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ASSESSMENT OF THE ECONOMIC VIABILITY OF USING HUMAN WASTE AT THE KUMASI (DOMPOASE) LANDFILL SITE FOR GENERATING BIOGAS AS A DOMESTIC FUEL

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SEPTEMBER, 2013

DECLARATION

STUDENT'S DECLARATION

I, Humphrey Wilfred Geraldo, declare that this Dissertation, with the exception of quotations and references contained in 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 Dissertation as laid down by the University of Education, Winneba.

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DEDICATION

I dedicate this dissertation first and foremost to Almighty God for seeing me through in my educational ladder this far and making this master's programme a reality.I also dedicate this dissertation to my dear Mum, late Dad, loved Wife, Children and Brothers.

TABLE OF CONTENT

Declaration: Student's Declaration and Supervisor's Declaration.....i

Acknowledgements.....ii

Dedication.....iii

Glossary.....ix

Abstract.....xii

Chapter One: Introduction.....1

1.1.1 General.....1

1.2.1 Statement of the Problem.....6

1.3.1 Purpose of the Study.....9

1.3.2 Specific Objectives.....9

1.4.1 Research Questions.....10

1.5.1 The Significance of the Study.....10

1.6.1 Limitations of the Study.....11

1.7.1 Organization of the Study.....12

Chapter Two: Literature Review.....13

2.1.1 Definition of Waste.....13

2.1.2 Backgroundto Biogas.....16

2.2.1 Introduction to Renewable Energy Technology (RET).....16

2.2.2 Possibility of Turning Waste into Wealth.....20

2.2.3 Existing Biogas units and Approach used.....21

2.3.1Obtaining a Cleaner Fuel.....23

2.3.2 Human Waste as a Cleaner Energy Source.....25

2.4.1 Collection of Waste and Cleanliness of the City.....25

2.4.2 Existing Sanitation System Situation.....26

2.5.1 Labour and Logistics for Effective Collection.....30

2.5.2 Political Context.....31

2.5.3 Socio-Cultural Context.....31

2.5.4 Economic Context.....31

2.5.5 Environmental Context.....32

2.6.1 Enough Funds for Biogas Project.....32

2.6.2 Access to Energy.....33

2.7.1 Benefits of the Biogas Project to the Citizens.....34

2.7.2 Fertilizer.....35

2.8.1 Review of Alternatives and Limitations.....35

2.9.1 Summary of the biogas project.....37

Chapter Three: Methodology.....39

3.1. Introduction.....39

3.2 Research Design.....39

3.3 Population.....39

3.4 Sample.....39

3.5 Sampling Procedure.....40

3.6 Data.....40

3.7 Secondary Data Collection.....40

3.8 Primary Data.....41

3.9 Data Collection Instruments.....41

3.10 The Questionnaire.....42

3.11 Data Collection Procedure.....43

3.12 Methods of Data Analysis.....44

Chapter Four: Presentation, Analysis and Discussion of Data.....45

4.1 Introduction.....45

4.2 Personal Data of Respondents.....45

4.3 Possibility of Turning Waste into Wealth.....47

4.4 Effects of Fuel Produced on the Pollution of the Atmosphere (Cleaner Fuel)....49

4.5 Collection/Processing of Human Waste Affecting the Cleanliness of the City...55

4.6 Labour and Logistics for Collection of Human Waste.....60

4.7 Enough Funds to Undertake the Project.....67

4.8 Benefits of the Biogas Project to the Citizens.....70

Chapter Five: Summary of Findings, Conclusion and Recommendations......76

5.1 Introduction.....76

5.2 Summary of Findings.....76

5.2.1 Findings on the Possibility of Turning Human Waste into Wealth.....76

5.2.2 Findings on the Effect of Fuel Produced on the Pollution of the Atmosphere (Cleaner Fuel).....76

5.2.3 Findings on How the Collection/Processing of Human Waste Affects the Cleanlinessof the City.....78

5.2.4 Findings on Labour and Logistics for Collection of Human Waste.....79

5.2.5 Findings on Enough Funds to Undertake the Biogas Project.....81

5.2.6 Findings on the Benefits of the Biogas Project to the Citizens.....81

5.3 Conclusions.....83

5.4 Recommendations.....84

5.5 Sugestions for Further Research.....85

References.....86

List of Tables

Table 1.1 Tonnage of Liquid Waste Received at the Dompoase Landfill from 2011 – 2013.....5

Table 4.1 Personal Data of Respondents.....45

Table 4.2 Using Fertilizer Derived From Human Waste on their Farms.....48

Table 4.3 The Extent to Which the Underlisted Contribute to Environmental Pollution.....49

Table 4.4 Biogas is Cheaper than Crude Oil Products.....54

Table 4.5 How the Collection/Processing of Human Waste Affects the Cleanliness of the City.....55

Table 4.6Fear of the Outbreak of Epidemic Due to Haphazard Disposal of Human Waste.....59

Table 4.7 Views on Labour and Logistics for Collection of Human Waste.....60

Table 4.8 Views on the Existence of bye-laws for handling Human Waste.....64

Table 4.9 Who Should Provide Vehicles for the Collection of Human Waste.....65

Table 4.10 KWML has the Human Resource and Logistics to do Effective Collection of Human Waste.....66

Table 4.11 Energy Source Appropriate for the Locality.....67

Table 4.12 Water Closets are still Relevant Despite Huge Water Bills.....68

Table 4.13 The Waste Management Project Would be Economically Viable.....69

Table 4.14 Views on the Benefits of the Biogas Project to the Citizens.....70

Table 4.15 Would You Prefer Manure Fertilizer to Chemical Fertilizer.....74

List of Figures (Figs.)

Fig. 1.1 Picture of some of the Ponds at the Kumasi (Dompoase) Landfill Site.....9

Fig. 1.2 Septic Tanker Discharging its Contents at the Kumasi (Dompoase) Landfill Site.....9

Fig. 2.1 Plant for Trapping Biodiesel.....22

Fig. 2.2 Bio-Digesters.....22

Fig. 2.3 A Worker Using the Biogas Analyser.....22

Fig. 2.4 A Worker Measuring the Quantity of Oxygen in a Bio-Digester.....22

Fig. 4.1 Where Human Waste from Home is Disposed of.....48

Fig. 4.2 Would You Use Toilet Gas Without Further Thoughts?.....48

Fig. 4.3 Biogas is Environmentally Friendly.....54

Fig. 4.4 Kind of Toilet Facility in the House.....59

Fig. 4.5 Views on Public Education Towards Keeping a Clean Toilet-Free Environment.....59

Fig. 4.6 Are there Enough Logistics to Collect Human Waste in Your Locality?.....64

Fig. 4.7 Ratings on the Performance of KWML in Handling Human Waste.....65

Fig. 4.8 Satisfaction with the Current Arrangement of Waste Management.....65

Fig. 4.9 Is it Prudent to Diversify into Other Sources of Energy?.....67

Fig. 4.10 Would Residents Contribute Positively Towards Establishing Energy Source in the Locality?.....67

Fig. 4.11 Governments Should Seek Funds to Convert Landfill Waste to Gas and Manure.....69

Fig. 4.12 Government Should Source for Funds to Implement the Biogas Project on Large Scale.....70

Fig. 4.13 Toilet-to-Gas Project can Solve the Haphazard Disposal of Human Waste.....73

APPENDIX 1

Interview (with Ato Fanyin-Martin Osei).....94

APPENDIX 2

Questionnaire.....96

GLOSSARY

Aerobic Treatment: The treatment of organic waste via cellular biomass production and respiration. This process requires constant input of relatively insoluble oxygen into aqueous solutions for waste waters.

Ammonia Toxicity: Inhibition of anaerobic activity due to high concentrations of ammonia. Ammonia interferes with transport of soluble organics in cell walls.

Anaerobic Digestion: A microbial process carried out by a naturally occurring community of micro-organisms that process organic matter into biogas, a liquid bio-fertilizer and recalcitrant fibre.

Anthropozoonotic: Diseases that originate from humans to animals. Unfortunately, the vice versa is almost always the case and can lead to difficult to control disease outbreaks.

Biochemical Oxygen Demand (BOD): The biodegradability of organic matter in a substance. Determining the amount of oxygen needed to degrade a substance over time usually tests BOD.

Bio-digester:A bio-digester is a sealed container that facilitates anaerobic digestion.

Bio-digester effluent: The liquid by-product from an anaerobic digester.

Bio-digester Process: A process that specially facilitates anaerobic digestion. The process may have various advantages such as sludge retention or polishing of effluent.

Bio-fertilizer: A biologically derived nutrient source.

Biogas: A bio-fuel derived from organic matter mostly containing methane and

carbon dioxide but also containing trace amounts of hydrogen sulphide, water vapour and ammonia.

Black Water: Wastewater containing human excrement. Usually refers to the portion of wastewater coming from a toilet.

Co-digestion: Anaerobic digestion of a source of organic material along with an additional organic material. Co-digestion can be used to solve toxicity factors, nutrient deficiencies and increase the robustness of the fermentation.

Composting: An aerobic treatment process of organic waste that uses cellular biomass production to convert organics and nutrients into a stabilized product (compost) and are most commonly used in homes or centres to treat food waste and turn them into an organic fertilizer.

Dead Zone: An area in a water body where nutrients have triggered an algal bloom that causes the complete consumption of oxygen on a nightly basis rendering the area uninhabitable for higher organisms.

Hydrolysis: The microbial process of turning insoluble organic material such as fats, starches and proteins into soluble by-products.

Irradiation Potential: The amount of sunlight a country receives on daily basis.

Leachate: The wastewater produced as waste digestion goes on.

Leachfield: An area where treated water is slowly dispersed.

Pathogen: Adisease causing vector such as bacteria or virus.

Phase Bio-digester: A bio-digester that separates one or more of the microbial processes into a separate phase.

Red Tide: A bloom of organisms that can sometimes produce toxins that leads to death of marine life and minor to severe skin irritations in humans.

Renewable energy: Is defined as an energy source which is replaced within a human lifetime, such as biomass, solar, photovoltaic (PV), hydro, wind or geothermal technology.

Sand Filter: Uses biological and physical removal processes to treat wastewaters.

Sanitary Landfill: Is a site where wastes are disposed of at a carefully selected location, constructed and maintained by means of engineering techniques that minimize pollution of air, water and soil, and other risks to mankind and animals.

Staged Biodigester: A series of biodigesters that while not separating out phases is capable of achieving more control of the process and a more polished effluent.

Treatment Wetland: A waste treatment technology that uses natural functions in a wetland to remove BOD, nutrients, heavy metals and pathogens.

Syngas: Syngas (from synthesis gas) is the name given to gasses of varying composition that are generated in coal gasification and some types of waste-to-energy facilities.

Synthesis gas: A mixture of carbon monoxide and hydrogen used especially in chemical synthesis.

4Rs: Reduce, Reuse, Recycle and Restoration of damaged resources of the environment, so that waste can be turned to wealth (defined by Watkins *et al*., 2012).

ABSTRACT

This study assessed the economic viability of using human waste at the Kumasi landfill site at Dompoase for generating biogas as a domestic fuel. With regards to the possibility of Turning Human Waste into Wealth, the results revealed that; methane gas can be trapped from human waste discharged at the landfill, 82.2% of respondents agreed that they would use gas obtained from toilet without further thoughts and also use fertilizer derived from human waste on their farms.The rate of collection of waste per week in a location, the number of toilets available in an area, the duration of opening and closing of public toilets, the scent/odour emanating from the public toilets, the availability of "flying toilets" in the area, urbanization,high population density, waste from breweries, sawmills and fitting shops, ineffective sewage system and leachate from landfillwere very seriousfactors thatmajority of the respondents consented to that these factorscontributed to environmental pollution and also affectedthe cleanliness of the city. A strong relationship should exist between the government and users of the biogas and manure products and this could be done through enough educative programmes. The study recommended that;the government (being the sole investor in landfill management) should seek funds and join hands with the private sector, NGOs and Corporate bodiesto convert landfill waste into biogas and manure and that it would be an economically viable project (as confirmed by 90% of the respondents). There is energy in waste and that waste should be treated like a resource and not a thrown away. This calls for recycling, restoration and re-using of waste in order to reduce environmental pollution.The reseacher is, therefore, of the conviction that for this project to succeed it will require a lot of effort from government, academia and the private sector.

CHAPTER ONE

INTRODUCTION

1.1.1 General

There exist different definitions of waste to suit a certain situation or context. For instance Merriam-Webster (n.d.) defines waste as "refuse from places of human or animal habitation". Waste is also defined as a "useless or worthless material or stuff to be thrown away" by the World Book Dictionary (n.d.). Waste creation is related to human activities. So the increase in population and the industrial revolution has necessitated high rates of urbanization and development of lots of wastes. For instance, the cities of Accra and Kumasi, in recent times, have witnessed rapid population growth resulting from the influx of migrants from rural areas.

> Urbanization is fuelled in part by migration that puts pressure on many socio-economic areas. Some of the problems that accompany urbanization are solid waste generation, pressure on housing, school facilities, transportation, road congestion, crime, immoral and indecent life styles. There have been difficulties in tackling these problems. There is an urgent need to work out effective policies, programmes and projects that would provide sustainable solutions to these and other problems (Ghana Statistical Service (GSS), 2010 p 186).

Urbanization brings about the concentration of industrial, commercial, infrastructural, administration and government activities in urban centres. Thus, as the population of cities grow, the rate of waste generation also increases. It is not surprising that “the metropolitan area of Kumasi generates about 1 100 tonnes of solid waste per day” (Wikner, 2009 p I). The volume of waste generated in any city is often a reflection of the intensity of human activities such as population, urbanization and social development, resources exploitation and unchecked technological advances. The

volume of waste generated has also increased tremendously and the implication of this is that more wastes have to be coped with (Adesina, 1983). According to the KMA (2006), bad attitudes of residents such as indiscriminate disposal of household waste and littering due to lack of effective environmental health education and service promotion strategy make people pollute the locality. It continues to say that poor infrastructural conditions particularly road networks and waste collection points, mostly in new settlements, impacts negatively on service delivery. Inappropriate design of communal container: the high reach of containers result in waste being thrown on the ground particularly by children. All these are contributing factors to the current unclean environment. "The high rate of urbanization in African countries implies a rapid accumulation of refuse and Ghana is of no exception" (Agyen, 2011 p 2).

The increasing human activities has brought about increased operational cost to the waste management companies in Ghana and for that matter the Kumasi Metropolitan Assembly (KMA) trying to collect the waste and discharge them at landfill sites.

> The operational cost of the collection and transportation of municipal solid waste to the Kumasi Metropolitan Assembly - Waste Management Department (KMA-WMD) was as at 2007 Gh¢ 9.00 (Nine Ghana Cedis) per tonne, an average of 850 tonnes of solid waste is generated per day in the municipality and this cost the KMA-WMD Gh¢ 7 650 per day. This means the WMD spends Gh¢ 229 500 per month or an annual cost of Gh¢ 2 754 000 (KMA-WMD, 2007, Final Annual Cost Report).

The collection and transportation of the solid waste is funded partly by the KMA and

partly by the government of Ghana (KMA-WMD, 2006, Final Annual Cost Report). Thus, the efficiency of waste collection from residential areas leaves much to be desired. “It is assumed that 70 % of the waste produced is collected” (Wikner, 2009 p I). Environmental pollution by this uncollected waste is on the ascendency as the waste is washed into rivers, streams and other water bodies. Animal waste also adds another dimension to the materials that pollute the atmosphere. Several tonnes of animal waste and dung produced from the slaughter house (abattoir) in Kumasi are just allowed to decompose without turning it into anything useful. Unfortunately, in Ghana, we treat human and animal wastes as “waste”. Luckily enough, modern technology is making it possible to turn both animal and human waste into something “useful”. According to Wade (2012) “there is energy in waste and that waste should be treated like a resource and not thrown away. So companies are piloting several different businesses in order to take waste and recycle it into a usable product”.

Clean energy for domestic and industrial use is currently a mirage as the nation is experiencing frequent power cuts for hours if not days. To aggravate matters, liquefied petroleum gas (LPG) which is widely and commonly used by many homes, hotels and industries as a source of fuel is also very scarce, difficult to come by and expensive. “A larger proportion of urban households (20%) use gas for cooking than rural households (9.5%). However, in Accra the proportion of households using gas is relatively high (34.5%)” (GSS), 2008 p 70). This is a confirmation that Ghanaians appreciate the use of LPG as a permanent source of energy. If this waste can, therefore, be converted into biogas or ethanol it can be used to power vehicles, domestic and industrial electrical generators, stoves and even boilers for timber industries. The society will then not be totally dependent on energy from the national grid.

It is, therefore, proper to ascertain whether it will be economically viable to add value to the human and animal waste to produce biogas and use the sludge from the waste to develop bio-fertilizer (natural manure). Concerning the use of clean energy, the current UN Secretary General (Ban-Ki Moon) says that we need a global clean energy revolution that makes energy available and affordable to all. This is essential for minimizing climate risk, for reducing poverty and improving global health, for empowering women and meeting the Millennium Development Goals (MDGs), for global economic growth, peace and security, and health of the planet (Moon, 2011).

