drum plant consists of a cylindrical or dome-shaped digester and a moving, floating gas-holder, or drum. The gasholder floats either directly in the fermenting slurry or in a separate water jacket. The drum in which the biogas collects has an internal and/or external guide frame that provides stability and keeps the drum upright. If biogas is produced, the drum moves up, if gas is consumed, the gas-holder sinks back. Floating-drum plants are easy to understand and operate. They provide gas at a constant pressure, and the stored gas-volume is immediately recognizable by the position of the drum. Gas tightnessis no problem, provided the gasholder is de-rusted and painted regularly. The steel drum is relatively expensive and maintenance-intensive. Removing rust and painting has to be carried out regularly. The life-time of the drum is short (up to 15 years; in tropical coastal regions about five years). If fibrous substrates are used, the gas-holder shows a tendency to get "stuck" in the resultant floating scum, Bhol et al (2011).

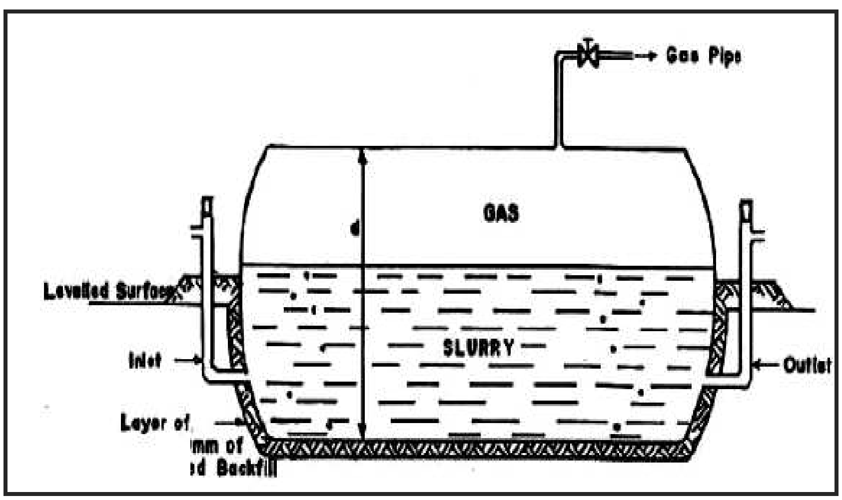


Figure 2. 4: Design of biogas plant-Flexible balloon

Source: Cited in Smith et al (2011)

According to, Kumar et al (2015), a balloon plant consists of a heat-sealed plastic or rubber bag (balloon), combining digester and gas-holder. The gas is stored in the upper part of the balloon. The inlet and outlet are attached directly to the skin of the balloon. The gas pressure can beincreased by placing weights on the balloon. If the gas pressure exceeds a limit that the balloon can withstand, it may damage the skin. Therefore, safety valves are required. If higher gas pressures are needed, a gas pump is required. Since the material has to be weather and UV resistant, specially stabilized, reinforced plastic or synthetic caoutchouc is given preference.

This study will focus on the balloon type of biogas plant for use in schools. It has been installed and proved to function well at Kaimosi Teachers' Training College in Vihiga County, Plate 2.1.

Plate 2. 1: Inflated gas bag at Kaimosi T.T.C

2.9 Environmental Impact of the Sewage Chemical and Microbial Characteristics

According to Mara (2004), human excreta contain moisture, organic matter, nitrogen, phosphorous, potassium, carbon, and calcium. They also contain pathogens that cause infectious diseases such as cholera, hepatitis, typhoid, schistosomiasis, and diarrhoeathrough faecal-oral contamination. The worm-like parasites (Helminthes), including human hookworms, roundworms and whipworms cause gastrointestinal infections that make up part of the excreta-related global health burden. These pathogens are particularly deadly in developing countries where diarrhoea alone kills 1.3 million children under the age of five each year. The WHO estimates that poor sanitary conditions and practices cause 85–90% of diarrheal cases in developing countries (Prüss-Üstünet al, 2004).

Many low-cost methods are able to treat excreta and sewage so that it can be reused. The most important step in treating human waste is reducing pathogens, particularly human intestinal nematodes and faecalbacteria since they are a health hazard. The guideline limit of WHO for faecal coli form bacteria is 1000 per 100 milliliters (Havelaar, et al, 2001). The Endgelberg guidelines limit nematodes to not more than one egg per litre. This implies that human excreta can be reused as fertilizer or for aquaculture once these standards are met. Table 2.1 illustrates the potential value of excreta as a productive resource. It indicates that one person's annual average excreta of 500 litre of urine and 50 litres of faeces equals the amount of fertilizer needed to produce230 kilograms of cereal for one person in a year.

Table 2. 1: Potential value of one person's annual average excreta

Fertiliser	500 litres urine	50 litres faeces	Total excreta	Fertiliser needed for 230 kg of cereal production
Nitrogen	5.6kg	0.009kg	5.7kg	5.6kg
Phosphorous	0.4kg	0.19kg	0.6kg	0.7kg
Potassium	1.0kg	0.17kg	1.2kg	1.2kg
Total(N+P+K)	7.0 kg (94%)	0.45 kg (6%)	7.5 kg (100%)	7.6 kg (100%)

Source: Austin & Van Vuuren (2001)

There is a clear demonstration in the Rwandan prisons that sewage can be utilized as a source of renewable energygeneratedfrom everyday human waste, KIST (2005). According to Barnhart (2012), there is need for research into the energy needs in places such as institutions to know if there are any existing sewage treatment plants or landfills that produce methane. Information about sewage biogas technology at the secondary school scale to improve both environmental and human health in Kakamega County is not readily available.

From the foregoing literature review, it could be established that measures needed to be taken in the human environment to ensure that human faecal disposal is not a threat to human health but instead be quantified and put to some use that can be beneficial to man without harming the surroundings. Such use was biogas utilisation. This implied that promotion of biogas technology was indispensable to economically harness sewage biogas while cleansing the environment. Information of how much biogas could be generated from 1m^3 of human excreta generally scanty. These were the gaps of knowledge that this study addressed.

2.10 Potential Economic and Environmental Benefits of AnaerobicDigestion of Sewage for Energy Generation

The potential economic and environmental benefits of anaerobic digestion of sewage for energy generation is presented in in two sections; Section 2.10.1 deals with Potential economic benefits of anaerobic digestion of sewage for energy generation. Section 2.10.2 deals with Potential environmental benefits of anaerobic digestion of Sewage for energy generation.

2.10.1 Potential Economic Benefits of Anaerobic Digestion of Sewage for Energy Generation

According to a survey by Sky Link (2011), Kenya's forest cover was diminishing rapidly making biogas very attractive as an alternative cooking fuel. The survey advocated for the expansion on the use of biogas in schools. This was meant to help cut down on the heavy wood use, serve as demonstrations for the wider community and bring the benefits of renewable energy to many people while benefiting the environment at the same time.

Most institutions such as schools, hospitals and restaurants in Kajiado and Kisii regions in Kenya depended on fuel wood from the local supply with no effort to produce their own (Musembi, et al, 2010). The study recommended that schools should plant their trees and generate biogas from waste to minimize dependence on fast depleting local supply of wood. The study further pointed out that only 21% of the institutions grew trees for their own consumption, another 21% did not give a response about their source of fuel wood but the remaining 58% got their wood fuel from the local market or contracted suppliers. This could be having implications on the environment especially the carbon sinks. A survey of institutional fuel wood utilization by Camp Kenya (2011) indicated that no study had been conducted to establish the quantity of wood fuel consumed by educational institutions.The consumption of wood fuel was still high although many institutions had embraced the use of energy efficient cooking stoves. This situation seemed to be worsening due to an increase in student enrolment resulting from free primary education.

Besides, Hope (2012) indicated that there were many research gaps that prevented a comprehensive understanding of sanitation technologies, including survey methods, implementation, and cost benefit analysis and health risks within specific contexts. The health risks associated with the reuse of excreta needed to be further evaluated. Researchers should study cost-incentive structures for community-based approaches and examine the roles of the stakeholders. Little research details the motivations of those who reuse human excreta and wastewater or the different modes of collaboration with stakeholders (Allison, 1998; Strauss & Blumenthal, 1990). Many sources assert that water, sanitation, and hygiene should be approached holistically, but few studies point the way forward.

According to ISAT (2011), the essential benefits of biogas plants were not manifested in individual cost-efficiency calculations. They could only take effect on a general economic scale and when entire areas became fairly well "saturated" with biogas systems. If too expensive, poor consumers would not be able to risk making the investment; but if it was not robust and could not be easily repaired, then consumers would not see the long term benefits. Therefore, public measures for the promotion of biogas technology were indispensablewhereby special attention was to be paid to widespread introduction.

A cost-benefit analysis which evaluated the national (Uganda, Rwanda, Ethiopia) and regional (Sub-Saharan Africa) integrated biogas and sanitation programs, had a shortage of the data needed for some estimates (Smith et al, 2011). This was because most of the calculations were based on assumptions and involved only household and societal levels. Therefore, there was an urgent need for the research to fill these data gaps. This study aimed at addressing the knowledge gap of cost-benefit analysis and health risks within the secondary school context and come up with findings that would motivate stakeholders to utilise sewage for energy and reuse human waste as well as waste water.

2.10.2 Potential Environmental Benefits of Anaerobic Digestion of Sewage for Energy Generation

The long term possibilities of using human waste should be considered further because of the potential for biogas digesters to improve sanitation and reduce pathogens in the water courses that originate from human faeces (Smithet al 2011). Health problems associated with spread of human wastes can occur due to pit toilets becoming overfull as a result of inadequate depth and toilets being sited too close to water sources. Human waste can also leach into ground water from a functioning pit toilet if sited on a highly permeable soil type.

According to Pritchard et al(2009), contamination of groundwater and reservoirs by running storm water and flash floods can result in significant sporadic pollution events. The type of contamination includes enterobacteria, enteroviruses and a range of fungal spore. Some key human/animal pathogens include *Salmonella typhi*, *Staphylococusspp*, *E. coli*, *Campylobacter coli*, *Listeria monocytogenes*, *Yersinia enterocolitica*, Hepatitis B and C viruses, Rotavirus, *Aspergillusspp*, *Candida spp,* *Trichophyton spp.*, *Cryptosporidium*, Mycobacteria, Leptospirosis, Toxoplasma and *Clostridium botulinum*(Pritchard et al, 2009).

Many of these pathogens are zoonoses, thus, they can be transmitted between animal and human populations. Cattle slurry introduces a range of pathogens including *Clostridium chavoie* (black leg disease), *Ascaris ova,E. coli* and *Salmonella spp.* as reported in cow dung slurries in Bauchi state, Nigeria (Yongabiet al., 2003); *Salmonella spp, E. coli,* yeasts and aerobic mesophilic bacteria in poultry wastes in Cameroon (Yongabi et al., 2009).

Pathogen prevalence in an environment is affected by local climate, soil type, animal host prevalence, topography, land cover and management, organic waste applications and hydrology (Gagliardi and Karns, 2000; Jamieson et al, 2002; Hutchison et al, 2004; Tyrrel and Quinton, 2003; Tate et al, 2006). Installation of biogas digesters has potential to reduce the risks of encountering these pathogens if operated properly. However, risks could be increased due to the person handling the materials undergoing increased direct contact with these pathogens, the digester amplifying the growth of certain pathogens, or the processed material from the digester being used as a fertiliser for agricultural crops where it would not otherwise have been used. The risks from these pathogens can be mitigated by developing a toolkit that includes safe operating instructions. Microbiological data should be generated for the pathogens or indicator organisms to determine the extent to which the levels change during the anaerobic digestion process.

Sludge from the anaerobic digestion can be used as a soil conditioner or composting asthe biogas is used as energy source for running all the devices of treatment plant and others as lighting, laboratory works etc. (Malik et al, 2009). This is a very important environmental benefit especially in Kakamega County where most soils seem to have lost a lot of their fertility.

2.11 Enhancement Strategies for Anaerobic Digestion of Sewage for Energy Generation and Environmental Protection

In Nepal, biogas is a household scale technology used to create a cooking fuel that replaces wood fuel and improves both environmental and human health(Barnhart, 2012). This study evaluated the strategies available in secondary schools for the utilisation of sewage to generate green energy in a bid to realize similar results.

According to NBPG (2007), institutional biogas plants are operated by boarding schools where human sewage from pupils is used to generate biogas as a cooking fuel in the institution's kitchen with success. This had clear benefits for both the local environments and the international efforts to reduce carbon dioxide emissions so as to conform to the Kyoto Protocol, a greenhouse gas (GHG) reduction treaty, (UNFCCC, 1997).Properly functioning biogas plants improve the health and living conditions of the general population, reduce the use of wood fuel and charcoal and enhance soil fertility leading to increased agricultural production (AGECC, 2010).

The main outcome of biogas technology for the local population is provision of a wide range of improvements in overall living conditions and also supports national economies and the environmental protection. Sanitary and health conditions improve and the quality of nutrition is enhanced by improved energy availability. In total about 4 % of the global anthropogenic methane emissions could be reduced by biogas technology. If fossil fuels and wood fuel are replaced by biogas additional CO_2-emissions can be avoided including a saving of forest resources which are a natural

CO_2 sink. Including all these effects about 420 Mil t of CO_2-equivalents are avoidable, (Table 2.2).

Table 2. 2: CO_2-Reduction through biogas utilization, saving of fossil fuels and fire wood

Item	**Amount**	**CO_2Reduction [Mil t CO_2/year]**
CH_4	13,24 Mil t/year CO_2-equivalent: methane x 25	330,9
Biogas	33.321 m^3/year	
Substitution of fossil fuels		44,7-52,7
Wood fuel savings		4,17 - 73,8
Total		388 - 449 = 418,5

Source: Smith et al(2011)

According to Smith et al (2011), three billion people globally are exposed to smoke from burning biomass fuels such as wood, charcoal and dried cow dung in their homes. Exposure to this smoke is linked to pneumonia, lung cancer, and chronic lung diseases. It is estimated that this leads to about 1.2 million premature deaths annually. The World Health Organisation estimated that indoor smoke from solid fuels is the 10th highest contributing factor to the global levels of premature death (Smith et al, 2005), 76% of the global exposure to particulate matter pollution occurring as indoor air pollution in developing countries (Smith, 1993). Ezzati and Kammen (2001) showed a strong relationship between exposure to particulates and acute respiratory infections in Kenya.

Studies of different types of biomass smoke in homes in India, Nepal and Malawi (Fullerton, et al., 2009) showed that fine particulate concentrations peaked during cooking periods, decreasing in the order cow dung/wood in India (820 g/m^3 24hr average), wood in Nepal (792 g/m^3 24hr average), charcoal/wood in Malawi (226 g/m^3 24hraverage), and LPG in Nepal (67 g/m^3 24hraverage).

The factors that determine particulate concentrations are cooking location, fuel type and house type (Fullerton, et al., 2009). Peak exposures can be as high as 20,000 g/m^3 and personal exposures may be even higher. Dried animal dung and crop residues give higher particulate and endotoxin exposures than wood, charcoal or LPG. Carbon monoxide levels showed similar peaks in concentrations at cooking times, with charcoal resulting in the highest exposures to CO. Work on LPG shows ten-fold or more reduction in particulate exposure. Similar results would be expected in homes using biogas digesters.

Potential interventions to reduce exposure to indoor air pollution include reducing the source of pollution (improved cooking devices, alternative fuel-cooker combinations, and reduced need for fire), improving ventilation and placement of the stove in the living environment, and reducing exposure to smoke by drying fuel, using pot lids, maintaining stoves and keeping children away from the smoke. One of the primary benefits of changing from burning dung, crop residues or fuel wood to biogas is likely to be reduced concentrations of indoor air pollutants.

The short and long term health improvements need to be quantified and used to educate householders of the potential health benefits of biogas, demonstrating the reduction of smoke in the home (Fullerton, et al., 2009). Besides, many urban water systems were designed long time ago when there was low population, more energy, but with limited understanding of the public health and environmental consequences. This knowledge gap creates a barrier towards alleviating public health and environmental issues. Based on the foregoing this study aimed at filling these gaps.

2.12 Methodological Approaches Relevant to the current study

From the foregoing literature review, the following methodological approaches were pointed out to be relevant to this study. A project on 'The feasibility of an on Campus Biogas Operation at the University of Waterloo' (Reid et al, 2005) was conducted using a triangulation method. The method consisted of: literature review, background research, case studies and direct interviews. The literaturereview and background research provided an initial overview of biogas. The sources described what biogas is, how it is produced, and how it could be used. The literature review transcribed studies that have been done in reference to biogas and currentprojects using biogas technology. Only recent journal articles were reviewed to increase the validity of the project.

Background research and case studies were reviewed for comparison to the potential University of Waterloo project,Reid et al (2005). This was to provide information for the size, capacity, and type of biogas plant that would best suit the university and the Region of Waterloo. Interviews were conducted to several local potential donators of organic wastes includingfarmers, restaurants, and food markets. The interview questions were reviewed and passed by University of Waterloos Office of Research Ethics. Approval from the Research Ethics office was needed to interview businesses and farmers. Consent forms, interview questions, information form and feedback forms were created for Ethicsclearance.Interview participants were selected based on the proximity of the participants to the potential plant and the volume of wastes that could be collected. Participants were contacted via telephone or e-mail. Questions were asked regarding where the waste goes and whether they were willing to donate their organic waste if it was picked up free of charge and the sludge donated to local agricultural farms. The collected data was assessed to determine extra amounts of organic waste needed for the biogas plant. The economic feasibility of the biogas plant was conducted with all data collected. This wasfollowed by a discussion, recommendations and alternatives for the feasibility of the project.

The method of triangulation used to minimize potential operational and start-up problems. The method also emphasized the benefits that biogas operation would have on the local community and the University of Waterloo. The survey only focused on the farmers, restaurants, and food markets. In the light of the foregoing, this study also used triangulation method but focused on secondary schools to fill the gap.

2.14 Conceptual Framework

Following the foregoing literature review, a conceptual framework, (Figure 2.5), was constructed to represent interplay of the key elements of wood fuel and sewage utilization for energy production and environmental protection in schools. Energy is the ability to do work. There are many forms of energy such as chemical, electrical, heat, kinetic and potential energy.

This conceptual framework was based on the principle of conservation of energy. According to the principle of conservation of energy, energy can neither be created nor destroyed but can only be converted from one form to another (Nolan, 1996).

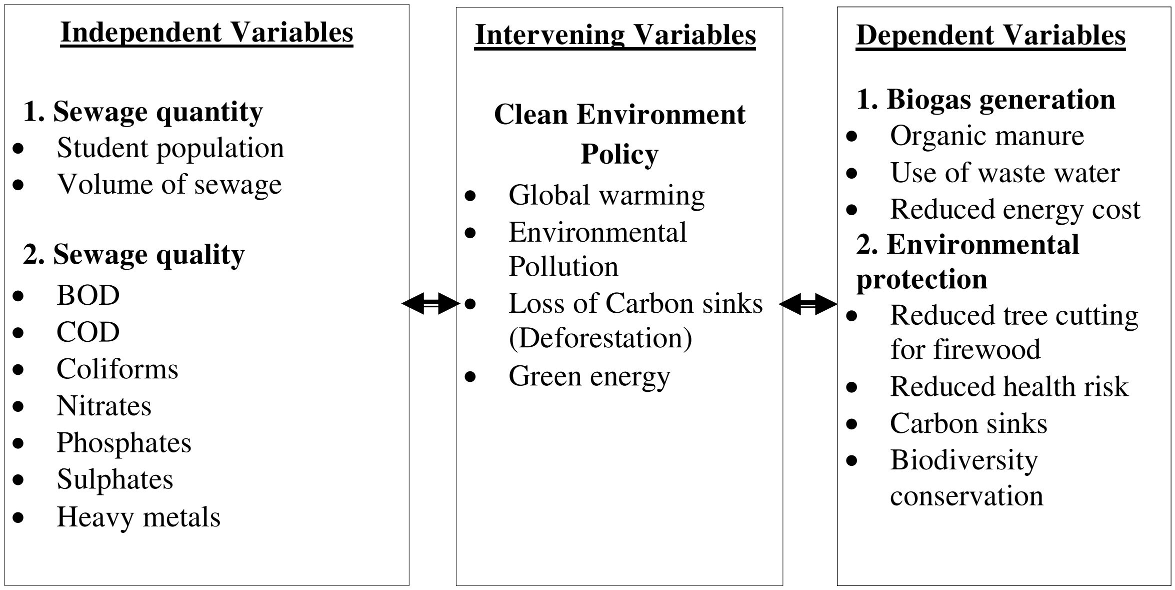


Figure 2. 5 Conceptual framework for the interaction of variables:*Source*: *Researcher (2013)*

The potential energy in sewage can be converted into chemical energy in biogas which can then be converted into heat energy for utilisation in many ways. Many biological, chemical and physical changes are accompanied by these energy changes Thus, the biogas technology can be embraced by schools to produce methane gas from the sewage for use as a source of green energy and reduce on wood fuel consumption and environmental health risks.

In this scheme clean environmental policy will impact on wood fuelconsumption and sewage management affect the quality of the environment by lowering its quality. With an evaluation of the school environment ethos and environmental quality, schools are able to realise the adverse effects of high wood fuelconsumption on their budget and the environment. On the other hand, sewage menace will be realized and proper management measures put in place for resilience. This implies that if secondary schools can embrace the biogas technology to utilise the sewage, then they will be able to save a lot on wood fuel expenses and enhance environmental health.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

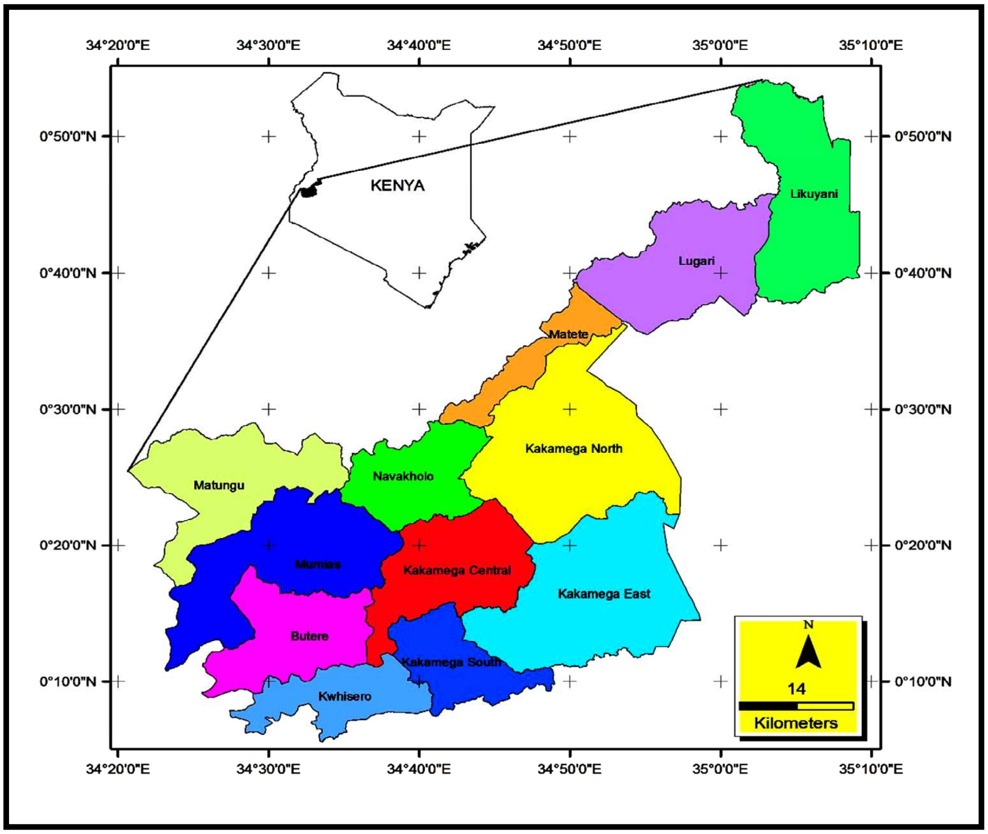
This study investigated the Potential forAnaerobic Digestion of Sewage for Energy Production and Environmental Protection in Secondary Schools of Kakamega County, Kenya. This was in the light of increased enrolment of students in schools and environmental challenges. This chapter presents the methodological procedures for the research process. It contains a description of the study site, study population, sampling strategy, data collection procedure, determination of validity and reliability of research instruments, ethical considerations, the assumptions, limitations and finally data analysis and presentation.

3.2Study Site

3.2.1 Location

The study was carried out in Kakamega County in Kenya (Figure 3.1). The County was chosen because of its number of schools and student population is remarkably increasing (Table 3.1). This would have a significant implication on the quantity of sewage generated for energy production. Kakamega County is one of the four Western Kenya Counties. Its geographiccoordinates are Latitude 0^0 16' 60.00" N and Longitude 34^0 45' 0.00" E. It borders Bungoma to the North, Trans Nzoia to the North East, Uasin Gishu and Nandi Counties to the East, Vihiga to the South, Siaya to the South West and Busia to the West. The County is composed of twelve sub-counties namely Butere, Kakamega Central, Kakamega East, Kakamega North, Kakamega South, Khwisero, Likuyani, Lugari, Matete, Matungu, Mumias and Navakholo. There are twelve constituencies. These are Butere, Khwisero, Ikolomani

Likuyani, Lugari, Lurambi, Malava, Matungu, Mumias, Mumias East, Navakholo and Shinyalu. There are 24 divisions, 72 locations and 233 sub locations.Its capital town is Kakamega.



Area= 3,051 km² Pop'n= 1,660,651

Figure 3. 1: Mapof Kakamega County, the study site. (*Source: GIS MMUST, 2014*)

The County lies within an altitude of 1,250m to 2,000m with an average annual rainfall ranging from 1250-1750mmper annum. Its average temperature is 22.50^{o}C.

3.2.2 Population

According to the Kenya Population and Housing Census of 2009, Kakamega County is home to 1,660,651 people with 800, 989 males (48%) and 859, 662 females (52%). This makes it the second most populous County after Nairobi (GoK, 2010). It has an area of 3,051 km² and a population density of 544 persons per km^2. There is an age distribution of: 0-14 years (46.6 %), 15-64 years (49.7 %), 65+ years (3.6 %).

Population growth rate is 2.5% and a fertility rate of 5.6 against the national average.In 2012 this population was projected to be 1,789,989. It is also expected to rise to 1,929,401 and 2,028,324 by 2015 and 2017 respectively.

3.2.3 Labour force

The labour force was projected to be 889,552 in 2012 representing 49.7% of the county population. This consisted of 471,779 females and 417,773 males. Local inhabitants are mostly the Luhya ethnic groups.In 2015, the labour force is projected to be 958,834 persons and projected to be 1,007,994 persons by 2017.According to the Population and Housing Census of 2009 (GoK, 2010), the unemployed population in the county was 196,938. This implies that majority of the people in the labour force are not gainfully employed. The employed people by various sectors were: 756,711 in the agriculture sector, 34,052 in self-employment, and 2,554 in wage employment, while 54 were in urban self-employment. Sectors which form a substantial number of self-employed persons includethe *Jua Kali*(informal sector), cottage industries and *boda*(bicycle and motorcycle taxis). In agriculture, self-employed persons engaged mostly in land ploughing, weeding, bush clearing, planting, harvesting and post-harvest handling. Others are engaged in mining, forestry, brick making and building construction.

