UNIVER SITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

AWARENESS AND WILLINGNESS OF HOUSEOWNERS TO USE BIODIGESTERS AS ALTERNATIVE SOURCE OF ENERGY AND DISPOSAL OF HUMAN EXCRETA: A CASE STUDY OF KUMASI METROPOLIS

PHILIP BENNEL-YINTEMAN

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PHILIP BENNEL-YINTEMAN

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A Dissertation in the Department of WOOD AND CONSTRUCTION TECHNOLOGY EDUCATION, Faculty of TECHICAL EDUCATION, submitted to the school of research and Graduate Studies. University of Education, Winneba, in partial fulfilment of the requirement for the award of Masters of Technology (Construction) degree.

AUGUST, 2016

DECLARATION

STUDENT'S DECLARATION

I, Philip Bennel-Yinteman, declare that this Project Report, with the exception of quotations and references contained in the published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE:......................

DATE:..................................

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of Project Report as laid down by the University of Education, Winneba.

NAME: Dr. Francis K. Bih

SIGNATURE..................................

DATE ....

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I am highly indebted to my supervisor, Dr. Francis Kofi Bih for his tremendous guidance and patience for me during the study. Special thanks to Dr. E.D. Aklaku (Lecturer)-Energy Centre of Engineering (KNUST) for his support in diverse ways. I wish to express my profound gratitude to my colleague students, Enoch Boadu and Yamoah Afrifa of University of Education, Winneba-Kumasi Campus for their advice and support.

DEDICATION

This work is dedicated to my wife, Cecilia Bennel-Yinteman for her wonderful support and my daughters Lariba and Asibi for their love.

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ABSTRACT

Despite the advantages of using biodigester as a means of disposing human excreta, the use of traditional septic tanks still abounds in Ghana. This study therefore sought to assess the level of awareness and willingness of landlords to adopt biodigester as alternative source of energy and disposal of human excreta in the Kumasi Metropolis. The study employed a descriptive cross sectional survey design with a mixed method approach.300 landlords from three selected communities in Kumasi as well as three biogas contractors were conveniently selected for the study. Questionnaire and interview were main data collection tools for this study. The data collected was analysed using SPSS and presented with descriptive statistics. The results show a low level of awareness of landlords in the Kumasi Metropolis on biodigesters as better alternative to septic tanks in the disposal of human excreta. Factors that challenge development of biogas production in Kumasi Metropolis include inadequate funding, lack of qualified personnel to handle biodigester construction and lack of funds to undertake the project by most houseowners. The government as well as NGOs, individuals, companies who are engaged in biogas have not helped greatly in creating adequate awareness on the need to use biogas in households. It is imperative for abled house owners to adopt the right attitudinal change towards biogas use in households since it has potential to help in saving cost and thus solve most of our sanitation problems resulting from the use traditional septic tanks.

C HAPTER ONE

INTRODUCTION

1.1 Background of the Study

The world is currently moving from petroleum-based to a bio-based global economy, in this instance, biological wastes, which is usually seen as low-valued materials, are now being transformed from high volume waste disposal environmental problems to constituting natural resources for the production of eco-friendly and sustainable fuels. Biological wastes contain high level of cellulose, hemicelluloses, lignin, starch, proteins, and lipids, and these are good options for the biotechnological production of liquid biofuels without having interference with the ever-growing need for world's food supply.

The rapid increase in world's population and the great development in industrial, commercial, and agricultural sectors require large quantities of energy and create large quantities of waste that should be disposed of with minimum negative environmental impacts and costs (Adeniran *et al.,* 2014). In Africa and for that matter Ghana to be precise, water pollution and access to energy resources present challenges to human health and economic development. In 21 sub-Saharan African countries, less than 10% of the populations have access to electricity. The need for alternative renewable energy sources from locally available resources cannot be over emphasized. Appropriate and economically feasible technologies that combine solid waste and waste water treatment and energy production can simultaneously protect the surrounding water resources and enhance energy availability. Biogas technology in which biogas is derived through anaerobic digestion of biomass, such as agricultural wastes, municipal and Industrial waste (water), is one such appropriate technology Africa should adopt to ease its energy and environmental problems. Anaerobic digestion consists of several interdependent, complex sequential and parallel biological reactions in the absence of oxygen, during which the products from one group of microorganisms serve as the substrates for the next, resulting in transformation of organic matter (biomass) mainly into a mixture of methane and carbon dioxide (Mshandete&Parawira, 2009).

Anaerobic digestion and biogas production are promising ways to achieve energy and environmental benefits at both the local and global level (Börjesson&Berglund, 2006, 2007). Biogas plants can provide an alternative energy source for rural households and mitigate environmental emissions from agricultural activities (Chen & Chen, 2012; Prochnow et al., 2009). Biogas is different from traditional forms of rural energy in two main ways: first, it replaces fossil fuels with clean methane, which reduces not only the release of greenhouse gases, but also other detrimental emissions; second, the multiple utilization of digesters (i.e., substitution for such materials as fertilizers, pesticides, and feed additives) facilitates more efficient use of organic waste or plant nutrients in daily agricultural practice (Collet, 2011; Rehl&Müller, 2011). Such procedures are of particular importance in coping with the increasing pressure of problems related to global energy scarcity and climate change.

The dependence on fossil fuels as primary energy source has led to global climate change, environmental degradation and human health problems. Freeman and Ryle (1997) reported that the initial interests in use of animal wastes as biofuels came from India where the obvious raw material has been cow dung.

Biogas technology helps treat organic waste materials hygienically without causing atmospheric pollution. Through this, a valuable renewable energy and organic fertilizer can be produced. The term “Biogas” is commonly used to refer to a gas which has been produced by the biological breakdown of organic matter in the absence of oxygen. The gases methane, hydrogen and carbon monoxide can be combusted or oxidized with oxygen and the resultant energy released allows biogas to be used as fuel. The production of biogas is of growing interest as fossil fuel resources decline (Igoni *et al.,* 2008). Biogas technology enables one to produce bio energy by treating the wastes generated in the houses and public places like markets, slaughter houses, hotels, convents etc.

According to Karki (2005), organic residues comprise materials of plant, animal and human origin. The waters produced form the organic. The wastes produced from these organic materials are the resources which can profitably be used to generate valuable energy and fertilizer. Generally effective handling of waste generated in communities in developing countries like Ghana with increasing population is a challenge (Opoku, 2011).

The first plant for obtaining methane from human waste was built in 1990 at the homeless Lapers Asylum, Matunga now known as Acworth Zeprocy Hospital, Wadala, India (Sathianathan, 1999). The production of biogas is of growing interest as fossil-fuel reserves decline (Igoni *et al.,* 2008). According to a report by Bouallagui *et al* (2003), various studies have proved that anaerobic biological treatment of organic fraction of Municipal Solid Waste (MSW) in a process has received an increased attention during the last few years. With the current developmental trends, high population increase and thus its impact on resources and the environment, Biogas plant building is a sure way. Jha

(2007) outlines the following as some of the benefits of constructing biogas plants for houses and institutions.

- No manual handling of human excreta is required at any stage.
- Aesthetically and socially accepted
- Technically appropriate and financially affordable
- Operational and maintenance cost almost nil
- Provides complete ecological satisfaction at community level
- Treated effluent is safe to reuse or discharge into any water body.
- In drought prone areas, treated effluent can be used for cleaning of floor of public toilet.

Questions related to the final disposal and treatment of domestic waste constitute one of the most serious problems of contemporary societies. This is neither economical nor environmentally friendly and moreover there is the problem of adequate land to dispose these waste (Fei-Baffoe, 2006). Construction of Biogas plants therefore resolves this bothering question as waste is treated and reused. When construction of biogas plants is promoted, it would reduce cost incurred on disposing waste from dosmestic activities.

1.2 Statement of the Problem

The quantum of energy utilized is regarded as the yardstick of techno-economic status of any society (Jha, 2007). The continuous and uncontrolled use of conventional fossil and geochemical sources of energy has resulted in their fast depletion and consequently continuous price rise of petroleum products. Currently Ghana faces a serious energy crisis in terms of electricity supply and intermittent gas shortage. Additionaly, safe and hygienic way of disposal of human wastes is an increasing problem in major cities in

Ghana (Fei-Baffoe, 2006). The accumulation and unhygienic handling of organic wastes creates several environmental problems including the emission of dangerous gas to the atmosphere. Organic waste water discharged from houses and institutions also emit methane as the main gas through anaerobic fermentation. A close study of the traditional septic tanks of domestic houses and institutions reveals the emission of such gases into the atmosphere through vents fixed on them. It is further noted that effluents from these tanks are removed for disposal periodically at a cost. Building may be affordable in terms of its production but not necessarily cost efficient in relation to its use over a period of time (Agbomanyi, 2008).

Environmentally, the removal of effluent poses so much health hazards with its high level of smell and handling difficulties. For Ghana to achieve the objectives of the Kyoto agreement as well as important issues related to human and animal health and food safety there is need to use suitable solutions for handling and recycling of animal manure and organic waste where biodigesters play an increasing important role (Holm-Nielsen et al., 2009). However, despite the advantages biodigesters offer in safe and economic handling of human excreta, landlords in Ghana continue to use septic tanks for this purpose. This study attempts to provide answers to questions pertaining to low levels of use of biodigesters as safe means of handling human excreta as well as generating biogas for energy by assessing landlords' awareness of the technology and the hindrances to its adoption using Kumasi Metropolis as case study.

1.3. Aims and Objectives of the Study

The study aims at assessing the awareness and willingness of households and institutions to accept Biogas plants as alternative to septic tanks for human waste disposal in the Kumasi Metropolis.

The specific objectives are as follows:

1. To determine the level of awareness of households and some institutions on the use of biogas plants as alternative to septic tanks
2. To find out the acceptance level of biogas plants by domestic households and institutional occupants.
3. Compare the environmental and economic impact of using biogas plants to that of the traditional septic tanks in Kumasi.

1.4 Research Questions

The following research questions were formulated to guide the study:

1. What is the level of awareness of households and some institutions on the use of biogas plants as alternative to septic tanks?
2. What is the acceptance level of biogas plants by domestic households and institutional occupants?
3. What are the environmental and economic impacts of using biogas plants to that of the traditional septic tanks in Kumasi?

1.5 Scope of the Study

The issue of waste management is a major challenge that runs through the entire country. This study however, would be limited to the management of organic waste in domestic and institutional buildings through the use of biogas plants for its utmost benefits in the Kumasi Metropolis.

1.6 Significance of the Study

The study is expected to add knowledge to existing literature on biogas. It can serve as a reference material for interested stakeholders in dealing with biogas. Policy makers can be guided by the use of this work in their decision making towards biogas. This study addresses major challenges to biogas production and its patronage by people. In view of this, the study would enlighten stakeholders in dealing with biogas and its significance. In the long run, it would promote the use of biogas as an alternative source of energy.

1.7 Limitations of the Study

The study encountered several challenges which posed difficulties to the researcher. Some houseowners were not available during daytime and this made it costly and stressful for the researcher to visit some homes in the afternoon as well as evening. Since the study was concentrated only within Kumasi Metropolis, it would be difficult to generalise the findings to cover the entire Ashanti Region and Ghana as a whole.

1.8 Organization of the Dissertation

The dissertation is structured into five chapters. Chapter One comprises the introductory chapter, the background of the study, problem statement, objectives of the study, key research questions, and the justification of the study. The Second Chapter presents literature review. It is used for a detailed review of existing work on the subject matter.

The Third Chapter looks at the methodology of the study. The Chapter comprises data sources, research variable definition and data analysis model. Chapter Four presents the analyses and discusses the results. This shows how the research questions are answered. Chapter Five presents the summary of findings, conclusions and recommendations.

CHAPTER TWO

2.0 LITERATURE REVIEW

This chapter presents literature review which consists of theoretical, conceptual and empirical studies on the use of biogas, emergence and development of the biogas sector, types of biogas plant, the contribution of biodigester technology to development at different levels, production of biogas, construction materials for domestic biogas plant, positive impact of biogas, environment and economic and human health problems associated with the use of biogas.

2.1 Definitions and Concept of Biogas

Biogas is a clean, renewable energy obtained from biodegradable organic material such as kitchen, animal and human waste. In the past, biogas digesters have been considered mainly as a means of producing combustible gas. The waste is put into a sealed tank (a digester) where it is heated and agitated. In the absence of oxygen, anaerobic bacteria consume the organic matter to multiply and produce biogas. Agbomanyi (2008) states bio gas originates from biogenic material and is a type of biofuel. Biogas is produced by anaerobic digestion fermentation manure, sewage, municipal waste, green waste, plant material energy crops and carbon dioxide.

Other types of gas generated by use of biomass are wood gas, which is created by gasification nitrogen, hydrogen, and carbon monoxide, with trace amounts of methane. That is the reason why consequential designing of every detail of constructions and elimination of thermal bridges is necessary. Also it is necessary to make a provision for existence of thermal bridges in calculations of thermo technological characteristics of constructions (Junga&Trávníček, 2014).

Biogas generated during the anaerobic digestion of sludge and other organic materials such as in landfills is considered a renewable energy source. These biogases are methane-rich, based on a typical composition of 60-65% methane; the balance being mostly carbon dioxide. However, trace amounts of undesirable compounds, such as hydrogen sulphide (H_2S) and siloxanes may also be present, which hinder their use in some energy recovery equipment. Issues related to H_2S presence in biogas and the possibilities for its removal, including biological methods, were previously discussed (Syed *et al.,* 2006).