The Kumasi (Dompoase) Landfill accepts both solid and liquid wastes produced by residents of Kumasi and its environs. According to the Business Executive Magazine (BEM), 2011, August p 15:

> The city's population has more than trebled in the last two decades, and as the population increased so has its waste management problems. The legendary city of the Asantes has drawn fame again by becoming the first metropolis to provide a population of over two million people with an ecologically sustainable landfill site and septic ponds. The metropolis generates roughly 20 000 metric tonnes of solid waste with a corresponding five thousand liquid waste daily, representing an increase of 70% rise in the last five years. This figure is expected to record a consistent rise on the average by 20% annually over the next decade. The design of the landfill enables technologists and engineers to trap methane gas through the composite solids.

The statistics provided by the BEM (2011) give a clue that the nine septic ponds at the Kumasi (Dompoase) Landfill are really under pressure as the population keeps increasing at this rate. This is further confirmed by figures of the tonnage of liquid waste received at the Dompoase Landfill for three consecutive years as indicated in Table 1.1. Comparing 2011 and 2012, there was 39.59% increase in tonnage received

in 2012 at the Landfill. But between the 2011 value and the 2013 values, there was an increment of 22.28%, an indication of a reduction of 17.31% over the 2012 figure. Table 1.1 gives a clear proof that the quantity of liquid waste being discharged at the Landfill is increasing by the day (above the 20% projected by BEM, 2011) though dwindling in terms of the rates of increase and warranting increased mantenance cost of the septic ponds.

Table 1.1 Tonnage of Liquid Waste Received at the Dompoase Landfill from 2011 – 2013

Month	Liquid Waste Received (tonnes)		
	2011	2012	2013
January	20,620.8	45,043.4	33,230.5
February	17,909.9	33,449.8	22,463.5
March	16,832.8	33,520.5	28,489.6
April	16,445.9	32,261.0	33,533.3
May	17,987.4	37,126.9	31,939.3
June	21,269.0	31,112.4	31,145.2
July	22,805.7	35,238.2	27,827.3
August	30,026.2	33,835.6	30,941.6
September	29,002.8	31,260.5	27,735.6
October	33,227.9	33,360.6	29,384.5
November	32,115.9	31,927.9	30,298.5
December	34,566.0	30,601.2	31,064.9
Total	**292,810.3**	**408,737.8**	**358,053.8**

Source: KMA (2014) Dompoase Landfill

A sanitary landfill is a site where wastes are disposed of at a carefully selected location, constructed and maintained by means of engineering techniques that minimize pollution of air, water and soil, and other risks to mankind and animals. According to Wikner (2009 p I), "the landfill is engineered and there are wells for gas collection, but the landfill gas is not collected at present". Loans or grants to construct

sanitary landfills do not necessarily result in sanitary landfill disposal. A positive correlation tends to exist between a community's income and the amount of solid and liquid wastes generated, whether individuals with higher incomes consume more than those with lower incomes which result in higher waste generation rate for the former (Adejobi and Olorunnimbe, 2012).

1.2.1 Statement of the Problem

The maxim that "for one to live another must die" applies to all human beings and living things. This means that for man to survive, he must eat other living things like cassava, cocoyam, mangoes, meat, and the list goes on. As nature also demands whatever food that enters the body is burnt to produce energy needed for the body to work. After the body has taken what it needs the rest becomes "waste". This "waste" then exits the body as excreta.

The Kumasi Metropolis has less public toilet facilities available for its inhabitants as compared to its population size. In the Ashanti Region "among urban dwelling units, 3.4% have no access to any toilet facility compared with 11.4% of rural dwelling units" (GSS, 2010 p 172). Unfortunately some of the facilities are in deplorable conditions. As if this situation was not enough, people who patronize these facilities have to pay as much as 50 Ghp and sometimes more each time one visits the place. Some landlords in the metropolis do not have toilet facilities attached to their homes. "The households in dwelling units that use public toilets are 43.3% and 6.3% have no toilet facility" (GSS, 2010 p 172) in the Ashanti Region. This means that people living in these houses will have to use the commercial public toilets that are available. Per the scenario given, it implies that people who cannot easily have access

to toilets (both in their houses and the public ones) and also find it difficult to pay for the public toilets defecate anyhow and anywhere in the metropolis including drains, street corners and car parks.

Many people walk long distances to a public toilet, or worse, they are forced to use other options like open defecation if necessary. Others defecate in plastic bags, fold it nicely and then drop it anywhere (flying toilet). So when it rains, these faeces are washed into drains and finally end up in streams and other water bodies. The health implications are that it promotes the spread of diseases such as cholera, malaria, and typhoid fever not forgetting the strong and objectionable stench accompanying the situation.

Treating human waste through anaerobic digestion is an incredibly ethical sanitation technology. Anaerobic digestion occurs in a bio-digester and produces a fuel (biogas), removes biochemical oxygen demand (BOD) from sewage, conserves nutrients (especially nitrogen compounds) and most importantly reduces pathogens. Human waste damages the environment because it is loaded with BOD, nutrients and anthropozoonotic diseases. This can cause a host of environmental problems that can lead to ecosystem collapse such as rendering a water body uninhabitable for many organisms (Watkins, Turner and Chriswaterguy's, 2012).

Most Ghanaians depend on water from the ground, rivers or streams for their household chores. “A sizeable proportion of households in urban areas (16%) have access to well water, while 11% have access to natural and other sources” (GSS, 2008 p 68). Concerning the rural areas, “most of the households (59%) get their water from a well or natural sources (26%). About half of rural households (49%) use boreholes or wells as source of drinking water” (GSS, 2008 p 68). This means that many people

who depend on natural sources of drinking water are at risk of drinking contaminated water as a result of haphazard disposal of human and animal wastes except may be those who use pipe-borne water. The health implications are obvious.

Waterborne diseases transmitted through human excrement are a leading cause of death worldwide, especially in the developing world. Some diseases caused by untreated human sewage are cholera, typhoid fever, paratyphoid fever, salmonella, dysentery, gastroenteritis, leptospirosis, meningitis, hepatitis and various parasitic diseases (Watkins *et al.*, 2012).

The contents of the toilets used in the metropolis are contained in tanks dug in the ground and have to be collected by septic tankers and transported to the Kumasi (Dompoase) Landfill for dumping. At the Landfill, there are nine septic ponds as shown in Fig. 1.1 to receive the human waste to allow anaerobic digestion to take place. Fig. 1.2a shows the ponds with a septic tanker discharging its contents into one of the ponds whilst the white excavator (marked X1 in Fig. 1.2b) is used to dislodge the sludge formed on the surface of the pond and then heaped beside the ponds for no other use. The effluent that exits from the septic ponds flows into the Oda River. This action could create some environmental and sanitation problems to those living in the area and all others who use River Oda. Considering the grave sanitation and environmental implications of not making effective use of human waste generated in the metropolis, the research work assessed the economic viability of using human waste at the Kumasi (Dompoase) Landfill to produce domestic fuel (biogas) so that this menace could be reduced or avoided.

Fig. 1.1 Picture of some of the Ponds at the Kumasi (Dompoase) Landfill Site

Fig. 1.2a **Fig.1.2b**

Fig. 1.2 Septic Tanker Discharging its Contents at the Kumasi (Dompoase) Landfill Site

1.3.1 Purpose of the Study

The purpose of the study is to ascertain the alternative positive uses of human waste and the benefits accrued to that.

1.3.2 Specific Objectives

The specific objectives were to:

- Assess the economic viability of using waste to create wealth
- Provide clean fuel for domestic use

- Achieve a clean environment
- Determine if there are enough labour and logistics for the collection of waste from the city
- Ascertain whether there are enough funds to establish a biogas project and
- Assess the benefits of the biogas project to the citizens.

1.4.1 Research Questions

In order to achieve the aims of the research, the following questions were asked:

- Is it economically possible to turn waste into wealth?
- Will this form of fuel obtained be cleaner?
- How does the collection and processing of this waste from the city affect the cleanliness of the city?
- Is there enough labour and vehicles or logistics to do effective collection of waste?
- Are there enough funds to undertake a biogas project?
- How does this project benefit the citizens?

1.5.1 The Significance of the Study

The study will help:

- Turn waste into wealth for domestic and possibly industrial uses.
- Use a fuel which is environmentally friendly (a cleaner fuel).

- Create an environment clean from filth and stench hence improving human health.
- Give guidelines to ensure that the maintenance cost of the septic ponds at the landfill is kept to the barest minimum.
- Serve as the basis for soliciting for enough funds to implement a biogas project in the metropolis and possibly duplicate such projects elsewhere in the country.
- Lead to benefits from turning human waste to wealth.

1.6.1 Limitations of the Study

Modern technology has started researching into and improving upon possibly better ways of using human waste for biogas and sludge for bio-fertilizer. Osei (2013) felt that "all that you need to produce biogas is a digester, faecal sludge and ruminants for inoculation". Some of the possible positive uses of human waste include trapping the biogas, using the sludge for bio-fertilizer, as well as treating the leachate into portable water for domestic use. The research work at the Kumasi (Dompoase) Landfill actually assessed whether it will be economically viable to trap methane gas from the human waste deposited there. The Kumasi (Dompoase) Landfill was chosen because that is the only engineered landfill available in the metropolis and also where almost all the human (liquid) waste generated in the city is deposited. Unfortunately due to the short and intense nature of the master's degree programme (on sandwich basis), very detailed laboratory analysis could not be performed. Laboratories for such analysis are also capital intensive and therefore was beyond this research.

1.7.1 Organization of the Study

The study has been organized under five chapters. Chapter One covers the background of the study, statement of the problem and research questions. The rest are the objectives, significance of the study, the scope and the limitations of the study. The Second chapter deals with a review of the relevant literature on the subject where ideas of some researchers and authors were reviewed. Chapter Three focuses on the methodology adopted in undertaking the research. The analysis of the data gathered is dealt with in Chapter Four. Chapter Five concerns itself with presentation of data gathered in Chapter Four and a summary of the key findings, recommendations, conclusions and suggestions for further research.

CHAPTER TWO

LITERATURE REVIEW

2.1.1 Definition of Waste

The word waste has been defined by different people in different ways. These numerous definitions are as a result of variations in the perception of the word by different people. Waste is "what is left of something after the valuable part of it has been used" (Macmillan English Dictionary, 2002 p1615). On the other hand, waste is considered as to "get rid of as worthless, damaged, or of no use" (Longman Dictionary Contemporary English, New Edition, 1987 p 1188). The European Union (1975) defines waste as an object the holder discards, intends to discard or is required to discard under the waste Framework Directive (European Directive 75|44|EC as amended). Cambridge International Dictionary of English (2002 p 1640) defines waste as "unwanted matter or material of any type, often that which is left after useful substances or parts have been removed".

Unfortunately, all these definitions reflect a widespread attitude that does not recognize waste as a resource. The word 'waste' and the act of 'wasting' are human inventions. Waste doesn't exist in nature. In nature, everything has a purpose. Wasting results in long-term harmful consequences for humans, nature and the economy (zerowasteamerica.org, n.d.). But Zero Waste America sees waste as "a resource that is not safely recycled back into the environment or the marketplace" (zerowasteamerica.org, n.d.). This definition takes into account the value of waste as a resource, as well as the threat unsafe recycling can present to the environment and public health hence suits the purpose of this resaearch. Should waste be considered as something of value then there is that high possibility of making a very good use of it.

In this vane Mensah (2012), observes that "the faecal sludge (FS) to biodiesel pilot project could potentially address sustainable sanitation and introduce a new dimension into the sanitation value chain - where waste is considered as something of value not only in Kumasi but globally, it helps to kill two birds with one stone". Mensah (2012) continues that "the Kumasi Metropolitan Assembly (KMA) is therefore delighted to be part of this novel partnership" (Admin, 2012:11:20).

In a given day individuals add to the waste stream and this calls for propper management techniques to control it. "Recent events in major urban centres in Africa have shown that the problem of waste management has become a "monster" that has aborted most efforts made by city authorities, state and federal governments, and professionals alike" (Agyen, 2011 p 2). It has been established that the process of waste management contributes to increasing generation of greenhouse gases (GHG) that cause climate change and ozone layer depletion. Waste generation is increasing at astronomical rate due to urbanization and industrialization releasing GHG into the atmosphere aside the serious health implications. However, the volume of waste generated does not actually constitute major environmental problems, but the inability of governments, individuals and waste disposal agencies to keep up with the task of proper and efficient management of waste, constituting the burden of environmental management (Adejobi *et al*., 2012). Attitudinal problem of the public to waste as material to be thrown away is a social challenge, this coupled with lack of infrastructures for waste management (including roads, facilities for waste collection, disposal and treatment, indiscriminate waste disposal on land, farms, surface waters, wetlands, etc.) constitute technical challenges (KMA, 2006).

Waste disposal rather than waste management is generally practiced in the Kumasi Metropolis. According to the Ghana Statistical Service (GSS, 2008 p 70) "the

most common way households dispose of rubbish is through public dump (58%). This is followed by dumping rubbish elsewhere (26%)". This elsewhere of rubbish dumping includes river bodies, drains, markets places, car parks, and the list goes on. Urbanization which entails increased resource consumption including energy, greater production and greater wastes generation, in the absence of integrated planning and effective management worsen the waste problems and compound poverty, poor sanitation, and health problems of the poor (KMA, 2006).

It appears that Ghana has a waste disposal problem since we generate several scores of tonnes of both liquid and solid wastes per year but fail to collect all and properly dispose of them. In this respect, waste management authorities must be responsive to public attitudes, collection, transportation, treatment and disposal process (Accra Metropolitan Assembly, AMA, 2003). The "4Rs - Reduce, Reuse, Recycle and Restoration of damaged resources of the environment" (Adejobi *et al.*, 2012 p 360) come into play so that the aim of turning waste to wealth is achieved. Benyus (2012) explains that nature merges waste and raw materials e.g. fallen leaves turn into fertilizer for new saplings in the forest. Benyus (2012) calls this "waste equals food". If we are to become sustainable, she suggests, we need to follow nature's lead.

> I don't expect we'll ever find ourselves eating municipal waste, but since we also have an energy problem, converting that waste into energy would certainly be the next best thing to do. Besides, what is food after all, if not a source of energy? Waste-to-energy is already happening today and there are many technologies to make the process cleaner and more efficient (Benyus, 2012).

To achieve success in waste management these three dimensions of sustainability, need to be integrated: stakeholders (government and private user), system-element

(waste reuse, recycling, treatment and disposal) and aspect (financial/economic, Social/cultural and Institutional, policy/legal/political).

2.1.2 Background to biogas

Biogas is a bio-fuel derived from organic matter mostly containing methane and carbon dioxide but also containing trace amounts of hydrogen sulphide, water vapour, and ammonia. Biogas is the shorthand label for the process of controlled anaerobic digestion of organic matter combined with methane gas capture. The process converts organic waste such as human and animal excreta and food wastes into methane, nutrient rich effluent (supernatant) and solid sludge suitable for soil conditioning. The technology has been established for over 30 years and several million units are apparently in operation worldwide. The technology is simple, highly economic and scalable: the smallest units serve individual households whilst the largest built process waste from thousands of livestock and humans. However, lessons learned in many countries indicate that the technology needs to be introduced with care because technical problems do occur and adapting the designs and operating systems to suit the local context is critical for its acceptance. Economic marginality is also an issue for many designs and settings (Haiti Biogas Programme Strategy, 2010-2012 p 4).

2.2.1 Introduction to Renewable Energy Technology (RET)

Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat (Wikipedia.org, n.d.). Technology to harness this energy is referred to as Renewable Energy Technology (RET) such as biomass, solar photovoltaic (PV), hydro, wind or geothermal technology. With proper management,

RET have nearly no impact on the environment as they produce little or no emission of GHGs or solid waste (Edjekumhene *et al*., 2002). RET is considered as "one of the strong contenders to improve the plight" (Painuly, 2001: 73) for more than 2 billion people in developing countries who don't have access to the clean modern energy which is essential to social and economic development (BMZ, 2006). RET is increasingly recognised for its contribution to development especially in rural areas, increasing health, energy independence and climate change mitigation.