3.2.4 Socio-Economic Activities

The main crops grown in Kakamega County are sugarcane, maize, bean, cassava, finger millet and sorghum. Maize forms the staple food for the county. Kakamega County serves as the headquarter of Kenya's largest sugar producing factory, Mumias. Cattle, is reared by 53.2% of the population while 22.2%, 11.2%, and 1.6% of the population rear sheep, goats and pigs respectively. Chicken rearing is pre-dominant with 92% of the households keeping them while 0.7% keep donkeys. About

19.15 million litres of milk are produced annually while 364,000 kg of beef is also produced per year(GoK, 2010).It is estimated that in 2012 only 38.6% of the population had title deeds for the land they occupy. This may be attributed to the lengthy adjudication processes and the land tenure system. In the county cases of landlessness within the county are few since most people live on their ancestral land. There are a few cases of internally displaced people as a result of the 2007/2008 post-election violence.

One of the natural resource bases is the Kakamega National Forest Reserve. It is the only existing tropical rainforest in Kenya (KIFCON, 1994). The Gazetted forest cover is 28, 199.72 hectares. This is a major tourist attraction in the area as well as an on-going project aimed at environmental conservation in the country and research sites for a number of institutions in the country. This is because the forest is a home to indigenous trees, large species of birds, butterflies, monkeys, snakes, baboons, hares, and rabbits. Other attractive activities include bull fighting and cock fighting. The 'crying'stone in Ilesi and the preserved ancient Wanga Kingdom in Mumias attract a number of people to the county. The forest is also a source of wood fuel and acts as a carbon sink and enhancement of the effects of climate change. It has three major rivers; Nzoia, Lusumu and Yala with the potential for irrigation and hydro-electric power generation and about 390 boreholes (KIFCON, 1994).

The county mines 592,941 tons of murram, 278,000 tons of sand, 51,968 tons of ballast, and 148,920 tons of hard-core every year. About 80,271 people in the county are engaged in mining and related activities. There is also a section of the community that is engaged in small scale gold mining.

3.2.5 Ecological Zones in Kakamega County

On land availability and use, there are two main ecological zones in KakamegaCounty. These are the Upper Medium (UM) and the Lower Medium (LM). The UM covers the central and southern parts of the county where intensive farming of maize, bean and horticulture is carried out by small scale farmers with a section of the population practicing large scale farming. The Lower Medium (LM) zone, covers a major portion of the northern part of the county where the main economic activity is sugarcane farming. The average land holding size in the county is 0.57ha. Generally Butere Mumias sub county, Kakamega East, North and South sub counties have lower average land holdings as compared to the upper parts of Lugari Sub County. This land subdivision due to the high population in the sub counties, other than Lugari, is considered to be uneconomical(GoK, 2010).

3.2.6 Climatic Characteristics

The annual rainfall range is between 2214.1mm and 1280.1 mm per year. This rainfall is evenly distributed all year round, with March and July receiving heavy rains while December and February receives light rains(GoK, 2010). The temperatures range is between 18^{0} C and 29^{0}C. The hottest months are November, December, January and February. Other months have relatively higher and similar temperatures. The county has an average humidity of 67%.

3.2.7 Education and Health Institutions

The region is an educational centre being home toMasinde Muliro University of Science and Technology, and also campuses of various universities such as Mount Kenya University, Jomo Kenyatta University of Agriculture and Technology as well as the University of Nairobi. Other Knowledge based institutions include Bukura

Agricultural College, Sigalagala Polytechnic, Bushiangala and Shamberere Technical Institutes and Kenya Agricultural and Livestock Research Organisation(KALRO) in Kakamega town. In 2012, the County had 303 public secondary schools with a student enrolment of 73,220 (Appendix VII). Out of these, two were national schools, (Kakamega High School and Butere Girls' High School).

The County has 214 health facilities in operation. These include one (1) Level Five Hospital (Kakamega County General Hospital), 11 Sub-County Hospitals (Butere, Iguhu, Lumakanda, Malava, Navakholo, among others), 101 Dispensaries, 40 Health Centres, 43 Medical Clinics, 10 Nursing Homes (Kakamega Central, Lumino, Nala, Royal, among others), and 7 other health facilities. Doctor to Population Ratio is 1:14, 246, an Infant Mortality Rate of 63.9/1000 and Under Five Mortality Rate of 122.5/1000.(explain) The four most prevalent diseases include Malaria, Diarrhoea, Skin diseases and Respiratory Tract Infections.

According to the PDP Western (2011), the County has been facing various challenges. Its poverty level stands at 52%. This was caused by low productivity of agricultural sector, poor marketing systems, poor infrastructure such as roads, water sanitation, energy distribution, insecurity, high cost of production, and environmental degradation.

Population increase together with climate variability, have added a challenge to the energy requirements and consumption in many secondary schools. The increase in the number of secondary schools and the student population due to free primary education in the country has made this region very vulnerable to the challenges of sewage disposal, environmental degradation and wood fuel energy requirements. Besides, Kakamega forest has been destroyed because of the ever increasing demand on wood fuel. It was for these reasons that Kakamega County was selected for purposes of documenting energy, health and environmental challenges that secondary schools in the County were facing. Thus, measures were needed to surmount these challenges of energy. Therefore, the potential of anaerobic digestion of sewage for energy production and environmental protection in secondary schools of KakamegaCounty was sought to find the possible solutions to these challenges.

3.3 Study Population

The target population was secondary schools in Kakamega County since they were considered centres of heavy waste generation with potential for biogas production as well as high health risks to the environment. They are also heavy consumers of wood fuel. In this study, each school was viewed as a single entity and treated as a unit of observation (Table 3.1). The respondents included school principals, deputy principals, boarding/senior teachers, teachers, school bursars, head cooks, school prefects, selected students, members of the Board of Management (BOM) and Parents Association (PA). Other units of analysis included the sewage systems, toilets, and kitchens, energy sources such as biogas plants, electricitysupplyand water points. Information was also obtained from stakeholders such as local leaders and relevant officers in, County Governor's office, County Director of Education office, Kenya Forest Service, Ministry of Energy and Public Health and NEMA officers.

At the time of the study, there were three hundred and three (321) public and thirteen (13) private secondary schools in Kakamega County with a total student population of 73, 220 (Table 3.1). Of these, 36, 844 and 36, 376 were Boys and Girls, respectively (GOK, 2012).

Table 3. 1: Kakamega County Public Secondary Schools Enrolment Summary 2012

KAKAMEGA COUNTY PUBLIC SECONDARY SCHOOL ENROLMENT SUMMARY PER DISTRICT 2012											
SUB-COUNTY	**FORM ONE**		**FORM TWO**		**FORM THREE**		**FORM FOUR**		**SUB- TOTAL**		**GRAND TOTAL**
	BOYS	**GIRLS**	**BOYS**	**GIRLS**	**BOYS**	**GIRLS**	**BOYS**	**GIRLS**	**BOYS**	**GIRLS**	
KAKAMEGA C.	858	1034	921	956	896	874	806	743	3481	3607	**7088**
LUGARI	1017	1142	1042	1118	949	1051	730	815	3738	4126	**7864**
BUTERE									3709	3866	**7575**
KAKAMEGA N.	1498	1479	1567	1470	1629	1358	1327	1116	6021	5423	**11444**
KAKAMEGA S.	1139	1301	1153	1195	1083	987	910	814	4285	4297	**8582**
KAKAMEGA E.	1656	1723	1694	1730	1488	1508	1271	1328	6109	6289	**12398**
MUMIAS											
MATETE	656	454	680	440	685	465	537	302	2558	1661	**4219**
KHWISERO	684	709	613	651	586	625	536	372	2419	2357	**4776**
MATUNGU	977	910	1001	946	1929	944	816	1801	4723	4601	**9324**
LIKUYANI	1009	1167	877	1116	834	961	790	771	3510	4015	**7525**
NAVAKHOLO											**7433**
TOTAL	**9494**	**9919**	**9548**	**9622**	**10079**	**8773**	**7723**	**8062**	**36844**	**36376**	**73220**

Source: GOK (2012)

There was a trend of increasing student enrolment in the secondary schools in the county from 2002 to 2011, (Table 3.2).

Table 3. 2: Secondary schools enrolment trends from 2002-2011

Year	Boys	Girls	Total	Increase	% Increase
2002	49401	48831	98232	-	-
2003	53558	55945	109503	11271	11.47
2004	60439	57787	118226	8723	7.97
2005	64141	55662	119803	1577	1.33
2006	71397	65856	137253	17450	14.57
2007	74497	68694	143191	5938	4.33
2008	100738	85037	185775	42584	29.74
2009	108085	95127	203212	17437	9.39
2010	72117	65182	137299	-65913	-32.44
2011	123090	114309	237399	100100	72.91

Source: GOK (2012)

3.4 Research Designs

The study employed a cross-section survey design for objective (i), experimental for objective (ii), correlational for objective (iii) and evaluative design for objective (iv). A co-relational research design was used to interpret the degree to which the variables tend to relate to each other and allow determination of the potential of anaerobic digestion of sewage biogas for energy generation and environmental protection.

Table 3.3 gives the matrix of specific objectives, study variables and research design.

Table 3. 3: Summary matrix of specific objectives, study variables and research design

Specific Objectives	Variables /Indicators	Research Design
i).To determine the quantity of sewage generated in secondary schools for potential energy generation in Kakamega county, Kenya	-sewers/pit latrine capacities -exhauster frequencies & quantity -student population -school sessions	-Cross-sectional survey
ii).To examine the potential environmental impact of chemical and microbial characteristics of sewage generated in secondary schools in Kakamega county, Kenya.	-Total coliforms -Heavy metals -Mineral composition	- Experimental
iii).To determine the potential economic and environmental benefits of anaerobic digestion of sewage in secondary schools of Kakamega county, Kenya.	-No. of sewer biogas plants -quantity of wood fuel present -wood fuel bills -effluents into the environment -sewage disposal costs	-Co-relational
iv).To evaluate the enhancement strategies in secondary schools for anaerobic digestion of sewage for energy generation and environmental protection in Kakamega county, Kenya.	-NEMA institution -legal policy framework -school routine programmes -conservation education programme	-Evaluative

Source: Researcher (2013)

3.5 Sampling Strategy

Trochim (2008) defines sampling as the process of selecting representative units such as people and organisations from an entire population of interest. This allows for fair generalization using the sample. Various methods of sampling were used in this study. According to Mugenda & Mugenda (1999), purposive sampling allows a researcher to use cases with the required information with respect to the objectives of the study. Population units purposively sampled included the sewage systems, kitchens, energy sources such as solar panels, biogas plants, electricity, water points and waste.

Multistage/cluster sampling was used to select both public and private secondary schools in the county. The schools categorized as private, extra-county, county and sub-county were randomly obtained by utilising a sample frame from the county education office. These schools formed the units of analysis. Key informants within the schools were the principals, their deputies, senior or boarding teachers, school bursars, nurses, head cooks and one member of the Board of Management (BOM). These key informants were selected purposively. Proportions were used to randomly pick the teachers and the students in the selected schools. Other key informants were stakeholders from organisations such as National Environment Management Authority (NEMA), Ministries of Education, Health, Energy& Petroleum, Environment and Natural Resources (Kenya Forest Services) from whom representatives of Focus Group Discussions (FGD) were sourced (Table 3.4).

Table 3. 4: Sampling Strategy for the study of Sewage Utilisation Potential for energy production

Study Population	Sampling Method	Sample Size	Instrument	Appendix No.
-Schools	-Random	75	Observation. check list	VIII
-Principals		75		III
-Deputy Principals		75		IV
-Senior/Boarding teachers		75	Interview	VI
-School Bursars	-Purposive	75		VII
-Observation schedule rep		14	Observational check list	VIII
-school nurse		75	Interview	VIII
-school head cook		75		VIII

-Teachers	Random	400	Questionnaire	VI
-Students		400		IX
-Ministry of Education Officers	Purposive	3	Interview	X
-Public Health Officers		3		X
-Ministry of Energy Officers		3		X
-NEMA		3		X
-KFS		3		X
-FGD reps.	-Quota	10	-FGD guide	X

Source: Researcher(2013)

A formula for estimation of sample size for random multistage sampling without replacement in a survey given below was used to estimate the sample size of the study (Nassiuma, 2000).This formula was used to get the cluster random sample size of the sampled schools as shown below:

$$n = \frac{n^1 N}{(N-1) + n^1} \qquad \textbf{\textit{(Equation 3.1)}}$$

Where $n =$ Sample size for random sampling without replacement.

$N =$ Population size of the secondary schools

$n^1 =$ Sample size estimated for simple random sampling without replacement.

But, n^1 is given by the formula,

$$n^1 = \left[\left(\frac{Z \frac{\alpha}{2}}{d^2} \right) \right] P(1-P) \qquad \textbf{\textit{(Equation 3.2)}}$$

Where, $Z\frac{\alpha}{2}$ = the degree of confidence taken as 1.96 at 95% confidence level

d = degree of accuracy taken as 0.05

P = variability of characteristics to be measured in the population taken as 10%

This formula is based on the Coefficient of Variation (C.V.) of a population. The CV tends to remain stable over time and with increasing population making it a reliable measure. The formula is, hence, appropriate for use in determination of sample size (Nassiuma, 2000).

By substituting in the formula:

$$n = \frac{n^1 N}{(N-1)+n^1} \quad \textbf{\textit{(Equation 3.1)}}$$

$$n^1 = \left[\left(\frac{Z\frac{\alpha}{2}}{d^2}\right)\right]P(1-P) \quad \textbf{\textit{(Equation 3.2)}}$$

By substituting in the formula (Equation 3.2): $n^1 = \left[\frac{1.96}{(0.05)^2}\right]\times 0.1(1-0.1)$

$= 70.56$

By substituting in the formula (Equation 3.1): $n = \frac{n^1 N}{(N-1)+n^1}$

$n = \frac{[70.56\times 321]}{(321-1)+70.56}$ =58 schools in cluster random sample.

The study took into account the possible non-response and therefore chose a higher proportion of the research population asthe sample to overcome this problem. This was done by estimating the percentage expected to respond, and then dividing the base sample size by the percentage of response (Watson, 2001).The base sample size is the number of responses a researcher must get back after conducting a survey. The researcher further took into consideration the method of survey used and the population involved. Besides, direct and multiple contacts with the population that would be interested in the issues of the study were done so as to increase the response rate.

The rates of response in previous similar surveys were also considered. In a previous study (Barasa, 2013), 97.42% of the school population surveyed responded. This study therefore used a response rate of 97%. According to Watson (2001), the new sample size was 60 secondary schools (58/0.97). Therefore, the final sample size was 75 schools due to non-responsiveness. This represented 23% of the target population which is considered acceptable (Watson, 2001).

The following Fischer's formula (2004) was used to calculate the cluster random

sample size of respondents: $n - \frac{Z^2 pq}{d^2}$ ***(Equation 3.3)***

Where, n = the desired sample size (no. of respondents) if the target is more than 10, 000.

Z = the standard normal deviate at the required confidence level (95 %) or Z= 1.96.

p = the proportion in the target population estimated to have the characteristics being investigated in this study = 0.5

q = 1-p = 0.5

d = the level of statistical significance required for level of precision (0.05).

By substituting in the formula (Equation 3.3): $n = \frac{Z^2 pq}{d^2}$

$$n = \frac{[(1.96^2)(0.5)(0.5)]}{(0,05^2)}$$ = 384.16 respondents (Students).

To the nearest whole number this translates to 384 respondents.Due to non-responsiveness and damage of some questionnaires 400 respondents were used for this study. The sample size and respective responses were as indicated in Table 3.5.

Table 3. 5: Estimation of respondents sample size for random multistage sampling

Respondents	**Size**	**Response**	**Response rate (%)**
Principals/D. Principals	75	68	90.67
Members of BOM	75	67	89.33
Teachers	400	370	92.5
Non-teaching staff	75	71	94.67
Students	400	395	98.75
Religious leaders	14	13	92.86

Source: Researcher(2013)

3.6 Data Collection Instruments

Data was collectedthrough use of Key InformantInterviews (Appendix III-V). Besides,questionnaires (Appendices VI-IX),Focused Group Discussions (Appendix X), ObservationCheck list (Appendix XI),document content analysis and digital camera were employed in their respective areas to collect both primary and secondary data.

3.6.1 Primary Data

Primary data were personally collected by the researcher through ObservationChecklist (OC), Key Informant Interviews ((KIIs), questionnaires and digital camera.

3.6.1.1 Key Informants Interviews (KIIs)

Key Informants Interviews (KIIs) were administered to stakeholdersfrom the Public Health, KFS, NEMA, WRMA, Ministry of Education and Energy, and school Boards of Management,(Appendices III-V).An interview schedule was used to conduct a set of the oral questions during the interview. The respondents answered identical questions. The interviewer only recorded the answers from the respondents. Before the interview, the interviewer gained a rapport or established a friendly and secure relationship with the subject or respondent. This revealed certain types of confidential information that the respondent was reluctant to put in writing. Because of limitations of resources and its conduct taking more time, the interview was applied to key informants who constituted a small sample. Key informants availed qualitative information. Participation was done at individual level to maintain confidentiality and to control bias among the respondents.

Key Informants interviews were used to solicit information that was addressing the issue of energy in the schools. This research was carried out by a core team which travelled to all of the target institutions in Kakamega County. The core team consisted of the principal researcher and threeassistants. Theprincipal researcher played an important interventionary role during this non-structured interview.

3.6.1.2 Questionnaires

Questionnaires used both closed and open-ended set of questions. In open-ended questionnaires the respondents used their own words to answer questions, whereas in closed-ended questionnaires prewritten response categories were provided. The questionnaires (Appendices II-IX),were self-administered whereby the respondents filled on their own in the absence of the researcher. This quantitative research was employed to collect primary data at the school level through school survey (Table 3.4).The questionnaires sought accurate information that formed the data which wasprocessed and analyzed. This provided the results which proved whether the objectives had been achieved or not.

3.6.1.3 Focus Group Discussions (FGD)

The FGD session was held in Kakamega town at Sunstar Hotel as shown on Plate 3.1. The FGD comprised of 10 participants selected purposively from key stakeholder organisations notably Public Health, KFS, NEMA, WRMA, Ministry of Education and Energy, School principals and members of BOM. FGDs help to gather information that is overlooked by questionnaires and allow shy respondents to communicate their concerns, Mukhovi (2009). All participants of the FGD were formally and informally notified in advance about the purpose of the discussion. The outcome of the discussion was given purely on consensus agreement about potentials of anaerobic digestion of sewage for energy production and environmental protection in secondary schools of Kakamega County. Plate 3.1 shows part of the discussion session.

Plate 3. 1: FGD session at Sunstar Hotel in Kakamega town

3.6.1.4 Observation Checklist (OC)

Observational studies were carried out using OC (Appendix XI) to find out the status of toilets, water source and kitchens. Events such as collapsed toilets, exposed manholes and stacks of wood fuel in schools were collected using digital cameras. In some areas, a direct observation approach was employed to source information from schools involved in sewage biogas production and those experiencing health risks.

Research assistants were trained in data collection techniques. They particularly assisted in the collection of sewage samples and issuing of questionnaires to students under the researcher's supervision. Both structured and unstructured questions were used to measure objectivity and subjectivity of the responses. Dialogue sessions were organised with the members of Board of Management and Parents Teachers Association members, officers in the Ministry of Energy, Forestry, Health and local leaders. This helped to evaluate the incidences and prevalence of public health risks and energy requirements in the sampled areas.

The quantity of sewage was determined through determined volumes in cubic metres. Thus, the depth, length and breadth of the sewers and pit latrines of the sampled schools were first predetermined. For the quality of sewage, samples of sewage were collected and taken to WRMA and Bora laboratories for the analysis of microbes, organic nutrients and heavy metals.

3.6.2 Secondary Data

Secondary data was used by the researcher to supplement the primary data collected. This is because of the high costs associated with collecting primary data. Document analysis was used by the researcher to corroborate various responses in the study. The response enhanced formulation of useful recommendations to the study. The secondary data that was reviewed includedjournals, publications online, reports and statistics from the government ministries such as education, energy and Healthand disaster management in Kenya. Besides, Education office surveyswere used to collect secondary data comprising of the schools in Kakamega County andtheir student population.

3.7 Reliability and Validity of Research Instruments

The researcher measured the quality of the research instruments through testing their reliability and validity. These are very pertinent for this quantitative type of research.

3.7.1 Validity

Validity of the instruments is concerned with the extent to which an instrument actually measures what it is intended to measure (Lovell and Lawson, 1970). This study limited itself to content validity and face validity. Content validity focused on the degree to which the instruments fully assess or measure the construct of interest. Face validity is a component of content validity. It was established after reviewing the instruments and concluding that they measured the characteristics or traits of interest.

According to Ruxton and Colegrave (2006) a pilot or pretest study is a small experiment designed to test logistics and gather general information prior to a larger study in order to improve the latter's quality and efficiency. The pilot study thus, revealed deficiencies in the design of a proposed questionnaire or procedure including the clarity of language. Such deficiencies were addressed by the supervisors who scrutinized their suitability against the set objectives. The researcher then incorporated their comments before embarking on the main study. To ensure further validity, the research assistants underwent some training and were involved in testing the reliability of the research instruments.

Theinstruments of the pilot study were assessed by the professionals especially the supervisors to identify weaknesses such as inaccurate responses and any other inconsistencies so as to ensure content and face validity. The instruments were modified accordingly and final validation was done by the supervisors. Attempts to ensure the validity of research results were taken into consideration by controlling extraneous variables that would affect the sampled schools and put them into consideration when interpreting results.

Face, construct and content validity of research instruments were assessed by subject experts from the Centre for Disaster Management and Humanitarian Assistance of Masinde Muliro University of Science and Technology. Findings of the pilot study helped in re-writing the questions and making necessary adjustments in the research instruments. Advice was sought from these experts before going to the field to carry out the pilot study. Further verification was done during pilot study. The suggestions and advice offered were used to modify the research instruments to make them more adaptable to the study.

3.7.2 Reliability

Reliability is a measure of the degree to which a research instrument yields consistent data or results or data after repeated trials (Mugenda & Mugenda, 1999). To test the reliability of instruments, the researcher used the test–retest method. Test-retest method was used to establish the correlation coefficient. A pilot study population was subjected to data collection instruments at different times within a period of two weeks. Inadequate variables were modified or discarded to improve the consistency of the items. The pretest schools were not used in the data collection.

For the purpose of pilot study, eight (8) schools in a neighbouring County that was not sampled for the study were used. This represented 10% of the target population.Reliability of instruments was ascertained using results of the pre-test study from respondents who were involved in the study population but were not included in the study sample. The results from the pre-test study were used to calculate Pearson Product Moment Correlation Coefficient. Pearson Product Moment Correlation Coefficient of 0.7 was used for the purpose of calculating the reliability score as well training of the research assistants. Thus, the formula given below was used:

$$r = \frac{N\sum XY}{\sqrt{\left(\left[\left(N\sum X^2\right)-\left(\sum X^2\right)\right]\left[\left(N\sum Y^2\right)-\left(\sum Y^2\right)\right]\right)}}$$

(***Equation 3.4***).

If r ≥ 0.7, then the instrumentis reliable for use and if the correlation coefficient r<0.7 then the instruments are not the correct tools for data collection. Therefore, there will be need to modify them to improve on their reliability. The pre-test were not included in the main data collection.

Reliability of the instruments was established by test-retest method during the pilot study. Pearson Product Moment Correlation Coefficient of 0.5 was used for the purpose of calculating the reliability score. Table 3.6 shows the results of the pilot study to test reliability of research instruments.

Table 3. 6: Results of pilot study to test reliability of research instruments

Student	X	Y	X^2	Y^2	XY
1a	64	56	4096	3136	3584
1b	63	71	3969	5041	4473
1c	81	73	6561	5329	5913
1d	62	72	3844	5184	4464
2a	65	73	4225	5329	4745
2b	72	75	5184	5625	5400
2c	76	70	5776	4900	5320
2d	70	66	4900	4356	4620
3a	79	60	6241	3600	4740
3b	65	75	4225	5625	4875
3c	68	71	4624	5041	4828
3d	75	67	5625	4489	5025
4a	81	72	6561	5184	5832
4b	80	75	6400	5625	6000
4c	78	72	6084	5184	5616
4d	77	67	5929	4489	5159
N=16	**∑X=1156**	**∑Y=1115**	**$\sum X^2$=84244**	**$\sum Y^2$=78137**	**∑XY=80594**

$$r = \frac{N\sum XY}{\sqrt{\left(\left[\left(N\sum X^2\right) - \left(\sum X^2\right)\right]\left[\left(N\sum Y^2\right) - \left(\sum Y^2\right)\right]\right)}}$$

$$r = \frac{16 \times 80594}{\sqrt{\left(\left[(16 \times 84244) - (84244)\right] \times \left[(16 \times 78137) - (78137)\right]\right)}}$$

$$= \frac{1289504}{\sqrt{\left([1347904 - 84244] \times [1250192 - 78137]\right)}}$$

$$= \frac{1289504}{\sqrt{1263660 \times 1172055}}$$

$$= \frac{1289504}{1216995.9}$$

$$= 1.0595796$$

$$r = 1.0595796$$

Since r> 0.5, the research instruments are reliable hence acceptable.

3.8 Ethical Considerations

According to Mugenda and Mugenda(1999) ethical considerations are important for any research issues including proper conduct of the researcher during the research process, avoidance of plagiarism and fraud. Confidentiality and privacy of the information obtained from the respondent is crucial. The study was conducted with ethical requirements as stipulated by all relevant Government Ministries as volunteer and informed consent from the respondents and dissemination of the findings wereall adhered to. Ethical authorisations were sought from the National Commissionof Science,Technologyand Innovation (NACOSTI) which provided a research permit (Appendix XIII).Considerations such as non-intrusive methods at various levels either by question or procedure that would embarrass the respondents were avoided. Personal data were collected, handled and stored with confidentiality and wereonlyused for this study.The respondents adhered to freedom of expression of ideas and consensus during data collection.

3.9Laboratory Procedures

Various materials and methods were used to investigate different parameters in the study. The parameters included Total Kjeldal Nitrogen, Total Phosphate (Total P_2O_5), heavy metals, pH, and microbial characteristics of the sewage.

3.9.1 Total Kjeldal Nitrogen (TKN)

1.0g sample was digested in 10ml H_2SO_4, distilled with 20ml NaOH into a flask containing boric acid and titrated with sulphuric acid to a violet end point (Koopmann, 2008a).

3.9.2 Total Phosphate (Total P_2O_5)

3.0 g sample was weighed and moistened with 1 ml water, swirled with 21 ml of hydrochloric acid followed by 7 ml of nitric acid plus boiling aids and heated for 2 hours, allowed to cool, filtered and phosphorus measured by ICP-OES (Koopmann, 2008b).

3.9.3 Heavy Metals Analysis in Sewage

1.0g of sample was digested with 20.0 ml nitric acid (1:1), heated at 120^oC for 30 minutes, cooled, filtered and the metals determined by Inductive Couple Plasma

Atomic Emission Spectrum (ICP-AES) at 226.502 nm for Cd and 220.353nm for Pb, (Aziz and Salif 2012).