Africa is a continent with abundant, diverse and unexploited renewable energy resources that are yet to be used for improving the livelihood of the vast majority of the population. The production of biogas via anaerobic digestion of large quantities of agricultural residues, municipal wastes and industrial waste (water) would benefit African society by providing a clean fuel from renewable feedstocks and help end energy poverty. There is a consensus that achieving the Millennium Development Goals (MDGs) in Africa will require a significant expansion of access to modern and alternative renewable energy. Biogas is a renewable, high quality fuel, which can be utilised for various energy services such as heat, combined heat and power, or a vehicle fuel. This would reduce the use of fossil-fuel-derived energy and reduce environmental impact, including global warming and pollution, improve sanitation, reduce demand for wood and charcoal for cooking and provide a high quality organic fertiliser. Biogas technology can serve as a means to overcome energy poverty, which poses a constant barrier to economic development in

Africa. Biogas production from agricultural residues, industrial, and municipal waste (water) does not compete for land, water and fertilisers with food crops like is the case with bioethanol and biodiesel production. Currently there is serious shortage of food in developing countries which will continue into the future. Therefore, food production is much more important and should compete out completely the production of energy crops for biodiesel and bioethanol. Unlike other forms of renewable energy, biogas production systems are relatively simple and can operate at small and large scales in urban and rural locations, there are no geographical limitations to the employment of this technology nor is it monopolistic (Mshandete&Parawira, 2009).

Biogas is a promising renewable fuel, which can be produced from a variety of organic raw materials and used for various energy services. For example ten percent of Swedish biogas production is currently upgraded and used as vehicle fuel in buses, distribution trucks and passenger cars and the remaining biogas is mainly used for heat or combined heat and power (Lantz *et al.,* 2007). Another use of biogas in practice is as non–traditional source of energy in drying techniques (Vitázek, 2011). Some authors state that biogas is a renewable energy with high increase developed in last few decades (Moravec *et al.*, 2011). The author also states that it is a big opportunity for economic stabilization of rural areas and agricultural sector. Biogas is produced through microorganisms that degrade organic materials in anaerobic environment.

Suthar (2010) noted that it is interesting that each year, human, livestock and crops produce approximately 38billions metric tonnes of organic waste worldwide, which may be an efficient source of organic matter supply in soils. This huge quantity of organic wastes, generated from different sources, can be converted into nutrient-rich bio-fertilizer (vermicompost) for sustainable land restoration practices. The vermicomposting is stabilization of organic material through the joint action of earthworms and microorganisms. While microbes are responsible for biochemical degradation of organic matter, earthworms are the important drivers of the process, conditioning the substrate and altering the biological activity. Earthworm's foregut acts as mechanical blenders and modifies the physical status of ingested organic wastes and consequently increases the surface area for digestive enzyme actions. In earthworm, the gut-associated-microbes provide several essential enzymes (exogenous) required for rapid digestions of ingested organic fractions. Moreover, the biological mutuality between earthworms and microflora produce a significant change in biological, physical and chemical characteristics of vermibeds. The egested material (worm cast or vermicompost) attracts detritus microbial communities (bacteria, fungi, actinomycetes, nematodes, microarthropods etc.) due to greater availability of forms of nutrients. The further mineralization of nutrients is carried out by microbial communities associated with freshly deposited worm casts.

Biogas is produced in special technological construction called biogas plant. The conceptions of biogas plants are very various and depend mainly on the type of technological process and processed feedstock. The most biogas plants in the Czech Republic are designed as farm biogas plants to processing biological materials such as maize silage and slurry. These biogas plants with continual process are intended for processing of liquid biological materials with 3–14% of dry matter. The main parts of biogas plant construction consist of mechanical pretreatment, feeding and transportation technological equipment and anaerobic reactors (fermenters). Other technological equipment is specified for mixing and heating of fermenters and for accumulation, cleaning and utilization of biogas (Pastorek *et al*., 2004). Most of farm biogas plants run in the mesophile mode at temperature 25–35°C (Schulz & Eder, 2004).

Generating methane from manure has considerable merit because it appears to offer at least a partial solution to two processing problems-environmental crisis and the energy shortage (Fulhage *et al.,* 1993). Livestock manure contains portion of organic solids such as proteins, carbohydrates and fats that are available as food and energy for growth of anaerobic bacteria. Obvious benefit from methane production is the energy value of the gas itself. But the gas production from manure depends mainly upon the efficiency of operating system for it. Gas yield can be a certain amount of gas produced per unit of solids degraded by the anaerobic bacteria (Fulhage *et al*., 1993). Cattle manure, human excreta and agriculture residues are used in anaerobic bioreactors in many parts of the world to produce methane gas, which is used for the purpose of cooking and lighting. Since such waste materials are readily available in farms, rural people of many developing countries have benefited from this technology. Besides, this technology is cheaper and simpler, thus gaining popularity throughout the world (Gautam, Baral&Heart, 2011).

Biogas is derived through anaerobic digestion of biomass, such as animal wastes, municipal wastewater, and landfill waste. Anaerobic digestion is a microbially mediated biochemical degradation of complex organic material into simple organics and dissolved nutrients. Digesters are physical structures that facilitate anaerobic digestion by providing an anaerobic environment for the organisms responsible for digestion (Lansing, Botero& Martin, 2008). Processing livestock manure through anaerobic digesters captures methane, which can be used as an energy source while reducing emissions of this greenhouse gas. Currently, digesters are concentrated in developing countries, with over 5 million household digesters constructed in China and India alone (Huttunen&Lampinen, 2005). Digesters built around the world vary in their design complexity, construction materials, and costs. In developed countries, digesters often are concrete stirred tank reactors (CSTRs), in which a portion of the produced biogas is utilized to heat the digester (Berglund&Borjesson, 2006).

Biogas is produced by anaerobic digestion of animal wastes, which is used for domestic purposes. In agriculture-based countries around the world, biogas is produced in household reactors known as biogas digesters to provide energy for lighting and cooking. Millions of people, especially farmers, have benefited from this technology and its popularity is ever growing (Gautam *et al*., 2011). According to a rough estimation there are thought to be about 2.5million household and community biogas plants installed around India. For commercial biogas production in India, cattle waste (dung) is the prime source. A considerable amount of biogas slurry is produced in biogas digesters. The spent biogas slurry (BGS) is a semi-liquid form of digested material in biogas digesters, which is, stabilized material with a variety of chemicals. In India, the majority of domestic biogas production units lack proper utilization of slurry from post methanation subunit. It is often deposited openly at nearby places of biogas unit, which later becomes an active breeding site for disease vector insects. The higher moisture content in freshly deposited slurry often attracts house flies to deposit eggs. In some cases dried or partially dried biogas slurry is used as manure for crop lands. Although, it can be utilized effectively as organic C pool in arable soils but low contents of NPK limits its potential use as bio-fertilizer in cropping system. On the other hand biogas slurry may be a potential source of earthworm culture due to containing easy digestible and assimilated carbohydrates and proteins. Nevertheless, the biogas slurry needs to be mixed with some plant nutrient-rich materials prior to using as substrate for vermiculture/vermicomposting. Crop residues appeared as potential source of earthworm feed and quality vermicompost production (Suthar, 2007, 2009).

Biogas systems have the potential to capture methane that would escape into the atmosphere and utilize it to create energy (e.g., electricity, heat, vehicle fuel). Other byproducts of biogas systems include non-energy products such as nutrient rich soil amendments, pelletized and pumpable fertilizers, and even feedstock for plastics and chemicals. Successful biogas systems capture and use gas from landfills and/or the anaerobic digestion of wastewater bio-solids, animal manure, and other organics for energy. Each system includes both the infrastructure to manage the organic wastes as well as the equipment to generate energy from the resulting biogas. These systems have been used on a commercial scale in the United States since the late 1970s(U.S. Department of Agriculture, U.S. Environmental Protection Agency, U.S. Department of Energy, 2014).

2.2 Basic Layout of a Biogas plant

A biogas plant consists of the following principal components; a digester, a gas holder, a gas engine, tubes, and mixers. Figure 2.1 is schematic layout of a typical biogas plant.

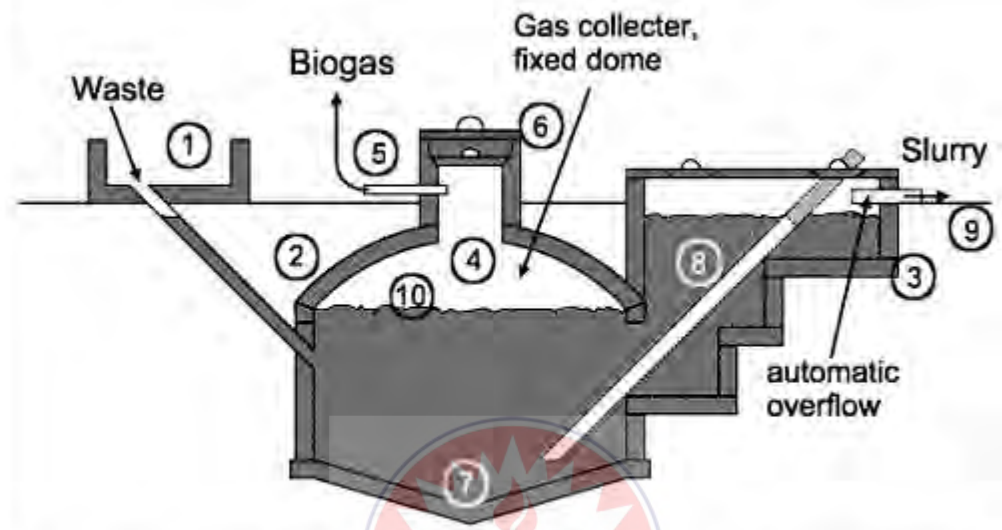

Figure 1: Fixed dome plant Nicarao design: 1. Mixing tank with inlet pipe and sand trap. 2. Digester. 3. Compensation and removal tank. 4. Gasholder. 5. Gaspipe. 6. Entry hatch, with gastight seal. 7. Accumulation of thick sludge. 8. Outlet pipe. 9. Reference level. 10. Supernatant scum, broken up by varying level.
Source: TBW

Figure 2.1: Schematic layout of a typical biogas plant (Fixed dome plant Nicarao design)

2.2.1 Function

A fixed-dome plant is made up of a closed, dome-shaped digester with an immovable, rigid gas-holder and a displacement pit which is also known as compensation tank. The gas is contained in the upper part of the digester. The production of gas is made evident by the displacement of the slurry into the compensating tank. As the volume of the gas stored increases, pressure of the gas also increases and this can be deduced knowing the difference in height of the two slurry levels.

2.2.2 Gas demand

In developing countries, the household energy demand is greatly influenced by eating and cooking habits. Gas demand for cooking is low in regions where the diet consists of vegetables, meat, milk products and small grain. The gas demand is higher in cultures with complicated cuisine and where whole grain maize or beans are part of the daily nourishment. As a rule of thumb, the cooking energy demand is higher for well-to-do families than for poor families. Energy demand is also a function of the energy price. Expensive or scarce energy is used more carefully than energy that is effluent and free of charge. The gas consumption for cooking per person lies between 300 and 900 liter per day, the gas consumption per 5-member family for 2 cooked meals between 1500 and 2400 liter per day. In industrialized countries, biogas almost always replaces existing energy sources like electricity, diesel or other gases. The objective of biogas production may be less to satisfy a certain demand, but to produce biogas as much and as cheap as possible. Whatever surplus is available can be fed as electricity into the grid. The gas demand is market-driven, while in developing countries, the gas demand is needs-driven.

2.3 Processes leading to a Constructed Biogas Plant in Households

Construction of Biogas plant (Wasaza plant)

1. Setting out

Having calculated the radius of the digester,

A digester of between $6m^3$ and $4m^3$ is appropriate

1) To determine the radius (r) for $4m^3$

$$= 4 = \frac{2\pi r^3}{3}$$

$= 12 = 2(3.142)r^3$

$= r^3 = \frac{12}{6.284}$

$= r^3 = 1.91$

r$= 1.24m$

Radius of digester = 1.24

2) To determine gas volume (vg) with 50cm water column

$= Vg = \pi(0.5)^2 \left(1.24 - \frac{0.5}{3}\right)$

$= Vg = 0.7855(1.24 - 0.167)$

Vg $= 0.7855 \times 1.073$

Vg = $0.84m^3$

Gas volume = $0.84m^3$

3) Determining Expansion chamber radius (re)

$= 0.84 = \frac{2xre^3}{3}$

= 2.52 = $6.284re^3$

= re^3 = 0.401

= re = 0.74m

Radius of expansion chamber = 0.74m

Note: Leaving a void gap of 10cm will make the designed pressure = 40cm

Table 2.1: Composition of Biogas

Substances	Symbol	Percentage
Methane	CH_4	50 - 70
Carbon Dioxide	CO_2	30-40
Hydrogen	H_2	5- 10
Nitrogen	N_2	1-2
Water vapour	H_2O	0.3
Hydrogen Sulphide	H_2S	Traces

Source: Field survey, 2015

Figure 2.2: Construction of Biogas plant (Wasaza plant)

Source: Authors construct, 2015

Based on the volume required, a point ie the centre is determined for the sitting. Two pieces of 10mm – 12mm rods can be used, one pegged at centre and the other connected with a line used for marking a circle on the ground.