According to the GSS (2008 p 70) "kerosene is the main light source for households in rural areas (72%), while electricity is the main source for urban households (79%)". In Ghana "more than half of households (54%) use wood as the main cooking fuel. Charcoal ranks second (31%). In urban areas, 53% of households use charcoal for cooking. In the rural areas, about four fifths of households use wood while 14% use charcoal" (GSS, 2008 p 70). GSS (2010 p 165) mentions the sources of cooking fuel and says "three sources stand out, namely, charcoal (39.3%), wood (29.8%) and gas (21.1%)". The above data clearly shows the energy consumption pattern of Ghanaians. RET is very important especially for off-grid areas such as in rural and remote areas where costs for grid connection are excessively expensive and where 80% of people without access to electricity live. It will be noted that "renewable technologies are also suited to rural and remote areas, where energy is often crucial in human development" (Wikipedia.org, n.d.). RET become even more competitive if environmental externalities are factored into the market price of competing fuels (Martinot *et al*., 2002). While traditional renewable energy sources like biomass (i.e. fuel wood, animal wastes and crop residues) provide 30 - 45% of the energy supply in developing countries (up to 90 % in rural Sub-Sahara-Africa) RET produce only about 2 % of the global energy supply, mostly in developed countries

(REN21, 2005). "New renewable (small hydro, modern biomass, wind, solar, geothermal, and bio-fuel) accounted for another 3% and are growing very rapidly" (Wikipedia.org, n.d.). For developing countries RET can bring major benefits for economic and social development, especially in rural areas. It was observed that over 44 million households use biogas made in household-scale digesters for lighting and or cooking, and more than 166 million households rely on a new generation of more-efficient biomass cook stoves, and this compelled Ban Ki-moon (United Nations' Secretary-General) to say that renewable energy has the ability to lift the poorest nations to new levels of prosperity (Moon, 2011).

A switch from oil to renewable resources and energy technology can reduce dependency on oil imports. Climate change concerns, coupled with high oil prices, peak oil, and increasing government support, are driving increasing renewable energy legislation, incentives and commercialization. The International Energy Agency (2011 projection) says "solar power generators may produce most of the world's electricity within 50 years, dramatically reducing the emissions of GHG that harm the environment". In the next few decades, large numbers of poor people in rural areas or in urban slums will remain not served by grid-based electricity mainly because of the high costs of grid extension (Reiche *et al*., 2000). Renewable energies can support developing countries to gain independency from fossil fuels (BMZ, 2006). One of Bailey's arguments for introducing RET in Ghana is that its oil imports are a major contributor to the country's excessive debt as 10 % of its GDP are spent for oil imports (Bailey, 2007).

Women and children in particular suffer from indoor air pollution due to burning biomass in the house without sufficient aeration. The World Health Organisation (WHO), (2002) estimates that about 1.6 million premature deaths can be

annually attributed to indoor cooking. Another major disadvantage derived is the substantial time used for collecting firewood or other forms of biomass. The collection time can be seen as a large non-monetary expenditure especially for women who are mostly responsible for collecting fuels.

> About 16% of global final energy consumption comes from renewable resources, with 10% of all energy from traditional biomass, mainly used for heating, and 3.4% from hydroelectricity. New renewable (small hydro, modern biomass, wind, solar, geothermal, and bio-fuel) accounted for another 3% and are growing very rapidly. The share of renewable in electricity generation is around 19%, with 16% of electricity coming from hydroelectricity and 3% from new renewable (Wikipedia.org, n.d.).

Where RET replaced former traditional biomass use, they therefore have an important positive impact on health and on time use, especially of women and children, both of whom can influence productivity of education, income generating or subsistence activities. Furthermore the substitution of biomass can reduce the exploitation of local natural resources (Reiche *et al*., 2000). In general, access to electrification can improve standards of living and economic development. Electric lighting in evenings and nights and access to modern media like TV, radio and computer can improve education. Furthermore they help to gain important information to improve their livelihoods about market prices, weather forecast or available support services (Reiche, *et al.*, 2000). Besides those important social improvements other major productive uses are for agriculture (e.g. irrigation, drying, processing grain mills), and small-scale industry. The use of biomass fuel in Ghana has contributed significantly to the degradation of the environment and most especially to the depletion of the forests. Over-reliance on wood fuel has been partly responsible for the decrease in Ghana's forest cover from 8.13 million hectares at the beginning of the 20th century to

1.6 million hectares in 2008 recording an average annual loss of 65 000 hectares. The stark reality is that, Ghana may eventually be a net importer of wood" (BEM, 2011 August, p 16).

2.2.2 Possibility of turning waste into wealth

The Kumasi Metropolis is noted to be generating roughly 20 000 tonnes of solid waste with a corresponding 5 000 tonnes of liquid waste daily. The GSS (2008 p 70) found out that "41% of households have their rubbish collected. Rural savannah has the largest percentage of households (66%) dumping their rubbish in sites other than the public dump. In addition, 10% of rural Savannah households burn their rubbish". This situation is a technical challenge facing the KMA and leads to environmental pollution.

Animal dung also takes another dimension of how effective we can put waste into good use. Several tonnes of animal dung produced from the slaughter house (abattoir) and other animal rearing areas in Kumasi are just allowed to decompose with its attendant amount of unbearable stench without turning it into anything useful. But Arthur *et al*., (2006) calculated the biogas potential of the dung of cattle, sheep, goats, pigs and poultry for 2006, which was about 350 million m^3. Modern technology can be employed to turn the several tonnes of both human and animal wastes into something useful like biogas on both small and large scales. According to Ahiataku-Togobo (2011) "we realise that biogas is technically viable but it is not economically suitable to promote it on a large scale for the sole purpose of energy" and continues to say that "so what the Ministry of Energy is doing now is promoting biogas for the sole purpose of addressing sanitation, mainly for treating waste (generated by households and institutions)".

2.2.3 Existing biogas units and approach used

Presently, Ghana government is building a pilot plant to convert human waste to bio-diesel or biogas by Waste Enterprisers Ltd and financed by the Gates Foundation. As at December 2012, the project was yet to start operating. The project is sited at the Kumasi (Dompoase) Landfill site. Funded through a $1.5 million grant from the Bill & Melinda Gates Foundation, the project is led by Kartik Chandran, an associate professor of Earth and Environmental Engineering at Columbia University's School of Engineering and Applied Science and Ashley Murray, Founder and CEO of Waste Enterprisers Ltd, a Ghanaian company that is working to reinvent the economics of sanitation in developing world.

Fig. 2.1 shows the plant used for trapping bio-diesel while Fig. 2.2 shows the digesters (12 in all) used for the project. Six bio-digesters are linked in series on each side and the two sets of series bio-digesters are then connected in parallel.

According to Chandran (2012):

> This is a very exciting project for us, we are aiming to create a next-generation urban sanitation facility that will set new standards and serve as a model around the world. With the capacity to receive and treat 10 000 litres, or 2 500 gallons - a full sanitation truck carrying concentrated faecal matter from at least 5 000 people - of faecal sludge (FS) per day, this facility reaches way beyond the lab scale.

Murray (2012), on the other hand, says:

> Our goal is to develop a revenue-generating FS-to-biodiesel facility that can transform sanitation from an expensive burden into a profitable venture. If we figure out a way to make waste management profitable, governments and citizens that currently bear the financial, environmental, and public health costs will all be better off.

Fig. 2.1 Plant for Trapping Biodiesel

Fig. 2.2 Bio digesters

Murray, (2012) again says "this project is about more than a technology breakthrough, it's about creating economically sustainable approaches to waste management that can eliminate the sanitation crisis in developing cities". Chandran (2012), however, expresses concern about the sustainability of the project and says "we are very grateful to the Bill & Melinda Gates Foundation for their recognition of the critical importance of sustainable sanitation across the globe, especially in developing countries", and added that "we hope our model can be replicated and adapted around the world". In Fig. 2.3 a worker at the pilot biodiesel and biogas plant situated at the Kumasi (Dompoase) Landfill is seen using the biogas analyser to measure the percentage of gases available in each bio-digester. According to Osei (2013) "the quantity of methane so far obtained from each digester is averavely 65% of 30 m^3 of

Fig. 2.3 Worker Using the Biogas Analyser

Fig. 2.4 Worker Measuring the Quantity of Oxygen in a Bio-Digester

the gases present in the FS". The gases "present in the digester are CO_2, methane,

hydrogen sulphide and oxygen, but the oxygen content should be zero" (Osei, 2013). Fig. 2.4 shows a worker measuring the quantity of oxygen present in a digester. "The quantity of methane present among the other gases is 60%" (Osei, 2013). These digesters could be used for the production of biodiesel and biogas. Ghana's policymakers should embrace abundant and clean biogas as a source of energy, to curb its reliance on dwindling wood resources for fuel. The country has huge potential for producing biogas, including the technical expertise to construct almost 280 000 biogas plants, but it faces many obstacles in achieving this (Renewable Energy, 2011 May). Bensah (2011) says "the obstacles include a lack of attention from politicians, who are not interested in implementing or disseminating the technology, the high cost of constructing biogas plants and the unwillingness of people to use biogas for cooking because they consider it to be 'toilet gas". According to Bensah (2011), "in other countries we see the politicians themselves getting involved in the dissemination of the technology, citing China, India and Japan" and adds that "setting up a national advocacy programme on biogas may help overcome some of these obstacles". Bensah (2011) maintains that biogas has wider applications and needs more attention and says "for biogas to make a big impact in households, (it) will require a lot of effort from government, academia and from the private sector". The Kumasi (Dompoase) "Landfill enables technologists and engineers to trap methane gas through composite solid" (BEM, 2011, August p 15).

2.3.1 Obtaining a cleaner fuel

As organic matter in landfills decomposes, it gives off several gases, primarily methane. Methane is the principal component of natural gas. It is also a potent GHG, 20 times stronger than CO_2. When this gas is collected, it can be used as a power source, rather than a contribution to global warming. When methane is burned to

generate electricity, the by-product is CO_2. Although CO_2 has global warming impacts of its own, the conversion is actually much better than you might think (Siegel, 2012), "for CO_2 is a lesser evil than methane gas should both gases be released into the atmosphere" (Osei, 2013). First of all, CO_2 is preferable to methane because of its lower heat-trapping effect. Methane capture at the landfill could be improved by adding some amount of ruminants from the abattoir to the FS (Osei, 2012). At present very little human waste is properly treated or made good use of in Ghana although some schools are using their human waste for biogas e.g. Adisadel College in Cape Coast. Most toilets are simply pit latrines or emptied either directly into storm water drains or into basic septic or holding tanks.

In Ghana "one in ten households use flush toilets, and another one in ten (12%) use KVIPs. Pit latrine is the most common form of toilet, and it is used by 32% of households", and that "about a fifth of households do not have any toilet facility, while 24% use public toilets" (GSS, 2008 p 71). In Kumasi, the contents of these underground tanks are collected by septic tankers/trucks and sent to the Kumasi (Dompoase) Landfill site. However, elsewhere like Accra the contents of the trucks are directly discharged directly into the sea which results in a very high level of pollution of the sea. This can cause serious human health problems including the recent cholera outbreaks that affected certain parts of the country in the second half of 2012 e.g. Accra, Kumasi, Obuasi, and Ejura which claimed several lives. On 11th April, 2012, the Ministry of Health notified WHO of a cholera outbreak in the Greater Accra Region. Between January and 6th May, 2012, a total of 3 216 cases and 28 deaths were reported from 20 districts (WHO, 2012, May 26). The cholera cases and deaths increased steadily with the Ghana Health Service reporting 6 000 cholera cases with 69 deaths by the end of August (IFRC, 2013, Jan., 4). For the year 2012 as a

whole, WHO reported 9 548 cases and 100 deaths (WHO, 2013, Feb. 7). The root causes of this epidemic disease demonstrate that long-term solutions to the disposal and sustainable treatment of human waste are more needed now than ever paying serious and prompt attention to the metropolitan and municipal areas.

2.3.2 Human waste as a cleaner energy source

Humans produce a lot of waste and when this waste is not treated, it can have very negative impacts on the environment. Untreated human waste can lower dissolved oxygen in water, spread coli and other harmful pathogens, raise nutrient concentrations to harmful levels, and wipe out aquatic life. Luckily, we can protect the environment from these hazards by putting this waste to good use such as trapping methane gas and using the sludge for bio-fertilizer. Wastewater treatment plants can be designed to produce methane and/or hydrogen (which are considered a higher quality fuel) and some plants can produce in excess to even serve the national grid.

2.4.1. Collection of waste and cleanliness of the city

Kumasi is a city situated about 270 km away from the national capital (Accra) and is the second largest city in Ghana. It is located almost in the central part of the country. For this reason it receives a lot of visitors from Burkina Faso, Mali, Cote D'Ivoire, Benin, and other neighbouring countries. It is the centre of trade for tropical commodities such as cocoa beans, palm fruits, timber products and also provides a thriving transit route linking other West Africa's landlocked countries and the sea ports of Tema and Takoradi. Kumasi's population has more than tripled in the past two decades and as the population increased so has the waste management problems (BEM, 2011, August edition, p 15). According to GSS (2010 p 23) the population of the Kumasi Metropolis is "2 035 064". The fast rising of population in the city and in

its outskirts moves the boundaries of the city each year since suburbs grow together with each other and with the city itself. Waste production is synonymous to the rise in population. Wade (2012) says, "with millions of tonnes of human waste being dumped into the environment every day, the result is significant damage to public health and the environment".

The biodiesel plants can eliminate dumping of FS into the environment while simultaneously offsetting fossil fuel consumption" (myjoyonline.com, 2012:08:29). So Whittington *et al.*, (1993) gave this summary that over 1 200 households in Kumasi, Ghana were interviewed concerning their current sanitation practices, perceptions of existing sanitation conditions, expenditures, and their knowledge of improved sanitation options. The results of the survey and related research revealed an appalling and, from a public health perspective, dangerous situation. Households were generating about 25 000 $m^3$of waste per month, but only about 10% of it was removed from the city. The remaining 90% was left in the urban environment. Handling of domestic-type refuse in the Kumasi metropolis has been a very challenging task from time immemorial, mainly due to the public's attitude and its multi-sectarian involvement (K.M.A, 2001, end of year report on solid waste).

2.4.2 Existing Sanitation System Situation

The research further revealed the unpleasant scenario that nearly 40% of the households use the 400 or so public latrines scattered throughout the city because they have no private facility in their buildings or compounds (AGWSl, 2011). For citizens of Kumasi who use public toilets, it "costs between $0.03 and $0.20 per use, have long lines in the mornings and evenings" reports Wyatt (2011:6). A few public latrines serve the downtown-central business district (CBD) and are very heavily patronized. It means that these toilets are scattered and hence "leads many to resort to

open defecation, a practice that spreads diseases and contaminates water, while also bringing shame upon the person" (Wyatt, 2011:6). If adults do it without fear or shame then what about the children? According to Wyatt (2011:6) "many children, however, openly defecate without stigma as it is socially acceptable for them to do so" because the adults do so without recourse to the effects on the environment. On the other hand, according to KMA (2006) most residents in the Metropolis (about 38%) still use public toilets for which they pay between 0.2 GHp and 0.5 GHp per visit depending on the type of facility. Another 25% use household WC facilities. The unhygienic bucket latrine system caters for 12% of the population, 8% rely on central sewerage (Asafo, 4BN, KATH, KNUST, Ahinsan and Chirapatre Housing Estates); whilst 10% use pit latrines (KVIP/Traditional) and 6% ease indiscriminately (KMA, 2006).

There is also the issue of "flying toilets" in Kumasi. This happens when one wants "to avoid an inconvenient and expensive trip to the public toilets in the dark of the night, many people will use a chamber pot and empty its contents into a plastic bag the following morning" and subsequently "these bags are often tossed in roadside ditches, garbage piles, or waterways" (Wyatt, 2011:6). This situation is so because "39% of households in urban areas use public toilets" (GSS, 2008 p 71). It provides facilities for some 150 000 non-residents who frequent the CBD and its immediate environs every day (Ministry of Local Government & Rural Development (MLGRD), 1996 p 98). Most of the public latrines are over 30 years old and are in very poor conditions. These public latrines are normally dislodged about once or twice per week. But for the very heavily patronized areas e.g. CBD, dislodging is about ten times. This is sent to the Kumasi (Dompoase) Landfill as its final destination. Only 13% of those in neighbourhood areas have a water tap, so it is nearly impossible to

keep them clean. “Generally, the levels of cleanliness at the toilet sites have improved considerably since the advent of the franchise management scheme. However, there is still a long way to go as far as the desired levels of service in terms of cleanliness are concerned” (Mensah, 1996 p 35). “The current system of public toilets in the city is inadequate. The quality of services delivered is very poor, the number of facilities is insufficient and there is a general lack of maintenance” (Mensah, 1996 p 39). These shortcomings have resulted in very high public health risks. Most of the public latrines (about 60%) are aqua privies (known locally as “bomber” latrines because of their tendency to accumulate methane which occasionally explodes). “One in ten households use flush toilets” (GSS, 2008 p 71) while approximately 25% of the public latrines are bucket latrines. A few relatively new Kumasi Ventilated Improved Pit Latrines (KVIPs) are in use. According to GSS, (2010 p 172) “the proportion of dwelling units that has private WC is highest in Kumasi Metropolis (40.1%)” although they are generally shared with other households. These WCs are not connected to the few sewer networks in Kumasi. “Although Kumasi does have a sewer system and three waste-water treatment plants, there are only about thousand homes connected to it in a city of over one million residents” (Wyatt, 2011:7). There is also the storm water drainage system, but this drainage system is essentially an open sewer, which discharges into the Subin, Aboabo and Sissai rivers and as a result beneficial users of these rivers are adversely affected for a number of kilometres downstream (KMA, 2006). Most of the WCs empty into concrete septic tanks below the ground, either next to the apartment buildings or inside the courtyards of compounds (Whittington *et al*., 1993).