3.9.4 Analysis of Heavy Metals in Water and Sewage Samples

Water and sewage samples were submitted to Bora biotech laboratories, Nairobi for analysis of copper and lead in water as described in standard methods of examination of water and waste water by the American Public Health Association (2005). Analysis of copper and lead was by atomic absorption (220.2) and (239.1), respectively using atomic absorption spectrophotometer (Shimadzu AA/6300 serial number A30524300923).

3.9.5 Microbiological Analysis

The sampling strategyemployedfor microbiological analysis of the waste and the surrounding water sources was as detailed in Table 3.7. The latrines that had been exhausted/emptied within two (2) weeks were used as the focal points for sampling the boreholes, springs and watering points of rivers found within a radius of 500 meters. In comparison, additional samples for latrines emptied more than 4 weeks and beyond a radius of 600m were also picked.

Table 3. 7: Microbiological analysis of the waste and the surrounding water sources

Source	N	Type of sample	Method of sampling	Number of samples
Anaerobic Digester	2	Raw sewage	Sampling bottle	6
	2	Sewage digestate	Sampling bottle	6
Borehole	6	Water	Pump or bucket	18
Latrines	10	Slurry (mixture of urine and fecal matter	Sampling bottle	30
River	2	Water	Sampling bottle	6

Septic Tank	2	water	Sampling bottle	10
Spring	10	water	Sampling bottle	30

Source: *Researcher (2013*)

Microbiological analysis of the samples was done within 24 hours after sampling. Microorganisms included in the study were: total coliforms, *E. coli*, Giardia and Cryptosporidium. A sample volume of 100 ml (in case of sewage, 0.1ml of either raw sewage or digestate in 99.9 ml of peptone saline -PS: 0.1 % peptone in 0.09 % saline) was passed through a membrane filter with a pore size of 0.45 µm, gridded, type HA, (Millipore Corp., Bedford, Mass.) to retain the microbes present in the sample. The filters were then transferred to M-Endo medium (Difco) and incubated at 35 °C± 0.5°C for 24 hours. Pink to dark red with a green metallic surface sheen colonies were counted. Colony Forming Units (C.F.U) was calculated as:

CFU/ml of original sample = No. of Colonies/ Inoculum size (ml) x Dilution Factor

Giardia and Cryptosporidium were concentrated in the samples by membrane filtration, (00) cysts separated from debris and other microorganisms with gradient centrifugation and finally enumerated by direct microscopy after staining with fluorescein isothiocyanate (FITC) according to the US EPA (2001).

3.9.6Estimation of Energy Equivalent

Data on wood fuel consumption forvarious schools were collected based on the interview, questionnaires and observation checklist. These data were used to establish the quantity of wood fuel consumed in schools. The assumptions made in the computation energy equivalence parameters included wood consumed in schools, energy derived from wood, amount of biogas from human waste, bioenergy (energy derived from biogas) and the estimated efficiency of the modern energy saving stoves used in secondary schools are presented in Table 3.8.

Table 3. 8: Computation of Energy equivalence parameters

Parameter	Estimated value	Reference
Human waste (Faecal matter)	0.3kg/person/day	TA (2011)
Wood consumption	0.524kg/student/day	Nyambane et al. (2014)
Energy from wood MJ/kg	20MJ/kg dry wood	Munalula et al. (2008)
Biogas from human waste	$0.028m^3$/student/day	GTZ(2010)
Energy from biogas (Bioenergy)	$30MJ/m^3$	GTZ(2010)
Stove efficiency	70%	GTZ(2010)
Carbon equivalence	1.83 kg of carbon/kg wood	IPCC (1996)
Biogas (m^3):wood fuel (kg) equivalence	5.5 kg	Kossmann et al. (1999)

Source: Researcher(2014)

Student population was used to compute the amount of wood required in schools based on the estimates by Nyambane et al. (2014). According to the authors, it is estimated that a student in secondary school consumes an average of 0.524 kg of wood fuel daily irrespective of the combustion device used for cooking, school type and number or types of meals cooked. Based on the predominant tree type (Eucalyptus) used for firewood, the energy equivalence for wood was computed as 20 MJ/kg of wood (Munalula and Meincken, 2008). The amount of combustible biogas was derived according to Martin (2007)from formula: $1m^3$ waste = 0.7 m^3 methane and finally the energy equivalence of combustible methane as 1 m^3 Methane = 20.00 MJ/m^3.

3.9.7Carbon Equivalence for Economic Estimation

Carbon sequestration described as long-term storage of carbon dioxide or other forms of carbon to either mitigate or defer global warming and avoid dangerous climate change was used to estimate the deferred CO_2 emission that would arise from use of fuel wood. Accordingly, the computation by IPCC (1996) was adopted. This states that 1kg fuel Wood emits =1.83 kg of CO_2.

3.10 Assumptions

The study assumed that:

i. The respondents in this study had sufficient knowledge about the sewage, environment, green energy and health hazards.
ii. The respondents in this study had would provide independent and honest views when responding to the questionnaires and interviews.
iii. The improved stove used in schools are 75% efficient.
iv. The wood density for eucalyptus is about $0.75kg/m^3$
v. The DM in wood that burns is 90% when sun dried.
vi. Students in Day schools spent half of their time in school
vii. Half of the students in Boarding & Dayschools spent half of the school academic days at home and half at school.

Assumptions VI and VII were used in computing the amount of sewage in the schools.

3.11 Limitations

Kakamega County has twelve (12) sub-counties, twelve(12) constituencies,twenty four (24) divisions, seventy two (72) locations, two hundred and thirty three (233) sub-locations, three hundred and twenty one (321)secondary schools. As such the following was the study limitations:

i. Data collection from all these schools was not possible due to limited time. However, this limitation was overcome by use of census sampling method to sample national schools. Multistage random sampling was used to sample extra-county, county, district and private schools in bid to ensure equal representation of schools. In each of these categories, random sampling was used to pick the schools that were used in the study. Purposive sampling was used on key informants and the FGD representatives.

ii. The methods of evaluation may not be very comprehensive and exhaustive as in summative evaluation. As such, intensive questions as well as exhaustive guidelines for observation checklists, structured interviews and discussions were developed to ensure that these instruments captured the details pertinent to the study.

3.12 Data Analysis and Presentation

Analysis is the computation of certain measures along with searching for patterns that exist among data groups (Kothari, 2004). In this study, the researcher edited coded, analysed, interpreted and presented data. Raw data was classified into purposeful and usable categories. Coded data were then subjected to descriptive analysis and Chi-square test for correlation analysis. Data was then transcribed, summarised and transformed into symbols and appropriately presented in tables, and bar graphs.

Microsoft excel was used for data management. Anova was used for the analysis of the means. Separation of means was done by Least Square Difference (LSD) based on the Bonferroni principles. Bonferroni method was used since the data had unequal sample sizes and also for ease of understanding. Chi-square was used to give the magnitude of difference and show association between the variables. Measures of spread were used to obtain the variability of spread between the levels of environmental protection in secondary schools with their respective quantities of sewage generated and the wood fuel consumed. Table 3.9 gives a summary of the data analysis methods.

Table 3. 9: Data Analysis Methods for Anaerobic Digestion of Sewage for Energy Production and Environmental Protection

Specific Objectives	Variables/Indicators	Research Design	Data Analysis Methods
i).To determine the quantity of sewage generated in secondary schools for potential energy generation in Kakamega County, Kenya**.**	-sewers/pit latrine capacities -exhauster frequencies -student population -school sessions	-Cross-sectional survey	-Cross-tabulation -Chi-square test -Descriptive
ii).To examine the potential environmental impact of chemical and microbial characteristics of sewage generated in secondary schools of Kakamega County, Kenya.	-Total coliforms -Heavy metals -Mineral composition	-Experimental	-Chi-square -Descriptive
iii).To determine the economic and environmental benefits of anaerobic digestion of sewage energy generation in secondary schools of Kakamega	-biogas plants from sewers -quantity of wood fuel -sewage disposal sites	-Correlational	-Descriptive -Chi-square

County, Kenya.	-effluents		
iv).To evaluate the enhancement strategies available in secondary schools for anaerobic digestion of sewage for energy generation and environmental protection in Kakamega County, Kenya.	-NEMA institution -Legal and Policy framework -Conservation programme	-Evaluative	-Descriptive -Chi-square

CHAPTER FOUR

QUANTITY OF SEWAGE GENERATED IN SECONDARY SCHOOLS FOR POTENTIAL ENERGY GENERATION IN KAKAMEGA COUNTY, KENYA

4.1 Introduction

This chapter discusses the results of the first specific objective and its respective research question. The objective was to determine the quantity of sewage generated in secondary schools for potential energy generation in Kakamega County, Kenya. The discussion involves the possible reasons why these results occurred and their implications. The findings are fitted in the context of the previous researches in the light of the literature review. To achieve this objective,data from sampled schools were used to obtain the averages of the respective school categories. The school categories comprised of Boarding, Boarding & Dayand Day schools.

Section 4.2 deals with school enrolment characteristics as section 4.3 deals with schools' disposal systems. Section 4.4 deals with methods used to empty septic tanks. Section 4.5 deals with the quantity of sewage generated in secondary schools for potential energy generation. The results are beefed up with information from FGDs, key informants, observations by the researcher and interviews with various respondents.

4.2 School Enrolment Characteristics

The school enrolment helped to establish the student population in the various sampled schools. This was an important parameter that helped determine the quantity of sewage in the respective school categories from the sampled schools, Figures 4.1.

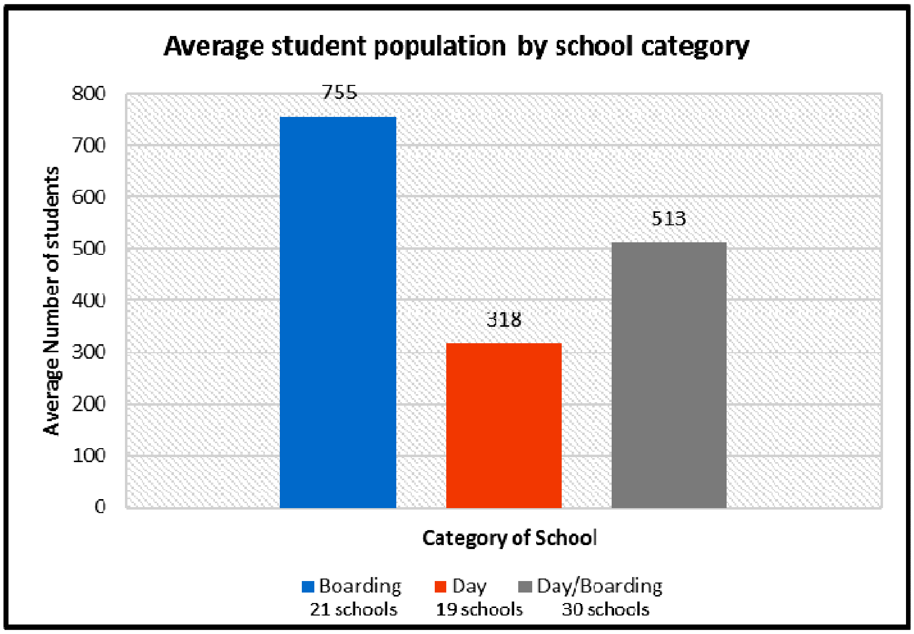


Figure 4. 1: Average student population by school category

A Chi Square test conducted on the data showed that there was a highly significant (P<0.01) variation in the responses ($\chi^2_{2,0.01} = 181.3$).

As presented in Figure 4.1, it was established that boarding schools had the highest mean student population of 755 (47.60% of the analysed student population) followed by Boarding & Day schools with a mean student population of 513 (32.35%). The least populated schools were the day schools with a mean population of 318 (20.05%). Analysis of variance indicated that the difference in student population was statistically significant (p<0.05) between all the three categories.

4.5 Quantity of Sewage Generated in Secondary Schools for Energy Generation

The quantity of human waste generated from different categories of schools was determined using the dimensions of the disposal systems in the respective schools and the frequency of getting filled up and emptying them. The total quantity of human waste generated isper school academic year of 273 days. The results were as presented in Figure 4.2.

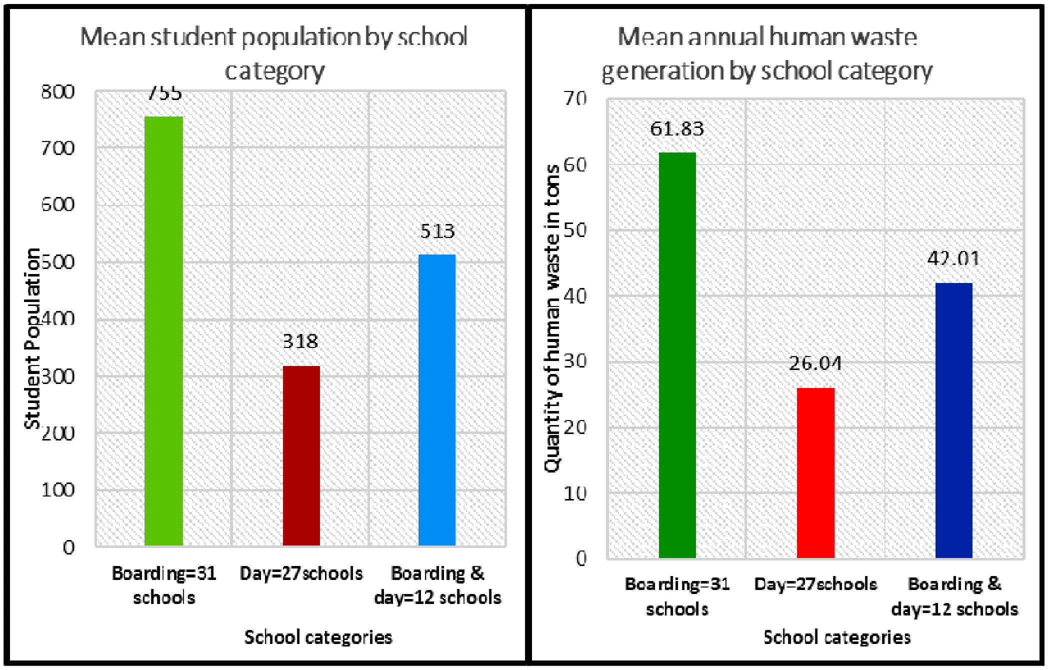


Figure 4. 2: Comparison of student population and human waste generation

A Chi Square test conducted on the data showed that there was a highly significant ($P<0.01$) variation in the quantity of human waste generated by the three categories of schools ($\chi^2_{2,0.01} = 14.85$).

The results show that boarding schools with a higher mean population of 755 students have the highest human waste generation of 61.83 tons(47.60% of the analysed human waste) per school academic year (39 weeks=273 days). This translates to 0.3kg of human waste production per student per day. They are followed by boarding&day schools that generate a mean of 42.01tons (32.35%) per school academic year. Day schools generate 26.04tons(20.05%) per school academic yearwith a mean of 43.29 tons per school per school academic year.A correlation analysis revealed that there was a highly significant correlation between student population and the quantity of human waste generated in the various school categories. A tabular correlation analysis using Graphpad prism software gave a *P* value of 0.0001 (alpha=0.05). A measured correlation coefficient (r) of 1.000 was also found to be highly significant. This implies that, Kakamega County with a total of 408 secondary schools (280 Boarding, 45 Day and 79 Boarding &Day with 116,732 students) generates 17, 662.32 tons of human waste per school academic year. This gives 43.29 tons of human waste generated per day per school.(17, 662.32/408). This translates to 0.37kg (43.29 tons/116,732 students) of human waste production per student per day.

4.3 Means of Waste Disposal Systems

The waste disposal systems were useful parameters as indicators of potential risks posed to the school and the surrounding population. Figure 4.3 presents some of the means used by schools for human waste disposal as Plate 4.1 shows some pit latrines that they used.

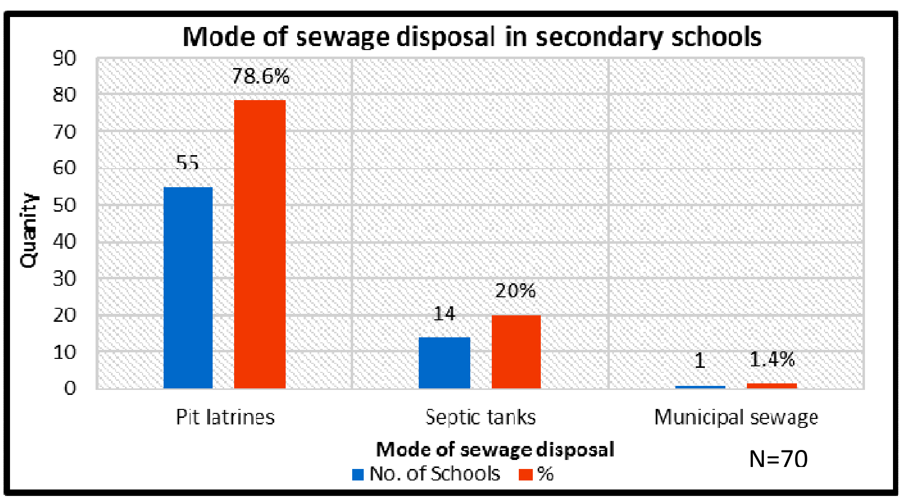


Figure 4. 3: Mode of sewage disposal in schools

Plate 4. 1: Pit Latrines used in some schools

A Chi Square test conducted on the data showed that there was a highly significant (P<0.01) variation in the mode of sewage disposal ($\chi^2_{2,0.01} = 97.39$).

As shown in Plate4.1, the dominant mode of human waste disposal system at the time of the study was pit latrines which were used by 55 schools (78.6%)out of the 70 sampled schools in Kakamega County. Out of these, 14 schools (20%)used improved systems of septic tanks and only 1school (1.4%) used piped sewerage system linked to the Municipal system.

Some of the sewage disposal systems were in a bad state as evidenced by the exposed manholes of the septic tanks, Plate 4.2.

Plate 4. 2: Septic tanks in different schools

Filled up and collapsed pit latrines were condemned since they posed serious danger to the students, Plates 4.3a and 4.3b.

Plate 4. 3a: Condemned pit latrines

Plate 4.3b: Collapsed pit latrines

4.4 Managementof the Disposal Systems

Schools had various means of managing their disposal systems that were full of human waste. Figure 4.5 gives a summary of various means that were used by the school to manage the full disposal systems.

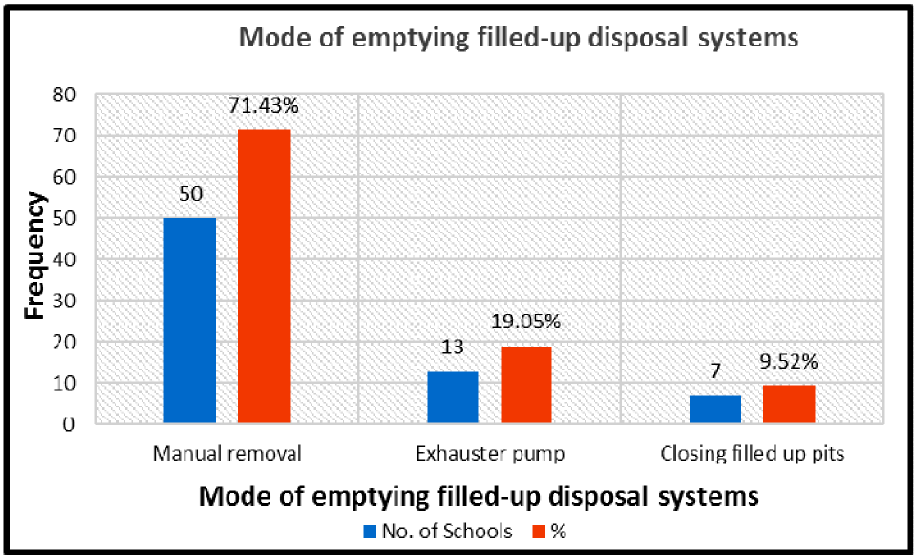


Figure 4. 4: Mode of emptying filled-up disposal systems

A Chi Square test conducted on the data showed that there was a highly significant (P<0.01) variation in the mode of emptying filled-up disposal systems ($\chi^2_{2,0.01} = 66.68$).

Schools used various means of waste disposal whenever pit latrines got filled. The predominant means of waste disposal was that of emptying them where 63(90%) of the sampled schools emptied their filled up disposal systems. The other 7 schools (10%) closed up their systems. It was established that 50 of the 70 sampled schools (71.43%) adopted manual means for emptying the pit latrines, 13 schools (19.05%) used exhauster pump for emptying, as 7 schools (9.05%) closed up the filled pit latrines and opted for digging up new ones. Plates 4.4 and 4.5 show the mechanical and manual means respectively used by some schools to empty their filled up pit latrines.

Plate 4. 4: Mechanical means of emptying pit latrines

Plate 4. 5: Manual means of emptying pit latrines

Mechanical means (municipal exhauster) of emptying the pit latrines were hired by schools at a fee. Some schools used manual means for emptying their filled up pit latrines, Plate 4.5. As evidenced from the plate, people carrying out the activity do not have any protective gear to safeguard them from the potential infections.

After emptying the pit latrines, schools were faced with the challenge of the final disposal of the faecal matter. This study established that schools used various means for the final disposal of sewage. Figure 4.5 shows the key findings.

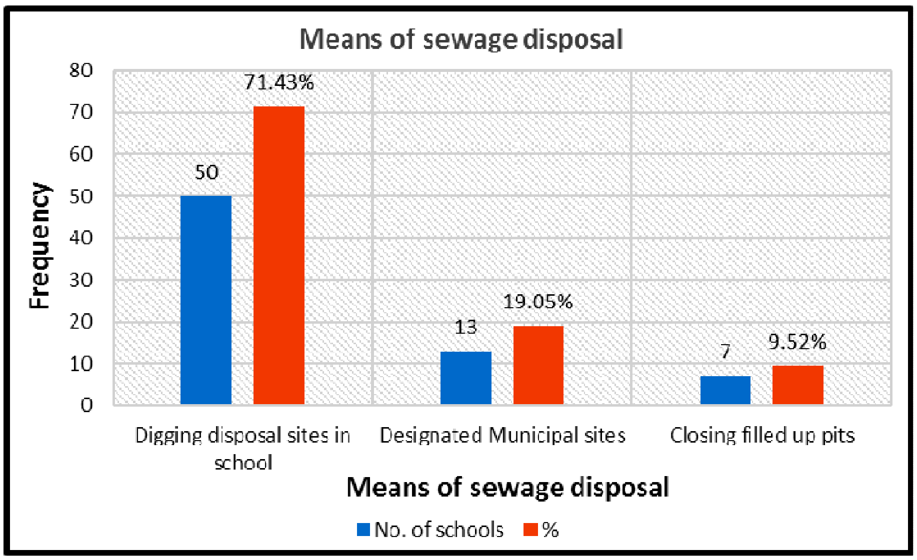


Figure 4. 5: Means of sewage disposal

A Chi Square test conducted on the data showed that there was a highly significant (P<0.01) variation in the means of sewage disposal ($\chi^2_{2,0.01} = 66.67$).

Figure 4.5 shows that 50 of the sampled schools (71.43%) disposed of their human wastes by digging up disposal sites within their school compounds, 13 schools (19.05%) disposed of their human waste at designated municipal waste disposal sites as 7 schools (9.52%) of schools disposed their wastes by closing filled up pits. This implies that majority of the schools dispose of their human waste by digging up disposal sites within their school compounds. Reasons advanced for this practice were financial constraints since hiring of mechanical means proved to be expensive to a large number of the sampled schools. Thus, it was established that schools faced some challenges during the final disposal of their sewage. The challenges were assummarised in Figure 4.6.

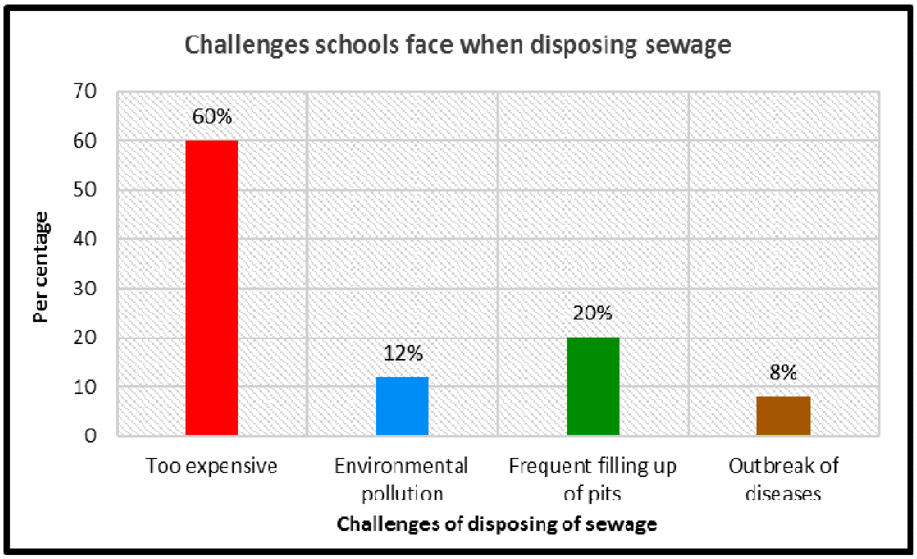


Figure 4. 6: Challenges schools face when disposing sewage

A Chi Square test conducted on the data showed that there was a highly significant (P<0.01) variation in the challenges of disposing of sewage ($\chi^2_{3,0.01} = 68.32$).

It can be seen from Figure 4.6 that during sewage disposal, schools faced different challenges that ranged from economic to health and social aspects. Of the 70 sampled schools, 42 schools(60%) found sewage disposal at designated municipal sites to be too expensive. Another 14 schools (20%) also experienced high costs through the frequent filling up of the pits with human waste;8 schools (12%) indicated that they experienced environmental hazards such as bad smell and contamination of water sources as6 schools (8%) showed that sewage disposal led to disease outbreaks.This implies that majority of the schools dug up disposal sites since they considered it cheaper than use of municipal exhauster. The challenges that schools face in sewage management have far reaching consequences especially on the environment. Schools that choose to dig up their own sewage disposal sites within their school premises ending up experiencing water-borne related cases. Besides, they face complains from the neighbouring communities due to the foul emanating from the latrine waste. This therefore calls for alternative methods of human waste disposal which some schools consider expensive. An ideal biogas digester that schools can adopt is as seen in Plate 4.6.

Plate 4. 6: Researcher at human faeces biogas digester at Kaimosi T.T.C.

CHAPTER FIVE

POTENTIAL ENVIRONMENTAL IMPACT OF CHEMICAL AND MICROBIAL CHARACTERISTICS OF THE SEWAGE GENERATED IN KAKAMEGA COUNTY, KENYA

5.1 Introduction

This chapter presents the findings of the study as guided by the specific study objective two and its research question. Section 5.2 presents a detailed examination of the potential environmental impact of chemical characteristics of the sewage generated in secondary schools in Kakamega County. Section. 5.3 deals with the potential environmental impact of microbial characteristics of the sewage generated in secondary schools in Kakamega County.