2. Excavation is then carried out to the required depth

   NB: Some can be carried out on concurrently for the expansion chamber and the Anaerobic Baffled Reactor (ABR) as shown Figure 2.2. The digestion and the expansion chamber are then constructed using bent bricks while the ABR is done with sandcrete blocks.

- Pipe works are also carried out as shown in Appendix B.
- Plastering and rendering are executed before closing the system.
- Gas pipe is now connected from the gas area of the digester to the usage point.

2.4 Uses of biogas

Biogas is increasingly becoming an attractive source of energy in many nations of the world. (For example, the Finnish magazine Suomeniuon reported that the gas is used to fuel a car owned by a farm owner. Sweden too has a similar story as many city-buses are powered by biogas, and some gas stations there offer biogas in addition to other fuels (Xuereb, 1997). In fact, all over the world, biogas has been variously used for heating purposes and/or electricity generation. For example, in the UK, Xuereb (1997) reported that, although the use of biogas for electricity generation was still at an experimental stage, it already accounts for about 0.5% of the total electricity output; and biogas fuels account for about 1% of US electricity generation, while achieving a climate-change benefit equivalent to reducing CO_2 emissions in the electricity sector by more than 10%.

Biogas is also presently used in India, China, Taiwan, Brazil, Singapore, etc. Tchobanoglous and Burton (1993) stated that, in large plants, digester gas may be used as a fuel for the boiler and internal-combustion engines, which are in turn used for pumping waste water, operating blowers and generating electricity. Despite the heating-and-electricity generation uses of biogas, in addition, the residues of such biogas production can be used as low-grade fertilizers.

Xuereb (1997) enumerated the characteristics of biogas:

• It is a flammable, potentially explosive and readily controllable source of energy.

• Its use helps to reduce the amount that would otherwise be released naturally into the atmosphere, and so reduces the excessive greenhouse-effect.

• Although on burning biogas, carbon dioxide is released, it is not considered as a net contributor to the global carbon-dioxide level because it originated from plants, which have absorbed it from the atmosphere. Hence this carbon dioxide does not make a net contribution to the 'greenhouse effect'. The harnessing of biogas also helps to minimize the unpleasant decomposition smells produced in landfill sites because, otherwise, these gases would be released directly into the atmosphere. Hence, especially where landfills are situated close to inhabited areas, the harnessing of LFG makes landfills slightly more socially acceptable (Igoni *et al.,* 2008).

2.5 Emergence and Development of the Biogas Sector

The technology of the generation of methane from the anaerobic fermentation of cattle manure, human excreta, wastewater, etc. gained popularity in India around 1950. Farmers in India used the biogas technology to generate cheap fuel and tackle the litter problem. Since Nepal shares many socioeconomic and geographic similarities with India, the development of the biogas sector in Nepal was greatly influenced by the development of the biogas sector in India (Gautam *et al.,* 2011).

In most African countries, for example, Burundi, Ivory Coast and Tanzania, biogas is produced through anaerobic digestion of human and animal excreta using the Chinese fixed-dome digester and the Indian floating-cover biogas digester, which are not reliable and have poor performance in most cases (Omer&Fadalla, 2003). These plants were built for schools, health clinics and mission hospitals and small scale farmers, in most cases by non-governmental organisations. Most of the plants have only operated for a short period due to poor technical quality. There is thus a need to introduce more efficient reactors to improve both the biogas yields and the reputation of the technology. The development of large-scale anaerobic digestion technology in Africa is still embryonic, although the potential is there. There is a need to learn from the past experiences, adapt the biogas technology from Europe and Asia for local circumstances through research. In developing countries, biogas energy research should be planned and conducted as part of the main factors leading to its contribution to the solution of energy problems. Keeping this in mind, the results of the research should be applicable on a nation-wide scale and constitute a part of the country's development plan. In many of the developing countries, there is still need for some basic research mostly on the quantity and potential biogas yield of fermentable organic wastes available, and the size and type of biogas digesters which can be economically viable for the potential consumers of the biogas technology (Mshandete&Parawira, 2009).

In Tanzania, co-digestion of organic wastes is a technology that is increasingly being applied for simultaneous treatment of several solid and liquid organic wastes. The main advantages of this technology are improved methane yield because of the supply of additional nutrients from the codigesters and more efficient use of equipment and cost-sharing by processing multiple waste streams in a single facility. Co-digestion of organic fractions of municipal solid waste, sisal leaf decortications residues, coffee hulls with chicken manure or fish waste or cow dung manure improved the digestibility of the materials resulting in increased methane productivity and methane yield (Kivaisi, 2002; Kivaisi&Mukisa, 2000; Mshandete *et al.,* 2004a).

The growth of the use of gas-fueled vehicles both large and small around the world has been substantial, particularly in Europe. In the United States biogas is quickly becoming a popular source of energy and a wide variety of feedstocks are being tested. It has been estimated that the methane biogases derived from cattle, pigs and chickens could be used to power millions of homes around the world whilst still reducing billions of metric tonnes of greenhouse gas emissions. In Pakistan and India the biogas produced from the anaerobic digestion of manure in small-scale digestion facilities is called 'gobar gas'. It is estimated that such small-scale facilities exist in over two million households in India and in hundreds of thousands in Pakistan, particularly North Punjab, due to the thriving population of lifestock. In other parts of the developing world, domestic biogas plants can convert livestock manure and night soil into biogas and slurry, the fermented manure. This technology is feasible for small scale users with livestock producing 50 kg manure per day the equivalent of about 6 pigs or 3 cows. This manure has to be collectable to mix it with water and feed it into the plant and toilets can also be connected (Biofuels Association of Australia, 2014).

In Nigeria, research into biogas technology and its practical application is on-going, though, has not really received the deserved attention. Lack of adequate funding from government and sponsorship by individuals or corporate bodies has hindered the development of this technology in Nigeria. The identification of feedstock substrate for an economically feasible biogas production in Nigeria, to include water lettuce, water hyacinth, dung, cassava leaves and processing waste, urban refuse, solid (including industrial) waste, agricultural residues and sewage have been made. Many other raw materials available in Nigeria have been critically assessed for their possible use in biogas production. They include refuse and sewage generated in urban areas, agricultural residues and manure. It was concluded that poultry manure generated in Nigerian homes and in commercial poultry farms could be economically feasible substrates for biogas production (Dahunsi&Oranusi, 2013).

2.6 Types of Biogas Plant

There are various types of plants. On the basis of the feed method, three different forms can be distinguished (Kossmann&Pönitz, 2011):

i. Batch plants
ii. Continuous plants
iii. Semi-batch plants

Batch plants are filled and then emptied completely after a fixed retention time. Each design and each fermentation material is suitable for batch filling, but batch plants require high labor input. As a major disadvantage, their gas-output is not steady (Kossmann&Pönitz, 2011).

Continuous plants are fed and emptied continuously. They empty automatically through the overflow whenever new material is filled in. Therefore, the substrate must be fluid and homogeneous. Continuous plants are suitable for rural households as the necessary work fits well into the daily routine. Gas production is constant, and higher than in batch plants. Today, nearly all biogas plants are operating on a continuous mode. If straw and dung are to be digested together, a biogas plant can be operated on a **semibatch** basis. The slowly digested straw-type material is fed in about twice a year as a batchload. The dung is added and removed regularly. Concerning the construction, two main types of simple biogas plants can be distinguished:

- ✓ fixed-dome plants
- ✓ floating-drum plants

But also other types of plants play a role, especially in past developments. In developing countries, the selection of appropriate design is determined largely by the prevailing design in the region. Typical design criteria are space, existing structures, cost minimization and substrate availability. The designs of biogas plants in industrialized countries reflect a different set of conditions (Kossmann&Pönitz, 2011).

2.7 Selection of appropriate design

In developing countries, the design selection is determined largely by the prevailing design in the region, which, in turn takes the climatic, economic and substrate specific conditions into consideration. Large plants are designed on a case-to-case basis. Typical design criteria are (Kossmann&Pönitz, 2011):

Space: determines mainly the decision if the fermenter is above-ground or underground, if it is to be constructed as an upright cylinder or as a horizontal plant. Existing structures may be used like a liquid manure tank, an empty hall or a steel container. To reduce costs, the planner may need to adjust the design to these existing structures (Kossmann&Pönitz, 2011). Minimizing costs can be an important design parameter, especially when the monetary benefits are expected to be low. In this case a flexible cover of the digester is usually the cheapest solution. Minimizing costs is often opposed to maximizing gas yield. Available substrate determines not only the size and shape of mixing pit but the digester volume (retention time!), the heating and agitation devices. Agitation through gas injection is only feasible with homogenous substrate and a dry matter content below 5%. Mechanical agitation becomes problematic above 10% dry matter (Kossmann&Pönitz, 2011).

2.8 Responsibilities of a Biogas Plant Constructor

The role of a biogas plant constructor is vital in successful installation of biodigesters. The following are some of the major responsibilities of a biogas plant constructor:

- Provide necessary information on benefits of biodigester to the users and motivate them for bio-digester installation
- Select proper size of bio-digester based upon the availability of feeding materials
- Ensure that the quality standards of construction materials and appliances are properly complied with.
- Follow strictly the design and drawing as provided to them during construction of biodigesters.

- Comply with the Construction Manuals while installing the biodigesters.
- Provide and maintain the users with minimum requirement of knowledge and skill to operate various components of bio-digester
- Ensure timely completion of the work
- Report progress and difficulties, if any, to supervisors regularly
- Work as extension worker and promoter of the technology in their areas of influences
- Provide regular follow-up and after-sales services to the users to ensure trouble-free functioning of completed plants (Rwanda Utilities Regulatory Agency, 2012).

2.9 Biogas plant

A biogas plant is an anaerobic digester of organic material for the purposes of treating waste and concurrently generating biogas fuel. The treated waste is a nutrient-rich, nitrogen-rich fertilizer while the biogas is mostly methane gas with inert gases including carbon dioxide and nitrogen. Biogas plants are a preferred alternative to burning dried animal dung as a fuel and can be used for the treatment of human waste. Other feedstock which can be used includes plant material, non-meat or grease food-wastes, and most types of animal dung. Over a million biogas plants have been constructed in the developing world for treatment of organic wastes, alternative energy supply to direct burning in the home, and overall improvement of human health and the environment. Many factors for selection of feedstock and site location must be researched before deciding to install a biogas plant (United States Forces – Afghanistan, 2011).

Successful construction of the biogas plant requires a proper design and adherence to follow correct construction methods. The success or failure of any biogas plant primarily depends upon the quality of construction work. The following instructions are based on the step-by-step instructions from the Government of Nepal Biogas Support Program Gobar Gas and Agricultural Equipment Development Company of Nepal has developed the design for model 2047 biogas plant. This biogas plant model for instance has become prolific across Asia and is known as a fixed-dome plant. The advantages of the fixed dome plant include the simplicity of design, few moving parts, low cost to construct and low maintenance. The disadvantages when compared to a floating-dome digester are primarily the inability to store gas for use on demand; gas from the fixed dome digester must be used as generated or expelled to avoid damaging the digester (United States Forces – Afghanistan, 2011).

2.10 The Contribution of Biodigester Technology to Development at Different Levels

Farmers may want to substitute inputs such as fertilizers, household and engine fuels by biodigester slurry and the biogas itself. A biogas system can relieve farmers from work that they have spent on dung disposal or dung application on their fields. By using biogas for cooking, lighting and heating, life quality for the whole family can improve. Improved stables, if they are part of the biogas system, can increase the output of animal husbandry. Improved farmyard manure may raise the yield of plant production (Lam, 2010).

Craftsmen, engineers and maintenance workers are finding employment due to the existence of a biodigester industry. A well developed biodigester sector opens up market niches for masons, plumbers, civil engineers and agronomists; they are often the most effective promoters of biogas technology (Lam, 2010). Governments have macro-economic interests that may render biogas technology an interesting option in overall development plans. On a national scale, a substantial number of working biogas systems will help reduce deforestation, increase agricultural production, raise employment, and substitute imports of fossil fuels and fertilisers. If macro-economic benefits are obvious and quantifiable, a government may even consider subsidising biogas systems to bridge a microeconomic profitability gap (Lam, 2010). International community is profiting from the reduction of greenhouse gas emissions and the absorption of greenhouse gasses due to lesser pressure on fuel wood resources and better manure management (Lam, 2010).

2.11Anaerobic digestion /Co-digestion

Anaerobic digestion is a biochemical technology for the treatment of organic wastes and the production of biogas, which can be used as a fuel for heating or co-generation of electricity and heat. Anaerobic digestion of animal manure has been extensively researched and demonstrated. In California, over 15 dairy manure digesters are either operating or under development. However, based on investment returns from energy production, the economics of dairy digesters are not favourable due to the relatively low biodegradability and biogas yield of dairy manure, as compared to many other types of organic wastes such as food waste (El-Mashad& Zhang, 2010). One of the approaches for improving the economics of dairy digesters is to increase their biogas production rate by co-digesting the manure with more degradable wastes as long as such wastes are available in the vicinity of dairy farms and the farm land can use the nutrients and salts of the wastes. Co-digestion of different materials may enhance the anaerobic digestion process due to better carbon and nutrient balance (Mshandete *et al*., 2004; Parawira *et al.*, 2004). According to Mata-Alvarez et al. (2000), digestion of more than one substrate in the same digester can establish positive synergism and the added nutrients can support microbial growth. During mesophilic anaerobic co-digestion of cattle manure and fruit and vegetable wastes (FVW) in a continuous stirred tank reactor (CSTR) at 35C, Misi and Forster (2001) found that batch codigestion, at 35 C, of cattle manure with molasses (50% on dry weight basis) increased the biogas yield from 60 to 230 L/kgVS added. Their biogas yield of cattle manure is lower than the yield reported by other researchers for dairy manure (Hill, 1983).