In short, four general forms of toilet facilities are available. These are:

- The aqua privy or “bomber” latrine.

- The bucket latrine which was transported by the head to a common pit (now officially phased out of the system).

- The Kumasi Ventilated Improved Pit (KVIP). KVIP latrines are very easy to maintain, aside from regular cleaning and repairs, it needs no further attention until the pit is nearly full" (Mensah, 1996 p 26)

- The WC which is very expensive. According to Wyatt (2011:7) "it costs $500-$700 to build a basic latrine in the home", and uses large quantities of water. This makes it very difficult to use without water. Flushing facilities often break down. "The WC facility currently in use in Kumasi is of the sitting type. Users who are accustomed to squatting (required for more traditional kinds of toilets) tend to continue this practice. The result is fouling of the toilet bowl, wetting of the floor, and more importantly, damage to the unit" (Mensah, 1996 p 27). Yet, all of these forms of toilet facilities are supposed to have their contents collected and transported to the Kumasi (Dompoase) Landfill. This means that enough human waste will always be available to be used to generate clean fuel. Effluent from the breweries, leachates from sawmills, waste oil spillages from the vehicle service centre at Suame and other industrial service areas are discharged into receiving waters without treatment (KMA, 2006). It continues to say that the principal generators of industrial wastewater are the two breweries, Guinness Ghana, Coca Cola Bottling Company and the Kumasi Abattoir. Together these generate about 1 510 m^3 of effluent daily all of which end up in the city's drains without treatment (KMA, 2006).

Light industrial activities at the Suame Magazine Complex and sawdust from sawmills also generate significant amount of waste, oil and leachate respectively which add to environmental degradation leading to environmental and health

problems. The domestic and commercial wastes are left in the various points of collection (KMA, 1996). This is promoting environmental and health nuisance by destroying the aesthetic nature of the environment, increasing air pollution and promoting outbreaks of waste related diseases like malaria, cholera and typhoid fever.

In order to reduce the environmental pollution and the associated health hazards, a FS-to-biodiesel plant (the Gate Foundation pilot project at the Dompoase Landfill), is replacing the outmoded concept of disposal-oriented treatment with a technology and business model for producing biodiesel. Wade (2012) says that "the initiative is creating a sanitation revolution in Ghana" and that "the biodiesel plants can eliminate dumping of FS into the environment while simultaneously offsetting fossil fuel consumption" of Ghanaians. Considering the progress of work at the faecal plant site, Wade (2012) again says:

> We hope to be at full pilot scale production with the biodiesel by the end of the summer and producing biodiesel at full scale for one year and we hope then from there to have enough information to begin looking for investors and to commercialize within another 6 months to a year. We hope that within 18-24 months, we'd actually be able to build and commercialize a full-scale plant that will treat the equivalent of 100 truck loads of waste every day.

2.5.1. Labour and Logistics for effective collection

The effectiveness and sustainability of urban waste management systems depend upon their adaptation to the prevailing context of the city and/or country in which they operate. Waste management helps to reduce the effects of the waste on the environment and human health, and also to recapture resources from the waste. The most important aspects in this respect are outlined as the political, socio-cultural and environmental levels. (Adejobi *et al.*, 2012 p 350)

2.5.2 Political Context

In the political context waste management is influenced in numerous ways. The existing relationship between local and central governments (the effective degree of decentralization for example), is the form and extent of citizens' participation in the public processes of policy making and the role of party politics in local government administration. All of these affect the character of management, governance and the type of management system which is possible and appropriate. (Adejobi *et al.*, 2012 p 350)

2.5.3 Socio-Cultural Context

Management of domestic waste involves a range of technologies associated with the control of the generation, storage, collection, transportation and disposal of all forms of solid wastes (Agyen, 2011). Programmes to disseminate knowledge and skills, or to improve behavioural patterns and attitudes regarding waste management, must be based on sound understanding of the social and cultural characteristics of the community. The effectiveness and sustainability of municipal waste management systems depends on the degree to which the served population identifies with and takes ownership of the systems and facilities. To this end, it is important that the people be involved from the onset in the planning of the local segments of waste management systems. Community involvement is particularly important regarding the selection of facilities such as waste transfer stations and landfill sites (Adejobi *et al*., 2012 p 350).

2.5.4 Economic Context

The character of waste management tasks and the technical and organizational

nature of appropriate solutions depend a great deal on the economic context of the country and/or city in question and, in fact, on the economic situation in the particular area of a city. The level of economic development is an important determinant of the volume and composition of wastes generated by residents and other users. The willingness and ability to pay for a particular level of service is also influenced by the economic context of a particular city or area (Adejobi *et al*., 2012 p 350).

2.5.5 Environmental Context

At the level of the built environment, the size and structure of a settlement has an important influence on the character and urgency of waste management needs. In urban areas, the physical characteristics of a settlement including such factors as density, width and condition of roads, topography, etc. need to be considered when selecting and/or designing waste collection procedures and equipment such as containers and vehicles (Adejobi *et al.,* 2012 p 352).

2.6.1 Enough funds for biogas project

For several months now Ghana is faced with acute energy problems. This has prompted the authorities to seek investment of as much as $1 billion to develop renewable-energy resources over the next eight years. There are policies in place to exploit the country's energy potential in solar, biomass, wind, as well as mini-hydro and is considering both Ghanaian and non-Ghanaian private-sector operators partnering government to develop these resources. The country "is currently processing a grant of Euro 22.8 million, which will be sufficient to add another 12 MW of capacity", of solar energy to the national grid (Awortwi, 2013).

Ghana has experienced more than twelve months of a nationwide electricity cuts and electricity rationing after a natural-gas pipeline off the coast of Togo was

damaged by the anchor of a ship in 2007. The pipe supplies gas to power the electrical thermal plants installed in Ghana. This pipeline runs from Nigeria through Benin and Togo to Ghana. Per this scenario it means that Ghana government should source funds to help implement the gas project to tap LPG from the jubilee oil field and also explore the other sources of renewable energy. The renewable-energy investments will add 500 MW of power to the nation's capacity and help expand electricity provision to all parts of the country.

Ghana's current 2 443 MW capacities feed 72% of the population and has almost 10 000 solar-panel installations in communities that don't have access to the national power grid. In March, 2013 President Mahama commissioned "the construction of the 2 MW solar power plant which is being undertaken and financed by the Volta River Authority, at a cost of US$ 8 million" (Jalulah, 2013) at Pungu south of Navrongo. According to Awortwi (2013), this act "signified the authority's commitment to diversifying its energy portfolio, from its current hydro and thermal sources, to include solar, wind, and biomass". Ghana is seriously considering making maximum use of LPG in its quest to making energy cheaper and yet available. Ghana is yet to fully develop its own natural-gas reserve which will be used to power the thermal plants.

2.6.2 Access to energy

There is a draft National Renewable Energy Strategy together with a draft Strategic National Energy Plan 2006–2020. This strategy tends to set a target 10% of renewable energy (not including large hydro power) in the energy mix by 2020. It includes wind, mini-hydro, modern biomass resources and solar-PV. Considering solar energy (Awortwi, 2013) revealed that Ghana receives sunlight 350 days of the

year. Although its irradiation potential – the amount of sunlight the country receives on a daily basis ranges from 4 to 6 kWh/day (Pungu has 5.5 kWh/day), in comparison with Germany, whose irradiation levels range from 3 to 4.5 kWh/day yet Germany currently has up to 7.5 GW of solar plants installed. This means Pungu plant will have enough sunlight energy. This brings to mind measures of laws that should be in place to regulate the production and use of this energy called the Renewable Energy Law. The objective is to develop and enforce standards and codes for RET. This will include standards for bio-fuels, solar lighting, solar driers and solar irrigation systems. To reach this goal, the Ghanaian Parliament passed the Renewable Energy Act in 2011 (Act 832) providing the legal and regulatory framework necessary for enhancing and expanding the country's renewable energy sector.

Ghana also agrees to promote the use of LPG, which is a cheaper and cleaner fuel than firewood and charcoal. Smoke inhalation from traditional cook stoves and open fires causes nearly 2 million premature deaths annually, with women and young children the most affected. Taking into account cultural acceptance, relative ease to store and transport gas from one point to another, biogas has the potential to provide a small but locally useful percentage of energy needs of Ghanaians especially with the recent nationwide shortages of LPG for some couple of years now (Haiti Biogas Programme Strategy, 2010-2012 p 6).

2.7.1 Benefits to citizens

Trapping methane gas from human waste is a project that is worth establishing because it has several benefits to man. Aside the biogas, fertilizer could also be obtained. It promotes a cleaner environment and good health.

2.7.2 Fertilizer

The outputs of a fully operational biogas plant include liquid effluent (supernatant) and solid residue (sludge). Both the liquids and the solids, though not sterile, contain high levels of organic and inorganic matters, particularly nitrogen, and are very suitable for use as fertilizers and soil conditioners. The viability of the use of these outputs is principally linked to material handling and transport costs – the materials need to be transported to the agricultural sites (Haiti Biogas Programme Strategy, 2010-2012 p 7). As an agricultural and developing country, Ghana needs such fertilizers since the nation is now applying this hybrid technology to most farming activities such as cocoa, cashew, vegetables, fruits and the likes. Ghanaians are now very conscious of the health effects of the excessive use and consumption of chemical fertilizers hence their preference for organic fertilizer. Of late, Ghanaian farmers tend to apply poultry farm waste on their farms to confirm their preference of it. It promotes a clean environment. The strong stench emanating from this waste is minimised and pollution of river bodies is also controlled.

2.8.1 Review of alternatives and limitations

This review focuses on waste to energy (biogas) than the other forms of energy since this improves sanitation and with added advantages such as the ability to get fertilizer as a by-product.

- Should this waste be left unattended to it can cause health problems (e.g. cholera outbreaks, malaria, etc.) for man in addition to environmental pollution although not attending to the waste is a less expensive path to have walked. The strong stench that will emanate from the uncollected waste will also be another health hazard to contend with. This method of not collecting the waste is not a viable long

term approach to be chosen.

- The basic alternative in use now consists of collecting the sludge in pits or portable toilets to be emptied by dislodging trucks or septic tankers at the landfill. This alternative can be associated with a treatment process on the final destination of the sludge.

- One viable but only partial alternative is an increase in the use of deep pit toilets and composting toilets. The pit toilets are relatively inexpensive but their long term application is largely limited to rural and municipal areas. The composting toilets can be used anywhere, but the compost needs to be brought to an area where farming is being done. This solution is yet to be given the needed attention.

- Another potentially viable alternative is the increased use of holding tanks and septic tanks with outfalls and infiltration systems. This would be a major improvement on the existing situation but would still result in large scale use of dislodging trucks and disposal of human waste from the full tanks.

- The next major alternative is the construction and operation of sewage treatment works for the human waste transported by trucks. The principal obstacle in this case is the cost – both for construction and for operations.

In theory, biogas has the ability to promote a friendly environment; its widespread use can be retarded by issues such as cultural differences, construction costs, space constraints, limited gas storage as well as safety in handling LPG. Kumasi is fortunate to have an abattoir that will supply enough animal dung to the project to enrich the process. All of these issues should be addressed at the feasibility and design stage to enhance sustainability and obtain real benefits (Haiti Biogas

Programme Strategy, 2010-2012 p 8).

2.9.1 Summary of the biogas project

Summarizing all that were said in the review, there is a clear and major need to improve sanitation and enhance the environment (conserve the forests) of Kumasi and Ghana and for that matter if replicated throughout the country help make Ghana clean. This will result in improved health for the citizens and reduced cost of health bills. It also serves as a long term solution to handling the human waste problems. The gas and fertilizer outputs are considered to be co-benefits and would assist principally in reducing the overall operating and maintenance costs of the machines/plants. This bio-fertilizer is preferred to the chemical fertilizer since it has little health effect on humans if even applied in excess. Marginal profits would be made which could help in maintaining the plants. It will also provide some energy respite for the rural areas as it has the capability of providing energy for heating and also for generating electricity.

In short, the benefits of using biogas generators when suggesting the construction of a biogas generator to a first time user will lead to improved speed and likelihood of acceptance of the idea that biogas:

- generators provide a safer and cleaner way of storing excreta and subsequently bring about related advantages linked to safe sanitation.
- generators provide free fuel for cooking, heating and lighting.
- generators provide fertilizer for crops.
- requires far less time and effort to collect than other fuels (e.g. wood).
- reduces the need for wood and therefore reduces deforestation and the burden on women of collecting wood.

- creates no smoke and therefore reduces health problems caused by burning other fuels indoors.
- is environmentally friendly and does not release as many GHG when burned as compared to other fuels e.g. fossil fuels.
- generator kills dangerous bacteria in faeces during digestion.
- generator produces a reliable fuel regardless of weather or daytime factors.
- produces the CO_2 emission that originates from the use of biogas which matches the same amount that plants need to grow and produce renewable resources hence environmentally compatible.
- energy is supplied where it is needed– no matter if the biogas plant is located in an industrial or rural area.

Summarising the disadvantages, it was observed that only if the biological biogas production is ended prematurely, methane could leak into the atmosphere when spreading the residue material out on the fields. This would trigger a waste of fuel and the release of the methane that is harmful to the climate. This effect cannot be avoided in its entirety, but if the biogas process is nearly finished the released methane is very low. Spreading the residue material on the field could change into ammonia gas if the sun is shining and the temperature is high. But filling the residue material quickly into the soil can easily prevent this effect.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The research was about *assessing the economic viability of using human waste at the Kumasi (Dompoase) Landfill for domestic fuel (methane gas).* The chapter concerns itself with information related to the population, research instruments and procedures for the collection of data relating to the topic.

3.2 Research Design

This study adopted descriptive method to gather the relevant data obtained from the research area. This method may be designed to discover whether there is any relationship between two variables (Agyedu *et al.*, 2011). Therefore it was used to describe the nature of the situation as it stood during the research period. It was because of the data and the plan of analysis that the descriptive study was used to seek to gather information so that a description of what is going on can be made.

3.3 Population

The population of this survey comprised everything the researcher wants to know about. In this regard, the population was made up of workers in the waste management division at the Kumasi (Dompoase) Landfill site, Ejura Municipal Assembly in Ashanti Region and the Koforidua Municipal Assembly in the Eastern Region. The respondents, ninety (90) in all, comprising drivers, managers, administrators, landfill engineers/mechanics and experts in the waste management division attended to the questionnaire.

3.4 Sample

Due to the huge nature of the workforce in the waste management division of the

various assemblies, it became necessary for the researcher to engage a population of ninety (90) workers. This, the researcher believed will make the results more valid and reliable since it is a fair representation of the population.

3.5 Sampling procedure

The 90 waste management workers were selected proportionally at random from the three (3) assemblies: Kumasi had 55, Ejura had 20, and Koforidua had 15. Kumasi had the highest number because the research used the Kumasi (Dompoase) Landfill as the case study. The research was extended to the other areas so as to have a fair representation of ideas of people in the waste management division. Kumasi has about 70 waste managemaent workers with Ejura employing about 30 workers while Koforidua had about 55 workers. The researcher chose a smaller number for Koforidua in order to improve the recovery rate due to its distance from Kumasi.

3.6 Data

Research data is classified into primary data and secondary data (Clarke and Dawson, 1999). The primary data was collected to satisfy the specific purpose of the study. Secondary data, nonetheless, is published findings from earlier research studies and may not pertain specifically to the current study. Secondary data is often collected at the beginning of research to provide background and basic information about the topic being researched (Anderson and Nylander, 1999).

3.7 Secondary Data Collection

Several forms of secondary data have been employed in this research. These included published possible uses of human and animal wastes and the effects (both adverse and non-adverse) on the environment. For instance, the researcher depended,

to a large extent, on research conducted outside our immediate environment bordering on the subject. This helped the researcher to gain a deeper understanding of the research problem that was presented. These secondary data were employed to a significant extent in the preparation and writing of the background and to a greater extent on the literature review and the drafting of the questionnaire. It could be said that although a major part of the data came from the field, secondary data in the forms of policy document of KMA, magazines and other stakeholders were equally useful.

3.8 Primary data

Primary data is the data which is collected by the researcher directly from his personal observations and experiences. Primary data for this study were collected using questionnaires and interviews with experts of the waste management system. The landfill staff provided me with liquid waste data and also permitted me to take pictures of the site.

3.9 Data Collection Instruments

The main instrument of data collection was the questionnaire. This study employed self-administered questionnaire. Some merits of questionnaires were enumerated by Mouly (1970) as:

1. It permits wide coverage at minimum expense both in terms of money and effort.

2. It affords wider geographic coverage and reaches persons who are difficult to contact.

3 It makes for greater validity of results through promoting the selection of a larger more representative sample.

4 Anonymity may elicit more candid and objective replies.

5 It allows for greater uniformity in the manner in which the questions are posed, ensuring greater comparability in the answers (Lacey, 2000).