5.2.1 Potential Environmental Impact of Chemical Characteristics of the Sewage

This section presents the findings of the potential environmental impact of chemical characteristics of the sewage generated in secondary schools.The chemical parameters that were analysed included the sewage TKN, Total $P_2O_{5,}$ $_{pH}$, heavy metals, Dry Matter (DM), and nutrient content. The data analysis and interpretation reveled the following major findings as summarised in Table 5.1.

Table 5. 1: Physical-chemical characteristics of human excreta influent

Parameters	DM (%)	TKN (mg/l)	Total P_2O_5 (mg/l)	pH	Cadmium (Cd)	Lead (Pb)
Influent SE	13.8± 0.66	8.3± 0.45	1.15± 0.46	5.75± 0.13	0.0249± 0.35	0.0046± 0.34

SE: Standard Error, TKN: Total Kjeldal Nitrogen, P_2O_5: Phosphate, DM: Dry matter

The results show that the TKN in the influent is 8.30 mg/l with SE of 0.45.The total P_2O_5in the influent of the human excreta was 1.15mg/l with SE of 0.46. This finding is consistent with a previous study in Ghana (Abdul-Aziz et al, 2012).

The analysis also revealed that the DM content of the influent of human excreta is 13.80% with SE of 0.66. This finding is consistent with similar results by Vetter et al. (1987), Pfundtner (2002),Berglund(2006)and Aziz et al (2012).

The influent of human excreta had a pH value of 5.75 with SE of 0.13. The finding agrees with similar findings by Smith et al. (2007). This implies that the pH of the influent is acidic.The analysis of heavy metals in the influents of human waste revealed that cadmium (Cd) and lead (Pb) were traceable. The quantity of Cd was 0.0249 mg/l and Pb was 0.0046 mg/l. This finding is in agreement with the report by Monnet (2003) and Abdul-Aziz (2012).

5.2.2 Potential Environmental Impact of Microbial Characteristics of the Influent of Human Excreta

This section presents the findings of the potential environmental impact of microbial characteristics of the Sewage generated in secondary schools.The microbial parameters analysed were *E.coli* and faecal coliforms.

First, respondents in the school management were asked whether their schools experienced any diseases associated with sewage disposal. The responses were as given in Figure 5.1.

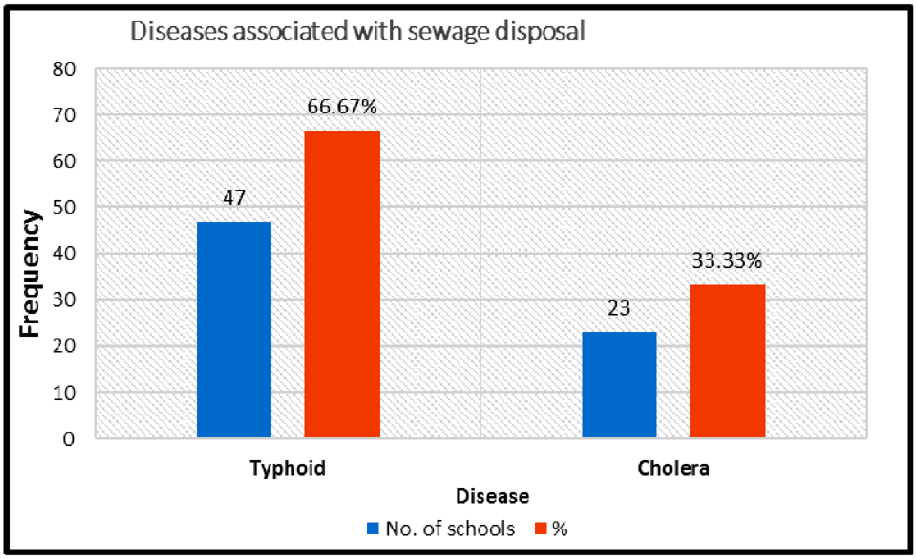


Figure 5. 1: Diseases associated with sewage disposal methods

A Chi Square test conducted on the data showed that there was a highly significant (P<0.01) variation in responses ($\chi^2_{1,0.01} = 10.46$).

Figure 5.2 shows that 47 of the 70 sampled schools (66.67%) experienced typhoid diseases and 23 schools (33.33%) experienced cholera diseases in relation to sewage disposal. This implies that majority of the sampled schools experienced many cases of typhoid compared to cholera disease.

The study then investigated the microbes present in the sewage that could be associated with these diseases. The results were as summarised in Table 5.2.

Table 5. 2: Microbes in the influent of human excreta

Parameters	*E.coli* (MPN/100mls	Faecal coliforms
Influent	390	450
WHO &NEMA	Nil	Nil

MPN: Most Probable Number, SE: Standard Error.

The content of *E.coli* in the influent was found to be 390 MPN/100mls while that of faecal coliforms was 450 MPN/100 mls.Thus, the *E.coli* concentration was 390 times higher than the WHO and NEMA standard levels (nil). Faecal coliform concentrations were 450 times higher than the WHO and NEMA standard levels (nil). Faecal coliforms are indicators of contamination. This means that the microbes in generated sewage in secondary schools could pose a health risk to the environment and human beings.

The study also sought to find out the possible impact of the underground sewage seepage on the water sources in the schools and their environs. In single pit latrines that are mostly used here, the main hazard is caused by underground contamination of groundwater that finally reaches the nearby water sources. If water from such sources is consumed by humans then the pathogens find their way into human congestion. The movement of protozoa and cysts and helminthes ova can be expected to be very limited because of their size.

Therefore, the study further sought to find out an association between the bio-chemical parameters in the school environs during the wet season and typhoid as well as cholera as reported in the schools. The findings were as summarised in Table 5.3.

Table 5. 3: Bio-chemical parameters in school environs

	Source of sample	**pH**	**Copper (mg/l)**	**Lead (mg/l)**	**Mercury (mg/l)**	***E. coli* (MPN/100mls)**	**Faecal coliforms(MPN/100 mls)**
1	**Borehole**	6.9	0.02	0.01	0.0	0.0	0.0
2	**River Lusumu**	6.4	**1.1**	**0.09**	0.0	125	195
3	**Sewage discharge point**	6.1	0.09	**0.07**	0.1	238	330
4	**Shallow wells**	6.8	0.02	**0.07**	0.006	15	390
5	**Storm water discharge point(river Isiukhu)**	7.2	**0.7**	**0.095**	0.015	320	240
6	**Tap water**	6.9	0.01	0.01	0.0	0.0	0.0
7	**WHO &NEMA STANDARD**	6.5 - 8.5	0.1	0.05	0.01	Nil	Nil

The results show that the pH at sewage discharge point was 6.1 which waslower than the WHO and NEMA standard of 6.5-8.5. This pH was 1.5 times lower than the average WHO and NEMA standard pH of 7.5. A pH of 6.1 is indicative of accumulation of acidic substances from thesewage discharge which can lead to a moreacidic medium in the environment therebyadversely affecting the general biota in the ecosystem.

The concentration of heavy metals was found to be 0.07mg/l of Lead and 0.1mg/l of Mercury. These heavy metal concentrations at the sewage discharge point were higher when compared to the WHO and NEMA standards of 0.05mg/l of Lead and 0.01mg/l of Mercury. Thus, the Lead metal concentrationwas 1.4 timeshigher than the 0.05 acceptable levels of the WHO and NEMA standards.Mercury levels were 10 times higher than the WHO and NEMA standard levels (0.01). These detected higher heavy metal concentrations exceeded WHO and NEMA concentration limits and are pointers to possible hazardous contamination by heavy metals in these school environs. As such, there is potential for the occurrence of deleterious health effects on humans and general biota in the surroundings.

The *E.coli* and faecal coliforms concentrations at the sewage discharge point were 238 MPN/100mls and 330 MPN/100mls respectively. These concentrations were 238 and 330 times higher than the WHO and NEMA standards that are nil. Water sources used by schools and the surrounding communities also experienced contamination by *E.coli* and faecal coliforms. The water sources sampled included storm water points at River Isiukhu and Lusumu, shallow wells, boreholes and tap waters. The *E.coli* in these water sources was 320 MPN/100mls, 125 MPN/100mls, 15 MPN/100mls 0.0 MPN/100mls and 0.0 MPN/100mls respectively. This is higher than the WHO and NEMA standard which is nil. This means that the *E.coli* was 320 times higher in River Isiukhu, 125 times higher in River Lusumu and 15 times higher in shallow wells than the WHO and NEMA standard levels.

The faecal coliforms concentrations in these water sources were 240 MPN/100mls, 195 MPN/100mls, 390 MPN/100mls, 0.0 MPN/100mls and 0.0 MPN/100mls. Thus, the faecal coliforms were 240 times higher in River Isiukhu, 195 times higher in River Lusumu and 390 times higher in shallow wells than the WHO and NEMA standard levels (0.0). Thus, the faecal coliform concentration is an indicator of sewage contamination of waterways and the possible presence of other pathogenic organisms implying that a potential health risk exists for individuals exposed to this water.Diseases and illnesses that can be contracted in water with high fecal coliform counts include typhoid fever, ear infections, hepatitis, gastroenteritis, and dysentery.

A study by Kiptum et al. (2012), carried out on well water contamination by pit latrines in Langas of Eldoret town, showed that most wells were contaminated and posed a health risk to the residents. The presence of toilets in the community was a probable source of contamination. However, the severity of the contamination will depend on the clay content of the soil in the region. Where the clay content is high (Southern, SW and NE parts of Kakamega County), the soil and groundwater contamination will be limited. The findings were as summarised in Table 5.3 and Figure 5.2 showing the clay content distribution in the soils of Kakamega County.

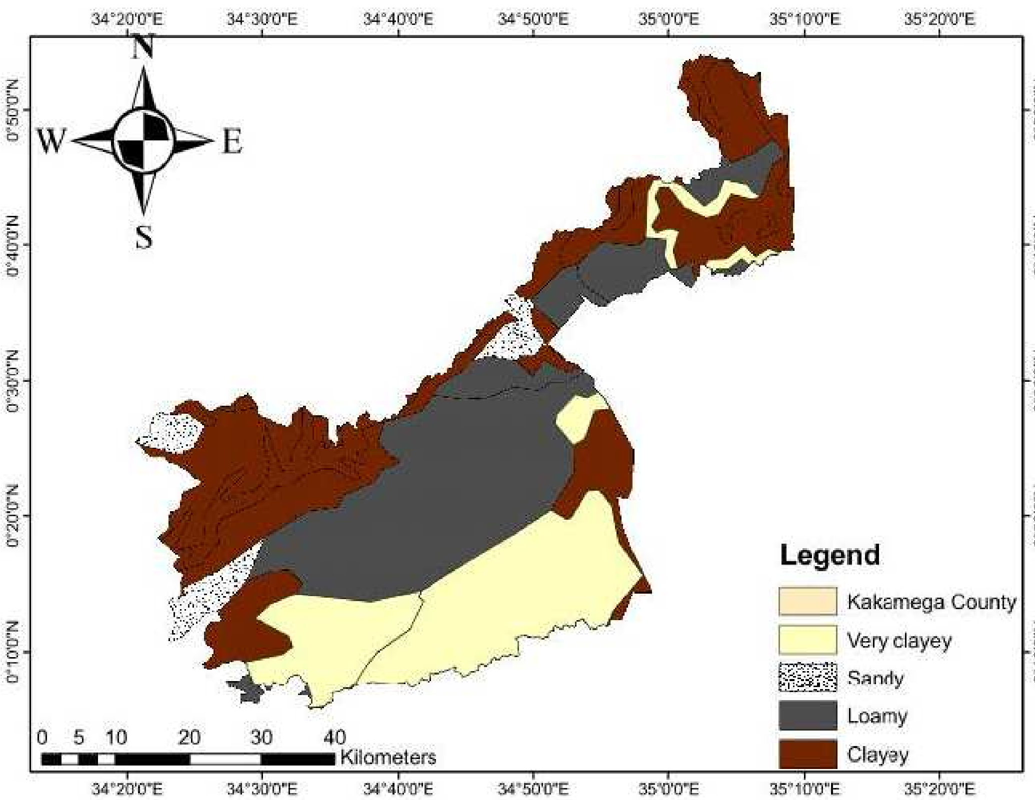


Figure 5. 2: A map of Kakamega County showing distribution of clay content in soil

During the focused group discussion, Mr. Omondi (NEMA) pointed out that the municipal sewerage plants in the town discharge partially treated or untreated wastewater into surface water courses posing significant environmental health hazards. Pit latrines and septic tanks in the municipality constitute a health risk in form of groundwater contamination. Similar findings on water quality status of Kakamega Municipality were reported by Onchiri (2011). No wonder we had the kind of diseases (dysentery and typhoid) observed atKakamega County General Hospital. Therefore, the study sought to find out if therewas any relationship between the biochemical parameters and the diseases recorded at Kakamega County General Hospital. Table 5.4 gives the summary of the findings.

Table 5. 4: Kakamega County Health data from 2009 to 2013

KAKAMEGA COUNTY HEALTH DATA FROM 2009 TO 2013										
YEAR	**2009**		**2010**		**2011**		**2012**		**2013**	
AGE(in years)	**<5**	**>5**	**<5**	**>5**	**<5**	**>5**	**<5**	**>5**	**<5**	**>5**
TYPHOID	205	3580	103	1749	154	6708	75	3683	202	3332
DYSENTRY	141	282	32	88	116	304	197	400	71	232
DIARRHOEA	8255	5289	2867	1530	6383	4182	6095	4134	5484	3750
MAL. CON	16042	26494	6840	10202	12906	21014	10118	17772	14738	28578
MAL. CL	53310	61930	24244	26369	29951	48558	25217	39120	11194	19111

Source: GoK 2014.

The results show that typhoid cases in the age group over 5 years were on an upward trend. This age group includes that of secondary school students for which this study was investigating. Most typhoid cases are not handled at the school level and therefore, they are referred to the Kakamega County General Hospital. Dysentery and typhoid are the likely causes of the diarrhoea cases recorded at the hospital.These findings imply that the microbes in generated sewage lead to health hazards in the environment through water and soil pollution.

Studies show that bacteria can travel a distance of up to 30m in sand and fine soils and up to several hundred metres in gravel and fractured rocks. Viruses can normally travel up to 60m with maximum recorded distance being 1.6km (cite source). In an area where there are many pit latrines there will always be a risk of pathogenic viruses and bacteria reaching underground water. During the rainy seasons, these latrines are always filled with filth all over the ground. A study in Ethiopia, (Navrekar, 1986) showed that 800 out of 836 wells from an area were contaminated with pathogens from pit latrines.

CHAPTER SIX

POTENTIAL ECONOMIC AND ENVIRONMENTAL BENEFITS OF ANAEROBIC DIGESTION OF SEWAGE FOR ENERGY IN SECONDARY SCHOOLS OF KAKAMEGA COUNTY, KENYA

6.1 Introduction

This chapter presents the findings of the study as guided by specific study objective three and its research question. Thus, the chapter presents the analysis of the potential economic and environmental benefits ofanaerobic digestion of sewage for energy in secondary schools of Kakamega County. These benefits are presented in two sections. Section 6.2 presents the economic benefits of anaerobic digestion of sewage for energy production. Section 6.3 presents the environmental benefits of anaerobic digestion of sewage for energy production. The benefits are both direct and indirect.

6.2 Potential EconomicBenefits of Anaerobic Digestion of Sewage for Energy

The study sought toexamine how much money schools spent annually on waste disposal (section 6.2.1), fuel wood consumption (section 6.2.2) and carbon equivalence for economic estimation (section 6.2.3). These costs have beentranslated into savings for schools if they were to harness sewage waste for energy production.

6.2.1 Annual Waste Disposal Costs for Schools

This section presents the annual waste disposal costs for secondary schools by school category to determine the potential economic benefits of anaerobic digestion of sewage for energy production. Table 6.1 gives a summary of the findings.

Table 6. 1: Mean Costs of Annual Waste Disposal for Schools by Category

School Category	N	Mean Cost of Annual waste Disposal in Ksh(x1000)	Std. Dev.
Boarding	31	158	224
Day	27	8	6
Boarding & Day	12	24	11

Source: Researcher, (2013)

The results show that boarding schools spent an average of Ksh.158, 000(83.16%), an equivalent of US$ 1580 on waste disposal annually. They are followed by Boarding&Day schools that on average spent Ksh.24, 000 (12.63%), an equivalent of US$ 240 on waste disposal annually. Day schools, on average, spent Ksh.8, 000(4.21%) an equivalent of US$ 80 annually on waste disposal. Schools can save these expenses if sewage bioenergy conversion can be embraced.

6.2.2 Annual Wood fuel Consumption for Schools

This section presents the annual wood fuel consumption costs for schools by school category to determine the potential economic benefits of anaerobic digestion of sewage for energy production. This was done by analysing the documents in the accounts office of the school bursars and accounts clerks. Table 6.2 gives a summary of the findings.

Table 6. 2: Mean Costs for Annual Wood fuel Consumption for Schools by Category

School Category	N	Mean Costs ofWood fuel in Ksh. (x1000)	Std. Dev.
Boarding	31	593	399
Day	27	81	23
Boarding & Day	12	200	169

Source: Researcher, (2013)

The results show that boarding schools spent an average of Ksh.593, 000 (67.85%) an equivalent of US$ 5, 930 on wood fuel annually. They were followed by Boarding&Day schools that on average spent Ksh.200, 000 (22.88%) an equivalent of US$ 200 on wood fuel consumption annually. Day schools, on average, spent Ksh.81, 000 (9.27%) an equivalent of US$ 810 annually on wood fuel consumption. This implies that schools spent a substantial amount of money on wood fuel annually which would be saved if they adopted cheaper alternative sources of energy.This high costs on wood fuel are as a result of the tendering process for the supply of the source of energy that is commonly used by the schools. Many schools do not have their lot of wood to meet their wood fuel needs.

6.2.3Wood fuel Consumption and Carbon Equivalence for Economic Estimation

This section presents the annual wood fuel consumption and Carbon equivalence for economic estimation in schools to determine the potential economic benefits of anaerobic digestion of sewage for energy productionby adopting IPCC (1996) formula. This states that 1kg fuel Wood emits =1.83 kg of CO2. Table 6.3 gives a summary of the results.

Table 6. 3: Wood fuel Consumption and Carbon Equivalence for Economic Estimation

School category	Amount of wood fuel consumed annually (kg)	Amount of carbon emission annually(kg)
Boarding schools	107, 980	197, 603.4
Boarding &Day schools	73, 430	134, 376.9
Day schools	45, 530	83, 319.9
Average	75, 646.7	138, 433.5

A Chi Square test conducted on the data showed that there was no significant (P>0.05) variation between the amount of wood fuel consumed and the amount of carbon emitted annually($\chi^2_{3,0.05} = 0.000$).

The results show that boarding schools use more wood fuel that averages 107,980kg (47.58%of the total analysed wood consumption) per school academic year and have the highest carbon emission of 197,603kg per school academic year. They are followed by Boarding&Day schools that use 73,430kg (32.36%) of wood fuel per school academic year with the carbon emission of 134,376.9kg per school academic year. Day schools use an average of 45,530kg (20.06%) of wood fuel per school academic year and have the least carbon emission of 83,319.9kg per school academic year. This gives an average wood fuel consumption of 75,646.7kg with an average carbon emission of 138,433.5kg per school academic year. This implies that wood fuel consumption in secondary schools is high in boarding schools therefore they release more carbon into the atmosphere followed by boarding and day schools. The least wood fuel consumption is in day schools and which, therefore, release the least amount of carbon into the atmosphere.

The study also sought to find out the quantity of wood fuel that would be replaced by sewage energy if the technology wouldbe embraced by the schools. This was done by converting mean annual wood consumption by school category (Table 6.4)into energy equivalents for comparison purposes. The results were as summarised in Figure 6.1.

Table 6. 4: Mean Daily and Annual wood consumption

School category	Mean daily wood consumption(kg)	Mean annual wood consumption(tons)
Boarding	395.54	107.98
Day	166.79	45.53
Boarding&Day	268.99	73.43

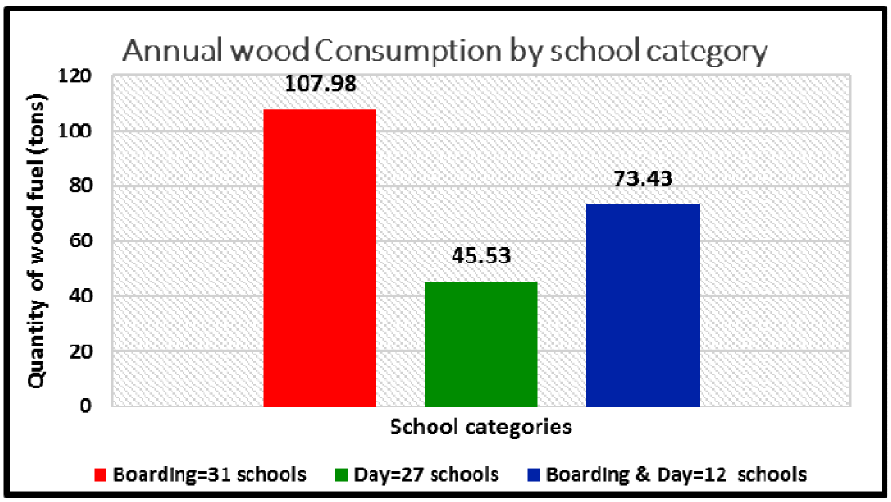


Figure 6. 1: Annual wood consumption

A Chi Square test of variation conducted on the data showed that there was a highly significant (P<0.01) variation in the annual wood consumption($\chi^2_{2,0.01} = 25.87$).

The results show that boarding schools have the highest wood fuel consumption of 107.98 tons (47.58% of the total analysed wood consumption) per school academic year. They are followed by boarding & day schools with 73.43 tons(32.36%) of wood fuel consumption per school academic year. Day schools have the least wood fuel consumption of 45.53tons (20.06%) per school academic year. This gives an average wood consumption of 74.82 tonsper school academic year in the sampled secondary schools. This implies that annual wood consumption in boarding schools is 2.4 times higher in day schools and 1.5 times higher than in boarding/day schools. It is 1.6 times higher in boarding/day than in day schools. It was quite evident that schools were using a lot of wood fuel as a source of energy for cooking and heating, Plate6.1.

Plate 6. 1: Researcher at collecting yard and store for wood fuel in schools

The sewage quantities were then translated into energy equivalents to get the energy potentials from various categories of schools. This was done by use of the formula: 1kg of wood (Dry) =20MJ (Munalula, et al., 2008) for wood energy and the formula: 1m^3 of methane gas = 30MJ (GTZ, 2010) for bioenergy.The results were assummarised in Table 6.5 and Figure 6.2.

Table 6. 5: Wood energy and Bioenergy potential

	Boarding Schools=31	**Boarding & Day Schools=12**	**Day Schools=27**	**Average**
Wood energy (GJ)	1201	687.1	389.56	759.22

Bioenergy (GJ)	346.57	115.9	62.15	174.88
Bioenergy: Wood energy ratio	0.28856786	0.16868	0.159539	0.205596
Energy Replacement rate (%)	29	17	16	21

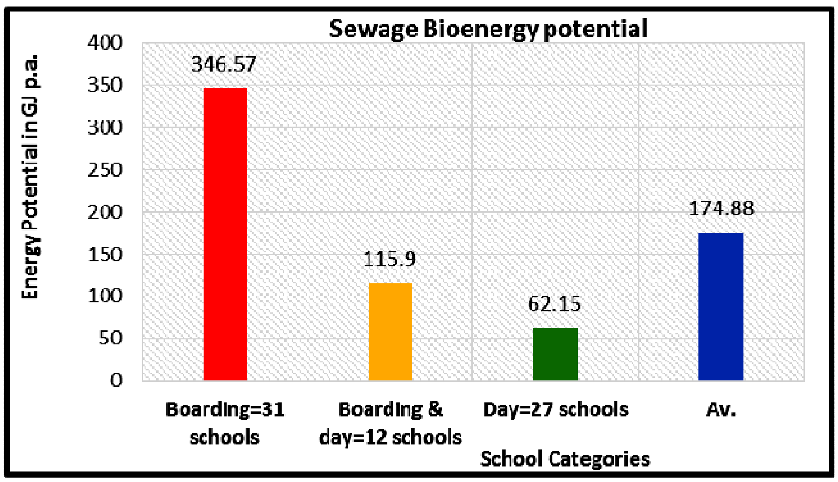


Figure 6. 2:Sewage bioenergy potential in schools by category

The results show that boarding schools have the highest bioenergy potential of 346.57GJ (66.06%of the total analysed sewage bioenergy potential) per school academic year. They are followed by Boarding & Dayschools with 115.9GJ (22.09%) of bioenergy potential per school academic year. Day schools have the least bioenergy potential of 62.15GJ (11.85%) per school academic year. This gives an average bioenergy potential of 174.88GJ per school academic year in the sampled secondary schools. This implies that the sewage bioenergy potential in boarding schools is 5.6

times higher in day schools and 3 times higher than in boarding/day schools. This is 1.9 times higher in boarding/day than in day schools.The energy production potential was as summarised in Figure 6.3.

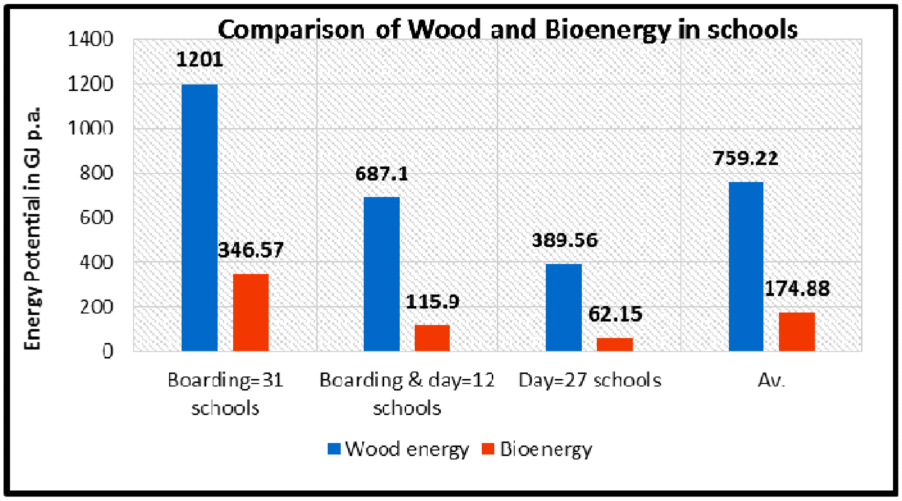


Figure 6. 3: Comparison of Wood and Bioenergy in schools

A Chi Square test of variation conducted on the data showed that there was a highly significant (P<0.01) association between wood energy and bioenergy in schools ($\chi^2_{3,0.01} = 30.74$).