Anaerobic digestion of organic material is composed of at least four process stages: hydrolysis, acidogenesis, acetogenesis and methanogenesis (Schattauer, Abdoun, Weiland, Plo¨chl&Heiermann, 2011). Methane formation by archaea is a consequent and necessary process stage following acetogenesis because the responsible bacteria are inhibited by their own products. Methanogenesis comprises two pathways: acetoclastic, i.e. the cleavage of acetic acid in methane and carbon dioxide and hydrogenotrophic, i.e. the formation of methane from hydrogen and carbon dioxide. Archaea, especially the strains involved in the hydrogenotrophic pathway (Nettmann *et al.,* 2010), need several trace elements as micronutrients of which cobalt, molybdenum, nickel, and seleniumare the most important (Gronauer *et al*., 2009; Lebuhn, Liu,Heuwinkel&Gronauer, 2008). In practice, it is expected that the deficiency of these trace elements leads to reduced anaerobic digestion performance. Trace elements are usually supplied with feedstock to biogas digesters. Hence, the selection of feedstock directly influences the abundance of trace elements. The trace elements investigated here were all defined as micro nutrients with concentrations in the range of several mg l-1 and below. They were manganese, molybdenum, zinc, copper, cobalt, nickel, selenium, chromium, and boron. The macro nutrients (with concentrations above50 mg l-1) magnesium, iron, sulphur, and calcium were also investigated.

Anaerobic digestion of waste lignocellulosic feedstocks for biogas production is a biological process that combines renewable energy generation with sustainable waste treatment. Waste lignocellulose includes agricultural residues such as straw, woodchips or biofibers from manure. Manure is one of the largest biomass resources in countries with high animal production such as Denmark, where many biogas plants utilize it as their primary feedstock. Manure has low biodegradability because of its high content of lignocellulosic biofibers (40–50% of the total solids). Inplants, lignocellulose is a complex and rigid structure resistant to enzymatic attack and insoluble in water because of the tight association between lignin (phenolic compound) and holocellulose(cellulose and hemicellulose, carbohydrates). Lignocellulosic feedstocks are relatively recalcitrant to anaerobic digestion and treatment is needed to degrade them. With steam treatment, the substrate is treated with steam at high temperature and pressure in a pressure vessel. After the set time, the steam is slowly released and the treated substrate is collected. The objective is to achieve sufficient solubilization of the lignocellulose to enhance the hydrolysis and to avoid the formation of inhibitors like furfural or HMF. Many parameters such as temperature, residence time, catalyst dosage, time of pre-soaking and moisture content of the substrate can be used to optimize the steam treatment (Bruni, Jensen &Angelidaki, 2010).

2.12 Anaerobic Digestion Process

The process of anaerobic digestion involves a number of microorganisms including acetic acid-forming bacteria (acetogens) and methane-forming archaea (methanogens). The initial feedstock is fed upon by these organisms and the feedstock undergoes a number of different processes converting it to intermediate molecules including sugars, hydrogen, and acetic acid, before finally being converted to biogas. In an anaerobic system the majority of the chemical energy contained within the starting material is released by methanogenic bacteria as methane (Fergusen&Mah, 2006).

Populations of anaerobic microorganisms typically take a significant period of time to establish themselves to be fully effective. Different species of bacteria are able to survive at different temperature ranges. Those that can live optimally at temperatures between 35–40 °C are mesophiles or mesophilic bacteria and those that can survive at the hotter and more hostile conditions of 55–60°C are thermophiles or thermophilic bacteria. It is therefore common practice to introduce anaerobic microorganisms from materials with existing populations, a process known as "seeding" the digesters, and typically takes place with the addition of sewage sludge or cattle slurry (Opoku, 2011).

2.13 Measuring in biogas environments

Biogas is part of the wet gas and condensing gas (or air) category that includes mist or fog in the gas stream. The mist or fog is predominately water vapor that condenses on the sides of pipes or stacks throughout the gas flow. Biogas environments include wastewater digesters, landfills, and animal feeding operations (covered livestock lagoons) (United Nations, 2010).

Ultrasonic flow meters are one of the few devices capable of measuring in a biogas atmosphere. Most thermal flow meters are unable to provide reliable data because the moisture causes steady high flow readings and continuous flow spiking, although there are single-point insertion thermal mass flow meters capable of accurately monitoring biogas flows with minimal pressure drop. They can handle moisture variations that occur in the flow stream because of daily and seasonal temperature fluctuations, and account for the moisture in the flow stream to produce a dry gas value (United Nations, 2010).

2.14 Production of biogas

The required quantity of feedstock and water is mixed in the inlet tank and the slurry is discharged to the digester vessel for digestion. The gas produced through methanogens bacteria in the digester is collected in the dome. The digested slurry flows to the outlet tank through the manhole. The slurry then flows through the overflow opening in the outlet tank to the compost pit. The gas is supplied from the dome to the point of application through a turret and pipeline. When a biogas plant is underfed the gas production will be low; in this case, the pressure of the gas might not be sufficient to fully displace the slurry in the outlet chamber. If too much material is fed into the digester and the volume of gas is consumed, the slurry may enter the gas pipe and to the appliances.

2.15 Construction Materials for Domestic biogas plant

If the construction materials to be used in the plant construction such as cement, sand, aggregate etc. are not of good quality, the quality of plant will be poor even if design and workmanship involved are excellent. In order to select these materials of best quality, a brief description regarding their specifications as provided by Bajgain(1994)has been given hereunder.

a) Cement

The cement to be used in the plant construction has to be of high quality Portland cement from a brand with a good reputation. It must be fresh, without lumps and stored in a dry place. Bags of cement should never be stacked directly on the floor or against the walls but wooden planks should be placed on the floor to protect cement from dampness.

b) Sand

Sand for construction purpose must be clean. Dirty sand has a very negative effect on the strength of the structure. If the sand contains 3% or more impurities, it must be washed. The quantity of impurities especially the mud in the sand can be determined by a simple test using a bottle. This is called the 'bottle test'. For this test, small quantity of sand is put in the bottle. After this, water is poured in and the bottle is stirred vigorously. The bottle is than left stationary to allow the sand to settle down. The particles of sand are heavier than those of mud so they settle down quickly. After 20-25 minutes, the layers of mud and inside the bottle are measured. Coarse and granular sand can be used for concreting work but fine sand will be better for plastering work.

c) Gravel

Gravel should not be too big or very small. It should not be bigger than 25% of the thickness of concrete product where it is used in. As the slabs and the top of the dome are not more than 3" thick, gravel should not be larger than 0.75" (2 cm) in size. Furthermore, the gravel must be clean. If it is dirty, it should be washed with clean water.

d) Water

Water is mainly used for preparing the mortar for masonry work, concreting work and plastering. It is also used to soak bricks/stones before using them. Besides these, water is also used for washing sand and aggregates. It is advised not to use water from ponds and irrigation canals for these purposes, as it is usually too dirty. Dirty water has an adverse effect on the strength of the structure; hence water to be used must be clean.

e) Bricks

Bricks must be of the best quality locally available. When hitting two bricks, the sound must be clear. They must be well baked and regular in shape. Before use, bricks must be soaked for few minutes in clean water. Such bricks will not soak moisture from the mortar afterwards.

f) Stones

If stones are to be used for masonry work, they have to be clean, strong and of good quality. Stones should be washed if they are dirty.

2.16 Positive impact of biogas

Some of the health related benefits achieved from the implementation of biogas plants in Nepal include: reduced smoke exposure in the indoor environment, reduced acute respiratory infections on population of all ages, improved infant mortality rates, reduced eye ailments, reduced concentrations of carbon monoxide, formaldehyde and suspended particles in indoor environments (Gautam *et al.,* 2011).

Due to the lack of wastewater collection and treatment infrastructures in rural Nepal, unmanaged human excreta and wastewater are major problems. Contagious diseases such as diarrhoea, cholera and tuberculosis, etc. are common occurrences in rural areas. However, the use of biogas digesters has helped improve the hygiene situation. It is estimated that 77,000 households in rural Nepal have now toilets that are connected to biogas plants (Gautam *et al.,* 2011).

There is a severe shortage of energy for lighting in the rural areas. This makes it impossible for children to be involved in any education related activities in the evening after sunset. Establishment of biogas digesters has provided energy for lighting in more than 20,000 households in rural areas. This has provided a convenient means for reading or study even in the dark (Gautam *et al.,* 2011). Approximately 11,000 people are employed in the biogas sector. The breakdown is as follows: technical 6,000, administrative/financial 2,700, local promoters 800, and the rest suppliers. The spin-off effect of employment in the biogas sector has been estimated to provide employment for around additional 65,000 people nationwide (Gautam *et al.,* 2011).

Since women and female children are involved in collecting the firewood, they have been able to reduce up to three hours everyday that they used to spend in collecting firewood. This is equivalent to a saving of more than 35,000 woman hours per annum based on the installation of 111,000 biogas plants in the country. Since the burning of biogas is not associated with the deposition of soot particles on the surface of cooking pots, it has also led to the saving of water consumption and time required to wash these utensils (Gautam *et al.*, 2011). In average, 0.7 kg of cattle dung is saved from being dried and burnt in inefficient cooking stoves in every household. As in the case of agricultural residues, the cattle manure is converted to an efficient energy in the form of methane gas (Gautam *et al.*, 2011).

Kerosene is widely used in Nepal for cooking and lighting purposes. Due to the installation of biogas plants, the use of kerosene has been reduced by almost 7.7 million liters per annum in Nepal. Since petroleum product is imported using hard earned foreign currency, the reduced use of kerosene has saved approximately US$2.1 million per annum (Gautam *et al.,* 2011).

Agbomanyi (2008) noted that in North America, utilization of biogas generates enough electricity to meet up to three percent of the continent's electricity expenditure. Normally, manure that is left to decompose releases two main gases that cause global warming: nitrous dioxide and methane. Nitrous oxide warms the atmosphere 310 times more than carbon dioxide and methane 21 times more than carbon dioxide. It is estimated that one cow can produce enough manure in one day to generate 3 kilowatt hours of electricity; only 2.4 kilowatt hours of electricity are needed to power a single one hundred watt light bulb for one day.

Conversion of waste from cow manure into biogas can reduce emission of greenhouse gases by nine million metric tons or 4%. The 30 million rural households in China that have biogas digesters enjoy 12 benefits: saving fossil fuels, saving time collecting firewood, protecting forests, using crop residues for animal fodder instead of fuel, saving money, saving cooking time, improving hygienic conditions, producing high- quality fertilizer, enabling local mechanization and electricity production, improving the rural standard of living, and reducing air and water pollution (Agbomanyi, 2008) The advantages of biogas have not been tapped to the benefit Ghanaians. The potential for the development biogas plant on both large and small scale for commercial and domestic use respectively is very high in developing countries such as Ghana due to the need for alternative energy sources (Agbomanyi, 2008).

2.17 Balancing Biogas Production and Energy Demand

Determining the biogas production

The quantity, quality and type of biomass available for use in the biogas plant constitutes the basic factor of biogas generation. The biogas incidence can and should also be calculated according to different methods applied in parallel.

- ✓ Measuring the biomass availability
- ✓ Determining the biomass supply via pertinent-literature data
- ✓ Determining the biomass supply via regional reference data
- ✓ Determining biomass supply via user survey

It should be kept in mind that the various methods of calculation can yield quite disparate results that not only require averaging by the planner, but which are also subject to seasonal variation.

The biomass supply should be divided into two categories:

- quick and easy to procure
- procurement difficult, involving a substantial amount of extra work (Kossmann&Pönitz, 2011).

Measuring the biomass availability (quantities of excrement and green substrate)

This is a time-consuming, cumbersome approach, but it is also a necessary means of adapting values from pertinent literature to unknown regions. The method is rather inaccurate if no total-solids measuring is included. Direct measurement can only provide indication of seasonal or fodder-related variance if sufficiently long series of measurements are conducted (Kossmann&Pönitz, 2011).

Determining the biomass supply via literature data

According to this method, the biomass supply can be determined at once on the basis of the livestock inventory. Data concerning how much manure is produced by different species and per liveweight of the livestock unit are preferable.

Dung yield = liveweight × number of animals × specific quantity of excrements [kg/d]

Often, specific quantities of excrement are given in % of liveweight per day, in the form of moist mass, total solids content or volatile solids content (Kossmann&Pönitz, 2011).

Determining the biomass supply via regional reference data

This approach leads to relatively accurate information, as long as other biogas plants are already in operation within the area in question.

Determining biomass availability via user survey

This approach is necessary if green matter is to be included as substrate.

Determining the energy demand

The energy demand of any given farm is equal to the sum of all present and future consumption situations, i.e. cooking, lighting, cooling, power generation etc (Kossmann&Pönitz, 2011).

2.18 Environment, Economic and Human Health problems associated with the use of Biogas

Biogas can be explosive when mixed one part biogas to 8-20 parts air. When the tank is opened for cleaning or repair work is being done open flames, sparks, and smoking should be avoided. If light is needed a flashlight or sunlight reflected off of a mirror should be used. Biogas leaks smell like rotten eggs (hydrogen sulfide). If someone enters a biogas digester they should always have someone with them in case they stop breathing due to low oxygen intake (United Nations, 2010).