Due to the reasons enumerated and the nature of research being conducted the questionnaire was found to be a highly appropriate data collection instrument to enable the researcher collect the kind of information needed with an interview complementing it.

3.10 The Questionnaire

The questionnaire was divided into two parts, Part One and Two. Part I contained the preamble while Part II had the entire questionnaire comprising 40 questionnaire items, consisting of 8 open-ended questions and 32 close-ended ones with 4 Tables of questions. The first four questions of Part II of the questionnaires (test) sought to elicit personal data from the respondents - their age, working experience, etc.

The remaining questions of Part II comprised questions and tables trying to elicit responses from the populace concerning the hypothesis. These were grouped into six different headings as:

- Possibility of turning waste into wealth
- Does fuel obtained from waste contribute to atmospheric pollution (cleaner fuel)?
- Does the collection and processing of human waste affect the cleanliness of the city?
- Labour and logistics for the collection of human waste

- Enough funds to undertake the project and
- Benefits of the biogas project to the citizens.

The first heading had 2 open-ended questions, 1 multiple choice/open-ended question, and 4 'yes', 'no', and or 'not sure' questions.

The second heading had 1open-ended question, 2 'yes', 'no', and or 'not sure' questions and 1 Table of questions.

The third heading has 2 multiple choice/open-ended questions, 2 multiple choice questions, 1 'yes' or 'no' and or "not sure" question and 1 Table of questions.

The fourth heading had 2 multiple choice questions, 3 'yes' or 'no' and or "not sure" questions, and a Table of questions.

The fifth heading had 1 multiple choice/open-ended question, and 7 'yes' or 'no' and or "not sure" questions.

The last heading had 1 open-ended question, 2 'yes' or 'no' and or "not sure" questions, and a Table of questions.

All the questions had bearings on the various headings listed and a good number of the questionnaire items were derived from the literature review.

3.11 Data Collection Procedure

The researcher chose different days and visited the various sites to administer the questionnaires as well as collect them. Although the recovery rate was 100% it was a very difficult task. Granting interview was another daunting task and the researcher had to reschedule meeting the Kumasi (Dompoase) Landfill manager (Mr. Lincoln Abakisi) several times although, finally, it never came off. Mr. Morrison

Nyarko who is the Landfill Manager for the KMA provided me with data on tonnages of liquid waste received. Nonetheless, I was fortunate to have met one of the experts of the Bill Gates Foundation working on the pilot project for collecting biodiesel (Mr. Osei). I had an audience with him. I first visited the Kumasi Landfill and later the Kumasi Waste Management Ltd (KWML), then Ejura Environmental Office, and the Koforidua Municipal Assembly on different occasions for the collection of data.

3.12 Methods of Data Analysis

The data obtained from the respondents was analysed using the Statistical Package for Social Sciences version (SPSS v 16). This was chosen for easier analysis and a better understanding of the study by interested parties.

CHAPTER FOUR

PRESENTATION, ANALYSIS AND DISCUSSION OF DATA

4.1 Introduction

In this section the researcher presents data from the workers in the waste management system at the Kumasi (Dompoase) Landfill, Ejura Municipal Assembly – Ashanti and Koforidua Municipal Assembly. The respondents, ninety (90) in all, comprised drivers, managers, administrators, landfill engineers/mechanics and experts in the waste management system who answered the questionnaire.

The data obtained using the research instruments were analyzed and presented in the form of tables and charts. The researcher further discusses the findings of the study and related it to the existing literature of the study. There was a perfect response rate of 100% to the questionnaire with the reason being that the researcher personally administered the questionnaire to the respondents.

4.2 PERSONAL DATA OF RESPONDENTS

This section presents the findings of the field research with respect to the demographic characteristics of the participants of the survey. Areas of particular interest to the researcher under this section were age group, educational level, number of years involved in waste management, and the number of years respondents have worked with their current employer.

Table 4.1 Personal Data of Respondents

Age Group			
Age (year)	Frequency	Percent	Valid Percent
20-29	18	20.0	20.0
30-39	32	35.6	35.6

	40-49	28	31.1	31.1
	≥ 50	12	13.3	13.3
	Total	**90**	**100.0**	**100.0**

Educational Level

	Age (year)	Frequency	Percent	Valid Percent
	Basic Education	13	14.4	14.4
	Secondary Education	17	18.9	18.9
	Technical Education	15	16.7	16.7
	Tertiary Education	45	50.0	50.0
	Total	**90**	**100.0**	**100.0**

Number of Years Involved in Waste Management

	Age (year)	Frequency	Percent	Valid Percent
Valid	1-5	30	33.3	33.3
	6-10	33	36.7	36.7
	11-15	10	11.1	11.1
	16-20	7	7.8	7.8
	> 20	10	11.1	11.1
	Total	**90**	**100.0**	**100.0**

Number of Years with the Current Employer

	Age (year)	Frequency	Percent	Valid Percent
Valid	1-5	36	40.0	40.0
	6-10	32	35.6	35.6
	11-15	10	11.1	11.1
	16-20	7	7.8	7.8
	> 20	5	5.6	5.6
	Total	**90**	**100.0**	**100.0**

Source: Field Survey, 2014

Table 4.1 outlines the personal data of respondents. Considering the age group of respondents, 18 respondents representing 20% indicated they were between 20-29 years, 32 of them representing 35.6% said they were between 30-39 years, 28 of them (31.1%) said they were between 40-49 years and 12 (13.3%) indicated they were above 50 years. This means that, most of the respondents were between 30-39 years followed by those who were also between 40-49 years.

On the Educational Level of respondents, 13 respondents (14.4%) indicated Basic Education, 17 respondents (18.9%) stated Secondary Education, 15 respondents (16.7%) indicated Technical Education and 45 respondents representing 50%

indicated Tertiary Education. This result revealed that most of the respondents had tertiary education.

Again, from Table 4.1, the researcher sought to find out on the number of years respondents have been involved in waste management. The results show that, 30 respondents (33.3%) indicated between 1-5 years, 33 respondents of 36.7% said between 6-10 years, and 10 respondents (11.1%) also indicated between 11-15 years. Meanwhile, 7 respondents (7.8%) indicated 16-20 years and 10 respondents also said they have been involved in the waste management for more that 20 years.

Finally, Table 4.1 further sought to determine the number of years respondents have worked with their current employer. From the findings, 36 of the respondents representing 40% indicated from 1-5 years, 32 of them (35.6%) indicated 6-10 years, 10 said they have been with their current employer from 11-15 years and 7 of them indicated between 16-20 years followed by 5 respondents who indicated greater than 20 years.

4.3 POSSIBILITY OF TURNING HUMAN WASTE INTO WEALTH

From Fig. 4.1, 71 respondents representing 78.9% indicated that human waste from home is disposed into septic tanks and later transported to the landfill, 8 respondents (8.9%) stated that, human waste from home is disposed into a covered hole or buried, and 5 of them said that human waste from home is disposed into drains and bomber respectively. This finding meant that about 71 respondents representing 78.9% indicated that human waste from home is disposed into septic tanks and later transported to the landfill in the study area.

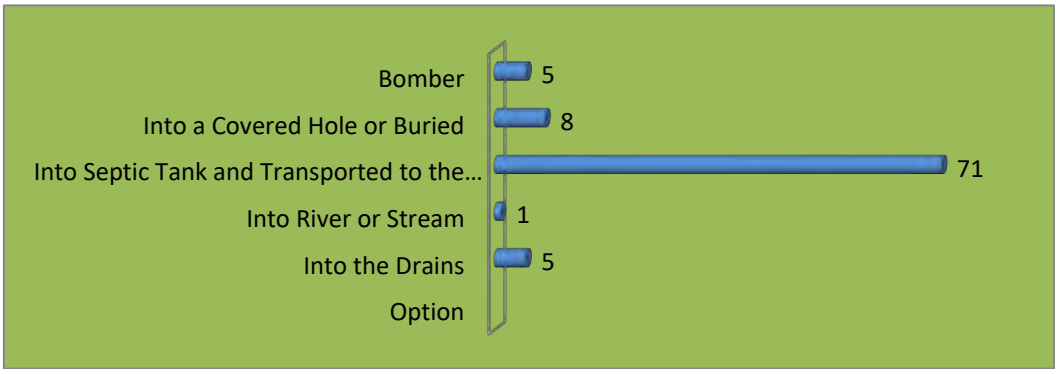

Fig. 4.1 Where Human Waste from Home is Disposed of (*Source: Field Survey, 2014)*

From Fig. 4.2, 52 respondents (about 58%) said yes, they would use toilet gas without further thoughts, 31 (34%) of them indicated no and 7 of respondents indicated they

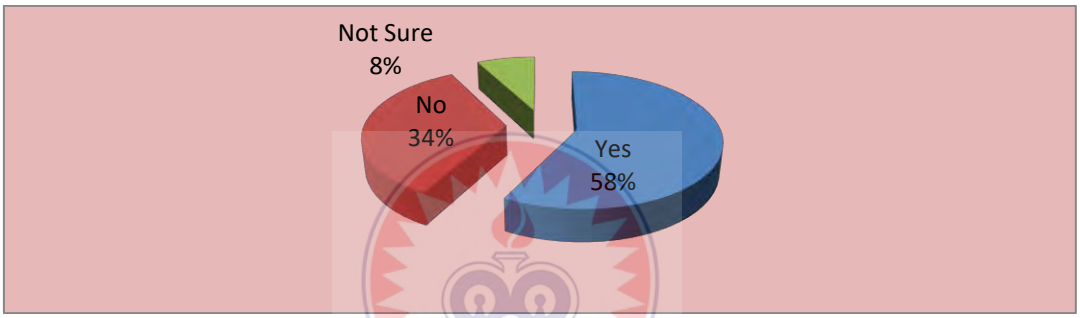

Fig. 4.2 Would You Use Toilet Gas Without Further Thoughts? (*Source: Field Survey, 2014)*

were not sure. This finding meant that most of the respondents agreed that they would use gas trapped from toilet without further thoughts.

Table 4.2 Using Fertilizer Derived From Human Waste on their Farms

Options	Frequency	Percent	Valid Percent
Yes	74	82.2	82.2
No	10	11.1	11.1
Not Sure	6	6.7	6.7
Total	**90**	**100.0**	**100.0**

Source: Field Survey, 2014

The views of respondents as to whether they would use fertilizer derived from human waste on their farms as per table 4.2 shows that, 74 of the participants

representing 82.2% indicated yes, 10 participants said no and 6 of them indicated that they were not sure. This result meant that majority of the respondents are of the view that they would use fertilizer derived from human waste on their farms.

4.4 EFFECT OF FUEL PRODUCED ON THE POLLUTION OF THE ATMOSPHERE (CLEANER FUEL)

Table 4.3 The Extent to Which the Underlisted Contribute to Environmental Pollution

Rate of Collection of Waste Per Week

		Frequency	Percent	Valid Percent
Valid	Not Serious	8	8.9	8.9
	Serious	17	18.9	18.9
	Very Serious	30	33.3	33.3
	Neither Serious Nor Acceptable	35	38.9	38.9
	Total	**90**	**100.0**	**100.0**

Number of Toilets Available in the Area

		Frequency	Percent	Valid Percent
Valid	Not Serious At All	2	2.2	2.2
	Not Serious	8	8.9	8.9
	Serious	15	16.7	16.7
	Very Serious	35	38.9	38.9
	Neither Serious Nor Acceptable	30	33.3	33.3
	Total	**90**	**100.0**	**100.0**

Duration of Opening and Closing of Public Toilets

		Frequency	Percent	Valid Percent
Valid	Not Serious	10	11.1	11.1
	Serious	22	24.4	24.4
	Very Serious	28	31.1	31.1
	Neither Serious Nor Acceptable	30	33.3	33.3
	Total	**90**	**100.0**	**100.0**

Scent/Odour at the Public Toilets

		Frequency	Percent	Valid Percent
Valid	Not Serious At All	6	6.7	6.7
	Not Serious	14	15.6	15.6
	Serious	9	10.0	10.0
	Very Serious	26	28.9	28.9
	Neither Serious Nor Acceptable	35	38.9	38.9
	Total	**90**	**100.0**	**100.0**

Availability of Flying Toilets in the Area

		Frequency	Percent	Valid Percent
Valid	Not Serious	10	11.1	11.1

	Serious	15	16.7	16.7
	Very Serious	32	35.6	35.6
	Neither Serious Nor Acceptable	33	36.7	36.7
	Total	**90**	**100.0**	**100.0**

Personal Hygiene at the Toilets (Water to Wash Hands)

		Frequency	Percent	Valid Percent
Valid	Not Serious At All	3	3.3	3.3
	Not Serious	15	16.7	16.7
	Serious	13	14.4	14.4
	Very Serious	25	27.8	27.8
	Neither Serious Nor Acceptable	34	37.8	37.8
	Total	**90**	**100.0**	**100.0**

Children's Reaction to the Toilet Situation in your area

		Frequency	Percent	Valid Percent
Valid	Not Serious At All	4	4.4	4.4
	Not Serious	11	12.2	12.2
	Serious	20	22.2	22.2
	Very Serious	31	34.4	34.4
	Neither Serious Nor Acceptable	24	26.7	26.7
	Total	**90**	**100.0**	**100.0**

Population Density

		Frequency	Percent	Valid Percent
Valid	Not Serious At All	3	3.3	3.3
	Not Serious	1	1.1	1.1
	Serious	11	12.2	12.2
	Very Serious	45	50.0	50.0
	Neither Serious Nor Acceptable	30	33.3	33.3
	Total	**90**	**100.0**	**100.0**

Waste from Breweries, Sawmills and Fitting Shops

		Frequency	Percent	Valid Percent
Valid	Not Serious At All	2	2.2	2.2
	Not Serious	4	4.4	4.4
	Serious	11	12.2	12.2
	Very Serious	43	47.8	47.8
	Neither Serious Nor Acceptable	30	33.3	33.3
	Total	**90**	**100.0**	**100.0**

Use of Firewood

		Frequency	Percent	Valid Percent
Valid	Not Serious At All	3	3.3	3.3
	Not Serious	7	7.8	7.8
	Serious	9	10.0	10.0
	Very Serious	33	36.7	36.7
	Neither Serious Nor Acceptable	38	42.2	42.2
	Total	**90**	**100.0**	**100.0**

Source: Field Survey, 2014

With regards the rate of collection of waste per week as a factor that contribute to environmental pollution; 6 respondents (8.9%) agreed that it was not serious, 17 respondents (18.9%) said it was serious, 30 respondents (33.3%) said it was very serious, and 35 of the respondents representing 38.9% indicated that it was neither serious nor acceptable.

Considering the number of toilets available in the study area as a factor that contribute to environmental pollution; 2 of them (2.2%) indicated not serious at all, 8 (8.9%) said not serious, 15 of them (16.7%) indicated serious, 35 of the respondents representing about 39% indicated very serious while 30 of them (33.3%) indicated it was neither serious nor acceptable.

Again, taking into considering the duration of opening and closing of public toilets as a factor that contribute to environmental pollution; 10 respondents of 11.1% said it was not serious, 22 respondents representing 24.4% indicated that it was serious, 28 of them representing 31.1% indicated it was very serious, and 30 of them (33.3%) indicated that it was neither serious nor acceptable.

Furthermore, on the scent/odour at the public toilets as a factor that contributed to environmental pollution; 6 respondents (6.7%) consented that it was not serious at all, 14 respondents representing 15.6% agreed that it was not serious, 9 of them (10.0%) said it was serious, meanwhile 26 of the respondents representing 28.9% consented that it was very serious with 35 of them (38.9%) agreeing that it was neither serious nor acceptable.

With regards the availability of flying toilets in the area as a factor that contributed to environmental pollution; 10 of them said it was not serious, 15 respondents representing 15.6% indicated it was serious, 32 respondents representing

35.6% affirmed that it was very serious, and 33 of them (36.7%) said it was neither serious nor acceptable.

More so, considering personal hygiene at the toilets (water to wash hands) as a factor that contributed to environmental pollution; 3 respondents said that personal hygiene at the toilets was not serious at all, 15 of the (16.7%) indicated that personal hygiene at the toilets was not serious, and 13 of them (14.4%) indicated that personal hygiene at the toilets was serious. On the other hand, 25 respondents representing 27.8% indicated that personal hygiene at the toilets was very serious, and 34 of them (37.8%) stated it was neither serious nor acceptable.

Regarding children's reaction to the toilet situation in their area, 4 of the respondents said it was not serious at all, 11 respondents (12.2%) said it was not serious, and 20 respondents (22.2%) indicated that children's reaction to the toilet situation in the area was a serious issue. It was also realized that, 31 of the respondents representing 34.4% said that children's reaction to the toilet situation in the area was very serious and contributed to environmental pollution, whilst 24 of them representing 26.7% said it was neither serious nor acceptable.