The results show that boarding schools use more wood energy that averages 1201.00GJ per school academic year and have the highest bioenergy potential of 346.57GJ (66.06%of the total analysed bioenergy potential) per school academic year. They are followed by Boarding & Dayschools that use 687.1 GJ of wood energy per school academic year with the bioenergy potential of 115.90 GJ (22.09%) mega joules per school academic year. Day schools use an average of 389.56 GJ of wood energy per school academic year and have the least bioenergy potential of 62.15 GJ (11.85%) per school academic year. This gives an average wood energy of 759.22GJper school academic year and bioenergy potential of 174.88 GJper school academic year in the secondary schools. This implies that the bioenergy generation and use will be more applicable in boarding schools than in Boarding & Dayand Day schools.

The study then sought to determine the potential of energy replacement rate (Bioenergy: Wood energy ratio) as a percentage. This was done by determining energy equivalents of wood fuel consumed by the various school categories and their respective quantities of sewage generated, Table 6.5. The results were assummarised in Figure 6.4.

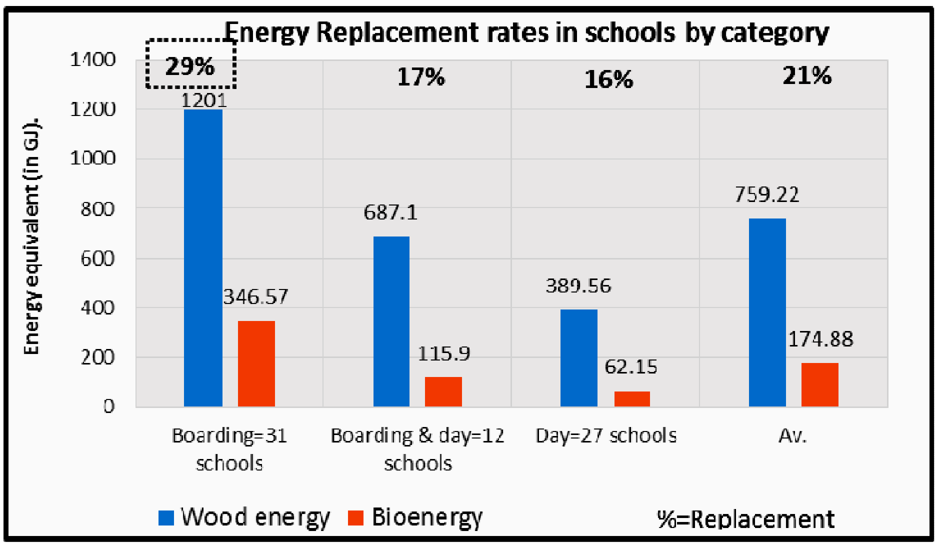


Figure 6. 4: Annual wood and bioenergy equivalent by school category

A Chi Square test of variation conducted on the data showed that there was a highly significant (P<0.01) association between wood energy and bioenergy in schools ($\chi^2_{3,0.01} = 30.74$).

The results show that Boarding schools have a higher energy replacement rate of 29% when they use an average wood energy of 1201 GJ with a bioenergy potential of 346.58 GJ per school academic year. The Boarding& Day schools have a higher energy replacement rate of 17% than Day schools when they use 687.10 GJ of wood energy with a bioenergy potential of 115.90 GJ per school academic year. Day schools which use an average of 389.56 GJ of wood energy with a bioenergy potential of 62.15GJ per school academic year have an energy replacement rate of 16%. This gives an average energy replacement rate of 21% and an average wood energy of 75.92 GJ with a sewage bioenergy potential of 174.88 GJ per school academic year. This implies that the bioenergy generation and use is more applicable in Boarding schools than in both Boarding&Day and Day schools since they have the highest energy replacement rate.However, this sewage bioenergy may not replace all the energy but can only supplement it.

The study sought to find out whether the anaerobic digestion of sewage for methane gas generation can be viable and economical for secondary schools. According to EU-GTZ(2010) the cost of installing a biogas plant of various sizes is as summarised in Table 6.6.

Table 6. 6: Some important biogas statistics

Digester size (in M^3)	**Maximum number of zero-grazed cows(Ave. Live Weight 300KG)**	**Constructio n materials approx. Ksh**	**Labour costs approx.Ks h**	**Total cost Ksh**	**Max. Biogas production approx. M^3 per day**	**Equivalent wood fuel in kg**	**Equivalent charcoal in kg**	**Equivalent fuel oil in litres**
12	6	88.781	35,000	123.781	4,3	10,8	3,9	2,2
16	8	103.961	40,000	143.961	5,8	14,4	5,2	2,9
32	16	154.726	55,000	209.726	11,5	28,8	10,4	5,8
48	25	190.856	65,000	255.856	18,0	45,0	16,2	9,0
70	36	239.965	80,000	319.965	25,9	64,8	23,3	13,0

91	47	261.899	90,000	351.899	33,8	84,6	30,5	16,9
24	65	314.721	100,000	414.721	46,8	117,0	42,1	23,4

Source: EU-GTZ PSDA (2010)

When computing the production cost of a biogas plant, the following assumptions were made:

i. That production cost takes the bulk of the inputs into the biogas plant.

ii. That the biogas plant is self-charging, hence, operational costs are minimal (only mixing of the sludge is done)

The findings of this objective imply that secondary schools can save on fuel costs when they embrace anaerobic digestion of sewage for bioenergy generation. Besides, there will be limited environmental pollution caused by smoke and raw sewage disposal. There will also be a reduction in carbon emission due to reduced wood fuel consumption and instead increase the carbon sinks. Use of methane gas reduces GHGs hence playing a role towards reducing greenhouse effect that results into climate change. Therefore, the environmental benefits include reduction in the volatile solids (Koosman et al, 1999; GTZ ISAT, 1999).

6.3 Potential Environmental Benefits of Anaerobic Digestion of Sewage for Energy

The potential environmental benefits of anaerobic digestion of sewage for energy was done by analysing the chemical and microbial parameters. The chemical parameters that were analysed included the sewage TKN, pH, heavy metals, Dry Matter (DM), and nutrient content. The microbial parameters analysed were *E.coli* and faecal coliforms. Table 6.7and Figure 6.5 give a summary of the major findings.

Table 6. 7: Macro-nutrients, microbes and heavy metals in the influent and effluent of human excreta

Parameter	Influent ± SE	Effluent ± SE	Deviation
DM (%)	13.80 ± 0.66	5.25 ± 0.30	-8.55 (62.0%)
pH	5.75 ± 0.13	7.25 ± 0.27	+1.5 (26.1%)
TKN (mg/l)	8.30 ± 0.45	8.98 ± 0.33	+0.68 (8.2%)
Total P_2O_5 (mg/l)	1.15± 0.46	1.17 ± 0.30	+0.02 (1.7%)
***E.coli* (MPN/100mls**	390	100	-290 (74.4%)
Faecal coliforms (MPN/100 mls)	450	50	-400 (88.89%)
Cadmium (Cd)	0.0249 ± 0.35	0.0249 ± 0.35	0
Lead (Pb)	0.0046 ± 0.34	0.0046 ± 0.33	0

SE: Standard Error, TKN: Total Kjeldal Nitrogen, P_2O_5: Phosphate, DM: Dry matter

The DM content of the influent of human excreta was 13.80% with SE of 0.66. After the process the effluent was found to contain 5.25% DM with SE of 0.30. This gives a negative deviation of 8.55 which represents 62.0% reduction in DM content in the effluent. The results therefore show that anaerobically digested effluent has lowerDM content than the influent. This is consistent with similar findings by Vetter et al.(1987) and Pfundtner (2002). The reduction in DM has a storage benefit and extended retention time. This leads to reduced frequency of exhausting the disposal systems, hence reduced cost.

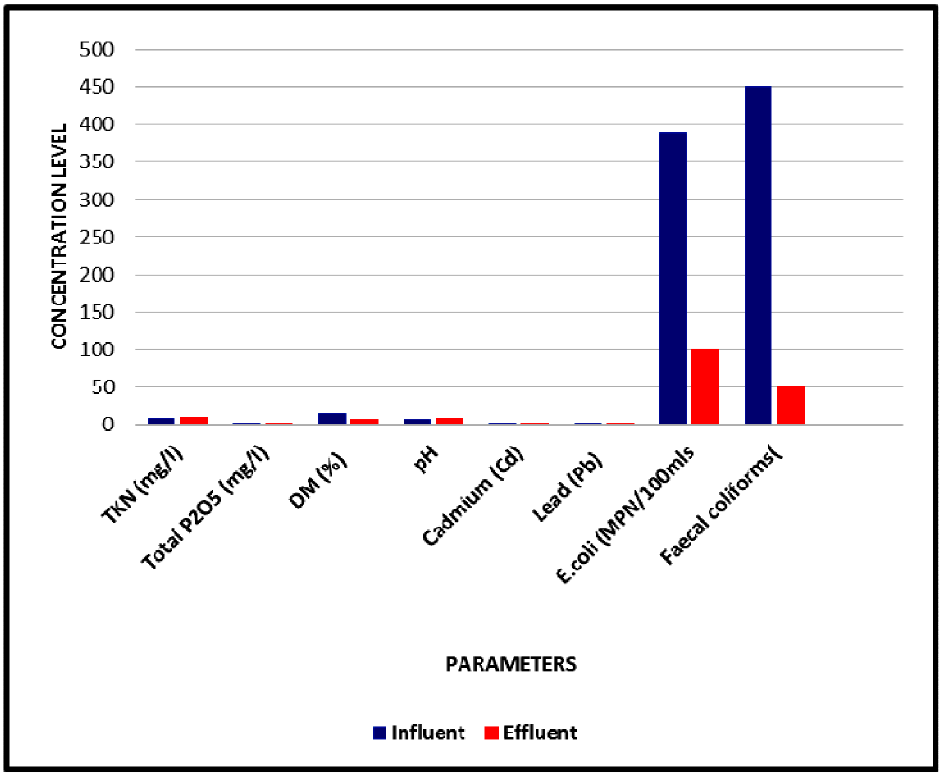


Figure 6. 5: Concentration levels of macro-nutrients, microbes and heavy metals in the influent and effluent of human excreta

The pH of the influent of human excreta recorded a value of 5.75 with SE of 0.13. As a result of the anaerobic digestion process, pH of the effluent increased to 7.25 with SE of 0.27. This gives a positive deviation of 1.5which represents 26.1% increase in the pH of the effluent.The finding shows that the pH of the anaerobically digested effluent is higher than the pH of undigested wastes (influent). This agrees with similar findings by Smith et al. (2007). The pH of the influent is acidic before anaerobic digestion and becomes neutral after digestion. This neutral pH is important to crop production. The high pH value recorded in the digester treating human excreta reflects the high content of NH4-N in the human excreta. Probably, the NH4-N content forms a significant contribution from urine. This is because ammonia is more alkaline than acidic, hence its influence on the pH value during anaerobic digestion.

The results show that the influent of human excreta had a total TKN of 8.30 mg/l and an SE of 0.45. After the anaerobic digestion process, the TKN in effluent was found to be 8.98 mg/l with SE of 0.33. This gives a positive deviation of 0.68 which represents 8.2% increase. This implies that the AD process leads to increase in the concentration of TKN in the effluent making it to become a bio nutrient.

The results show that the influent of human excreta had a total $P_2O_5$of 1.15mg/l and an SE of 0.46. After the anaerobic digestion of the influent, the total P_2O_5in the effluent was found to be 1.17 mg/l and an SE of 0.30. This gives a positive deviation of 0.02 which represents 1.7% increase in the total P_2O_5in the effluent.This finding is consistent with a previous study in Ghana (Abdul-Aziz et al, 2012). This implies that the AD process leads to increase in the concentration of P_2O_5 in the effluent making it to become a bio nutrient.

The analysis of heavy metals in the influents of human waste revealed that cadmium (Cd) and lead (Pb) were quite traceable. The quantities of Cd were 0.0249 mg/l and Pb was 0.0046 mg/l. After the anaerobic digestion process, the effluent was found to contain 0.0249 mg/l Cd and 0.0046mg/l Pb. The results therefore, showed that the heavy metals remained unchanged in their respective effluents after the AD process.This finding is in agreement with the report by Monnet (2003) and Abdul-Aziz et al (2012). This may probably be due to the inability of putrefactive bacteria to degrade these elements during hydrolysis, acetogenesis and methanogenesis. However, the levels of Cd and Pb did not exceed the Kenya Environmental Protection Agency regulations for disposal of effluents which are 5.0 mg/l and 0.1mg/l for Cd and Pb, respectively.

Data analysis and interpretation of the levels of microbes present in the sewage revealed the following major findings. The *E.coli* in the influent was 390 MPN/100mls while in the effluent it was 100 MPN/100mls. This gave a negative deviation of 290 which represents 74.4% reduction in the *E.coli* concentration in the effluent. The content of faecal coliforms in the influent was 450 MPN/100 mls and 50 MPN/100 mls in the effluent. This gave a negative deviation of 400 which represents 88.89% reduction in faecal coliforms concentration in the effluent. This implies that anaerobic digestion of sewage acts as a disinfectant to the environment by creating a non-conducive environment for the survival of pathogens. Thus, the digester has the ability to disinfect the sewage thereby protecting the environment.

The study further sought to find out the bacterial characteristics of sewage before and after fermentation to show the impact of AD on environmental protection. Table 6.8 gives a summary of major selected genera involving mean relative abundance in Human faecal material before and after anaerobic fermentation.

Table 6. 8:Microbe relative abundance in Human faecal matter before and after anaerobic fermentation

	Portion by Percentage

Contaminants (Bacteria)	***Before anaerobic fermentation***	***After anaerobic fermentation***
Lactobacillus	80.3%	0.0
Actinobacteria	1.3%	0.0
Streptococcus	0.5%	0.0
Escherichia coli	0.5%	0.0
Clostridia	0.2%	0.0
Fusobacteria	0.2%	0.0

Source: Researcher (2016)

The results of culturing the contaminants show the isolation of the following species of bacteria: *Lactobacillus* (80.3%), *Actinobacteria* (1.3%), *Streptococcus* (0.5%), *Escherichia coli* (0.5%), *Clostridia* (0.2%), *Bacillus* (0.0%) and *Enterococcus* (0.0%). The rest (17.2%) could be other contaminants like *Staphylococcus.Lactobacillus* is more since it is a fermenter. This shows that before the AD process there are pathogens in the human faecal matter and after the process methanogens are present in the digestate. It is therefore evident that only methanogens survive after the fermentation process. Methanogens are not pathogens. These results imply that anaerobic digestion of sewage for energy production acts as a disinfectant to the environment by creating a non-conducive environment for the survival of pathogens. Thus, the digester has the ability to disinfect the sewage thereby protecting the environment. If influent retention time can be increased, then sanitation can be further enhanced.

Methane is the second most important greenhouse gas that contributes 20% of the greenhouse effect while carbondioxide causes 62%, Cassada et al.,(1990). It also has a 25times higher global warming potential compared with carbon dioxide in a time horizon of 100 years.

6.8 Chapter Summary

These findings indicate that there was 8.2% increase in the TKN content in the effluent after the anaerobic digestion (AD) process with a Standard Error (SE) of 0.33. The P_2O_5 in the effluent increased by 1.7% after the AD process with SE of 0.46. The pH anaerobic digested effluents also increased by 26.1% with SE of 0.27. However, there was 62.0% reduction in DM content in the effluent with SE of 0.30 after the AD process. Thus, anaerobically digested effluent has lower DM content than the influent.The reduction in DM has a storage benefit and extended retention time. This leads to reduced frequency of exhausting the disposal systems, hence reduced expenditure.

There was also a reduction in the *E.coli* and faecal coliforms concentrations after the AD process by 74.4% and 88.9% respectively. The heavy metals (Cd and Pb) remained unchanged in their respective effluents after the AD process. The effluent is, therefore, more nutritious and less risky. Microbial characteristics of the human waste undergo sterilization through the process of AD leading to a safe environment.This implies that the effluents undergo sterilisation through anaerobic digestion leading to a safe environment. Thus, the effluent can be used safely on soils as organic manure due to reduced E. coli and faecal coliforms which are pathogenic.

The gist of advocating for sewage anaerobic digestion for energy production in secondary schools is to make them embrace the technology in the search for renewable sources of energy with aspects of environmental protection and greenhouse gas reduction. Environmental protection entails the mitigation of deforestation and soil erosion through the substitution of wood fuel as an energy source.

Due to the foregoing, the following can be regarded as potential biogas benefits in schools and the entire community:

i. Savings in the cost of sewage disposal,

ii. Improvement of sanitary and environmental health conditions through reduction of the pathogens.

iii. Eye infections and respiratory problems attributable to soot and smoke from the burning of wood fuel are mitigated.

iv. Substitution of mineral fertilisers with bio-fertiliser and where applicable.

v. Reduced gastrointestinal diseases or epidemics of schistosomiasis, ancylostomiasis and dysentery caused by the transmission of pathogens via ova contained in faecal matter since anaerobic digestion of human wastes and effluents extensively detoxifies such material by killing most of the ova and pathogenic bacteria. The widespread popularisation of biogas in China has had immediate beneficial effects on the sanitary conditions of the areas concerned. This eliminated some of the main sources of infectious diseases such as Schistosomiasis, which previously was widespread in rural China, and has now been reduced by 99% through the introduction of biogas technology as the number of tapeworm infections has been reduced to 13% of the pre-biogas level (GTZ, 2010).

vi. Climatic twin effect where the use of renewable energy reduces the CO_2-emissions through a reduction of the demand for fossil fuels and also by capturing uncontrolled methane emissions that is the second most important greenhouse gas. Methane contributes to 20% greenhouse effect while carbon dioxide causes 62% and it also has a 25 times higher global warming potential compared with carbon dioxide in a time horizon of 100 years (GTZ ISAT, 2010). The reduction of 1 kg methane is equivalent to the reduction of 25 kg CO2. The reduction of greenhouse gases with a high global warming potential can be more efficient compared with the reduction of CO_2.

vii. By helping to counter deforestation and degradation caused by overusing ecosystems as sources of wood fuel and by amelioration of soil conditions biogas technology reduces CO_2 releases from these processes and sustains the capability of forests and woodlands to act as a carbon sink.

CHAPTER SEVEN

ENHANCEMENT STRATEGIES IN SECONDARY SCHOOLS FOR ANAEROBIC DIGESTION OF SEWAGE FOR ENERGY IN KAKAMEGA COUNTY, KENYA

7.1 Introduction

The fourth specific objective was to evaluate the enhancement strategies in secondary schools foranaerobic digestion of sewage for energy generation and environmental protectionin Kakamega County, Kenya. These enhancement strategies are basically the acceptance of the biogas technology by the various stakeholders including the students, school management, the school sponsors and even the community in the school environs.

Some of the environmental challenges in schools and their surroundings emanate from the heavy and long term usage of wood fuel and sewage management.Clearing of trees for wood fuel reduces the carbon sinks as their burning increases the carbon concentration in the atmosphere. The decomposition of sewage produces methane that evaporates to the atmosphere leading to the escalation of the GHGs. Such environmental pollution can be mitigated by having concerted efforts from the stakeholder including the Ministry of Health (Public Health sector), the Kenya Forest Service, NEMA, school fraternity, the Ministry of Education, Science and Technology and the Ministry of Energy.

Effortsshould be directed towards ameliorating health risks and general environmental protection by utilising sewage for energy to supplement the wood fuelto reduce

GHGs. School sponsors, NGOs and development partners should therefore, put structures in place to sustainably use the existing tree resources.

The enhancement strategies for anaerobic digestion of sewage for energy generation in schools necessitated the collection of views from stakeholders who included students, the teachers as well as the school managers. Equally important were the views of the religious leaders who are the sponsors of various schools. The views range from socio-cultural to economic and ethical factors. Although most of the stakeholders were positive about utilising sewage for energy production, there were some concerns about the smell, cost, and method of generating energy as well as the quantity and health aspects of the practice.Most of these concerns were bordering on the knowledge base of the technology as many were excited about the concept but had no idea about how and whether it works or not. However, most of the top religious leaders in the County, except for the Hinduism, were in full support of anaerobic digestion of sewage for biogas generation in their sponsored schools.

Out of 14 top religious leaders interviewed, 12 (85.71%) would accepted biogas generation from sewage in their schools. The remaining 2 religious leaders (14.29%) would not accept the biogas generation from sewage biogas in their schools. This means that majority of the religious leaders would have no objection to biogas generation from sewage in their schools. A Chi-square test of independence showed that there was no statistically significant ($p>0.05$) association between the religion of the religious leaders and their acceptance of biogas generation from sewage in their schools [χ (1) = 0.1167, p = 0.7326782614]. This implies that there issupport from the religious leaders for the use of sewage in schools to generate bioenergy.

The study also sought the views of the beneficiaries of sewage biogas who are the students. A Chi-Square test of association carried out on the students' views gave results as summarised in Table 7.1.

Table 7. 1: School status * students highly recommend utilization of sewage for biogas production

Crosstab

Count

		students highly recommend utilization of sewage for biogas production		Total
		agree	undecided	
School status	Boarding school	194	0	194
	Day school	67	0	67
	Both boarding and day	63	6	69
Total		324	6	330

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	23.116[a]	2	.000
Likelihood Ratio	19.208	2	.000
Linear-by-Linear Association	17.724	1	.000
N of Valid Cases	330		

a. 3 cells (50.0%) have expected count less than 5. The minimum expected count is 1.22.

The results show that there is a significant ($p<0.05$) statistical relationship between the category of school and the students' recommendation for sewage utilisation for energy production since the sig value is less than .05 (.000). Out of the 330 students, 324 (98.18%) recommended the utilisation of sewage for energy generation in their school. The other 6 (1.82%) of students were undecided. Of the 324 students who recommended use sewage for biogas generation, 194 (59.88%) were students from boarding schools. Another 67 (20.68%) were students from Day schools and 63 (19.44%) were from Boarding & Dayschools. This implies that majority of the students, regardless of the category of school that they belong to, support the use of anaerobic digestion of sewage in schools to generate bioenergy for use in schools. This support from students is a crucial one given that they are the ones who will directly benefit from the advantages that accrue from sewage utilisation for bioenergy generation.According to Amrit(2008), methane generation from human faeces is in limited scale in most developing countries due to social or religious reservation with an exception of China where it is traditionally and socially acceptable. The acceptability of latrine waste has increased in the recent past in Nepal as about 40 percent of the installed biogas plants are attached tolatrines. The acceptability from stakeholders such as students to the use of human faeces for bioenergy generation is a good step towards embracing anaerobic digestion of sewage technology in the society.

The findings from FGD, key informants and other stakeholders indicated that for anaerobic digestion of sewage for bioenergy generation in secondary schools to be realised the following need to be put in place. There is need for creation of awareness among stakeholders and the general public about anaerobic digestion of sewage for energy generation. Dissemination of information to potential beneficiaries is of paramount importance. Besides, acceptance of biogas generation from sewage by the potential beneficiaries is another important enhancement strategy.If the socio-economic and cultural factors are considered then utilisation of sewage for energy generation in secondary schools can be made a reality since the potential is there.

When seeking the means of supplementing energy requirements in secondary schools, 89% of the stakeholders expressed their support for use of readily available sewage to generate bioenergy so as to help reduce costs of using wood fuel. When seeking for a long lasting solution to the sewage menace, the school management expressed their willingness (80.77%) to use the sewage for energy generation to mitigate the challenge while 19.23% were skeptical citing socio-economic factors.

Most of the stakeholders were positive about anaerobic digestion of sewage for energy generation, although there were some concerns about the smell, cost, method as well as the quantity and health aspects of the practice. These concerns were bordering on the knowledge base of the technology since they had no idea about how and whether it works or not. However, this concern was demystified by the expert from the Ministry of Energy during the FGD. To make it a reality, the Ministry of Energy in conjunction with Kaimosi Teachers' College and other development partners launched an AD sewage plant at the college for sewage energy generation. The digester is now functional. Therefore, dissemination of information is key in the adoption of the technology.

AChi-square test of associationwas used to establish if there is a relationship between religion of the target groups and their acceptance of biogas generation from sewage in their schools.Results showed that there was statistically significant ($p<0.05$) associationbetween religion of the target groups and their acceptance of biogas generation from sewage in their schools. The results (Table 7.3) indicate χ (1) = 11.8005, $p = 0.00059$. This means that there is a statistically significant association between the students' religion and their acceptance of biogas generation from sewage in their schools. Out of 395 students, 391 (98.99%) would accept biogas generation from sewage in their schools. The remaining 4 (1.01%) would not accept the biogas generation from sewage biogas in their schools. This means that majority of the students would have no objection to the biogas technology of generating biogas from sewage in their schools.

Table 7. 2: Chi-square test of association between students' religion and their acceptance of sewage biogas

Strata 1 | Strata 2 | Strata 3 | Strata 4 | Strata 5 | Strata 6 | Strata 7 | Strata 8 | Strata 9

Outcome

Exposure		Yes	No	Total
Yes		353	1	354
	Row %	99.72 %	0.28 %	100.00 %
	Col %	90.28 %	25.00 %	89.62 %
No		38	3	41
	Row %	92.68 %	7.32 %	100.00 %
	Col %	9.72 %	75.00 %	10.38 %
Total		391	4	395
	Row %	98.99 %	1.01 %	100.00 %
	Col %	100.00 %	100.00 %	100.00 %

Odds-based Parameters

	Estimate	Lower	Upper
Odds Ratio	27.8684	2.8283	274.5991
MLE Odds Ratio (Mid-P)	27.3564	2.8472	735.0574
Fisher-Exact		2.1376	1466.7689

Statistical Tests

	X^2	2 Tailed P
Uncorrected	18.1395	0.0000205301
Mantel-Haenszel	18.0936	0.0000210312
Corrected	11.8005	0.0005921479

Risk-based Parameters

	Estimate	Lower	Upper
Risk Ratio	1.0759	0.9871	1.1727
Risk Difference	7.0346	-0.9559	15.0251

	1 Tailed P	2 Tailed P
Mid-P Exact	0.0019901021	
Fisher Exact	0.0038788316	0.0038788316

Out of 370 teachers, 367 (99.19%) would accept biogas generation from sewage in their schools. The remaining 3 teachers (0.81%) would not accept the biogas generation from sewage biogas in their schools. This means that majority of the teachers would have no objection to the biogas technology of generating biogas from sewage in their schools. A Chi-square test of association was used to establish the relation between the religion of the teachers and their acceptance of biogas generation from sewage in their schools. Results showed that there was a statistically significant ($p<0.05$) association between religion of the teachers and their acceptance of biogas generation from sewage in their schools. The results indicate χ (1) = 5.3217, p = 0.0210616041. This means that there is a statistically significant association between the teachers' religion and their acceptance of biogas generation from sewage in their schools.

AChi-square test of associationwas used to establish the relation between the religion of the non-teaching staff and their acceptance of biogas generation from sewage in their schools. Results showed that there was a statistically significant ($p<0.05$) association between religion of the teachers and their acceptance of biogas generation from sewage in their schools. The resultsindicate χ (1) = 8.3734, p = 0.0038074411. This means that there is a statistically significant association between the religion of non-teaching staff and their acceptance of biogas generation from sewage in schools. Out of 71 non-teaching, 70 (98.59%) would accept biogas generation from sewage in their schools. Only 1 (1.41%) of the non-teaching staff would not accept the biogas generation from sewage biogas in their schools. This means that majority of the non-teaching staff would have no objection to the biogas technology of generating biogas from sewage in their schools.