It is important that a biogas system never have negative pressure as this could cause an explosion or kill the digesting bacteria. Negative gas pressure can occur if too much gas is removed or leaked. Because of this biogas should not be used at pressures below one column inch of water, measured by a pressure gauge (United Nations, 2010). Frequent smell checks must be performed on a biogas system. If biogas is smelled anywhere windows and doors should be opened immediately. If there is a fire the gas should be shut off at the gate valve of the biogas system (United Nations, 2010).

CHAPTER THREE

METHODOLOGY

This chapter presents the methodology used in the study. This consists of areas such as research design, population, sample and sampling technique, sources of data collection tools and procedure, and data analysis.

3.1 Research Design

The study used a cross sectional descriptive survey with a mixed method approach to achieve its objectives. This design was used because data was collected at a single point in time with questionnaire and interview for basis of analysis. In addition, the design was deemed appropriate because the study involves different stakeholders of different ages, experiences, and status. The choice of the descriptive survey design for the study was based on the advantages associated with the design. First, the total cost of a sample is much less than that of a complete enumeration covering the same items of inquiry. Secondly, surveys use the sampling technique, which covers a greater scope regarding the variety of information required. The study was centred or focused on some selected houses in the Kumasi Metropolis. Kwadaso, Manhyia and Old-Tafo were used as the case study. The communities were selected based on the existence of some biogas plants in some of the households and institutions. These communities were selected to determine the awareness and use of biogas as alternative energy in their household, and to ascertain the economic/social impact to the people and the way forward. In the quest to achieve this, both quantitative and qualitative techniques were employed to ensure that the study was successful. The population of the selected area was obtained from Kumasi Metropolitan Assembly statistics. The details of that is shown in Table 3.1.

3.2 Population

The population of the study consists of all landlords in the selected communities. Landlords were used because they were responsible for any construction activities of the residential buildings. In addition to this, biogas contractors in the metropolis were taken into consideration.

3.3 Sample Size

The sample selected was based on data obtained from statistics of KMA on the number of landlords in the selected communities in Kumasi. The sample size obtained after using the mathematical formula by Brewer and Miller (2003) was 303. This formula was adopted to get a fair fraction of the targeted population to be selected from each community for the sample. Three biogas experts were consulted and interviewed on how biogas plants were executed in households.

Table 3.1 Sample Size

Community/Contractors	Landlords/Landladies	Sample Size
Kwadaso	60,233	100
Old-Tafo	38,052	100
Manhyia	44,767	100
Contractor (Biogas Experts)	3	3
Total	**143,055**	**303**

Source: Kumasi Metropolitan Assembly, 2015

3.4 Sampling Technique

The sample for the study consisted of 300 landlords conveniently selected from the three selected communities. Three biogas expert/contractors were also interviewed for their views on biogas.

The sample size for each community was obtained / calculated using mathematical computations adopted from Brewer and Miller (2003).

Where $n = \frac{N}{1+N(\&)^2}$

N= sample frame

α= 10% margin of Error

Kwadaso

$= \frac{60233}{1+60233(0.1)^2}$

$= \frac{54}{1+60233(0.01)}$

$= \frac{60233}{1+602.330}$

$= \frac{60233}{603.33}$

= **99.83**

= **100**

Total= 100

3.5 Data Collection tools and procedure

The study employed questionnaire and interview as the main data collection tools. Responses from the answered questionnaires and interviews were the focal point upon which analysis was effected. The questionnaire was presented into sections which include demographic data of respondents, the awareness creation and use of biogas as an alternative energy considering the current energy crisis facing the Ghanaian economy. The questionnaires were given to the participants to be completed within a week and interviews were conducted alongside based on the mode of preference and the educational background of the participants. The interview was drafted to suit the same line as that of questionnaire. The interview was done to elucidate further on issues concerning the objectives of the study and to some extent the educational background of the participant. The triangulation approach which consists of both quantitative and qualitative techniques were adopted for the study.

3.6 Data Analysis

Data gathered were carefully sorted and grouped in their respective categories such as gender, educational background, awareness creation on biogas and impact on the economy and society. The purpose of data analysis is to make the gathered data a more presentable and meaningful in a way that, it can be easily communicated. The data was arranged and carefully coded to ensure that there would be reliability and consistency. Descriptive and inferential statistics were employed in the process to discuss and present the results in the form of tables and charts. The descriptive statistics was meant to describe what the data is and the inferential statistics dealt with going beyond the face value of the data and infer possibilities that the data might show.

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CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

Chapter four presents the discussion of issues pertaining to the study. It includes presentation of demographic characteristics of respondents, awareness creation of biogas plant usage as an alternative source of energy for households, challenges to the development of biogas plant production in Ghana, impact of biogas on lives of people and processes involved in the construction of biogas plant in households within Kumasi Metropolis. It was realised that 286 out 303 participants selected for the study responded and this thereby gave a response rate of 94% which was encouraging.

4.2 Demographic Characteristics of the Respondents

In ascertaining the demographic characteristics of respondents, factors such as their gender, age, educational background, religion and net-monthly income were considered and presented.

4.2.1 Gender of Respondents

It is evidenced from Figure 4.1 that males constituted 58% of the total respondents whilst 42% were females. Since the study targeted house owners within Kumasi Metropolis, it was prudent to ascertain gender of respondents to the study. Even though, it was found that males dominated the respondents, there was no correlation of a person's gender and that of his/her willingness to use biogas plant as an alternative to handling human excreta and source of energy in households that were selected for the exercise.

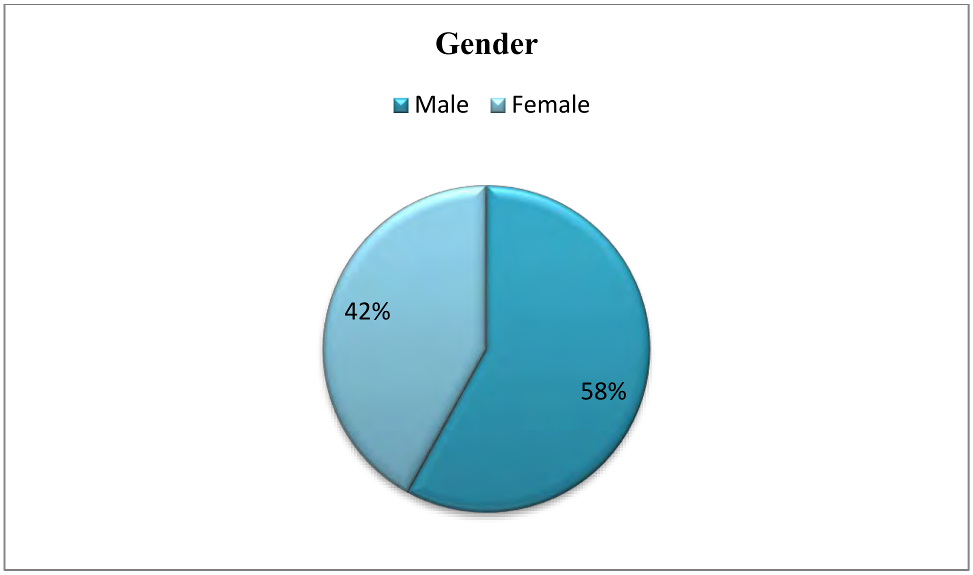

Figure 4.1: Gender of Respondents

However, it was found that majority of landlords who showed interest in pursuing the use of biogas as an alternative to handling human excreta and source of energy in future were males.

4.2.2 Age of Respondents

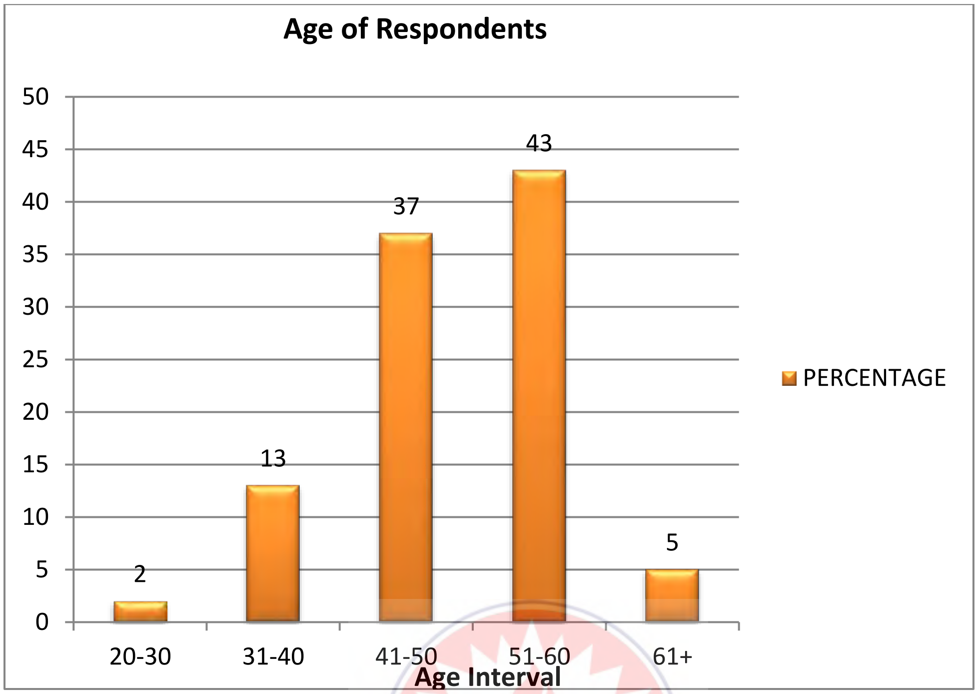

Figure 4.2: Age of Respondents

After knowing respondents gender, it became imperative to ascertain their ages. The response in Figure 4.2 shows that 43% of respondents were 51-60years and constituted majority. Moreover, 37% were found to be 41-50years, 13% were 31-40years, 3% accounted for those with 61 and above whilst 2% were 20-30years. The study showed no significant correlation of a person's age and interest in the use of biogas as an alternative to handling human excreta and source of energy.

4.2.3 Educational Background of Respondents

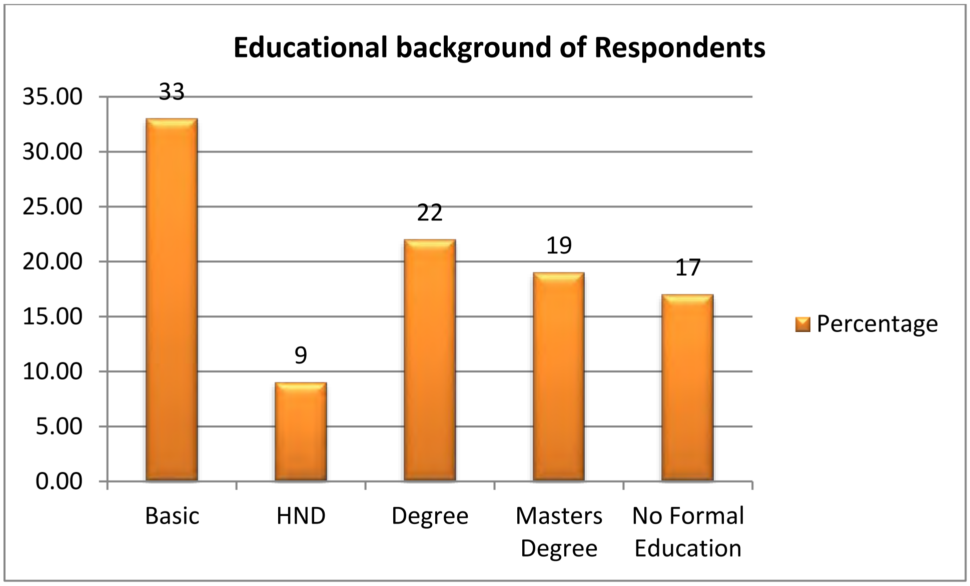

Figure 4.3: Educational Background of Respondents

Respondents were probed further to ascertain their educational background. The responses shown in Figure 4.3 reveal that majority of houseowners had completed basic education as their highest level of attainment in schooling (33%). This was followed by those who had attained degrees from various disciplines of study (22%). It is also evident that 19% had attained master's degree and 17% with no formal education. The acceptance level of biogas plant production as an alternative source of energy had some bearing on some respondents' educational background. It was found that majority of houseowners who indicated willingness to use biogas as alternative to handling human excreta and a source of energy when financially sound were people with moderate level of formal education. This is in line with the theory of adoption of innovation as proposed by Agmomanyi (2008). Biodigesters as an alternative to handling human excreta and source of energy is fairly new technology and those with a certain level of formal education are expected to understand and adopt it earlier than those without formal education.