Considering population density; 3 respondents indicated that it was not serious at all, 12 respondents (13.3%) affirmed that population density was a serious factor while 45 of the respondents (50%) indicated that population density was a very serious factor that contributed to environmental pollution; and 30 of them (33.3%) said it was neither serious nor acceptable. Since population density is linked to urbanization this finding affirms AMA (2003) ideas that, urbanization which entails increased resource consumption including energy, greater production and greater wastes generation, in the absence of integrated planning and effective management

worsen the waste problems and compound poverty, poor sanitation, and health problems of the poor. These call for the waste management authorities to be responsive to public attitudes, collection, transportation, treatment and disposal of waste.

In assessing waste from breweries, sawmills and fitting shops as a factor that contribute to environmental pollution; 2 respondents indicated that it was not serious at all, 4 of them said not serious, and 11 of them representing 12.2% said it was serious. Meanwhile, 43 of them representing 47.8% indicated that waste from breweries, sawmills and fitting shops was a very serious factor that contribute to environmental pollution; and 30 respondents (33.3%) said it was neither serious nor acceptable.

On the use of firewood as a factor that contributed to environmental pollution; 3 respondents said it was not serious at all, 7 said not serious, 9 of them (10.0%) confirmed that it was serious, 33 of the respondents representing 36.7% indicated it was a very serious contributing factor to environmental pollution, while 38 of them (42.2%) indicated neither serious nor acceptable.

Respondents further reiterated the following as things to be done to reduce pollution of the atmosphere such as;

- organizing regular cleaning at the toilets,
- entreating landlords to provide toilets in their homes,
- enacting enough enforceable legislation regarding the production of waste especially, the indiscriminate disposal of human waste in the area.

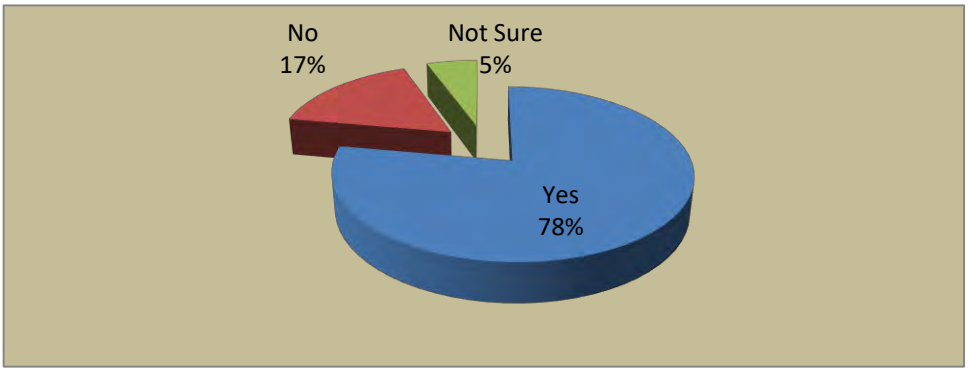

Fig. 4.3 Biogas is Environmentally Friendly (*Source: Field Survey, 2014*)

From Fig. 4.3, the results show that 70 of the respondent representing 78% indicated that in their opinion, biogas is environmentally friendly, 15 of them (17%) said no and 5 of them (5.6%) were not sure whether the biogas is environmentally friendly or not. This agrees with Murray (2012) who says that, "this project is about more than a technology breakthrough, it's about creating economically sustainable approaches to waste management that can eliminate the sanitation crisis in developing cities".

Table 4.4 Biogas is Cheaper than Crude Oil Products

		Frequency	Percent	Valid Percent
Valid	Yes	70	77.8	77.8
	No	18	20.0.	20.0
	Not Sure	2	2.2	2.2
	Total	90	100.0	100.0

Source: Field Survey, 2014

From Table 4.4 above, 70 respondents representing 77.8% indicated yes that biogas was cheaper than crude oil products, 18 of them said no and 2 respondents indicated that they were not sure. This result shows that, most of the respondents are of the view that biogas was cheaper than crude oil products and agrees with Murray (2012) that "the goal is to develop a revenue-generating faecal-sludge-to-biodiesel facility that can transform sanitation from an expensive burden into a profitable

venture. If we figure out a way to make waste management profitable, governments and citizens that currently bear the financial, environmental, and public health costs will all be better off".

4.5 COLLECTION/PROCESSING OF HUMAN WASTE AFFECTING THE CLEANLINESS OF THE CITY

Table 4.5 How the Collection/Processing of Human Waste Affects the Cleanliness of the City

Rate of Collection of Waste Per Week

		Frequency	Percent	Valid Percent
Valid	Not serious at all	18	20.0	20.0
	Not Serious	16	17.8	17.8
	Serious	25	27.8	27.8
	Very serious	28	31.1	31.1
	Neither serious nor acceptable	3	3.3	3.3
	Total	**90**	**100.0**	**100.0**

Number of Toilets Available in the Area

		Frequency	Percent	Valid Percent
Valid	Not serious at all	15	16.7	16.7
	Not Serious	25	27.8	27.8
	Serious	24	26.7	26.7
	Very Serious	26	28.9	28.9
	Total	**90**	**100.0**	**100.0**

Fear of Outbreak of Epidemic

		Frequency	Percent	Valid Percent
Valid	Not serious at all	10	11.1	11.1
	Not Serious	15	16.7	16.7
	Serious	42	46.7	46.7
	Very Serious	23	25.6	25.6
	Total	**90**	**100.0**	**100.0**

Duration of Opening and Closing of Public Toilets

		Frequency	Percent	Valid Percent
Valid	Not serious at all	10	11.1	11.1
	Not Serious	15	16.7	16.7
	Serious	48	53.3	53.3
	Very Serious	17	18.9	18.9
	Total	**90**	**100.0**	**100.0**

Scent/Odour at the Public Toilet

		Frequency	Percent	Valid Percent
Valid	Not serious at all	15	16.7	16.7
	Not Serious	20	22.2	22.2
	Serious	25	27.8	27.8
	Very Serious	22	24.4	24.4

	Neither serious nor acceptable	8	8.9	8.9
	Total	**90**	**100.0**	**100.0**

Availability of Flying Toilets in the Area

		Frequency	Percent	Valid Percent
Valid	Not serious at all	12	13.3	13.3
	Not Serious	23	25.6	25.6
	Serious	25	27.8	27.8
	Very Serious	22	24.4	24.4
	Neither serious nor acceptable	8	8.9	8.9
	Total	**90**	**100.0**	**100.0**

Children's Reaction to the Toilet Situation in the Area

		Frequency	Percent	Valid Percent
Valid	Not serious at all	10	11.1	11.1
	Not Serious	11	12.2	12.2
	Serious	38	42.2	42.2
	Very Serious	26	28.9	28.9
	Neither serious nor acceptable	5	5.6	5.6
	Total	**90**	**100.0**	**100.0**

Volume of Waste Generated

		Frequency	Percent	Valid Percent
Valid	Not serious at all	20	22.2	22.2
	Not Serious	12	13.3	13.3
	Serious	30	33.3	33.3
	Very Serious	28	31.1	31.1
	Total	**90**	**100.0**	**100.0**

Willingness of Locals to help Maintain Sanitary Conditions

		Frequency	Percent	Valid Percent
Valid	Not Serious at all	5	5.6	5.6
	Not Serious	13	14.4	14.4
	Serious	30	33.3	33.3
	Very Serious	42	46.6	46.6
	Total	**90**	**100.0**	**100.0**

Source: Field Survey, 2014

Table 4.5 shows respondents' views on how the collection and processing of human waste could affect the cleanliness of the city. Regarding the rate of collection of waste per week and how it affects the cleanliness of the city; 34 respondents representing 37.8% said it was not serious, 25 respondents representing 27.8% indicated that it was serious and 31 of them (34.4%) indicated that it was very serious.

Considering the number of toilets available in the area and how it affects the cleanliness of the city, 30 respondents of 44.5% indicated that it was not serious, 24 of

them representing 26.7% said it was serious with 26 respondents representing 28.9% agreed that the availability of a number of toilets was a very serious factor that affected the cleanliness of the city.

With regards the fear of outbreak of epidemics; 25 respondents (27.8%) said it was not serious, 42 respondents (46.7%) indicated that the fear of outbreak of epidemic was serious, and 23 respondents representing 25.6% also indicated that the fear of outbreak of epidemic was a very serious issue.

Duration of opening and closing of public toilets and how it affects the cleanliness of the city; 10 respondents (11.1%) said it was not serious at all, 15 respondents (16.7%) indicated that it was not serious, with 65 respondents (72.2%) indicating that the duration of opening and closing of public toilets was serious.

Scent/odour at the public toilets and how it affects the cleanliness of the city;

out of the 90 respondents, 35 of them (38.9%) indicated not serious, 25 of them (27.8%) said it was serious, and 30 respondents representing 33.3% indicated that the scent/odour at the public toilet was very serious.

Looking at the availability of flying toilets in the area and how it affects the cleanliness of the city, 35 respondents (38.9%) stated not serious, 25 respondents representing 27.8% said serious, and 30 respondents representing 43.3% indicated that the availability of flying toilets in the area was very serious.

Concerning children's reaction to the toilet situation in the area and how it affects the cleanliness of the city; 21 respondents (23.3%) indicated not serious, 43 respondents (47.8%) indicated that children's reaction to the toilet situation in the area was serious, and 26 respondents (28.9%) said it was very serious.

Considering the issue of the volume of waste generated in the area and how it affects the cleanliness of the city; 20 respondents (22.2%) confirmed that it was not serious at all, 12 respondents (13.3%) said it was not serious, 30 respondents representing 33.3% accepted that it was serious, whilst 28 respondents (31.1%) indicated that the volume of waste generated in the area was very serious and affects the cleanliness of the city. This finding confirms that of Adesina (1983) that, the volume of waste generated has also increased tremendously and the implication of this is that we have more waste to cope with. This is as a result of bad attitude of residents and weak bye-laws.

Finally, regarding the willingness of locals to help maintain sanitary conditions; 18 respondents (20.0%) said not serious, 30 respondents representing 33.3% indicated that the willingness of locals to help maintain sanitary conditions was serious and 42 respondents (46.6%) said it was very serious.

Fig. 4.4 sought to gather views from respondents on the kind of toilet facility used in their houses. Out of a total number of 90 respondents, 21 (23.3%) indicated that they use the "bomber" (Aqua Privy) toilet facility at home, 51 respondents (56.7%) indicated they use WCs, 12 participants (13.3%) use the KVIP and 6 respondents stated that they use the bucket (head pan) as a kind of toilet facility at home. It is clear from this finding that most of the respondents (56.7%) use water closets followed by those who use the "bomber". This finding agrees with GSS, (2010 p 172) that "the proportion of dwelling units that has private WC is highest in Kumasi Metropolis (40.1%)" although they are generally shared with other house-holds. In short, four general forms of toilet facilities are available. These are the "bomber latrine", the KVIP, the WC and the head pan.

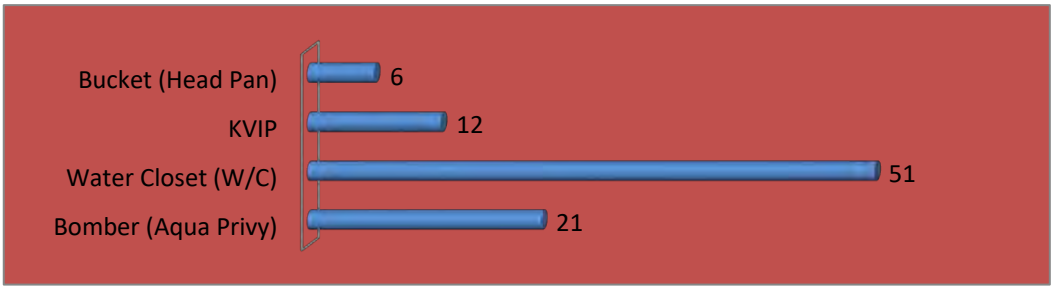

Fig. 4.4 Kind of Toilet Facility in the House (*Source: Field Survey, 2014)*

Table 4.7 displays the views of respondents on whether they fear the outbreak of epidemic due to haphazard disposal of human waste. Out of the 90 respondents, 75 of them representing 83.3% indicated yes, they feared the outbreak of epidemic due to

Table 4.6 Do You Fear the Outbreak of Epidemic Due to Haphazard Disposal of Human Waste

	Options	Frequency	Percent	Valid Percent
Valid	Yes	75	83.3	83.3
	No	10	11.1	11.1
	Not Sure	5	5.6	5.6
	Total	**90**	**100.0**	**100.0**

Source: Field Survey, 2014

the haphazard disposal of human waste in the area, 10 respondents (11.1%) indicated no and 5 respondents (5.6%) stated that, they were not sure. This finding confirms WHO (2012, May 26) that "between January and 6th May, 2012, a total of 3 216 cases and 28 deaths were reported from 20 districts"

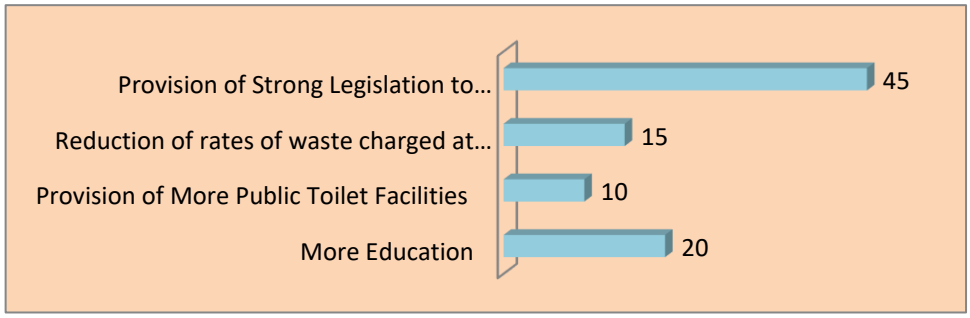

Fig. 4.5 Views on Public Education Towards Keeping a Clean Toilet-Free Environment

Source: Field Survey, 2014

From Fig. 4.5, 20 respondents (22.2%) said they would prefer more education, 15 respondents (16.7%) said they prefer reduction in rates of waste charged at the commercial toilets and 45 respondents (50%) indicated that they want legislation to punish offenders who dispose of waste indiscriminately while 10 respondents representing (11.1%) indicated that they need more public toilets. This result shows that, the respondents are of the view that there should be provision of legislation to punish offenders who dispose human waste indiscriminately in the area in order to keep the environment clean and free from toilet. This finding is in line with programmes to disseminate knowledge and skills, or to improve behavioural patterns and attitudes regarding waste management based on sound understanding of the social and cultural characteristics of the people. For the programme to succeed it calls for the authorities to involve the locals even at the planning stage.

4.6 LABOUR AND LOGISTICS FOR COLLECTION OF HUMAN WASTE

Table 4.7 Views on Labour and Logistics for Collection of Human Waste

		Frequency	Percent	Valid Percent
Zoning Collection of Waste in the Area				
	Not Important	4	4.4	4.4
	Important	41	45.6	45.6
	Very Important	45	50.0	50.0
	Total	**90**	**100.0**	**100.0**
Asking Landlords to Provide More Toilets				
	Not Important	2	2.2	2.2
	Important	28	31.1	31.1
	Very Important	60	66.7	66.7
	Total	**90**	**100.0**	**100.0**
Biogas Project for the Metropolis				
		Frequency	Percent	Valid Percent
Valid	Not Important	6	6.7	6.7
	Important	29	32.2	32.2
	Very Important	55	61.1	61.1

	Total	**90**	**100.0**	**100.0**

Strong Relationship Between the Government and Local Authority

		Frequency	Percent	Valid Percent
	Not Important	5	5.5	5.5
	Important	35	38.9	38.9
	Very Important	50	55.5	55.5
	Total	**90**	**100.0**	**100.0**

Enough Educative Programmes

		Frequency	Percent	Valid Percent
Valid	Not Important	5	5.6	5.6
	Important	40	44.4	44.4
	Very Important	45	50.0	50.0
	Total	**90**	**100.0**	**100.0**

Population Density

		Frequency	Percent	Valid Percent
Valid	Not important at all	6	6.7	6.7
	Not Important	10	11.1	11.1
	Important	33	36.7	36.7
	Very Important	39	43.3	43.3
	Neither Important Nor Unimportant	2	2.2	2.2
	Total	**90**	**100.0**	**100.0**

Willingness to Pay for Services

		Frequency	Percent	Valid Percent
Valid	Not Important at All	3	3.3	3.3
	Not Important	5	5.6	5.6
	Important	46	51.1	51.1
	Very Important	36	40.0	40.0
	Total	**90**	**100.0**	**100.0**

Residents Attitude towards Waste as a 'Throwaway'

		Frequency	Percent	Valid Percent
Valid	Not Important at All	5	5.6	5.6
	Not Important	7	7.8	7.8
	Important	43	47.8	47.8
	Very Important	35	38.9	38.9
	Total	**90**	**100.0**	**100.0**

Source: Field Survey, 2014

Table 4.7 shows the views of respondents on labour and logistics for collection of human waste. Considering zoning of the collection of waste in the area; 4 respondents (4.4%) indicated not important, 41 respondents representing 45.6% indicated that it is important to zone the collection of waste in the area, and 45 of

them representing 50% indicated that it was very important to zone the collection of waste in the area. This meant that most of the respondents agreed that it was important to zone the collection of waste in the study area.