Out of 68 principals, 68 (100.00%) would accept biogas generation from sewage in their schools. This means all the principals would have no objection to the biogas technology of generating biogas from sewage in their schools. AChi-square test of associationbetween the religion of the principals and their acceptance of biogas generation from sewage in their schools. Results showed that there was a statistically significant ($p<0.05$) association between religion of the principals and their acceptance of biogas generation from sewage in their schools. The results indicate χ (1) = 14.2930, p = 0.0001564467. This means that there is a statistically significant association between the teachers' religion and their acceptance of biogas generation from sewage in their schools. This implies that majority of school principals were willing to support the use of anaerobic digestion on sewage to generate biogas since they felt this could assist them in the management of sewage that posed challenges such as foul smell and cost on its final disposal. They were, however, keen on the economic viability of the project to the school.

At the FGD, Mr. Fred Amutavi (Kakamega County Public Health Officer), observed that if schools can be able utilise the human waste for energy generation then this would help them ameliorate the challenges they face from poor sewage management. These views were shared byMr. Omondi Were(Kakamega County NEMA Chief Executive officer) who reiterated that the big challenge from sewage in many schools would be something of the past once schools embrace the biogas technology. Similar views came from Mrs. Caroline Busuru (officer. Kenya Forest Service) who expressed her full support to schools that would utilise human waste for energy to as to help give resilience to our diminishing forest. Mr.Ramadhan Barasa, a BOM chairman of Namirama girls' secondary school, indicated that his school would be willing to embrace the technology to help tackle the challenge from the pit latrines that frequently fill up. Mr. Steven Stingo,a technical officer from the Ministry of Energy seconded to Bukura Institute of Agriculture and Technology, gave an assurance to FGD participants that the technology was readily available and revealed the costs of construction as indicated in Table 7.3.

Table 7. 3: Some important biogas statistic

Digester size (in M^3)	Maximum number of zero-grazed cows(Ave. Live Weight 300KG)	Constructio n materials approx. Ksh	Labour costs approx. Ksh	Total cost Ksh	Max. Biogas production approx. M^3 per day	Equivalent wood fuel in kg	Equivalent charcoal in kg	Equivalent fuel oil in litres
12	6	88.781	35,000	123.781	4,3	10,8	3,9	2,2
16	8	103.961	40,000	143.961	5,8	14,4	5,2	2,9
32	16	154.726	55,000	209.726	11,5	28,8	10,4	5,8
48	25	190.856	65,000	255.856	18,0	45,0	16,2	9,0
70	36	239.965	80,000	319.965	25,9	64,8	23,3	13,0
91	47	261.899	90,000	351.899	33,8	84,6	30,5	16,9
24	65	314.721	100,000	414.721	46,8	117,0	42,1	23,4

Source: EU-GTZ PSDA (2010)

From the foregoing findings, there was a clear indication that there is a will-power from the stakeholders to have AD of sewage for energy generation in secondary schools. These findings imply that the acceptance of the practice of sewage AD in schools and the society at large can be a break through the socio-economic barrier hence benefit the entire society by helping the world reduce on some of the sources of GHGs hence help mitigate the climate change and make the world more resilient. Thus, it is important to realize that in a decision-making process, acceptance sums up factors such as the willingness, hopes, fears, expected reactions from the society, economic considerations in favor or against biogas technology.

CHAPTER EIGHT

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

8.1 Introduction

This chapter presents conclusions drawn, implications for practice, recommendations of the study and suggestions for further research. Thus, section 8.2 presents the summary, section 8.3 conclusions, section 8.4 the recommendations and section 8.5 the suggestions for further research.

8.2 Summary

The study investigated the Potential of Anaerobic Digestion of Sewage for Energy Production and Environmental Protection in Secondary Schools of Kakamega County, Kenya. It was intended to investigate reduction in costs that accrue from wood fuel consumption together with the benefits that accrue from AD of sewage for clean energy generation. Environmentalists and policy makers will benefit from the protection of trees and safer environment that will make Kenya less vulnerable but more resilient. This was in relation to the increased student enrolment in schools due to the enactment of free primary education. The increase in student population has led to increased sewage generation and demand for wood fuel in the secondary schools. Consequently, challenges on environment also increase.

The study specifically sought to determine the quantity of sewage generated by secondary schools in Kakamega County for potential energy generation; examine the potential environmental impact of the chemical and microbial characteristics of sewage generated in in secondary schools; determine the potential economic and environmental benefits of anaerobic digestion of sewage for energy generation in secondary schools and evaluate the enhancement strategies available in secondary schools energy generation. The study established that:

i. The Quantity of Sewage generated in Kakamega County secondary schools for potential sewage energy production is 17,662.3 tons of human waste per school academic year of 273 days with an energy equivalent of 43,273.6GJ.
ii. The chemical characteristics in the sewage generated are: TKN 8.30 mg/l with SE of 0.45; pH 5.75 with SE of 0.13; P_2O_5 1.15mg/l with SE of 0.46; Cd 0.0249 mg/l; Pb 0.0046 mg/l; DM 13.80% with SE of 0.66. The microbial characteristics in the sewage generated are: *E.coli* 390 MPN/100mls and faecal coliforms 450 MPN/100 mls.
iii. The anaerobically digested effluent increased its concentration of TKN and P_2O_5 by 8.2% and 1.7% respectively. Its pH also increased by 26.1%. However, the DM, *E.coli* and faecal coliforms reduced by 61.8%, 74.4% and 88.89% respectively. The traceable quantities of heavy metals remained unchanged in the effluent after the AD process.
iv. The infrastructure, socio-economic factors and concerted efforts of all stakeholders are of paramount importance in realising the AD of sewage in secondary schools for bioenergy production. Key players in this respect are the school sponsors majority of whom highly recommended the use of sewage for energy generation in their schools. The students who are the direct beneficiaries of sewage energy generation and the boards of management are also in full support of the technology.

The amount of bioenergy produced was as summarised in Table 8.1.

Table 8. 1: Summary of the bioenergy produced by the secondary schools

	Boarding Schools=31	**Boarding & Day Schools=12**	**Day Schools=27**	**Average**
Wood energy (GJ)	1201	687.1	389.56	759.22
Bioenergy (GJ)	346.57	115.9	62.15	174.88
Bioenergy:Wood energy ratio	0.28856786	0.16868	0.159539	0.205596
Energy Replacement rate (%)	29	17	16	21

8.3 Conclusions

In view of these findings, the study concludes that:

There is a substantial quantity of sewage that is generated in secondary schools of Kakamega County for potential sewage energy generation. If everything is held constant wood fuel would be replaced by sewage energy.

The microbial characteristics of the sewage generated in secondary schools have a negative impact on the environment by causing pollution of the soils and water.

Economically, AD of sewage will supplement the wood fuel used by schools for their cooking and heating needs. Environmentally, AD of sewage for energy generation reduces the *E.coli* and faecal coliforms concentrations in the effluent to harmless trace levels. The decrease in DM means that less space will be required hence reduced rate of refilling. It also means that some biological process is going on and this is environmentally as evidenced by the decrease in *E.coli* and faecal coliforms. The increase in P_2O_5 and TKN as well as the pH will benefit the soils. Generally, use of sewage bioenergy will help reduce the effect of methane on the biosphere.

There is adequate support from the stakeholders for the use of sewage in secondary schools to generate energy with very low socio-economic objection that is due to lack of knowledge.

8.4 Recommendations

Basing generalisations on the findings and arguments in this study, the researcher recommends that:

i. Schools should make use of the large quantities of sewage readily available in their premises for anaerobic digestion to generate biogas.

ii. Schools should properly dispose of their sewage waste due to their potential hazardous effect caused by the *E.coli* and faecal coliforms.

iii. Schools with student populations of 700 and above can economically utilise AD of sewage for bioenergy generation with a lot ease since they are well endowed with sewage that can sustain the energy generation compared to those with a lower student population.

iv. Schools should embrace the idea of AD of sewage for bioenergy generation that will save many carbon sinks and reduce GHG generation, environmental degradation and pollution that lead to climate change.

8.4 Suggestions for Further Research

The following suggestions for further study were made since they were underscored:

(i) Since this study only investigated the potential of anaerobic digestion of sewage in secondary schools for bioenergy generation in Kakamega County, the study suggests similar studies in Secondary schools of other Counties.

(ii) The study did not look at the conditions necessary for methanogenesis. Therefore, this study suggests that these conditions be studied to find out their impact on biogas generation in schools.

(iii) The study did not look at how biogas technology for bioenergy generation can be realised in our schools at a minimal cost. This study therefore recommends an investigation into how schools can anaerobically generate sewage bioenergy at affordable costs to make the project economically viable or cost effective.

(iv) The study did not look at the relationships between diet, political factors and public opinion on AD of sewage for bioenergy generation. Therefore, this study proposes investigation of these factors.

REFERENCES

AGECC (2010). Summary Report and Recommendations. Advisory Group on Energy and Climate Change, 28th April, 2010, New York.

Aicha, B., &Keophet, P. (2002). Study on Local Coping Mechanisms in Disaster Management: Case studies from the Lao PDR.

Amrit, B., K. (2008). Biogas as Renewable Energy from Organic Waste. Biotechnology –Vol. X. Available from:https//pdfs.semanticscholar.org/42ed/80879f3a506582561bd2e2fcca12b7623f5b.pdf. Accessed on 08/11/2016

Andersson, K., Rosemarin, A., Lamizana,B., Kvarnström, E., McConville, J., Seidu, R.,Dickin, S. and Trimmer, C. (2016). Sanitation,Wastewater Management and Sustainability:from Waste Disposal to Resource Recovery. Nairobi and Stockholm: United Nations Environment Programme and StockholmEnvironment Institute.

Anne, N., Mary, N, Phanuel, O., Peris, M., Caroline, O., Oliver, J.,and Miyuki, I. (2014). Sustainable wood fuel access and utilization Achieving cross-sectoral integration in Kenya. World Agroforestry Centre /5Stockholm Environment Institute Technical brief - May 2014.

Aziz, I., and Salifu, T. (2012). Nutrient value in the effluent of human excreta and fruit waste in two fixed dome biogas plants. Journal of Agricultural and Biological Science ©2006-2012. Asian Research Publishing Network (ARPN). VOL. 7, NO. 10, OCTOBER 2012:798-802. ISSN 1990-6145.Available: www.arpnjournals.com

Barasa, I. (2013). Attitude and knowledge of students on alternative sources of energy. LAP LAMBERT Academic Publishing (January 2, 2013). ISBN-13: 978-3846510926. Available:https://www.amazon.com/Attitude-knowledge-students-alternative-sources/dp/3846510920. Accessed on 09/11/2016.

Barnhart, S. (2012). Teaching Sustainability across Scale and Culture: Biogas in Context. Journal of Sustainability Education. Vol. 3, March 2012. ISSN: 2151-7452.

Berglund, M. (2006). Biogas Production from a System Analytical Perspective. PhD Thesis. Lund University, Lund, Sweden.

Berkes, F., &Jolly, D. (2001). Adapting to climate change: social-ecological resilience in a Canadian western Arctic community. Conservation Ecology 5(2): 18. [Online] URL: http://www.consecol.org/vol5/iss2/art18.

Bhol, J., Sahoo, B., & Mishra, K. (2011). National Conference on Renewable and New Energy Systems (RNES-2011), 22 – 23 December, 2011, SIET, Odisha. Biogas Digesters in India: A Review. Available from; https://www.researchgate.net/publication/282284360. Accessed on 08/11/2016

Brown, V., J. (2006). Biogas a bright idea for Africa. Environmental Health Perspectives 114:301-303.

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., &Herrero, M. (2011). Coping with Climate Variability and Adapting to Climate Change in Kenya: Household and Community Strategies and Determinants.

Burns, N. (2000). The Practice of Nursing Research: Conduct, Critic and Citation. Third Edition. London: Saunders.

Camp Kenya (2011). Institutional Fuel Wood Utilization in Kinango District, Kwale County, Kenya.htm. Camps International Project Diary Survey.

Cassada, M. E., and Safley, L.M. (1990). Global Methane Emissions from Livestock and Poultry Manure. EPA CX-816200-010. https://energypedia.info/wiki/Environmental_Frame_Conditions_of_Bi.

Davidson, O., R. (1992). Energy issues in Sub-Sahara Africa: Future directions. Annual review of environment and resources 17:359-403.

Dixon, R., and Nicholas, S. (2012). In Nairobi, Kenya, biogas from human waste wins over few cooks. November 16, 2012. Los Angeles Times.

Fischer, W. V. (2004). Climate Change and Agricultural vulnerability-The Climate Institute. www.climate.org/resources/climate/agriculture-impacts/agriculture. Accessed; 10th October, 2014.

Gagliardi, J.V., Karns, J. (2000). Leaching of *Escherichia coli* O157:H7 in diverse soils under various agricultural management practices. Applied and Environmental Microbiology. 66, 877-883.

GESAMP (2001). Protecting the oceans from land-based activities: Land-based sources and activities affecting the quality and uses of the marine, coastal and associated freshwater environment (GESAMP No. 71). New York: UN Environment Programme.

Government of Kenya (2004). Report of the Kenya Sector Energy Needs: Assessment Workshop.9-10 December 2004. Safari park hotel – Nairobi.

Government of Kenya (2006).Kenya Vision 2030.

Government of Kenya (2010).National Climate Change Response Strategy. Ministry of Environment and Mineral Resources. Nairobi, Kenya.

Government of Kenya(2010). The 2009 Kenya Population and Housing Census;"Counting Our People for the Implementation of Vision 2030". Volume 1C: Population Distribution by age, Sex and Administrative Units. KNBS, Nairobi, Kenya. P174-178.

Government of Kenya (2010). The Constitution of Kenya. National Council for Law Reporting. Nairobi, Kenya. Pg. 49.

Government of Kenya (2012). Kenya Health Policy 2012-2030. Government Printer. Nairobi, Kenya. Pg. -25.

Government of Kenya (2014). Basic Education Statistical Booklet.Pg78-79.

GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit) (2009):Biogas-Application and Product. DevelopmentBiogas Digest.Volume II; ISAT, Germany.Pg. 8.Available at http://www.gtz.de/de/dokumente/en-biogas-volume2.pdf. Accessed on 16/9/2012.

GTZ ISAT (1999). Biogas Digest Volume III Biogas Costs and Benefits and Biogas – Programme Implementation Information and Advisory Service on Appropriate Technology (ISAT) GTZ. Pg. 31. Availableathttp://www.snvworld.org/sites/www.snvworld.org/files/publications/biogas_digest_volume_3_biogas_costs_and_benefits_and_programme_implementation.pdf.pdf. Accessed on 16/9/2012.

GTZ (2010). Agro-industrial biogas in Kenya: Potentials, Estimates for Tariffs, Policy and Business Recommendations. Renewable Energy Project Development Programme East Africa. German Biomass Research Centre.

Gustavsson, M. (2000).Biogas technology: Solution in search of its problem: A Study of small-scale rural technology introduction and integration. (Human Ecology Reports Series 1). Doctoral dissertation, Goteborg University, Sweden.

GVEP KENYA (2006). Energy Road Map to Achieving MDG Targets Kenya Sectorial Energy Requirements, Final Report. The Global Village Energy Partnership, September 2006.

Hope, A., and H. (2012). Low-cost Sanitation: An overview of available methods. http://www.wilsoncenter.org/sites/default/files/WaterStoriesSanitation.pdf. Accessed on 16/09/2012.

Hornby, A., S. (2010). Oxford Advanced Learners' Dictionary of Current English. University Press. Great Clarendon Street, Oxford ox2 6DP.

Hutchison, M.L., Walters, L.D., Moore, A., Crookes, K.M., Avery, S.M. (2004). Effect of length of time before incorporation on survival of pathogenic bacteria present in livestock wastes applied to agricultural soil. American Society for Microbiology. 70, 5111-5118.

IPCC (1996). Revised IPCC Guidelines for National Greenhouse Gas Inventories. (Intergovernmental Panel on Climate Change)

IPCC (2007).Climate change 2007: Synthesis report. Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, UK.

Jamieson, R.C., Gordon, R.J., Sharples, K.E., Stratton, G.W., Madani, A. (2002). Movement and persistence of fecal bacteria in agricultural soils and subsurface drainage water: a review. Can. Biosyst. Eng. 44, 1.1–1.9.

Johansen, J., and O. (2009). Sewage biogas fuels public transport buses in Oslo. Oslo Water and Sewage Works. Sludge Management. World Water and Environmental Engineering. March/April 2009.Pg. 2-12.

Kumar, A., & Sharma, A., (2015). Advancement in Biogas Digester: Chapter in Green Energy and Technology. Available from: https://www.researchgate.net/publication/275273428 DOI: 10.1007/978-81-322-2337-5_14. Accessed on 08/11/2017

Lovell, K. & Lawson, K. S. (1970). Understanding research in education.London: University of London P.

KAMFOR (2002). Kenya: Integrated assessment of the Energy Policy-With focus on the transport andhousehold energy sectors. Available from:https://unep.ch/etb/areas/pdf/Kenya%20ReportFINAL.pdf. Accessed on 13/11/2015.

KFS (2013). Forester: A quarterly Magazine of the Kenya Forest Service. Issue No. 10. October, 2013. Pg. 11.

KIFCON (1994). Kakamega Forest: People and Forest in Balance. Majestic Printing Works Ltd. Nairobi, Kenya. Pg.9-45.

Kiptum, C., K., and Ndambuki, J., M., (2012). Well water contamination by pit latrines: A case study of Langas. International Journal of Water Resources and Environmental Engineering. Vol 4 (2):35-43. Available: http://www.academicjournals.org/IJWREE. DOI: 10.5897/IJWREE11.084 ISSN: 1991-637X.

KIST (2005). Biogas plants in Rwandan prisons treat sewage, generate biogas and

Crop fertilizer, and save trees. Kigali Institute of Science, Technology and Management Kigali. Rwanda.

KNBS (2010). Kenya Population and Housing Census Report, Government Printers, Nairobi. Pg. 57-63

Kothari, C.R. (2004). Research Methodology, Methods and Techniques. Second Edition. New Age International (P) Ltd., Publishers, New Delhi.

Koopmann, R. (2008a). Determination of Kjeldal Nitrogen in soil, bio-waste and sewage sludge. http://www.ecn.nl/docs/society/horizontal/STD6161_KjN.pdf.

Koopmann, R.(2008b). Total phosphorus in soil, bio waste and sewage sludge. http://www.ecn.nl/docs/society/horizontal/STD6163_TP.pdf.

Lovley, D., R.(2006). Microbial fuel cells: Novel microbial physiologies and engineering approaches. Energy biotechnology. Elsevier Ltd.

Malik, D., S., and Umesh, B.(2009).Biogas production from Sludge of Sewage Treatment Plant at Haridwar (Uttarakhand).Asian J. Exp. Sci., Vol. 23, No. 1, 2009; 95-98

Mara, D. (2004). Domestic wastewater treatment in developing countries. London, Sterling VA: Earth scan. Pg. 25-36.

Monnet, F. (2003). An Introduction to Anaerobic Digestion of Organic Wastes. http://www.biogasmax.co.uk/media/introanaerobicdigestion__073323000_1011_24042007.pdf.

Mugenda, M., &Mugenda, A., G. (1999). Research Methods: Quantity and Quality Approaches. Nairobi: African Centre for Technology Studies (ACTS) Press.

Mukhovi, S. M. (2009). The impact of farm technologies on household food security among small households in Western Province of Kenya; A gendered perspective. Unpublished PhD Thesis, UoN. Pp.82.

Munalula F., and Meincken M. (2008). An Evaluation of South African Fuel wood with regards to calorific value and Environmental Impact. Biomass & Bioenergy. Vol. 33 Issue 3. P415-420. Elsevier.

Musembi, F., J., Nandokha, T., Njeru,P., Mbure,G., N., Matere, S., &Emongor, R. (2010).Baseline Study on Status of Biofuel Technology in Kajiado and Kisii regions.

Nachmias, C., F., &Nachmias, D. (1996). Research Methods in the Social Sciences, Fifth Edition, New York, Oxford University Press.

Nassiuma, D., K. (2000). Survey sampling: Theory and methods. Njoro, Kenya: Egerton University Press.

NBPG (2007). Biogas Sector in Nepal: Highlighting Historical Heights and Present Status. Kathmandu: Nepal Biogas Promotion Group.

OCHA (2010).Energy Security and Humanitarian Action: Key Emerging Trends and Challenges. OCHA Occasional Policy Briefing Series, Brief No. 3.UN Office for the Coordination of Humanitarian Affairs. Policy Development and Studies Branch (PDSB).

Onchiri, R.(2011).Assessment of water quality in Kakamega municipality. International journal of disaster management and risk reduction. Vol 3 no.3.

Pfundtner, E. (2002). Limits and Merits of Sludge Utilization-Land Application. European Workshop on Impact of Waste Management Legislation on Biogas Technology, Tulln, Austria, September 12-14.

Pritchard, M., Mkandawire, T., Edmondson, A., O'Neill, J., G., &Kululanga, G.

(2009). Potential of using plant extracts for purification of Shallow well water in Malawi. Physics and Chemistry of the Earth, 34, 799-805.

REN21 (2011). UNEP report: Global Trends in Renewable Energy Investment 2011. Renewables 2011. Global Status Report, Version 2.1 | 08/2011, Paris. France. www.ren21.net.

Shelton, D. (2002). Human Rights, Health & Environmental Protection: Linkages in Law &Practice. A Background Paper for the World Health Organization. Health and Human Rights Working Paper Series No 1. Notre Dame London Law Centre, London. Pg. 6. http://www.who.int/hhr/information/en/Series. Accessed on 18/08/2013

Shokri, S. (2012). Biogas Technology, Applications, Perspectives and Implications. International Journal of Agricultural Science and Research, 2(3), 53-60

Smith, K., A., Jeffrey W., A., Metcalfe, J., P., Sinclair, A., H., and Williams, J., R. (2007). Nutrient value of digestate from farm-based biogas plants. Available:http://www.ramiran.net/ramiran2010/docs/Ramiran2010_0171_final .pdf.

Smith, J., et al (2011). The Potential of Small-Scale Biogas Digesters to Alleviate Poverty and Improve Long Term Sustainability of Ecosystem Services in Sub-Saharan Africa Interdisciplinary Expert Workshop - Makerere University, Uganda, 24-28 January, 2011. DFID NET-RC A06502.

Smit, B., & Olga, P. (2008). Adaptation to Climate Change in the Context of Sustainable Development and Equity. Sustainable Energy Solutions in East Africa (2009): Status, Experiences and Policy Recommendations from NGOs in Tanzania, Kenya and Uganda. Report 2.

Sphere Project (2004). Humanitarian Charter and Minimum Standards in Disaster Response. The Sphere Project. Geneva, Switzerland. http://www.sphereproject.org.

TA (2011).Sewage as a source of plant macro-nutrients. SOWTech.

Tate, K., Atwill, E., Bartolome, J.W., Naderd, G. (2006). Significant *Escherichia coli* attenuation by vegetative buffers on annual grasslands. Journal of Environmental Quality. 35, 795-805.

Trochim, M., K., W. (2008), as cited in Bernard, H., R., (2008): Social Research Methods: Qualitative and Quantitative Approaches. Thousand oaks, CA: Sage.

Tyrell, S., F., Quinton, J., N. (2003). Overland flow transport of pathogens from agricultural land receiving faecal wastes. Journal of Applied and Environmental Microbiology. 94, 87S-93S.

UNEP/GEMS (2006). *Water Quality for Ecosystemand Human Health*. Burlington, ON: UNEP/ UNGlobal Environmental Monitoring Systems GEMS.Available from:http://www.unep.org/gemswater/Portals/24154/publications/pdfs/water_quality_human_health.df.

UNEP (2008).Decision adopted by the Conference of the Parties to the Convention On Biological Diversity at its ninth meeting. Conference of the Parties to the Convention on Biological Diversity. UNEP/CBD/COP/DEC/IX/5. Bonn.

UNEP (2011). Renewable Energy: Investing in energy and resource efficiency. Pg. 24.

United Nations Department of Economic and Social Affairs (1989). United Nations Conference on Environment and Development. General Assembly. A/RES/44/228.

US EPA (2012b). *Global Anthropogenic Emissionsof Non-*CO_2 *Greenhouse Gases:*

1990–2030, 430–R-12-006. Washington, DC: Office of AtmosphericPrograms, Climate Change Division, USEnvironmental Protection Agency. Available fromhttp://www.epa.gov/climatechange/EPAactivities/economics/nonco2projections.html.

Vetter, H., Steffens, G., and Schröpel, R. (1987). The influence of different processing Methods for slurry upon its fertilizer value on grassland. Available:http://www.cranfield.ac.uk/sas/cas/projects/page49589.html.

Watson, J. (2001). How to Determine a Sample Size: Tip sheet #60.University Park, PA: Penn State Cooperative Extension. Pp.1-15. Available at http: //www.extension.psu.edu/evaluation/pdf/TS60.pdf. Accessed on 7/7/2013

World Bank (2010).Development in a Changing Climate: Concept note. Washington, DC: World Bank.

Yongabi, K.A., Harris, P.L., Sambo, A.S., Agho, M.O. (2003).Managing cow dung with a cheap, low tech plastic digester. Proceedings of the 29 WEDC International Conference on Water and Environmental Sanitation co-organised by Water Engineering Development Centre of Loughborough University, UK, in conjunction with the Ministry of water resources, Abuja holding at Abuja on September 22-26., (2003) PP486-489. Proceedings at wedc web page (2004) online: http://wedc.lboro.ac.uk/conferences/pdfs/29/yongabi1.pdf PP74-77.

Yongabi, K.A., Harris, P.L., Lewis, D.M. (2009). Poultry faeces management with a simple low cost plastic digester. African Journal of Biotechnology. 8, 1560-1566.

APPENDICES

APPENDIX I

Introduction letter to Respondents

Dear Sir/ Madam,

I am a graduate student at Masinde Muliro University of Science and Technology carrying out a study on **'Anaerobic Digestion of Sewage for Energy Production and Environmental Protection in Secondary Schools of Kakamega County, Kenya'**. I hereby request you as an important opinion leader to spare some 10 minutes to participate in the study. By being cooperative you will be making crucial contribution to the study whose findings will assist the policy and decision makers regarding the potential of sewage utilisation for energy production and environmental protection in Kakamega County.

The basis of your participation is purely voluntary. Yourresponse will be used for the purpose of the study only and therefore there are no risks involved. Information obtained from you will be treated with strict confidentiality and your names shall not be used in the write up of the study report or on other data information that they may be linked in any other forum.

Thank you for participating!

Yours faithfully,

Barasa O. Ibrahim.

September, 2013.

APPENDIX II

Introduction letter to School Principals

Centre for Disaster Management &
Humanitarian Assistance, MMUST.
P.O. Box 190-50100,
KAKAMEGA.
22NDSept, 2013.

Dear Sir/Madam,

RE: RESEARCH VISIT

This is to inform you that I intent to visit your school for the purpose of carrying out a research. The research is entitled '**Anaerobic Digestion of Sewage for Energy Production and Environmental Protection in Secondary Schools of Kakamega County, Kenya**'. The study is a requirement in my pursuance of a PhD degree in Disaster Management & Humanitarian Assistance. The intended research visit will take place on any weekday in the course of the month of September to October, 2013. I will need to briefly interview you and a few stakeholders and administer questionnaires to some of them.