4.2.4 Religion of Respondents

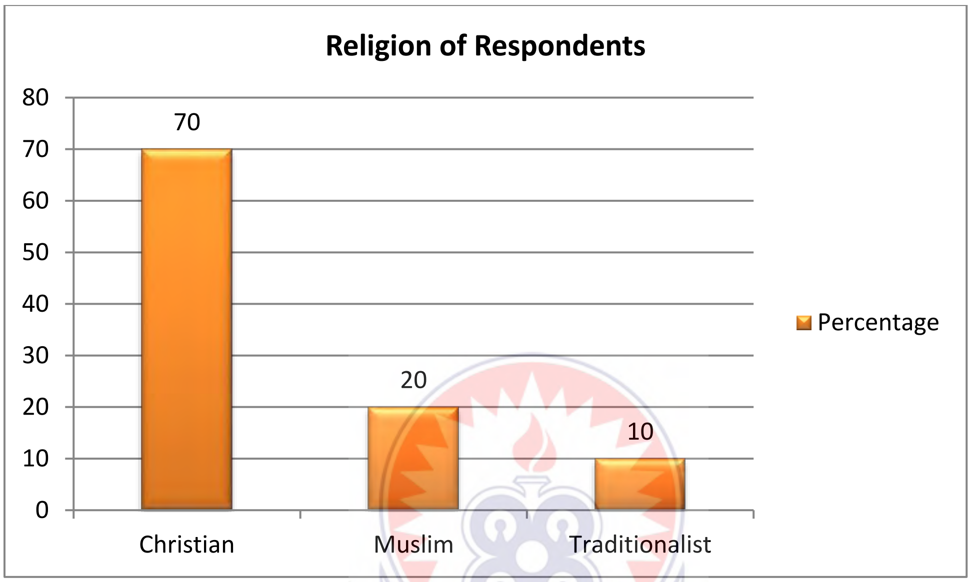

Figure 4.4: Religion of Respondents

The researcher probed further to know whether respondents' religion affiliation can have influence on their acceptance level of biogas usage in households. The results indicated that 70% of respondents were Christian, 20% Muslim and 10% Traditionalist. Once again, it came to light that none of the respondents indicated the use of biogas in households was contrary to their religious beliefs and prevents them from endorsing such technology in their households.

4.2.5 Respondents Net Monthly Income

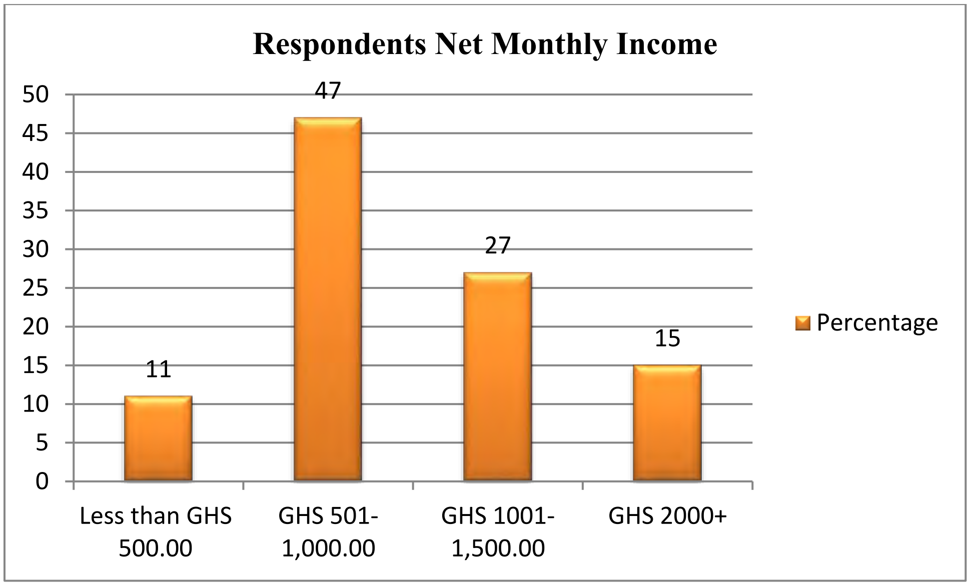

Figure 4.5: Net monthly income of Respondents

Since the construction of biogas plant requires substantial amount of money, it was appropriate for the study to take into consideration the financial capacity of respondents to undertake such a project. From Figure 4.5, it was revealed that 47% of house owners earn GH¢501-1000.00 a month. In addition, 27% of them earn GH¢1001-1,500.00, 15% earn beyond GH¢2000 and 11% had monthly income of less than GH500.00. The results indicate that considering Ghana's economic credentials and status, majority of houseowners do not earn up to GH¢2000.00 and this makes it difficult to commit enough funds into building a biogas plant. In view of this, it is appropriate to state that inadequate financial resources have direct bearing on people's desire for biogas usage as it depends on affordability.

4.3 Awareness of the use of biogas in Households

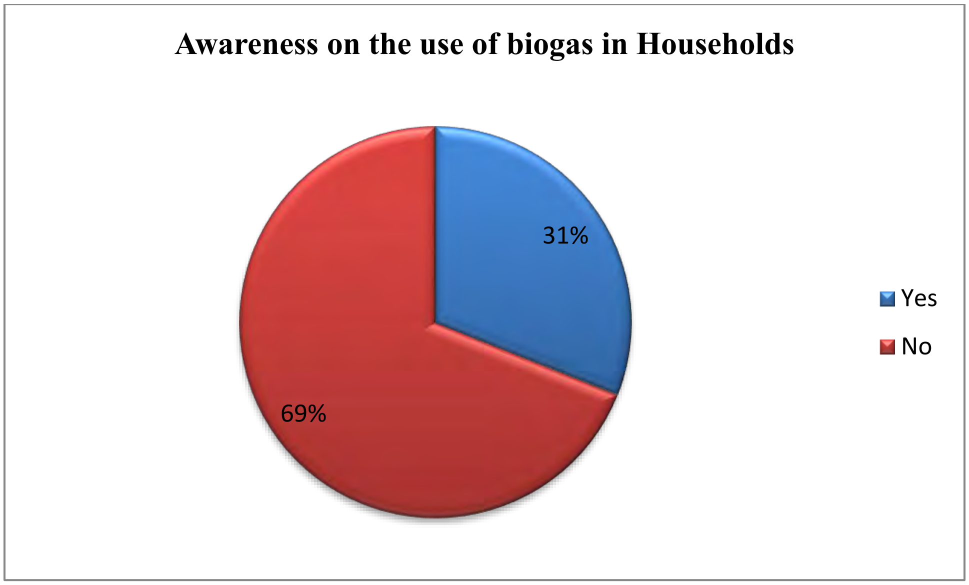

Figure 4.6: Respondents Awareness on the use of biogas in households

As shown in Figure 4.6, respondents were probed further to ascertain their awareness on use of biogas plant in households. Results of this probe indicated that majority of house owners were unaware of usage of biogas as an alternative to handling human excreta andsource of energy for cooking. The 69% assertion on this signifies low level of knowledge on the use of biogas in the Kumasi Metropolis. The lack of awareness creation on use of biogas has deepened the rate at which people rely only on electricity, charcoal and firewood as sources of energy in households which are costly, thereby causing economic hardships on people. The failure on the part of houseowners to properly handle human excreta in homes have brought cost burden coupled with its related inconveniences. The findings support the work of Dahunsi and Oranusi (2013) that research into biogas technology and practical application is on-going, though, it has not really received the deserved attention in countries such as Ghana and Nigeria.

4.4 Respondents awareness on constructed biogas plant

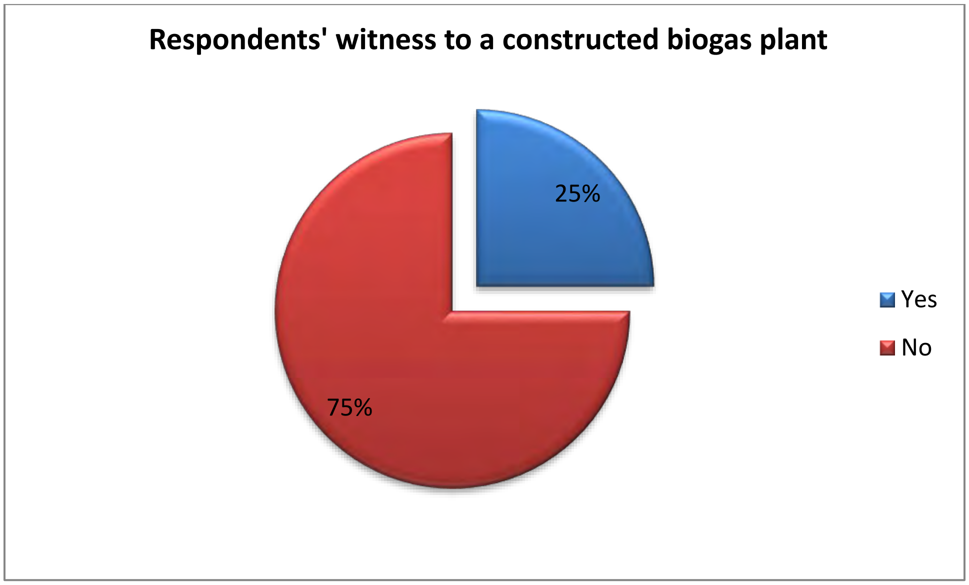

Figure 4.7: Respondents' witness/encounter to a constructed biogas plant

In the quest to ascertain the familiarity of respondents with a constructed biogas plant, they were asked to indicate whether they have witnessed / seen a constructed biogas plant before. Responses shown in Figure 4.7 reveal that 75% of houseowners had not witnessed or seen a constructed biogas plant before, whether in their locality or elsewhere. This points to the fact that biogas usage has not gained the necessary popularity in the Kumasi Metropolis. However, 25% noted that they have witnessed a constructed biogas plant before but were quick to add that it was not from their vicinity but areas such as Kwadaso, Kotei, Adwase and its environs. This might have been as a result of KNUST being located near such areas except Kwadaso. The university has some few professionals in dealing with biogas plant production and this appears to influence the existence of few of such plants in certain areas.

4.5 Awareness on the significance of biogas plant in households within Kumasi Metropolis

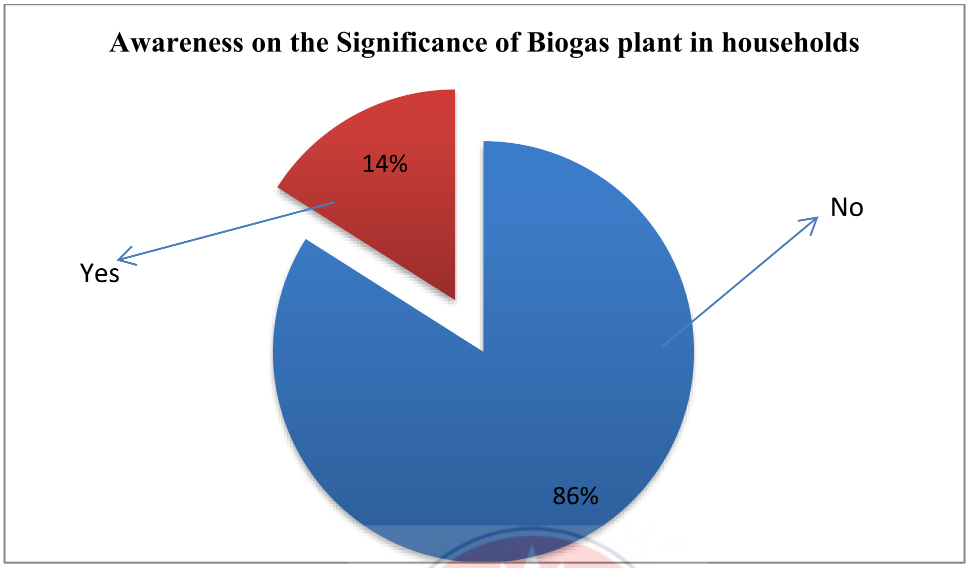

Figure 4.8: Respondents' awareness on the significant need for biogas plant as an alternative source of energy in households

The results presented in Figure 4.8 testify that majority of houseowners did not have knowledge on significance attached to use of biogas in households. It was found that overwhelming number of houseowners posited or displayed their ignorance towards significance of biogas (86%). This assertion can be said to have been influenced by the extreme lack of education and support from government as well as low level of taught courses in academic institutions in relation to biogas production and its usage. However, 14% of respondents stressed on their conversance towards biogas significance. Igoni et al (2008) emphasised that biogas technology enables one to produce bio-energy by treating the waste generated in houses and public places such as markets, hotels and convents.

4.6 Feasibility of Biogas project as an alternative source of Energy

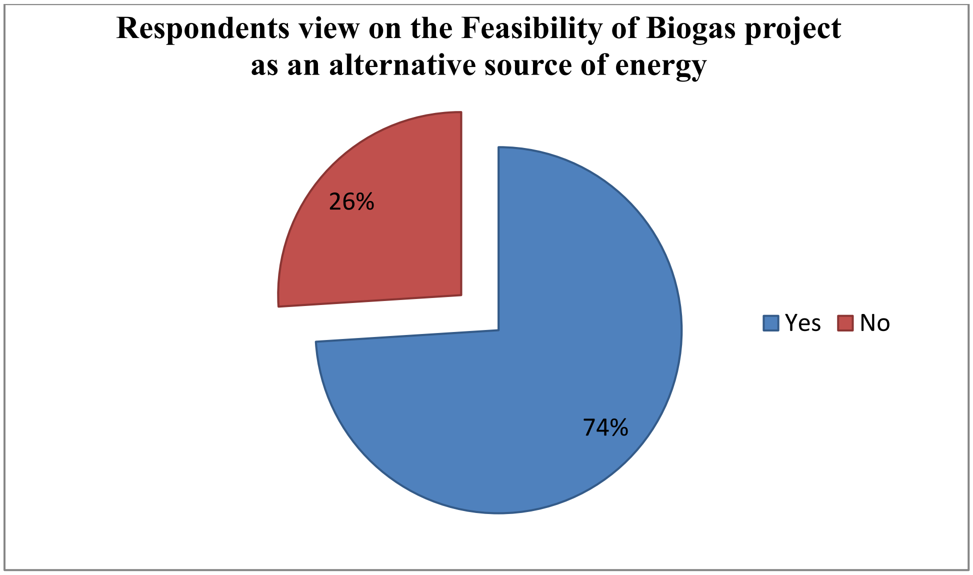

Figure 4.9: Feasibility of Biogas project as an alternative source of energy

From the study, respondents were probed to indicate their position towards the use of biogas as a feasible alternative source of energy. This was meant to ascertain their readiness and behaviour towards biogas use in households, in case affordability does not become a problem. The results show 74% of houseowners posited their readiness to use biogas as a source of energy. From the interview, one of the houseowners stated that;

"I believe biogas is a comprehensive, reliable, sustainable and great project to curb the problem of high tariffs on electricity but the difficulty lies with cost"

Even though most house owners perceived and accepted biogas as a laudable project that can bring comfort to the various households, a major hindrance to this dwells on its cost. The cost of constructing biogas was to some extent difficult for most houseowners based on their income levels. Adeniran et al (2014) stressed that biogas technology was a feasible project that serves as an alternative renewable energy sources with its associated positive impact on environment and health.