On the issue of asking landlords to provide more toilets in the study area; 2 of them (2.2%) chose not important, 28 respondents (31.1%) indicated important, and 60 respondents representing 66.7% indicated it was very important for landlords to provide more toilets. Here, the results revealed that, respondents are of the firm belief that it should be made mandatory for landlords to provide toilets for every house.

Again, on the need for a biogas project for the metropolis, 6 respondents (6.7%) indicated not important, 29 respondents (32.2%) indicated that it was important for a biogas project in the metropolis, and 55 respondents (61.1%) indicated that it was very important for biogas project in the metropolis. This clearly shows that, according to the respondents it was important for the setting up of a biogas project in the metropolis.

Considering the need to build strong relationship between the government and local authorities to boost logistic needs for the collection of human waste; 5 of the respondents (5.6%) indicated not important, 35 of them (38.9%) affimed that it was important, 50 respondents (55.5%) confirmed that it was very important to build strong relationship between the government and local authorities in terms of labour and logistics for the collection of human waste and 2 respondents (2.2%) indicated it was neither important nor unimportant.

Regarding enough educative programmes to enhance the labour and logistics needs for the collection of human waste; 5 respondents (5.6%) indicated that, enough educative programmes was not important, 40 respondents (44.4%) accepted that it

was important, and 45 respondents representing 50% indicated that it was very important to have enough educative programmes.

The need for the community residents being co-owners of the facility in order to beef up the labour and logistics for collection of human waste; 5 respondents representing 5.6% said it was not important, 40 respondents (44.4%) indicated that it was important for self-help by community residents since they are co-owners of the facility and 45 of them (50%) accepted that it was very important for self-help by community residents.

Concerrning population density, 6 respondents (6.7%) said population density was not important at all, 10 of them (11.1%) indicated that it was not important, 33 of the respondents representing 36.7% believed that population density was important, and 39 respondents (43.3%) agreed that population density was very important.

Furthermore, on the willingness to pay for services, 3 respondents (3.3%) indicated not important at all, 5 of them (5.6%) said it was not important, 46 of them (51.1%) accepted that willingness of users to pay for services of the biogas project was important, whilst 36 of the respondents (40%) affirmed that it was very important. This finding will give the authorities hope that the end product will be consumed.

Finally, on residents' attitudes towards waste as a 'throwaway', 12 respondents (13.4%) indicated not important, 43 of the respondents (47.8%) accepted that it was important and 35 respondents (38.9%) confirmed that attitude of residents towards waste as a 'throwaway' was very important.

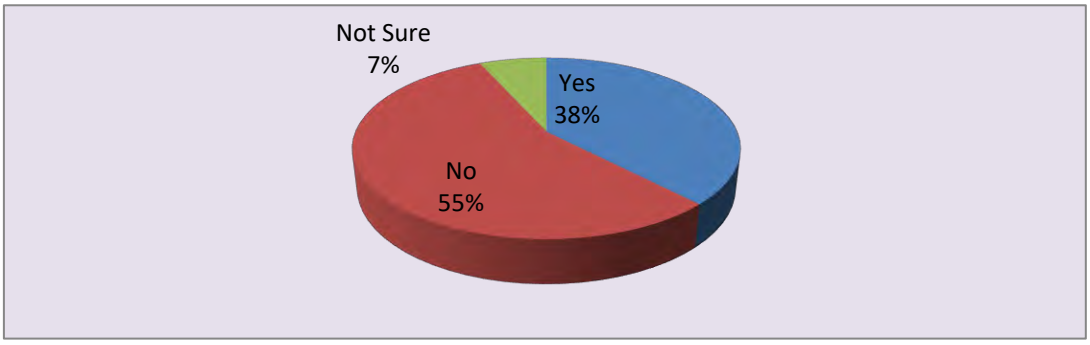

Fig. 4.6 Are There Enough Logistics to Collect Human Waste in Your Locality? ***Source: Field Survey, 2014***

Fig. 4.6 sought to seek the views of respondents as whether there are enough logistics to collect human waste in their locality. Thirty four (34) of them (38%) said yes there are enough logistics to collect human waste in their locality, 50 respondents (55%) said no and 6 of them (6.7%) indicated they were not sure. This result shows that most of the respondents indicated that there are not enough logistics to collect human waste in their locality. Whittington *et al*. (1993) agrees with the position that there was not enough logistics since households were generating about 25 000 $m^3$of waste per month, but only about 10% of it was removed from the city.

Table 4.8 Views on the Existence of Bye-Laws for Handling Human Waste

	Options	Frequency	Percent	Valid Percent
Valid	Non-Existent	13	14.5	14.5
	Very Weak	50	55.6	55.6
	Weak	17	18.9	18.9
	Good	6	6.7	6.7
	Total	90	100.0	100.0

Source: Field Survey, 2014

Table 4.8 sought the views of respondents on the existence of bye-laws for handling human waste in their area. Thirteen (13) respondents (14.5%) said there were non-existent bye-laws, 50 of them (55.6%) believed that these bye-laws were very weak, 17 respondents (18.9%) said it was weak, and 6 of them (6.7%) acceped

that there were good bye-laws. The finding indicates that, there are weak bye-laws for handling human waste in their areas.

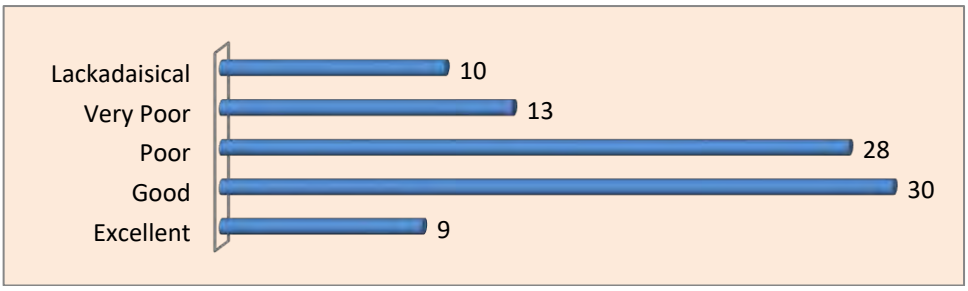

Fig. 4.7 Ratings on the Performance of KWML in Handling Human Waste (*Source: Field Survey, 2014)*

As to how respondents would rate the performance of Kumasi Waste Management Limited (KWML) in handling human waste, 30 of them representing 33.3% indicated that the performance of KWML in handling human waste was good, 28 respondents (31.1%) said it was poor, 13 respondents (14.4%) said it was very poor, 10 respondents (11.1%) said the workers were lackadaisical and only 9 respondents (10.0%) of them indicated excellent. This finding revealed that, about 51 of the respondents which is more than 50% of respondents were not happy with the performance of the KWML in handling human waste.

Table 4.9 Who Should Provide Vehicles for the Collection of Human Waste

	Options	Frequency	Percent	Valid Percent
Valid	Government	33	36.7	36.7
	Private Company	40	44.4	44.4
	Both	17	18.9	18.9
	Total	**90**	**100.0**	**100.0**

Source: Field Survey, 2014

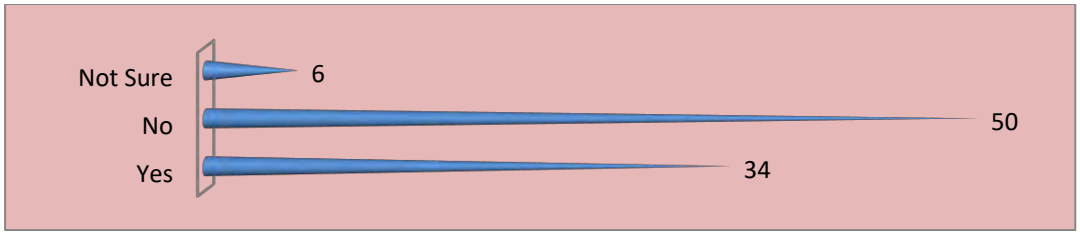

Fig. 4.8 Satisfaction with the Current Arrangement of Waste Management (*Source: Field Survey, 2014)*

From Table 4.9, respondents were asked the question who they think should provide vehicles for the collection of human waste. Out of the 90 respondents, 40 of them representing 44.4% beleived that a private company, 33 respondents (36.7%) of them accepted that the government should provide vehicles for the collection of human waste, and 17 of them (18.9%) said both the private company and government should team up to provide vehicles for the collection of human waste. This result meant that, most of the respondents agreed that private companies should be in charge of providing vehicles for the collection of human waste in the study area.

From Fig. 4.8, 50 out of the 90 respondents (55.6%) indicated no, they were not satisfied with the current arrangement of waste management in the area, 34 respondents (37.8%) agreed that they were satisfied with the current arrangement of waste management, and 6 respondents (6.7%) were not sure. The finding shows that 50 out of the 90 respondents representing 55.6% were not satisfied with the current arrangement of waste management in the study area.

Table 4.10 KWML has the Human Resource and Logistics to do Effective Collection of Human Waste

	Options	Frequency	Percent	Valid Percent
Valid	Yes	40	44.4	44.4
	No	46	51.1	51.1
	Not Sure	4	4.4	4.4
	Total	90	100.0	100.0

Source: Field Survey, 2014

Table 4.10 sought the views of respondents as to whether they think KWML has the human resource and logistics to do effective collection of human waste. Out of the 90 respondents, 40 respondents (44.4%) indicated yes they think KWML has the human resource and logistics to do effective collection of human waste, 46 respondents representing 51% indicated no and 4 participants (4.4%) said they were not sure. This result shows that most of the respondents do not think that KWML has

the human resource and logistics to do effective collection of human waste and that it is a contributing factor to why only 10% of human waste is collected from the city.

4.7 ENOUGH FUNDS TO UNDERTAKE THE PROJECT

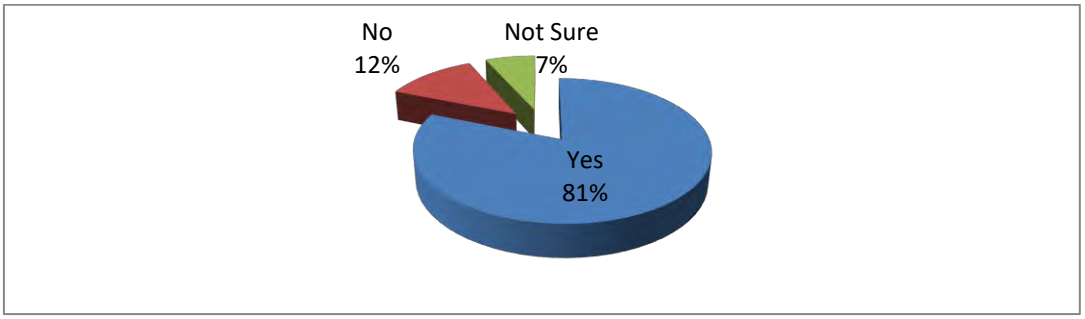

Fig. 4.9 Is it Prudent to Diversify into Other Sources of Energy? (*Source: Field Survey, 2014)*

From Fig. 4.9, 73 respondents (81%) indicated yes it is prudent to diversify into other sources of energy, 11 respondents (12%) said no and 6 respondents (7%) said they were not sure whether it is prudent to diversify into other sources of energy. This result meant that most of the respondents are of the view that, it is prudent to

Table 4.11 Energy Source Appropriate for the Locality

	Options	Frequency	Percent	Valid Percent
Valid	Solar	45	50.0	50.0
	Mini Hydro Dam	10	11.1	11.1
	Bio-gas	33	36.7	36.7
	Bio-Mass	2	2.2	2.2
	Total	**90**	**100.0**	**100.0**

Source: Field Survey, 2014

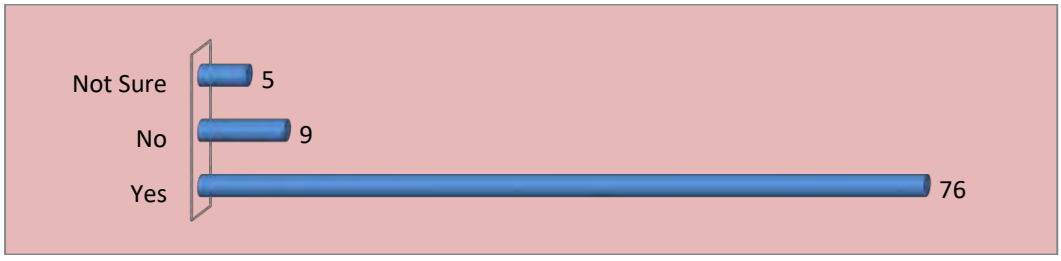

Fig. 4.10 Would Residents Contribute Positively towards Establishing Energy Source in the Locality

Source: Field Survey, 2014

diversify into other sources of energy. A switch from oil to renewable resources and energy technology can reduce dependency on oil imports. Renewable energies can support developing countries to gain independence from fossil fuels (BMZ, 2006).

Table 4.11 sought to gather respondents' views on the energy source appropriate for their locality. Out of the 90 respondents, 45 of them (50%) indicated solar energy would be appropriate for them, 33 (36.7%) indicated biogas and 10 respondents indicated mini hydro dam. This finding clearly revealed that, solar energy followed by biogas would be appropriate for the study area.

Fig. 4.10 sought to collect views of respondents as to whether they would contribute positively towards establishing an energy source in their locality. Seventy six (76) respondents (84.4%) affirmed that they would contribute positively towards establishing such an energy source in their locality, 9 of them (10.0%) said no with the remaining 5 respondents (5.6%) indicating that they were not sure. This result shows that most of the respondents are more willing to contribute positively towards the establishment of energy source in their locality. This results confirms the indication that policies are in place to exploit the country's energy potential in solar, biomass, wind, as well as mini-hydro e.g. the Renewable Energy Act (2011, Act 832).

Table 4.12 Water Closets are Still Relevant Despite Huge Water Bills

	Options	Frequency	Percent	Valid Percent
Valid	Yes	56	62.2	62.2
	No	23	25.6	25.6
	Not Sure	11	12.2	12.2
	Total	90	100.0	100.0

Source: Field Survey, 2014

Table 4.12 shows the views of respondents as to whether WCs are still relevant despite huge water bills, 56 respondents (62.2%) said yes, 23 respondents (25.6%) said no and 11 respondents (12.2%) were not sure. On the other hand, 70

respondents (77.8%) said they need an improved version of WCs and 12 respondents (13.3%) said no while 8 respondents (8.9%) were not sure.

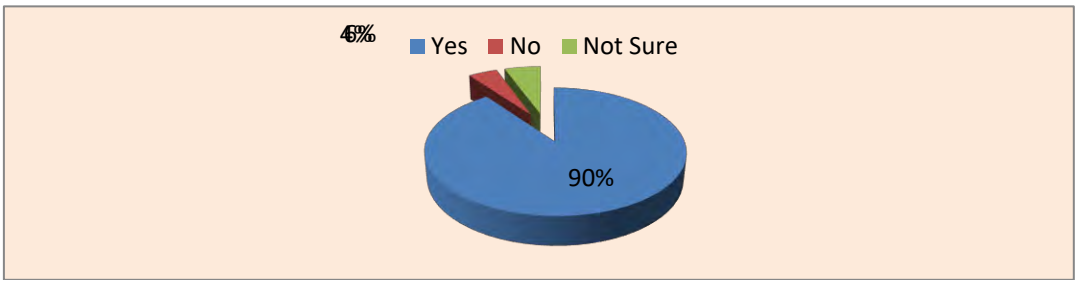

Fig. 4.11 Governments Should Seek Funds to Convert Landfill Waste to Gas and Manure

Source: Field Survey, 2014

On the question of whether government should seek funds to convert landfill waste to gas and manure as displayed by Fig. 4.11, 81 respondents (90%) said yes, 4 respondents (4.4%) indicated no with 5 respondents (5.6%) saying that they were not sure. It is clear from the result that almost all of the respondents overwhelmingly were of the view that the government should seek funds to convert landfill waste to gas and manure.

Table 4.13 The Waste Management Project Would be Economically Viable

	Option	Frequency	Percent	Valid Percent
Valid	Yes	74	82.2	82.2
	No	10	11.1	11.1
	Not Sure	6	6.7	6.7
	Total	**90**	**100.0**	**100.0**

Source: Field Survey, 2014

From Table 4.13, seventy four (74) respondents (82.2%) said yes and that the waste management project would be economically viable, 10 of them (11.1%) said no and 6 respondents (6.7%) said they were not sure whether the waste management project would be economically viable or not. This result meant that majority of the respondents were of the view that the waste management project would be economically viable.