I am looking forward to your kind consideration and cooperation for the exercise.

Thanking very much in advance.

Yours truly,

Barasa O. Ibrahim

0722 433 085

CC: Kakamega County Education Officer

APPENDIX III

Interview Schedule for Principals of Kakamega County Secondary Schools

Part 1: Background information

Interviewee:………………………………Date of Interview:…………………...…….

Place:…………………………..…Time of Interview: ……….……………………..

Duration of Interview: ……………………………….…

Part 2: Interview questions

Section A: Quantity of Sewage generated and its Impact

This section seeks to elicit information about the quantity of sewage generated in secondary schools of Kakamega Countyand its impact on the environment.

1. What is the category of your school? (**Please Tick**, √ **one)**

A. National school	B. Extra-County School	C. County school	D. District School

2. Is your school a Boys' or Girls' or both a Boys & Girls' school?

A. Boys only	B. Girls only	C. Mixed Boys & Girls

3. Is your school a Boarding or a Day-school?

A. Boarding	B. Day	C. Boarding & Day

4. What is the student population in your school?

A. Below 100	B. 101-499	C. 500-1000	D. Above 1000

5. How many pit latrines does your school have?

……..………………………………………………………………………………….

6. Are these latrines adequate for your student population?

…..…………………………………………………………………………………

If no, how does your school address this challenge?

………………………………………………………………………………………

7. Which of the following means does the school use to handle its sewage?

A. Pit latrine	B. Soak pits	C. Municipal sewage system	D. Other(Specify

8. What is the volume capacity of your septic tanks/latrines?

………………………………………………………………………………………

9. What means does your school use to empty the full septic tanks /latrines?

………………………………………………………………………………………

10. What is the volume capacity of your sewers/latrines?

………………………………………………………………………………………

11. How often does your school empty the full septic tanks/pit latrines?

..……………………………………………………………………………………

12. Where does the school dispose of the sewage after emptying the septic tanks/latrines?

………………………………………………………………………………………

13. What challenges does the school face when disposing of the sewage? (Please **rank** them in order of their magnitude).

i…….……………………………..……………………………………………………

ii………………………….……………………………………………………………

iii…..……………………………………………………………..……………………

14. Has there been any outbreak of diseases associated with the school's sewage disposal?

………………………………………………………………………………………

15. How much does it cost your school to empty the septic tanks/latrines?

....

Section B: Impact of Energy generation from Sewage

This section seeks to elicit information about the impact of energy generation from sewage on the cost and benefits of energy use in secondary schools.

16. How much wood fuel does the school use in the school kitchen in a week?

    i. In lorries..…………………….……………………………………

    ii. In stacks……………………………………………………………

17. How much does the school spend on wood fuel in a term?

……………..………………………………………………………………….

18. In which way has the increase in student population affected the school budget on firewood?

……………………………………………………………………………….

19. What means does the school use to sustain this budget on firewood?

……………………………………………………………………………….

20. What steps are being taken by the school to reduce the costs of wood fuel consumption in your school? (Please **rank** them according to importance)

    i. ………………………………………………………………………

    ii. ………………………………………………………………………

    iii. ………………………………………………………………………

    iv. ………………………………………………………………………

21. What steps are being taken by the school to reduce the effects of wood fuel consumption in your school?(Please **rank** them according to importance)

    i. ………………………………………………………………………………
    ii. ………………………………………………………………………………
    iii. ………………………………………………………………………………
    iv. ………………………………………………..……………………..

Section C: Potential Effect of Energy generation from Sewage on the Environmental Protection

This section seeks to elicit information on the potential effect of energy generation from sewage on environmental protection in secondary schools in Kakamega County.

22. What complains does the school fraternity have about toilets?

………………………………………………………………………………….

………………………………………………………………………………….

23. What health risks are associated with the school's sewage disposal?

………………………………………………………………………………….

24. What solutions have been put in place by the school to tackle these health risks?

………………………………………………………………………………….

25. What is the general health status of your School?

………………………………………………………………………………….

26. Which source of energy does your school kitchen use for cooking food or heating?

………………………………………………………………………………….

27. Where does your school kitchen getwood fuel supplies from?

…………………………………………………………………………………….

28. What challenges does your school face when using wood fuel in the school kitchen?

………………………………………………………………………………………

………………………………………………………………………………………

29. How has your school tried to solve these challenges?

………………………………………………………………………………………

30. Has your school taken any steps to reduce wood fuel consumption in the kitchen?

…………………………………..…………………………………………………….

If yes, which ones has your school taken to reduce wood fuel consumption?

………………………………………………………………………………………

31. Is there any health risk associated with wood fuel consumption in your school?

………………………………………………………………………………………

If yes, specify the nature of the health hazard…….……………………...…………………………………….................

Section D: Strategies for enabling Sewage Utilisation for Environmental Protection

This section seeks to establish the strategies available for enabling sewage utilisation as green energy source for environmental protection and energy needs in secondary schools in Kakamega County.

32. Does the school have any interest in biogas energy?

………………………………………………………………………………………

33. Would the school be willing to use its sewage for generation of biogas as green energy?

……………………………………………………………………………………………

34. Would the school be willing to pay for the installation of the biogas digester plant in its premises?

……………………………………………………………………………………………

35. What plans does the school have to utilise sewage for biogas energy generation?

……………………………………………………………………………………………

36. Does the school have any organic waste for disposal?

……………………………………………………………………………………………

37. Will the school be willing to utilise the organic waste for biogas generation?

……………………………………………………………………………………………

38. Do you think your school has the capacity to utilise sewage for energy production?

……………………………………………………………………………………………

39. How would your school plan to utilise the sewage for energy production?

……………………………………………………………………………………………

Thank you very much for your co-operation

APPENDIX IV

Interview Schedule for Deputy Principals in Kakamega County

Part 1: Background information

Interviewee:………………………………Date of Interview:…………………....…….

Place:………………………..…………Time of Interview: …….……………………..

Duration of Interview: …………………………………..…

Part 2: Interview questions

Section A

This section seeks to elicit information about the impact of the quantity of sewage generated in secondary schools in Kakamega County on the surrounding.

1. What is the category of your school??(**Please Tick**, √ **one)**

A. National school	B. Extra-County School	C. County school	D. District School

2. Is your school a Boys' or Girls' or both a Boys & Girls' school?

A. Boys only	B. Girls only	C. Mixed Boys & Girls

3. Is your school a Boarding or a Day-school?

A. Boarding	B. Day	C. Boarding & Day

4. What is the student population in your school?

A. Below 100	B. 101-499	C. 500-1000	D. Above 1000

5. How many pit latrines does your school have?

……..……………………………………………………………………………….

6. Are these latrines adequate for your student population?

…..……………………………………………………………………………….

If no, how does your school address this challenge?

…………………………………………………………………………………

7. Which of the following means does the school use to handle its sewage?

A. Pit latrine	B. Soak pits	C. Municipal sewage system	D. Other(Specify

8. What is the volume capacity of your septic tanks/latrines?

…………………………………………………………………………………

9. What means does your school use to empty the full septic tanks /latrines?

…………………………………………………………………………………

10. What is the volume capacity of your sewers/latrines?

…………………………………………………………………………………

11. How often does your school empty the full septic tanks/pit latrines?

..……………………………………………………………………………….

12. Where does the school dispose of the sewage after emptying the septic tanks/latrines?

…………………………………………………………………………………

13. What challenges does the school face when disposing of the sewage? (Please **rank** them in order of their magnitude).

i……..……………………………………………………………………………

ii…………………………………………………………………………………

iii….…..……………………………………………………..……………………

14. Has there been any outbreak of diseases associated with the school's sewage disposal?

………………………………………………………………………………………

15. How much does it cost your school to empty the septic tanks/latrines?

....

Section B

This section seeks to elicit information about the impact of energy generation from sewage on the cost and benefits of energy use in secondary schools.

16. How much wood fuel does the school use in the school kitchen in a week?

    iii. In lorries..…………………….…………………………………………

    iv. In stacks…………………………………………………………………

17. How much does the school spend on wood fuel in a term?

……………..……………………………………………………………………….

18. In which way has the increase in student population affected the school budget on firewood?

……………………………………………………………………………………….

19. What means does the school use to sustain this budget on firewood?

……………………………………………………………………………………….

20. What steps are being taken by the school to reduce the costs of wood fuel consumption in your school? (Please **rank** them according to importance)

    v. ……………………………………………………………………………

    vi. ……………………………………………………………………………

    vii. ……………………………………………………………………………

    viii. ……………………………………………………………………………

21. What steps are being taken by the school to reduce the effects of wood fuel consumption in your school?(Please **rank** them according to importance)

v. …………………………………………………………………………

vi. …………………………………………………………………………

vii. …………………………………………………………………………

viii. ……………………………………………..……………………..

Section C

This section seeks to elicit information on the potential effect of energy generation from sewage on environmental protection in secondary schools in Kakamega County.

22. What complains does the school fraternity have about toilets?

…………………………………………………………………………………….

…………………………………………………………………………………….

23. What health risks are associated with the school's sewage disposal?

…………………………………………………………………………………….

24. What solutions have been put in place by the school to tackle these health risks?

…………………………………………………………………………………….

25. What is the general health status of your School?

…………………………………………………………………………………….

26. Which source of energy does your school kitchen use for cooking food or heating?

…………………………………………………………………………………….

27. Where does your school kitchen getwood fuel supplies from?

…………………………………………………………………………………….

28. What challenges does your school face when using wood fuel in the school kitchen?

………………………………………………………………………………………

………………………………………………………………………………………

29. How has your school tried to solve these challenges?

………………………………………………………………………………………

30. Has your school taken any steps to reduce wood fuel consumption in the kitchen?

……………………………………..………………………………………………….

If yes, which ones has your school taken to reduce wood fuel consumption?

………………………………………………………………………………………

31. Is there any health risk associated with wood fuel consumption in your school?

………………………………………………………………………………………

If yes, specify the nature of the health hazard…….…………………………..……………………………………….…............

Section D

This section seeks to establish the strategies available for enabling sewage utilisation as green energy source for environmental protection and energy needs in secondary schools in Kakamega County.

32. Does the school have any interest in biogas energy?

………………………………………………………………………………………

33. Would the school be willing to use its sewage for generation of biogas as green energy?

………………………………………………………………………………………

34. Would the school be willing to pay for the installation of the biogas digester plant in its premises?

………………………………………………………………………………………

35. What plans does the school have to utilise sewage for biogas energy generation?

………………………………………………………………………………………

36. Does the school have any organic waste for disposal?

………………………………………………………………………………………

37. Will the school be willing to utilise the organic waste for biogas generation?

………………………………………………………………………………………

38. Do you think your school has the capacity to utilise sewage for energy production?

………………………………………………………………………………………

39. How would your school plan to utilise the sewage for energy production?

………………………………………………………………………………………

Thank you very much for your co-operation

APPENDIX V

Interview Schedule for other stakeholders (BOM/PA)

Part 1: Background information

Interviewee:………………………..Date of Interview: ………………...…………….

Place:……………………..……Time of Interview: ………………………………..

Duration of Interview: …………………………………….……………………...…

Part 2: Interview questions

1. How many students does the school have?

   ………………………………………………………………………………

2. How many latrines does the school have?

   ………………………………………………………………………………

3. How much sewage does your school generate?

   ………………………………………………………………………………

4. How is the school currently dealing with this sewage?

   ………………………………………………………………………………

5. What are some of the challenges that your school faces from the sewage menace?

   ………………………………………………………………………………

   ………………………………………………………………………………

6. Are there any health risks associated with this sewage?

   ………………………………………………………………………………

   ………………………………………………………………………………

7. Does the surrounding community experience any problems from the school sewage?

   ………………………………………………………………………………

8. How frequent does the school empty these latrines/septic tanks?

………………………………………………………………………………………

9. How much does it cost the school to empty its septic tanks/latrines?

………………………………………………………………………………………

………………………………………………………………………………………

10. What sources of energy does the school currently use?

………………………………………………………………………………………

………………………………………………………………………………………

11. How much does the school spend on each one of these sources of energy?

………………………………………………………………………………………

………………………………………………………………………………………

12. Does the school experience any challenges from using this source of energy?

………………………………………………………………………………………

………………………………………………………………………………………

13. Which source of energy does the school kitchen use for cooking food or heating?

………………………………………………………………………………………

………………………………………………………………………………………

14. Where does the school get itswood fuel supplies from?

……………………………………………………………………………………..

15. What challenges does the school face when using wood fuel in the school kitchen?

……………………………………………………………………………………...

………………………………………………………………………………………

16. How is the school handlingthesechallenges?

………………………………………………………………………………………

17. How much does the school spend on firewood?

………………………………………………………………………………………

18. Does the school have any woodlots for use as firewood?

………………………………………………………………………………………

………………………………………………………………………………………

19. How does the school replenish these woodlots to ensure a continuous supply of firewood?

……………………………………………………………………………………..

20. Would the school be interested in constructing a biogas digester plant in its premisesin order to get benefits of free energy?

………………………………………………………………………………………

21. Would the school be willing to pay for the installation of biogas digester plant in its compound?

………………………………………………………………………………………

………………………………………………………………………………………

22. Does the school you have any organic waste in for disposal?

………………………………………………………………………………………

………………………………………………………………………………………

23. Would the school be interested in utilising it for biogas production?

………………………………………………………………………………………

Thank you very much for your co-operation!

APPENDIX VI

Questionnaire for Boarding /Senior Teachers/Teachers

Part 1: Background information

Interviewee:………………………..Date of Interview: ……...………...…………….

Place.:……………………………Time of Interview: …….………………………..

Duration of Interview: ……………………………………………….……………...…

Part 2: Interview questions

Section A

This section seeks to elicit information about the impact of the quantity of sewage generated in secondary schools in Kakamega County on the surrounding.

1. What is the category of your school??(**Please Tick**, √ **one)**

A. National school	B. Extra-County School	C. County school	D. District School

2. Is your school a Boys' or Girls' or both a Boys & Girls' school?

A. Boys only	B. Girls only	C. Mixed Boys & Girls

3. Is your school a Boarding or a Day-school?

A. Boarding	B. Day	C. Boarding & Day

4. What is the student population in your school?

A. Below 100	B. 101-499	C. 500-1000	D. Above 1000

5. How many pit latrines does your school have?

……………………………………………………………………………………….

6. Are these latrines adequate for your student population?

……………………………………………………………………………………….

If no, how does your school address this challenge?

………………………………………………………………………………………..

7. Which of the following means does the school use to handle its sewage?

A. Pit latrine	B. Soak pits	C. Municipal sewage system	D. Other(Specify

8. What is the volume capacity of your septic tanks/latrines?

…………………………………………………………………………………………

9. What means does your school use to empty the full septic tanks /latrines?

…………………………………………………………………………………………

10. What is the volume capacity of your sewers/latrines?

…………………………………………………………………………………………

11. How often does your school empty the full septic tanks/pit latrines?

..……………………………………………………………………………………….

12. Where does the school dispose of the sewage after emptying the septic tanks/latrines?

…………………………………………………………………………………………

13. What challenges does the school face when disposing of the sewage? Please rank them in order of their magnitude.

    i.……..…………………………………………………………………………

    ii.………..………………………………………………………………………

    iii.……..…………………………………………………………………..……

14. Has there been any outbreak of diseases associated with the school's sewage disposal?

………………………………………………………………………………………

15. How much does it cost your school to empty the septic tanks/latrines?

....

Section B

This section seeks to elicit information about the impact of energy generation from sewage on the cost and benefits of energy use in secondary schools.

16. How much wood fuel does the school use in the school kitchen in a week?
    i. In lorries………..……………………………………………………….
    ii. In stacks…………..…………………………………………………….
17. How much does the school spend on wood fuel in a term?

…………..………………………………………………………………………….

18. In which way has the increase in student population affected the school budget on firewood?

……………………………………………………………………………………….

19. What means does the school use to sustain this budget on firewood?

……………………………………………………………………………………….

……………………………………………………………………………………….

20. What steps are being taken by the school to reduce the costs of wood fuel consumption in your school? (Please **rank** them according to importance)
    i. …………………………………………………………………………
    ii. …………………………………………………………………………
    iii. …………………………………………………………………………
    iv. …………………………………………………………………………

21. What steps are being taken by the school to reduce the effects of wood fuel consumption in your school?(Please **rank** them according to importance)

i. ……………………………………………………………………………

ii. ……………………………………………………………………………

iii. ……………………………………………………………………………

iv. ………………………………………………..……………………..

Section C

This section seeks to elicit information on the potential effect of energy generation from sewage on environmental protection in secondary schools in Kakamega County.

22. What complains does the school fraternity have about toilets?

……………………………………………………………………………….

……………………………………………………………………………….

23. What health risks are associated with the school's sewage disposal?

……………………………………………………………………………….

24. What solutions have been put in place by the school to tackle these health risks?

……………………………………………………………………………….

25. What is the general health status of your School?

……………………………………………………………………………….

26. Which source of energy does your school kitchen use for cooking food or heating?

……………………………………………………………………………….

27. Where does your school kitchen getwood fuel supplies from?

……………………………………………………………………………….

28. What challenges does your school face when using wood fuel in the school kitchen?

………………………………………………………………………………………

………………………………………………………………………………………

29. How has your school tried to solve these challenges?

………………………………………………………………………………………

30. Has your school taken such steps to reduce wood fuel consumption in the kitchen?

……………………………………………………………………………………….

31. If yes, which ones has your school taken to reduce wood fuel consumption?

………………………………………………………………………………………

32. Is there any health risk associated with wood fuel consumption in your school?

……………………………………………………………………………………….

If yes, specify the nature of the health hazard……………………..……………………………………….................

Section D

This section seeks to establish the strategies available for enabling sewage utilisation as green energy source for environmental protection and energy needs in secondary schools in Kakamega County.

33. Does the school have any interest in biogas energy?

…………………………………………………………………………………………

34. Would the school be willing to use its sewage for generation of biogas as green energy?

…………………………………………………………………………………………

35. Would the school be willing to pay for the installation of the biogas digester plant in its premises?

……………………………………………………………………………………

36. Does the school have any organic waste for disposal?

……………………………………………………………………………………

37. Will the school be willing to utilise the organic waste for biogas generation?

……………………………………………………………………………………

38. Do you think your school has the capacity to utilise sewage for energy production?

……………………………………………………………………………………

39. How would your school plan to utilise the sewage for energy production?

……………………………………………………………………………………

Thank you very much for your co-operation

APPENDIX VII

Questionnaire for School Bursars

Part 1: Background information

Interviewee:………………………..Date of Interview: ……………………………….

Place:…………………..………Time of Interview: ………………………………..

Duration of Interview: ……………………………………….……………………...…

Part 2: Interview questions

Section A

This section seeks to elicit information about the impact of the quantity of sewage generated in secondary schools in Kakamega County on the surrounding.

1. What is the category of your school??(**Please Tick**, √ **one)**

A. National school	B. Extra-County School	C. County school	D. District School

2. Is your school a Boys' or Girls' or both a Boys & Girls' school?

A. Boys only	B. Girls only	C. Mixed Boys & Girls

3. Is your school a Boarding or a Day-school?

A. Boarding	B. Day	C. Boarding & Day

4. What is the student population in your school?

A. Below 100	B. 101-499	C. 500-1000	D. Above 1000

5. How many pit latrines does your school have?

…………………………………………………………………………………….

6. Are these latrines adequate for your student population?

…………………………………………………………………………………….

If no, how does your school address this challenge?

……………………………………………………………………………………..

7. Which of the following means does the school use to handle its sewage?

A. Pit latrine	B. Soak pits	C. Municipal sewage system	D. Other(Specify

8. What is the volume capacity of your septic tanks/latrines?

………………………………………………………………………………………

9. What means does your school use to empty the full septic tanks /latrines?

………………………………………………………………………………………

10. What is the volume capacity of your sewers/latrines?

………………………………………………………………………………………

11. How often does your school empty the full septic tanks/pit latrines?

..…………………………………………………………………………………….

12. Where does the school dispose of the sewage after emptying the septic tanks/latrines?

………………………………………………………………………………………

13. What challenges does the school face when disposing of the sewage? Please rank them in order of their magnitude.

   i. ……………………………………………………………………………

   ii. ……………………………………………………………………………

   iii. ……………………………………………………………………………

14. Has there been any outbreak of diseases associated with the school's sewage disposal?

    …………………………………………………………………………………

15. How much does it cost your school to empty the septic tanks/latrines?

    ....

Section B

This section seeks to elicit information about the impact of energy generation from sewage on the cost and benefits of energy use in secondary schools.

16. How much wood fuel does the school use in the school kitchen in a week?
    - i. In Lorries……………………………………………………………….
    - ii. In stacks……………………………………………………………….

17. How much does the school spend on wood fuel in a term?

    ……………………………………………………………………………….

18. In which way has the increase in student population affected the school budget on firewood?

    …………………………………………………………………………………

19. What means does the school use to sustain this budget on firewood?

    ……………………………………………………………………………….

    ……………………………………………………………………………….

20. What steps are being taken by the school to reduce the costs of wood fuel consumption in your school? (Please **rank** them according to importance)
    - i. …………………………………………………………………………
    - ii. …………………………………………………………………………
    - iii. …………………………………………………………………………
    - iv. …………………………………………………………………………

21. What steps are being taken by the school to reduce the effects of wood fuel consumption in your school?(Please **rank** them according to importance)

i. ……………………………………………………………………………

ii. ……………………………………………………………………………

iii. ……………………………………………………………………………

iv. ……………………………………………………..……………………..

Section C

This section seeks to elicit information on the potential effect of energy generation from sewage on environmental protection in secondary schools in Kakamega County.

22. What complains does the school fraternity have about toilets?

……………………………………………………………………………….

……………………………………………………………………………….

23. What health risks are associated with the school's sewage disposal?

……………………………………………………………………………….

24. What solutions have been put in place by the school to tackle these health risks?

……………………………………………………………………………….

25. What is the general health status of your School?

……………………………………………………………………………….

26. Which source of energy does your school kitchen use for cooking food or heating?

……………………………………………………………………………….

27. Where does your school kitchen getwood fuel supplies from?

……………………………………………………………………………….

28. What challenges does your school face when using wood fuel in the school kitchen?

…………………………………………………………………………………

…………………………………………………………………………………

29. How has your school tried to solve these challenges?

…………………………………………………………………………………

30. Has your school taken such steps to reduce wood fuel consumption in the kitchen?

………………………………………………………………………………….

31. If yes, which ones has your school taken to reduce wood fuel consumption?

…………………………………………………………………………………

32. Is there any health risk associated with wood fuel consumption in your school?

………………………………………………………………………………….

If yes, specify the nature of the health hazard……………………..…………………………………………...............

Section D

This section seeks to establish the strategies available for enabling sewage utilisation as green energy source for environmental protection and energy needs in secondary schools in Kakamega County.

33. Does the school have any interest in biogas energy?

…………………………………………………………………………………

34. Would the school be willing to use its sewage for generation of biogas as green energy?

…………………………………………………………………………………

35. Would the school be willing to pay for the installation of the biogas digester plant in its premises?

………………………………………………………………………………………

36. Does the school have any organic waste for disposal?

………………………………………………………………………………………

37. Will the school be willing to utilise the organic waste for biogas generation?

………………………………………………………………………………………

38. Do you think your school has the capacity to utilise sewage for energy production?

………………………………………………………………………………………

39. How would your school plan to utilise the sewage for energy production?

………………………………………………………………………………………

Thank you very much for your co-operation

APPENDIX VIII

Questionnaire for School Nurses/Head Cooks

Part 1: Background information

Interviewee:………………………..Date of Interview: ……………………….…….

Place:…………………..………Time of Interview: ………………….…………..

Duration of Interview: ……………………………………..……………………..…

Part 2: Interview questions

Section A

This section seeks to elicit information about the impact of the quantity of sewage generated in secondary schools in Kakamega County on the surrounding.

1. How many pit latrines does your school have?

   ……………………………………………………………………………….

2. Are these latrines adequate for your student population?

   ……………………………………………………………………………….

   If no, how does your school address this challenge?

   ………………………………………………………………………………..

3. Which of the following means does the school use to handle its sewage?

A. Pit latrine	B. Soak pits	C. Municipal sewage system	D. Other(Specify

4. What is the volume capacity of your septic tanks/latrines?

   ………………………………………………………………………………

5. What means does your school use to empty the full septic tanks /latrines?

   ………………………………………………………………………………

6. What is the volume capacity of your sewers/latrines?

   ………………………………………………………………………………

7. How often does your school empty the full septic tanks/pit latrines?

   ……………………………………………………………………………………….

8. Where does the school dispose of the sewage after emptying the septic tanks/latrines?

   ………………………………………………………………………………………

9. What challenges does the school face when disposing of the sewage? Please rank them in order of their magnitude.

   i. ……………………………………………………………………………

   ii. ……………………………………………………………………………

   iii. ……………………………………………………………………………

10. Has there been any outbreak of diseases associated with the school's sewage disposal?

    ………………………………………………………………………………………

11. How much does it cost your school to empty the septic tanks/latrines?

    ....

Section B

This section seeks to elicit information about the impact of energy generation from sewage on the cost and benefits of energy use in secondary schools.

12. How much wood fuel does the school use in the school kitchen in a week?

    i. In Lorries…………………………………………………………………….

    ii. In stacks…………………………………………………………………….

13. How much does the school spend on wood fuel in a term?

    …………………………………………………………………………………….

14. In which way has the increase in student population affected the school budget on firewood?…………………………………………………………………….

15. What means does the school use to sustain this budget on firewood?

    ………………………………………………………………………………….

16. What steps are being taken by the school to reduce the costs of wood fuel consumption in your school? (Please **rank** them according to importance)

    i. ……………………………………………………………………………
    ii. ……………………………………………………………………………
    iii. ……………………………………………………………………………
    iv. ……………………………………………………………………………

17. What steps are being taken by the school to reduce the effects of wood fuel consumption in your school?(Please **rank** them according to importance)

    i. ……………………………………………………………………………
    ii. ……………………………………………………………………………
    iii. ……………………………………………………………………………
    iv. ………………………………………………...……………………..

Section C

This section seeks to elicit information on the potential effect of energy generation from sewage on environmental protection in secondary schools in Kakamega County.

18. What complains does the school fraternity have about toilets?

    ………………………………………………………………………………….

    ………………………………………………………………………………….

19. What health risks are associated with the school's sewage disposal?

    ………………………………………………………………………………….

20. What solutions have been put in place by the school to tackle these health risks?

    ……………………………………………………………………………….

21. What is the general health status of your School?

……………………………………………………………………………………….

22. Which source of energy does your school kitchen use for cooking food or heating?

……………………………………………………………………………………….

23. Where does your school kitchen getwood fuel supplies from?

……………………………………………………………………………………….

24. What challenges does your school face when using wood fuel in the school kitchen?

………………………………………………………………………………………

………………………………………………………………………………………

25. How has your school tried to solve these challenges?

………………………………………………………………………………………

26. Has your school taken such steps to reduce wood fuel consumption in the kitchen?

……………………………………………………………………………………….