4.7 Respondents' preference on the use of Biogas to traditional source of energy

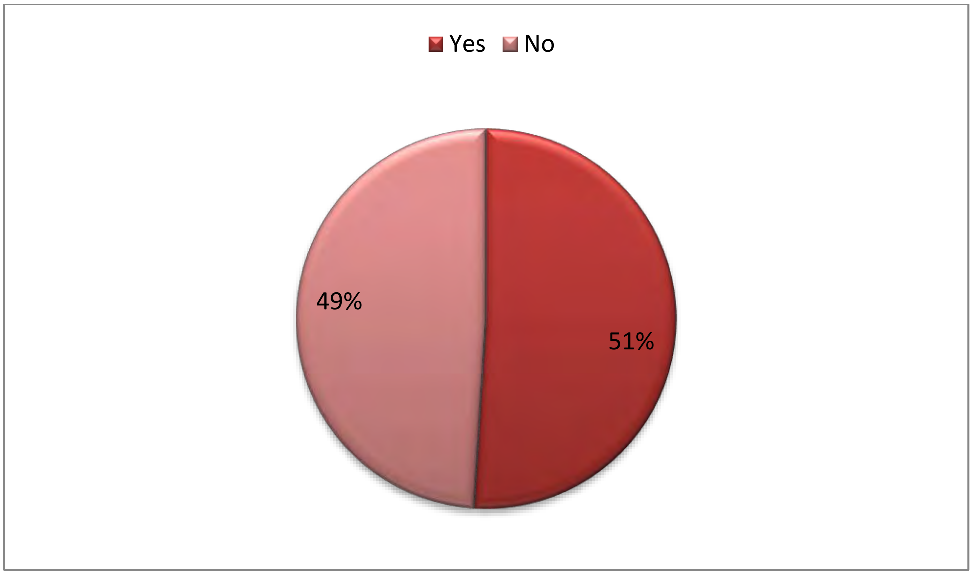

Figure 4.10: Respondents preference on the use of Biogas to traditional source of energy

In presenting responses on preference of biogas use to traditional source of energy, it is shown in Figure 4.10 that 51% were more eager to use biogas than traditional source of energy whilst 49% on the other hand did not show interest in its use. Mshandefe and Parawira (2009) noted that biogas is becoming an attractive source of energy and there is the need for biogas energy research planned and conducted as part of the main factors leading to contribution to solution of energy problems.

4.8 Accessing services of personnel who undertake biogas plant production

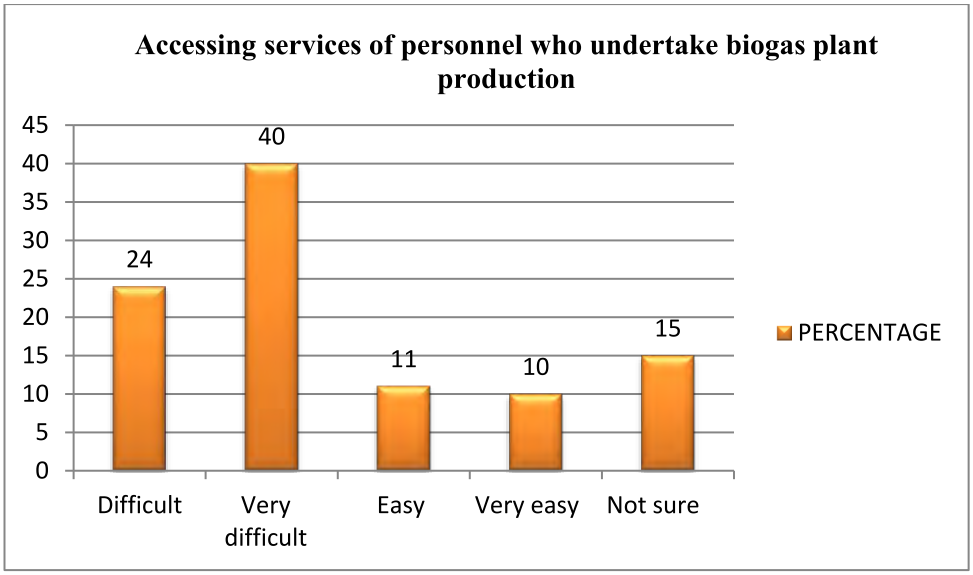

Figure 4.11: Accessing services of personnel who undertake biogas plant production

From Figure 4.11, it was shown clearly that majority of houseowners indicated accessing service of biogas plant expert was very difficult (40%). This was partly attributed to inadequate personnel available for such an area of profession. However, 10% and 11% of respondents respectively emphasised that it was easy getting personnel to undertake biogas project provided one can afford its financial requirements / demands. It was established that 24% of respondents were of the view that it was difficult to access services of biogas plant experts. However, 15% of respondents were not sure on the matter as to whether it easy or difficult in accessing services of experts on biogas. Based on the results, it can be stated that awareness creation on biogas plant has not been effective due to inadequate professionals to undertake it.

4.9 Challenges to the Development of Biogas plant production in Ghana

Table 4.1: Challenges to the Development of Biogas Plant Production in Ghana

	Statement	N	∑w	Mean	RII	Rank
1	Lack of adequate funding from government	286	1,088	3.80	0.035	4th
2	Lack of sponsorship	286	1,146	4.00	0.028	3rd
3	Lack of adequate qualified personnel to handle biogas	286	1,261	4.40	0.026	1st
4	Lack of funds to undertake such projects by people	286	1,096	3.83	0.026	5th
5	Lack of adequate education on significance of biogas	286	1,195	4.17	0.026	2nd
6	Poor construction works on biogas plant	286	974	3.40	0.022	6th
7	Negative attitudes to change	286	936	3.27	0.034	7th

Where N= Total number of respondents

W= The weighting given to each cause by respondents, ranging from 1 to 5,

A= The highest weight

RII= Relative importance Index

Table 4.1 presents challenges confronting stakeholders in the development of biogas plant production in Ghana. Respondents were of the view that lack of adequate qualified personnel to handle biogas production in the Kumasi Metropolis (Mean=4.40, R=1st) was the most important factor militating against growth of biogas in the metropolis. Unavailability of enough professionals to work on biogas projects poses a major difficulty in the construction industry. This has affected the rate at which biogas has gained popularity in Kumasi Metropolis. The few ones available are also hard to access. The issue of poor construction works on biogas plant was a critical factor that undermines the quality of work done on biogas projects. Bajgain (1994) emphasised that the success or failure of any biogas plant largely depends on quality of construction works. In view of this, inappropriate and poor construction methods executed on biogas project do not contribute positively to its development. The study found that some constructed biogas plants could not last longer due to shoddy works done by some contractors. This was largely blamed on lack of adequate supervision and monitoring of activities on site during implementation stages of biogas projects by some contractors. The failure to coordinate activities on site during biogas project implementation was said to have led to shoddy activities, especially when employees are not highly skilled with needed experience on their job.

Moreover, another striking factor hindering activities on biogas project in households was lack of funds by the people (M=3.83, R=5th). Financial constraints have prevented houseowners who have interest to undertake such projects but the question has to do with their affordability.

A major challenge to biogas development in Kumasi Metropolis has to do with lack of adequate funding from government and sponsorship by individuals or corporate bodies (M=3.80, R=4th and M=4.00, R=3rd) respectively. Government of Ghana over the years have not attached any importance to development of biodigesters as alternative to handle human waste from households and institutions. Little attention has been given in this sector and this contributes immensely towards the poor awareness creation on the subject matter. Aside government failure to cushion households and institutions to adopt biogas as an alternative source of energy and effective ways of handling human excreta, capable corporate bodies have in the same vein failed to promote and support the sector. This has made it very difficult for the patronage of biogas as a source of energy. Dahuusi and Oranusi (2013) reiterated that lack of adequate finding from government and sponsorship by individuals and corporate bodies has hindered development of biogas technology in Nigeria.

It is evident from Table 4.1 that lack of adequate education on significance of biogas has retarded its patronage and acceptance level among houseowners. Poor education on the need to use biogas energy in households have not promoted positive image for its development. The state has failed in this sense and corporate bodies, and NGOs have in turn not played their role effectively in enhancing this area. When there is poor education on relevant issues, its significance cannot be highlighted for public consumption. Negative attitudes to change by people frustrate their acceptance level in reference to biogas usage in households. The inertia to change attitudes towards the use of biogas as an alternative source of energy by some houseowners have triggered and contributed to its difficulties. Some people are just simply reluctant to change and therefore prefer to keep their ways as it pleases them. This affects effective implementation and education on biogas to achieve its purposes. When people are unwilling to change their ways, no amount of education can help improve awareness creation on biogas.

4.11 Impact of biogas production on lives of people

Table 4.2: Impact of Biogas Plant Production on Lives of People

	Statement	N	∑w	Mean	RII	Rank
1	Alternative energy source for households and mitigate environmental emissions from agricultural activities	286	965	3.37	0.036	10th
2	Reducing air and water pollution	286	1,111	3.88	0.031	4th
3	Provides complete ecological satisfaction at community level	286	1,066	3.72	0.035	6th
4	Operational and maintenance cost almost nil	286	1,053	3.68	0.030	7th
5	Providing a clean fuel from renewable feedstocks and help end energy poverty	286	1,147	4.01	0.029	3rd
6	Improve sanitation	286	1,097	3.83	0.028	5th
7	Reduce demand for wood and charcoal for cooking and provide a high quality organic fertiliser	286	1,023	3.57	0.033	8th
8	Biogas has the tendency to raise employment, and substitute imports of fossil fuels and fertilisers	286	1,015	3.54	0.030	9th
9	A substantial number of working biogas systems will help reduce deforestation	286	1,153	4.03	0.029	2nd
10	Reduced acute respiratory infections on population of all ages	286	1,193	4.17	0.025	1st

Where N= Total number of respondents

W= The weighting given to each cause by respondents, ranging from 1 to 5,

A= The highest weight

RII= Relative importance Index

It is shown in Table 4.2 that the use of biogas reduces acute respiratory infections on population of all ages in households and commercial areas (M=4.17, R=1st). The use of charcoal and wood for cooking in households has the tendency to cause serious respiratory problems for occupants. The generated smoke causes infections in the respiratory organs which lead to all sorts of sickness which can lead to loss of lives in the long run. Adopting biogas as a source of energy reduces the extent to which people can be infected with smoke related health problems. Gautama et al. (2011) listed that implementation of biogas plants in Nepal led to reduce smoke exposure in the indoor environment and has reduced acute respiratory infections on people.

A large number of respondents (with a mean of 4.03 and ranking of 2nd) emphasised that a substantial number of working biogas systems will help reduce deforestation. This stems from reduction of cutting down trees meant for firewood and charcoal in catchment areas. Rapid use of firewood as well as over-relying of charcoal usage has led to deforestation. This hinders sustainability of the environment. The use of biogas curtails use of such natural resources and this helps in preserving the environment. According to Gautan *et al.* (2011) excessive exploitation of forest wood has caused deforestation and the introduction of biogas has come to save the situation.

Biogas was found to provide a clean fuel from renewable feedstocks and help end energy poverty (M=4.01, R=3rd). In this current economic hardships, it was emphasised by some houseowners that indeed use of biogas can relief them from paying high utility tariffs such as electricity. This would enhance consumption of energy without having to pay huge and outrageous prices as the price of LPG keeps on increasing. This is economically prudent since it helps save cost for other equally important issues. Moreover, biogas helps in reducing air and water pollution (M=3.88, R=4th). Biogas as compared to wood and charcoal do not cause air and water pollution with its associated health hazards such as eye ailments, respiratory problems and diarrhoea. Agbomany (2008) stressed that one major benefit of biogas has to do with reduction of air and water pollution.

It is also noted in Table 4.2 that biogas has the tendency of creating employment opportunities. The construction of biogas requires masons and other construction workers. All these activities have direct bearing on employment creation in the Kumasi Metropolis. Creating employment has a ripple effect of reducing crime rate and other negative behaviours by frustrated unemployed people in the country and the metropolis to be specific. As shown in Table 4.2, biogas was found to have improved sanitation. This is because refuse are not scattered on the environment but confined at a better place. This ensures good sanitation and prevent outbreak of diseases likely to be caused from poor sanitation practices by people. This also serves as an alternative energy source for households and mitigate environmental emissions from agricultural activities. It provides complete ecological satisfaction at community level. It was further reiterated and elucidated by majority of respondents that operational and maintenance cost on biogas is almost nill. This suggests that much funds are not needed to maintain biogas and this makes it economically feasible and good to use in terms of cost analysis.

Majority of houseowners indicated they have not witnessed a constructed biogas plant. The few ones who had come across such plants indicated they have such in areas such as Kwadaso SDA Hospital and Adwase, Kote and Offinso which was not part of the study coverage. It was no surprise to the researcher when majority of houseowners reiterated their unawareness on significance of biogas plant in households. It was however posited by most houseowners that biogas projects were a feasible alternative source of energy and therefore preferred its usage to the traditional source of energy for households activities such as cooking. They indicated it was much preferred to use of charcoal and wood for cooking. In ascertaining the accessibility of services of personnel indulged in biogas plant production, majority were of the opinion that, it was difficult in getting professionals who undertake biogas projects in the metropolis.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents a summary of key findings of the study, conclusions drawn on the findings and moreover, recommendations which emanated based on the findings. Emphasis was laid on suggestions for future studies.

5.1 Summary of Findings

Awareness creation on the use of biogas in most households in the Kumasi Metropolis was extremely poor. Lack of adequate awareness on biogas in the metropolis has tremendously contributed to poor patronage and acceptance of it as an alternative to handling human excreta and as source of energy as well as conserving the environment through sustainable waste management methods. When people are ignorant of the existence of something, promoting its significance becomes a very difficult exercise. The government as well as NGOs and individual companies who are engaged in biogas have not helped greatly in creating adequate awareness on the need to use it in households as well as institutions. Majority of houseowners indicated they have not witnessed a constructed biogas plant. The few ones who had come across such plants indicated they have seen constructed biogas in areas like Kwadaso SDA Hospital, Kotei, Adwase and Offinso which was not part of the study coverage. It was not surprising to the researcher when majority of houseowners reiterated their unawareness on significance of biogas plant in households. It was however posited by most houseowners that biogas project was a feasible alternative source of energy and therefore preferred its usage to the traditional source of energy for household activities such as cooking. In ascertaining the accessibility of services of personnel indulged in biogas plant production, majority were of the opinion that, it was difficult in getting professionals who undertake biogas projects in the metropolis.

Some of the impacts of biogas usage in households include reduced acute respiratory infections on population of all ages. The use of biogas reduces emission of smoke and other hazardous particles that emanate from firewood. Smoke has the potential to cause problems in respiratory organs in the body. Using biogas significantly reduce possibility of this occurrence and this enhances health status of individuals who might have been affected by smoke and other particles. The patronage of biogas leads to reduction and prevention of deforestation. The cutting down of trees for firewood disturbs sustainability of forest since they are not replanted. This act of negligence and negative behaviour on the part of some people render the environment degraded. Other issues found had to do with reduction of air and water pollution, provides complete ecological satisfaction at community level moderate and effective in its operational and maintenance costs; provide a clean fuel from renewable feedstock's and help end energy poverty. In addition, it has the tendency to raise employment and substitute imports of fossil fuels and fertilizers. The study however found that factors that challenge development of biogas production in the Kumasi Metropolis include lack of adequate finding from government, lack of qualified personnel to handle biogas, lack of funds to undertake the project by most houseowners, and lack of adequate education on significance of biogas.

5.3 Conclusions

The use of biogas in households has not gained adequate attention in the Kumasi Metropolis. This has been triggered mostly by lack of adequate awareness creation on the significance of biogas digesters in houses. Most house owners are ignorant of the existence and benefits of biogas. Even though, biogas project in the area has been challenged by factors such as lack of adequate funds, inadequate biogas personnel and lack of sponsorship from government and individuals, it was evident that majority of house owners were ready to patronise it when cost of biogas project are moderate for them. The use of biogas appears to be an expensive venture to most house owners but it has the potential of reducing health related issues such as respiratory problems, reduction of air and water pollution, decrease of deforestation. It is imperative for able houseowners to adopt the right attitudinal change towards biogas use in households since it has potential to help in saving cost.

5.4 Recommendations

The following recommendations are given based on the findings:

It is imperative for government, corporate bodies, NGOs and interested individuals to help in awareness creation on the use of biogas as an alternative source of energy. Adequate education on significance of biogas would help attract high patronage of its use in households. When people are enlightened on existence of commodities they can heavily rely on with effective cost, it improves their taste on such things in question and biogas is no exception. Moreover, the government and NGOs should sponsor and help in funding biogas projects with households getting access to it in a moderate or affordable way. Government in order to make it effective can subsidize the cost of constructing biogas to households. This would reduce the overall cost that scares houseowners to adopt biogas use in households. These cannot be achieved when more people are not trained in biogas services. It is only when there exist adequate personnel to man its operation and maintenance can the system survive. In view of this, it is appropriate for the state to train more people to engage in biogas activities.

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APPENDIX A

QUESTIONNAIRE FOR PROMOTING THE CONSTRUCTION OF BIOGAS PLANTS FOR GHANAIAN HOUSEHOLDS AND INSTITUTIONS – A CASE STUDY IN THE KUMASI METROPOLIS

A. Personal Details

1. Please Tick [√] to indicate your gender

a) Male [ ]

b) Female [ ]

2. Please Tick [√] to indicate your age.

a) 20-30 [ ]

b) 31-40 [ ]

c) 41-50 [ ]

d) 51-60 [ ]

e) Others,please specify ……………………………………………………….

3. Tick [√] to indicate your educational level

a) Intermediate [ ]

b) Advance level [ ]

c) Higher National Diploma [ ]

d) Degree [ ]

e) No formal Education [ ]

f) Others, please specify ………………………..

4. Religion:

(a) Christian [ ]

(b) Muslim [ ]

(c) Traditional [ ]

(d) Buddhist [ ]

(e) Other [ ] Specify..

5. Are you the house owner? Yes [ ] No [ ]

6. Net Monthly income

a) Less than GHS 500.00 [ ]

b) GHS 501-1,000.00 [ ]

c) GHS 1001-1,500.00 [ ]

d) GHS 2000+ [ ]

Section B

KNOWLEDGE ON THE USE OF BIOGAS PLANT IN HOUSEHOLDS IN THE KUMASI METROPOLIS

7. Have you heard anything on biogas before?

1=Yes [ ]

2=No [ ]

8. Have you seen/witnessed a constructed biogas plant in households?

1=Yes [ ]

2=No [ ]

9.Are you aware of the significance need for biogas plant as an alternative source of energy in households?

Yes [ ]

No [ ]

10. If Yes, how effective has it been?..

……………………………………………………………………………………………………

……………………………………………………………………………………………………

11. What are the processes involved in the construction of biogas plant in households?

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

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

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

12. Is biogas plant a feasible project for alternative source of energy in your view?

Yes [ ]

No [ ]

If Yes how?

If No why?

13. Do you prefer the use of biogas to the traditional source of energy?..........

Yes [ ]

No [ ]

14. How accessible are services of personnel who undertake biogas plant production?

a) Difficult [ ]

b) Very difficult [ ]

c) Easy [ ]

d) Very easy [ ]

e) Not sure [ ]

15 Give reasons for your answer in question 14………………………………………………..

……………………………………………………………………………………………

Section C

Please indicate the extent to which you agree or disagree with the following statement regarding , the IMPACT OF BIOGAS PLANT PRODUCTION ON LIVES OF PEOPLE where Strongly Disagree (1) Disagree(2) Neutral (3) Agree (4) Strongly Agree(5)

	Statements	**5**	**4**	**3**	**2**	**1**	**Interpretation**
16.	Alternative energy source for households and mitigate environmental emissions from agricultural activities						
17.	Reducing air and water pollution						
18.	Provides complete ecological satisfaction at community level						
19	Operational and maintenance cost almost nil						
20	Provides complete ecological satisfaction at community level						
21	In drought prone areas, treated effluent can be used for cleaning of floor of public toilet.						
22	Providing a clean fuel from renewable feedstocks						

	and help end energy poverty.						
23	Improve sanitation						
24	Reduce demand for wood and charcoal for cookingand provide a high quality organic fertiliser						
25	Can serve as a means to overcome energy poverty, which poses a constant barrier to economic development						
26	Biogas has the tendency to raise employment, andsubstitute imports of fossil fuels and fertilisers						
27	A substantial number of working biogas systems will help reduce deforestation						
28	Reduced smoke exposure in the indoor environment						
29	Reduced acute respiratory infections on population of all ages						
30	Improving hygienic conditions						

Please indicate the extent to which you agree or disagree with the following statement regarding , CHALLENGES TO THE DEVELOPMENT OF BIOGAS PLANT PRODUCTION IN GHANA where Strongly Disagree (1) Disagree(2) Neutral (3) Agree (4) Strongly Agree(5)

	Variable	**5**	**4**	**3**	**2**	**1**	**Interpretation**
31.	Lack of adequate funding from government						
32.	Lack of sponsorship						
33.	Lack of adequate qualified personnel to handle biogas						
34	Lack of funds to undertake such projects by people						
35	Lack of adequate education on significance of biogas						
36	Poor construction works on biogas plant						
37	Others (specify)						

38. What measures can be put in place to improve and promote biogasusage by households in Kumasi metropolis?

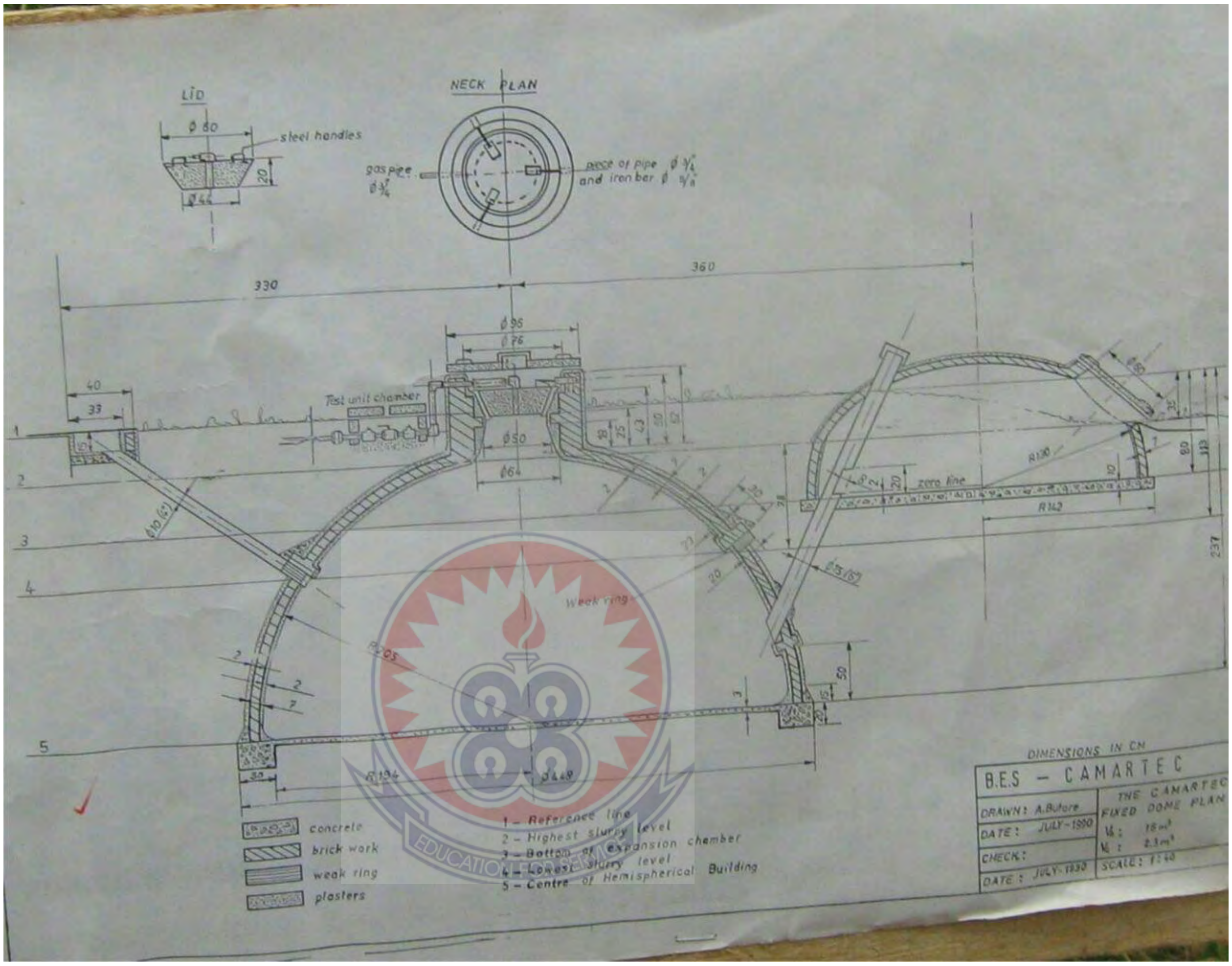
……………………………………………………………………………………………

……………………………………………………………………………………………..

……………………………………………………………………………………………

APPENDIX B

PICTURES INDICATING BIOGAS PRODUCTION PROCESSES



Designed biogas plant to be constructed

Dug area for the plant

Masons laying bricks

Plastering of the plant