27. If yes, which ones has your school taken to reduce wood fuel consumption?

………………………………………………………………………………………

28. Is there any health risk associated with wood fuel consumption in your school?

……………………………………………………………………………………….

If yes, specify the nature of the health hazard.

……..………………………..……………………………………………..............

Section D

This section seeks to establish the strategies available for enabling sewage utilisation as green energy source for environmental protection and energy needs in secondary schools in Kakamega County.

29. Does the school have any interest in biogas energy?

    ……………………………………………………………………………………

30. Would the school be willing to use its sewage for generation of biogas as green energy?

    ……………………………………………………………………………………

31. Would the school be willing to pay for the installation of the biogas digester plant in its premises?

    ……………………………………………………………………………………

32. Does the school have any organic waste for disposal?

    ……………………………………………………………………………………

33. Will the school be willing to utilise the organic waste for biogas generation?

    ……………………………………………………………………………………

34. Do you think your school has the capacity to utilise sewage for energy production?

    ……………………………………………………………………………………

35. How would your school plan to utilise the sewage for energy production?

    ……………………………………………………………………………………

Thank you very much for your co-operation

APPENDIX IX

Students' Questionnaire

Dear Respondent,

I am a post graduate student of Masinde Muliro University of Science and Technology. My study entails investigating the **'Sewage Utilisation Potential for Energy Production and Environmental Protection in Secondary Schools in Kakamega County'**. It is important that I obtain your position regarding the potential of sewage utilisation for energy needs in secondary school in and environmental protection.

You are requested to complete the following short questionnaire regarding the sewage utilization for enhancement of energy issues and environmental protection. Approximately 10- 15 minutes are needed to complete this questionnaire. Please bear the following in mind while you complete the questionnaire:

• Do not write your name on the questionnaire - it remains anonymous.

• There are no correct or incorrect answers - I require your honest opinion.

• Please respond to all questions.

• Your first spontaneous reaction is the most valid. So work quickly and accurately. Do not ponder too long over a particular question item.

• If you would like to change an answer, do so by clearly crossing out the undesired response and ticking your best response.

• Information gathered in this survey will assist the policy-makers and curriculum developers as a decision-making tool and changing the stakeholders' attitude towards the environment as well as the utilization of its scarce resources.

Section A

This section seeks to elicit information about the quantity of sewage generated in secondary schools in Kakamega County.

1. Which of the following categories apply to your school?(**Please Tick**, √ **one)**

A. National school	B. Extra-County School	C. County school	D. District School

2. Is your school a Boarding or a Day-school?

A. Boarding	B. Day	C. Boarding & Day

3. What is the student population in your school?

   ……………………………………………………………………………………

4. How many pit latrines does your school have?

   ……………………………………………………………………………………

5. Are these latrines adequate for your student population?

Yes	
No	

   If no, how does your school address this challenge?

   ……………………………………………………………………………………..

6. Which of the following sewage systems exist in your school?

A. Pit latrine	B. Soak pits	C. Piped sewage	D. Other(Specify

7. How often does your school empty the Septic tanks/latrines?

A	Every term	
B	Twice a year	
C	Once a year	

8. Which means does your school use to empty the septic tanks/latrines?

A. Human labour	
B. Exhauster	
C. Both methods	
D. Others(Specify)	

Section B

This section seeks to elicit information about the impact of energy generation from sewage on the cost and benefits of energy use in secondary schools in Kakamega County.

9. What is the rate of wood fuel consumption in your school?

High	
Low	

If high, what immediate action should be taken to reduce wood fuel consumption in your school?

…………………………………………………………………………………………………

10. Does the school have any woodlots for use as firewood?

Yes	
No	

11. Does your school use energy efficient stoves for cooking and heating?

Yes	
No	

12. Do you think that some action needs to be taken immediately to reduce the effects of wood fuel consumption in your school?

Yes	
No	

If yes, which steps need to be taken to reduce wood fuel consumption?

…………………………………………………………………………………………..

Section C

This section seeks to elicit information on potential effect of energy generation from sewage in secondary schools on environmental protection.

13. Are there any public heath reports to show the environmental health status of your school?

Yes	
No	

14. Has there been any health risk associated with the school's sewage system?

Yes	
No	

15. Does the school have any challenges from sewage disposal?

Yes	
No	

16. Would you support the use of sewage to generate biogas in your school?

Yes	
No	

17. What is the general health status of your School?

Good	
Fair	
Bad	

18. Which source of energy does your school kitchen use for cooking food or heating?

(**Please Tick**, √ **one)**

A. Firewood	B. HEP electricity	C. Biogas	D. Solar

19. Where does your school kitchen getwood fuel supplies from?

………………………………………………………………………………….…..

20. What challenges does your school face when using wood fuel in the school kitchen?

……………………………………………………………………………………..

..……………………………………………………………………………………

21. How has your school tried to solve these challenges?

……………………………………………………………………………………

22. Has your school taken such steps to reduce wood fuel consumption in the kitchen?

Yes	
No	

23. If yes, which ones has your school taken to reduce wood fuel consumption?

    …………………………………………………………………………………

24. Is there any health risk associated with wood fuel consumption in your school?

Yes	
No	

    If yes, specify the nature of the health hazard……………………………………………………………………..............

    ………………………………………..………………………………………

25. What benefits would your school get if it starts utilising sewage for energy production?

    (Please **rank** them from top to bottom)

    i……………………………………………………………………………….…

    ii…………………………………………………………………………………

    iii……………………….…………………………………………………….

Section D

This section seeks for the opinion about the strategic options that can be employed to increase sewage biogas utilisation as green energy for environmental protection and energy needs in secondary schools in Kakamega County.

Instructions: Please pick the best response by ticking against Strongly Agree (**SA**), Agree (**A**), Undecided (**U**), Disagree (**D**) or Strongly Disagree (**SD**).

Item	Description	SA	A	U	D	SD
29.	Our school is well informed about biogas energy					
30.	Biogas utilisation benefits the environment					
31.	Our school has a keen interest in biogas energy					
32.	Our school can be very willing to install biogas plant					
33.	Our school is willing to use its sewage for generation of biogas as green energy					
34.	Our school is willing to pay for the installation of the biogas digester plant in its premises					
35.	The school does not have any organic waste for disposal					
36.	The school can be willing to use its organic waste for biogas generation					
37.	Sewage biogas production in school can benefit the school immensely					
38.	The school can extend biogas benefits to its neighbours					
39.	I highly recommend the use of sewage in schools for biogas generation					

Thank you very much for completing this questionnaire!

APPENDIX X

Focused Group Discussion Guide

VENUE: SUNSTAR HOTEL, KAKAMEGA

DATE: 27THNOVEMBER, 2013

TIME: 10.00 AM

Topic of Discussion: Sewage Utilisation Potential for Energy Production and Environmental Protection in Secondary Schools in Kakamega County.

Host: *Mr. Ibrahim O. Barasa*

1. What is the impact of the quantity of sewage generated in secondary schools on the environment?

………………………………………………………………………………………

………………………………………………………………………………………

2. What is the impact of the quality of sewage generated in secondary schools on the environment?

………………………………………………………………………………………

………………………………………………………………………………………

3. Is energy generation potential from sewage cost effective in secondary schools?

………………………………………………………………………………………

………………………………………………………………………………………

4. Do you think energy generation from sewage has a significant effect on environmental protection in secondary schools? Please elaborate.

………………………………………………………………………………………

………………………………………………………………………………………

5. As a stakeholder, which strategies would you adviseschools to employ to enable schools utilise sewage as a source of green energy to mitigate their challenges of energy needs and environmental protection?

………………………………………………………………………………………

………………………………………………………………………………………

APPENDIX XI

RESEARCHER'S OBSERVATION CHECKLIST

Practices, Impacts, Challenges	Comments
i. Number of latrines	
ii. Status of latrines	
iii. Status of sewage system	
iv. Number of urinals	
v. Status of urinals	
vi. Status of compost heaps	
vii. Status of school surroundings	
viii. Reports of any disease out break	
ix. Status of school kitchen	
x. Size of wood fuel heap	
xi. Evidence of school woodlots	
xii. Evidence of efforts to use solid waste	
xiii. Presence of animal houses	
xiv. Availability of biogas plant	

APPENDIX XII

PLATES OF STUDY ACTIVITIES

Plate 1: Collapsed pit latrines in at Bishop Sulumeti Girls (Kakamega Central)

Plate 2: Collapsed pit latrines-Bishop Sulumeti Girls (Kakamega Central) &Chiliva Primary School (Kakamega North)

Plate 3: Eco San type of pit latrines used in some schools

Plate 4: Open manholes in some of the schools

Plate 5:Mechanical method of emptying filled up pit latrines in some schools

Plate 6: Manual method of emptying filled up pit latrines in some schools

Plate 7: Manual method of emptying filled up pit latrines & disposal

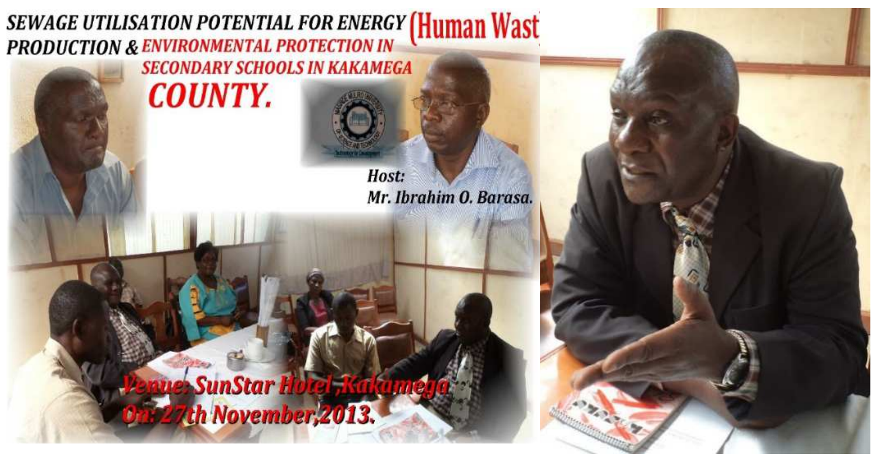


Plate 8: The Supervisor Prof. Wakhungu and the researcher at the FGD

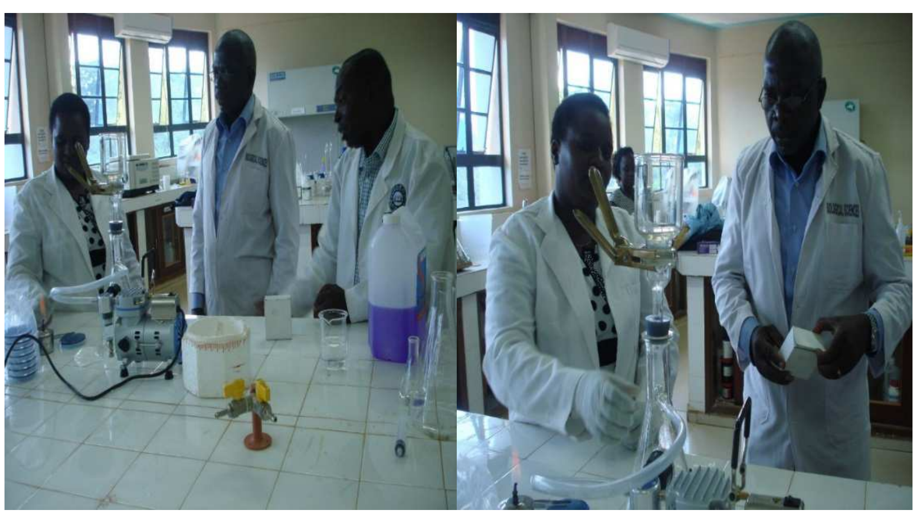


Plate 9: Researcher with Supervisor Pro. Siamba in the microbiology lab.

Plate 10: Isolating Process in the microbiology Lab.

Plate 11: The Researcher at the heaps & stacks of wood fuel in some schools

Plate 12: 10m^{3}Biogas Digester Plant under construction and a functional one

Plate 13: Improved stoves and chimneys used in secondary schools

Plate 14: FGD session in progress: Bottom right-Supervisor Prof Wakhungu

Plate 15: Inspection of the sewage biogas digester at Kaimosi T.T.C.

Plate 16: Researcher Supervisor & Engineers at the Kaimosi TTC sewage biogas plant

Plate 17: Researcher at main sewage biogas digester of Kaimosi T.T.C.

Plate 18:Researcher at the sewage mixer point of the sewage biogas digester

Plate 19: Biogas collecting point

Plate 20: Removal of sulphur traces before delivering gas to the kitchen

Plate 21: Collection of influent just before the digester

Plate 22: Collection of effluent sample

Plate 23: Collection of effluent sample from the digester

Plate 24: Collection of effluent sample immediately after the digester

Plate 25: Gas line from the digester to the kitchen

Plate 26: Gas storage and purification point

Plate 27: Biogas stoves in Kaimosi TTC kitchen

APPENDIX XIII: Research Authorisation

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone: +254-20-2213471, 2241349, 310571, 2219420
Fax: +254-20-318245, 318249
Email: secretary@nacosti.go.ke
Website: www.nacosti.go.ke
When replying please quote

9th Floor, Utalii House
Uhuru Highway
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No.

Date:

13th January, 2015

NACOSTI/P/15/3565/4511

Ibrahim Barasa Olunga
Masinde Muliro University of Science
And Technology
P.O. Box 190-50100
KAKAMEGA.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Sewage utilisation potential for energy production and environmental protection in secondary schools in Kakamega County, Kenya,"*** I am pleased to inform you that you have been authorized to undertake research in **Kakamega County** for a period ending **31st December, 2016.**

You are advised to report **the County Commissioner and the County Director of Education, Kakamega County** before embarking on the research project.

On completion of the research, you are required to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.

SAID HUSSEIN
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Kakamega County.

The County Director of Education
Kakamega County.

National Commission for Science, Technology and Innovation is ISO 9001: 2008 Certified

CONDITIONS

1. You must report to the County Commissioner and the County Education Officer of the area before embarking on your research. Failure to do that may lead to the cancellation of your permit
2. Government Officers will not be interviewed without prior appointment.
3. No questionnaire will be used unless it has been approved.
4. Excavation, filming and collection of biological specimens are subject to further permission from the relevant Government Ministries.
5. You are required to submit at least two(2) hard copies and one(1) soft copy of your final report.
6. The Government of Kenya reserves the right to modify the conditions of this permit including its cancellation without notice

REPUBLIC OF KENYA

NACOSTI

National Commission for Science, Technology and Innovation

RESEARCH CLEARANCE PERMIT

Serial No. A 3985

CONDITIONS: see back page

THIS IS TO CERTIFY THAT:
MR. IBRAHIM BARASA OLUNGA
of MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY, 2003-50100 Kakamega,has been permitted to conduct research in *Kakamega County*

on the topic: *SEWAGE UTILISATION POTENTIAL FOR ENERGY PRODUCTION AND ENVIRONMENTAL PROTECTION IN SECONDARY SCHOOLS IN KAKAMEGA COUNTY, KENYA*

for the period ending:
31st December,2016

Permit No : NACOSTI/P/15/3565/4511
Date Of Issue : 13th January,2015
Fee Recieved :Ksh 2,000

....
Applicant's Signature

....
Secretary
National Commission for Science, Technology & Innovation

APPENDIX IV

SAS Data Analysis Output

sewage volumes in schools data sewage 90
03:32 03:32, may 20, 2015, 2015

Obs	Category	Pop	Annual waste	Costofdisposal	Annual wood	Cost fuel
1	1	610	972.00	45.0	105	210
2	1	320	253.50	20.0	75	150
3	1	650	270.75	43.0	168	336
4	1	670	168.75	38.0	189	378
5	1	720	507.00	38.0	385	770
6	1	810	2812.50	89.0	420	840
7	1	615	675.00	30.0	110	220
8	1	480	234.38	22.0	120	240
9	1	970	4186.13	85.0	490	980
10	1	510	1378.13	58.0	90	180
11	1	400	600.00	21.0	84	168
12	1	410	600.00	24.0	84	168
13	1	420	600.00	27.0	90	180
14	1	380	937.50	26.0	80	160
15	1	780	1875.00	35.0	390	780
16	1	410	600.00	21.0	88	176
17	1	1070	7200.00	60.0	525	1050
18	1	820	5512.50	89.0	410	810
19	1	1010	4186.13	930.0	490	980
20	1	1030	7481.25	830.0	490	980
21	1	1270	5760.00	300.0	539	1078
22	1	1005	5760.00	300.0	490	980
23	1	1020	5512.50	300.0	490	980
24	1	870	3784.50	267.0	420	840
25	1	1300	11250.00	300.0	560	1120
26	1	890	1800.00	267.0	420	840
27	1	1320	8951.63	300.0	630	1260
28	1	1220	5512.50	300.0	525	1050
29	1	400	150.00	10.0	84	168
30	1	410	96.00	10.0	84	168
31	1	610	675.00	30.0	70	140
32	2	600	270.75	30.0	70	140
33	2	360	37.50	6.0	49	98
34	2	340	937.50	5.0	35	70
35	2	220	337.50	2.0	28	56
36	2	380	937.50	6.5	42	84
37	2	210	9.38	2.0	49	98
38	2	200	300.00	2.0	28	56
39	2	210	63.38	2.0	28	56
40	2	220	150.00	3.0	28	56
41	2	420	75.00	8.0	49	98
42	2	200	60.75	3.0	28	56
43	2	205	11.34	8.0	28	56
44	2	208	75.00	8.0	28	56
45	2	400	150.00	10.0	49	98
46	2	400	37.50	12.0	49	98
47	2	206	24.00	8.0	28	56
48	2	460	253.50	10.0	49	98
49	2	420	937.50	12.0	49	98
50	2	400	150.00	13.0	49	98

sewage volumes in schools data sewage 91
03:32 03:32, may 20, 2015, 2015

Obs	Category	Pop	Annual waste	Costofdisposal	Annual wood	Cost fuel
51	2	215	75.00	2	28	56
52	2	409	337.50	12	49	98
53	2	205	22.69	3	28	56
54	2	407	121.50	13	49	98
55	2	340	37.50	6	49	98
56	2	204	108.00	3	28	56
57	2	365	150.00	12	49	98

58	2	390	150.00	12	49	98
59	3	230	150.00	12	55	110
60	3	450	330.75	18	84	168
61	3	750	468.75	40	350	700
62	3	620	507.00	30	95	190
63	3	400	165.38	18	63	126
64	3	600	468.75	30	70	140
65	3	510	108.00	30	70	140
66	3	350	150.00	8	49	98
67	3	600	300.00	30	70	140
68	3	410	337.50	15	63	126
69	3	430	937.50	18	63	126
70	3	810	1012.50	40	168	336

Sewage volumes in schools data sewage 92
03:32 03:32, May 20, 2015, 2015

Class Level Information

Class	Levels	Values
Category	3	1 2 3

70

Sewage volumes in schools data sewage 93
03:32 03:32, may 20, 2015, 2015

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
	2	2764687.282	1382343.641	26.84	<.0001
	67	3450698.490	51502.963		
	69	6215385.771			

R-Square	Coeff Var	Root MSE	Pop Mean
0.444813	41.63649	226.9426	545.0571

Source	DF	SS	Mean Square	F Value	Pr > F
Category	2	2764687.282	1382343.641	26.84	<.0001

Source	DF	SS	Mean Square	F Value	Pr > F
Category	2	2764687.282	1382343.641	26.84	<.0001

sewage volumes in schools data sewage 94
03:32 03:32, may 20, 2015, 2015

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
	2	120436584.5	60218292.2	14.28	<.0001
	67	282564236.4	4217376.7		
	69	403000820.9			

R-Square	Coeff Var	Root MSE	Annual waste Mean
0.298849	142.2473	2053.625	1443.700

Source	DF	SS	Mean Square	F Value	Pr > F
Category	2	120436584.5	60218292.2	14.28	<.0001

Source	DF	SS	Mean Square	F Value	Pr > F

Category	2	120436584.5	60218292.2	14.28	<.0001

sewage volumes in schools data sewage 95
03:32 03:32, may 20, 2015, 2015

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
	2	368637.834	184318.917	8.22	0.0006
	67	1503043.613	22433.487		
	69	1871681.446			

R-Square	Coeff Var	Root MSE	Costofdisposal Mean
0.196955	193.5296	149.7781	77.39286

Source	DF	SS	Mean Square	F Value	Pr > F
Category	2	368637.8338	184318.9169	8.22	0.0006

Source	DF	SS	Mean Square	F Value	Pr > F
Category	2	368637.8338	184318.9169	8.22	0.0006

sewage volumes in schools data sewage 96
03:32 03:32, may 20, 2015, 2015

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
	2	1006504.278	503252.139	26.42	<.0001
	67	1276002.022	19044.806		
	69	2282506.300			

R-Square	Coeff Var	Root MSE	Annualwood Mean
0.440965	84.09684	138.0029	164.1000

Source	DF	SS	Mean Square	F Value	Pr > F
Category	2	1006504.278	503252.139	26.42	<.0001

Source	DF	SS	Mean Square	F Value	Pr > F
Category	2	1006504.278	503252.139	26.42	<.0001

sewage volumes in schools data sewage 97
03:32 03:32, may 20, 2015

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
	2	4020718.395	2010359.198	26.41	<.0001
	67	5099569.376	76112.976		
	69	9120287.771			

R-Square	Coeff Var	Root MSE	Cost of fuel Mean
0.440854	84.09687	275.8858	328.0571

Source	DF	SS	Mean Square	F Value	Pr > F
Category	2	4020718.395	2010359.198	26.41	<.0001

Source	DF	SS	Mean Square	F Value	Pr > F
Category	2	4020718.395	2010359.198	26.41	<.0001

Bonferroni (Dunn) t Tests for Pop

NOTE: This test controls the Type I experiment wise error rate, but it generally has a higher Type II error rate than Tukey's for all pairwise comparisons.

Alpha	0.05
Error Degrees of Freedom	67
Error Mean Square	51502.96
Critical Value of t	2.45557

Comparisons significant at the 0.05 level are indicated by ***.

Category Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
1 - 3	241.51	52.04	430.97	***
1 - 2	436.54	289.85	583.24	***
3 - 1	-241.51	-430.97	-52.04	***
3 - 2	195.04	1.69	388.38	***
2 - 1	-436.54	-583.24	-289.85	***
2 - 3	-195.04	-388.38	-1.69	***

Bonferroni (Dunn) t Tests for Annual waste

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than Tukey's for all pairwise comparisons.

Alpha	0.05
Error Degrees of Freedom	67
Error Mean Square	4217377
Critical Value of t	2.45557

Comparisons significant at the 0.05 level are indicated by ***.

Category Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
1 - 3	2501.6	787.1	4216.1	***
1 - 2	2697.4	1370.0	4024.9	***
3 - 1	-2501.6	-4216.1	-787.1	***
3 - 2	195.8	-1553.8	1945.4	***
2 - 1	-2697.4	-4024.9	-1370.0	***
2 - 3	-195.8	-1945.4	1553.8	***

Bonferroni (Dunn) t Tests for Costofdisposal

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than Tukey's for all pairwise comparisons.

Alpha	0.05
Error Degrees of Freedom	67
Error Mean Square	22433.49
Critical Value of t	2.45557

Comparisons significant at the 0.05 level are indicated by ***.

Category Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
1 - 3	134.47	9.42	259.51	***
1 - 2	150.64	53.82	247.46	***
3 - 1	-134.47	-259.51	-9.42	***
3 - 2	16.18	-111.43	143.78	***
2 - 1	-150.64	-247.46	-53.82	***
2 - 3	-16.18	-143.78	111.43	***

sewage volumes in schools data sewage 101
03:32, May 20, 2015

Bonferroni (Dunn) t Tests for Annualwood

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than Tukey's for all pairwise comparisons.

Alpha	0.05
Error Degrees of Freedom	67
Error Mean Square	19044.81
Critical Value of t	2.45557

Comparisons significant at the 0.05 level are indicated by ***.

Category Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
1 - 3	196.61	81.40	311.83	***
1 - 2	256.17	166.96	345.37	***
3 - 1	-196.61	-311.83	-81.40	***
3 - 2	59.56	-58.02	177.13	***
2 - 1	-256.17	-345.37	-166.96	***
2 - 3	-59.56	-177.13	58.02	***

sewage volumes in schools data sewage 102
03:32, May 20, 2015

Bonferroni (Dunn) t Tests for Costfuel

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than Tukey's for all pairwise comparisons.

Alpha	0.05
Error Degrees of Freedom	67
Error Mean Square	76112.98
Critical Value of t	2.45557

Comparisons significant at the 0.05 level are indicated by ***.

Category Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
1 - 3	392.90	162.58	623.23	***
1 - 2	512.01	333.68	690.35	***
3 - 1	-392.90	-623.23	-162.58	***
3 - 2	119.11	-115.93	354.15	***
2 - 1	-512.01	-690.35	-333.68	***
2 - 3	-119.11	-354.15	115.93	***

sewage volumes in schools data sewage 103
03:32, may 20, 2015

-- Category=1 --

The MEANS Procedure

```
Variable         N          Mean         Std Dev        Minimum        Maximum
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Pop             31     754.8387097     306.8020096     320.0000000        1320.00
Annual waste    31        2912.99         3052.81      96.0000000       11250.00
Costofdisposal  31     158.5483871     223.6722064     10.0000000     930.0000000
Annualwood      31     296.6129032     199.4662340     70.0000000     630.0000000
Cost of fuel    31     592.9032258     398.7469837    140.0000000        1260.00
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ

------------------------------------------- Category=2 -------------------------------------------

Variable         N          Mean         Std Dev        Minimum        Maximum
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Pop             27     318.2962963     110.0712409    200.0000000     600.0000000
Annual waste    27     215.5659722     277.7989535      9.3750000     937.5000000
Costofdisposal  27       7.9074074       5.9517887      2.0000000      30.0000000
Annualwood      27      40.4444444      11.7025090     28.0000000      70.0000000
Cost of fuel    27      80.8888889      23.4050181     56.0000000     140.0000000
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ

------------------------------------------- Category=3 -------------------------------------------

Variable         N          Mean         Std Dev        Minimum        Maximum
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Pop             12     513.3333333     168.3790817    230.0000000     810.0000000
Annual waste    12     411.3437500     296.5613780    108.0000000        1012.50
Costofdisposal  12      24.0833333      10.6383383      8.0000000      40.0000000
Annualwood      12     100.0000000      84.6586730     49.0000000     350.0000000
Cost of fuel    12     200.0000000     169.3173459     98.0000000     700.0000000
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
```

	N	**Population (mean)**	**Mean annual waste disposal in tons**	**Mean waste disposal cost in Ksh (x1000)**	**Mean wood consumption in tons**	**Mean wood fuel cost in Ksh (x1000)**
Boys	21	710*	2164*	164a	259.14	518.29
Girls	30	545	1690	59	169.77	339.20
Mixed	19	362	259	11	50.11	100.21
Boarding	31	755[a]	2913a	159a	296.61a	592.90a
Day	27	318[b]	216b	8b	40.44b	80.89b
Day/BOARDING	12	513[c]	411c	24c	100.00c	200.00c
Total	70					