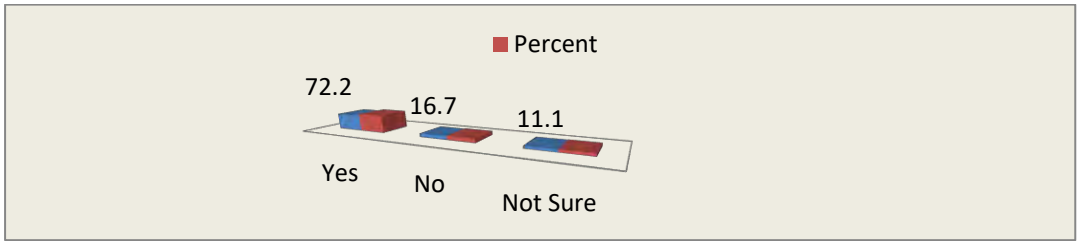

Fig. 4.12 Government Should Source for Funds to Implement the Biogas Project on Large Scale.

(***Source: Field Survey, 2014)***

Fig. 4.12 displays the views of respondents on whether the government should source for funds to implement the biogas project on large scale basis. Out of the 90 respondents, 65 respondents representing 72.2% said yes, the government should source for funds to implement the biogas project in large scale basis in the study area, 15 of the respondents (16.7%) said no with 10 of them (11.1%) indicating that they were not sure of the point. This finding shows that most of the respondents representing 72.2% agreed that the government and other non-governmental organizations should look for funds to implement the biogas project on a large scale.

4.8 BENEFITS OF THE BIOGAS PROJECT TO THE CITIZENS

Table 4.14 Views on the Benefits of the Biogas Project to the Citizens

Rate of collection of waste per week

		Frequency	Percent	Valid Percent
Valid	No Benefit	10	11.1	11.1
	Few Benefits	20	22.2	22.2
	Much Benefits	60	66.7	66.7
	Total	**90**	**100.0**	**100.0**

Reducing the rate of firewood collection and using biogas

		Frequency	Percent	Valid Percent
	No Benefit	9	10.0	10.0
	Few Benefits	26	28.9	28.9
	Much Benefits	55	61.1	61.1
	Total	**90**	**100.0**	**100.0**

Increasing time of opening and closing of public toilets

		Frequency	Percent	Valid Percent
Valid	No Benefit at All	6	6.7	6.7
	No Benefit	14	15.6	15.6
	Few Benefits	28	31.1	31.1
	Much Benefits	42	46.6	46.6
	Total	**90**	**100.0**	**100.0**

Reducing scent/Odour at the public toilets

		Frequency	Percent	Valid Percent
Valid	No Benefit at All	11	12.2	12.2
	No Benefit	17	18.9	18.9
	Few Benefits	29	32.2	32.2
	Much Benefits	33	36.6	36.6
	Total	**90**	**100.0**	**100.0**

Asking landlords to provide toilets in their homes

		Frequency	Percent	Valid Percent
Valid	No Benefit at All	6	6.6	6.6
	No Benefit	10	11.1	11.1
	Few Benefits	12	13.3	13.3
	Much Benefits	62	68.9	68.9
	Total	**90**	**100.0**	**100.0**

Avoiding "flying toilets" in the area

		Frequency	Percent	Valid Percent
Valid	No Benefit at All	16	17.8	17.8
	No Benefit	18	20.0	18.9
	Few Benefits	20	22.2	22.2
	Much Benefits	36	40.0	40.0
	Total	**90**	**100.0**	**100.0**

Biogas to power plants for electricity and off-grid Applications

		Frequency	Percent	Valid Percent
Valid	No Benefit at All	15	16.7	16.7
	No Benefit	19	21.1	21.1
	Few Benefits	22	24.4	24.4
	Much Benefits	34	37.7	37.7
	Total	**90**	**100.0**	**100.0**

Biogas for Rural Farmers for Drying Farm Produce

		Frequency	Percent	Valid Percent
Valid	No Benefit at All	10	11.1	11.1
	No Benefit	15	16.7	16.7
	Few Benefits	30	33.3	33.3
	Much Benefits	35	38.9	35.6
	Total	**90**	**100.0**	**100.0**

Bio-gas for irrigation in rural areas

		Frequency	Percent	Valid Percent
	No Benefit	5	5.5	5.5
	Few Benefits	23	25.6	25.6
	Much Benefits	62	68.9	68.9
	Total	**90**	**100.0**	**100.0**

Source: Field Survey, 2014

Table 4.14 outlined the Views of respondents on how the biogas project would benefit them. Considering the rate of collection of waste per week; 10 respondents (11.1%) said no benefit, 20 of them (22.2%) said few benefits, and 60 of them representing 66.7% affirmed that it was of much benefit.

On reducing the rate of firewood collection and using biogas; 9 respondents (10.0%) said no benefit, 26 of them representing 28.9% indicated few benefits, and 55 of them which is more than 50% of the total number of respondents agreed that it was of much benefit.

Also, on increasing time of opening and closing of public toilets; 6 respondents (6.7%) said it has no benefit at all, 14 of them (15.6%) were of the view that, it had no benefit, 28 respondents (31.1%) indicated it had few benefits, and 42 of the respondents (46.6%) indicated that, it had much benefit.

About reducing the scent/odour at the public toilets; 11 respondents (12.2%) indicated no benefit at all, 17 of them (18.9%) indicated no benefit, while 29 of them representing 32.2% indicated few benefits, and 33 of the respondents representing 36.6% indicated that it had much benefits.

On assessing respondent's views as to whether asking landlords to provide toilets in their homes was important, 6 of them representing 6.6% said no benefit at all, 10 respondents (11.1%) said no benefit, 12 of them (13.3%) also indicated few benefits, and 62 of them representing 68.9% indicated that, asking landlords to provide toilets in their homes has much benefits.

Avoiding "flying toilets" in the area; 16 respondents (17.8%) said no benefit at all, 18 of them (20.0%) stated no benefit, 20 of them representing 22.2% indicated

few benefits, and 36 of them representing 40.0% accepted that avoiding "flying toilets" in the area was of much benefit.

Furthermore, on using biogas to power plants for electricity and off-grid applications; 15 respondents (16.7%) said it has no benefit at all, 19 of them representing 21.1% said it has no benefit, 22 of them representing 24.4% indicated that it has few benefits, and 34 of them (37.7%) indicated that using biogas to power plants for electricity and off-grid applications has much benefits. In addition to that, as to whether, biogas can be used by rural farmers for drying farm produce; 10 respondents (11.1%) said no benefit at all, 15 respondents (16.7%) indicated no benefit, whilst 30 respondents representing 33.3% said few benefits, and 35 of the respondents representing 38.9% indicated much benefits. If this waste can, therefore, be converted into biogas or ethanol it can be used to power vehicles, domestic and industrial electrical generators, stoves and boilers for the timber industries. The society will then not be totally dependent on energy from the national grid.

Finally, as to whether biogas can be used to power irrigation systems in rural areas; 5 respondents (5.5%) chose no benefit, 23 respondents (25.6%) said a few benefits, and 62 of the respondents (68.9%) indicated much benefits. Besides those important social improvements other major productive uses are for agriculture (e.g. irrigation, drying processes, grain mills), and small-scale industry.

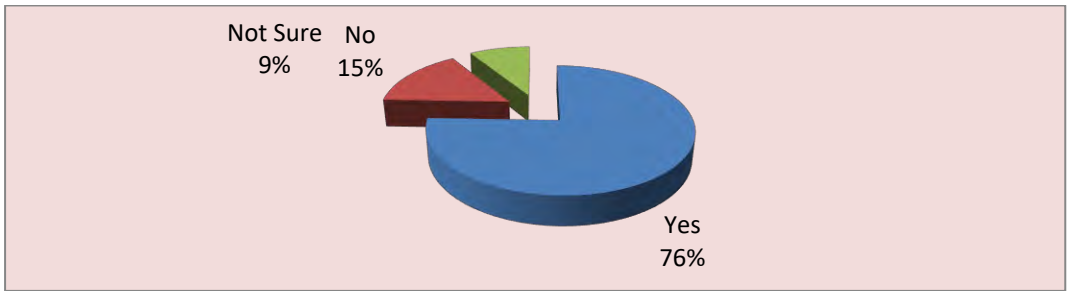

Fig. 4.13 Toilet-to-Gas Poject can Solve the Haphazard Disposal of Human Waste

Source: Field Survey, 2014

Concerning whether the toilet-to-gas project can solve the haphazard disposal of human waste, 68 respondents (75.6%) said yes, the toilet-to-gas project can solve the haphazard disposal of human waste, 14 of them (15.6%) indicated no and 8 (8.9%) of the respondents were not sure whether the toilet to gas project could solve the haphazard disposal of human waste. This confirmed the view of Ahiataku-Togobo (2011) that the ministry is now promoting biogas for the sole purpose of addressing sanitation, mainly for treating waste (generated by households and institutions).

Table 4.15 Would You Prefer Manure Fertilizer to Chemical Fertilizer?

	Options	Frequency	Percent	Valid Percent
Valid	Yes	73	81.1	81.1
	No	11	12.2	12.2
	Not Sure	6	6.7	6.7
	Total	**90**	**100.0**	**100.0**

Source: Field Survey, 2014

Table 4.15 shows the views of respondents on whether they would prefer manure fertilizer to chemical fertilizer. From the table, 73 respondents (81.1%) accepted that they would prefer manure to chemical fertilizers, 11 respondents (12.2%) said no with 6 of them (6.7%) indicating that they were not sure whether they would prefer manure to chemical fertilizers. It could be deduced from the results that, most respondents prefer manure to chemical fertilizers.

As to whether the environment would be safe if it is free from human waste, respondents indicated that;

- The environment would be clean and free from diseases thereby promoting the culture of hygiene among the citizens.
- It would create room for the gathering of all wastes at a required place ensuring proper disposal which would be used for biogas.

- It would also give way for the provision of sufficient logistics for the collection and treatment of human waste, give room for the enactment of more bye-laws and ensuring that the provision of toilets by landlords among others are strictly adhered to. The country has huge potential for producing biogas so Bensah (2011) maintains that biogas has wider applications, needs more attention and can make a biger impact in households if governments, academia and the private sector could put in more effort.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a summary of the main findings of the study, conclusions and recommendations and areas that call for further research.

5.2 Summary of Findings

The following are the summary of findings of the study:

5.2.1 Findings on the Possibility of Turning Human Waste into Wealth

The results show that;

- Most of the respondents 71 which represented 78.9% indicated that human waste from home is disposed into septic tanks and later transported to the landfill in the study area.
- That methane gas can be trapped from human waste discharged at the landfill.
- Respondents agreed that they would use gas made of toilet without further thoughts and also use fertilizer derived from human waste on their farms.

5.2.2 Findings on the Effect of Fuel Produced on the Pollution of the Atmosphere (Cleaner Fuel)

On the factors that could contribute to environmental pollution, the results show that:

- The rate of collection of waste per week as a factor that contribute to environmental pollution, most of the respondents (52.2%) indicated that it was very serious and contributes to environmental pollution.

- The small number of toilets available in the study area was a serious factor that could contribute to environmental pollution.
- The duration of opening and closing of public toilets was also seen as a factor that contributed to environmental pollution - thus the rate at which people defecate at the open was dependent upon the duration of opening and closing of public toilets.
- Furthermore, on the scent/odour at public toilets, most of the respondents (38.9%) indicated that it was neither serious nor acceptable.
- The availability of flying toilets in the area was seen as a factor that contributed to environmental pollution with 52.2% indicating it was serious.
- More so, most of the respondents (42.2%) indicated that, personal hygiene at the toilets (availabilty of water to wash hands) was a very serious factor that contributed to environmental pollution.
- Fifty-one (51) respondents (56.6%) indicated that children's reaction to the toilet situation in the area was serious and contributed to environmental pollution.
- On population density, about 50% of the respondents indicated that high population density was a very serious factor that contributed to environmental pollution.
- Most of the respondents about 54 of them stated that, waste from breweries, sawmills, fitting shops and ineffective sewage system was a serious factor that contribute to environmental pollution.

- The use of firewood was also a serious factor that contributed to environmental pollution.

- Seventy (70) of the respondents (78%) indicated that in their opinion, biogas is environmentally friendly and cheaper than crude oil products so the project should be implemented.

Respondents further suggested the following measures to reduce the pollution of the atmosphere such as;

- organiszing regular cleaning at the toilets, asking landlords to provide toilets in their homes and fining defaulters heavily to deter others.

- enacting and enfrcing enforceable legislation regarding the production of waste especially, the indiscriminate disposal of human waste in the area.

5.2.3 Findings on How the Collection/Processing of Human Waste Affects the Cleanliness of the City

The results on how the collection/processing of human waste affects the cleanliness of the city revealed that:

- The collection and processing of human waste could affect the cleanliness of the city.
- The rate of collection of waste per week as well as the number of toilets available in the area affects the cleanliness of the city.

- It was a serious matter that respondents (72.3%) are afraid of outbreaks of cholera epidemic due to the haphazard disposal of human waste.

- About 65 respondents (72.2%) indicated that the duration of opening and closing of public toilets was serious alongside the scent/odour of the public toilets and affects the cleanliness of the city.

- The availability of flying toilets in the area had a very serious effect on the cleanliness of the city as stated by 71.1% of the respondents.

- Sixty nine (69) respondents (76.7%) indicated that, children's reaction to the toilet situation in the area affects the cleanliness of the city.

- The volume of waste generated in the area affects the cleanliness of the city and about 72 respondents (79.9%) also indicated that the willingness of locals to help maintain sanitary conditions in the area was serious and affects the cleanliness of the city.

- On the kind of toilet facility used by respondents in their houses, it was clear that 23.3% of the respondents used the "bomber" (Aqua Privy) toilet facility, 56.7% used WCs, 13.3% used the KVIP and 6.7% used the bucket (head pan).

5.2.4 Findings on Labour and Logistics for Collection of Human Waste

- Half of the respondents (50%) agreed that it was very important to zone the collection of waste in the study area.

- Most of the respondents (66.7%) are of the firm belief that it should be made mandatory for land lords to provide toilets for every house.

- The results (93.3%) overwhelmingly show that, it was important for the setting up of a biogas project in the metropolis.

- Most of the respondents (94.5%) indicate that, there was the need to build strong relationship between the government and local authorities in order to enhance the provision of labour and logistics.

- The results revealed that there should be enough educative programmes on the labour and logistics needs for the collection of human waste in the study area.

- The results show that, most of the respondents (94.4%) agreed that the community, being co-owners, should provide self-help projects.
- The respondents (78.85%) indicated that the economic situation of the community was a contributing factor to the provision of logistics.
- Most respondents (80%) confirmed that population density affects the provision of labour and logistics.
- A greater number of the respondents (91.1%) said they were willing to pay for the servivces rendered them by the waste management authorities.
- According to the respondents (86.6%) the size and structure of the residents affects the provision of logistics and labour to collect human waste.
- The results lay bare the fact that 86.7% of the respondents show concern about residents' attitude towards waste as a "throwaway" influenced the provision of labour and logistics.
- The research revealed that 55% of respondents feared there is not enough logistics, 74.5% of respondents said there are weak bye-laws for handling human waste with about 51% of respondents not being happy with the performance of the KWML in handling human waste.
- The results show that many of the respondents (44.4%) wanted private companies to provide vehicles, they are not satisfied with the waste managem-

ent authorities and that the KWML does not have the the human resource and logistics to do effective work.

5.2.5 Findings on Enough Funds to Undertake the Biogas Project

- About 73 respondents (81%) indicated that it was prudent to diversify into other sources of energy such as biogas and solar energy in the study area.
- The results show that most of the respondents (84.4%) would be more willing to contribute positively towards the establishment of an energy source in their locality.
- Most respondents (56.7%) preferred WC, they would, however, need an improved version of WCs due to the huge water bills in order to effectively use WCs.
- Eighty-one of the respondents (90%) are of the view that the government should seek funds to convert landfill waste to gas and manure and that it would be an economically viable project.
- The finding further shows that most of the respondents (72.2%) agreeing that the government and other non-governmental organizations should source for funds to implement the biogas project on large scale basis in the study area and beyond.

5.2.6 Findings on the Benefits of the Biogas Project to the Citizens

The findings on the benefits of the biogas project to the citizens revealed that;

- The rate of collection of waste per week was of much benefit as 66.7% of the respondents alluded to that.

- Reducing the rate of firewood collection and using biogas was of much benefit as proposed by 61.1% of the rspondents.

- About reducing the scent/odour at the public toilets most of the respondents indicated that it had much benefits.

- On assessing respondent's views as to whether asking landlords to provide toilets in their homes was important, 81.2% respondents indicated that, asking landlords to provide toilets in their homes and avoiding "flying toilets" in the area were both of much benefit.

- Furthermore, on using biogas to power plants for electricity and off-grid applications, about 62.1% of the respondents said it has much benefit.

- In addition to that, respondents agreed that, biogas is of much benefit to rural farmers by providing energy for drying of farm produce and irrigation of crops on the farm.

- The toilet-to-gas project can solve the haphazard disposal of human waste, 68 respondents representing 75.6% said yes.
- The result further revealed that, most of the respondents (81.1%) are of the view that they would prefer manure fertilizer to chemical fertilizer.

  As to whether the environment would be safe if it is free from human waste, respondents indicated that:

- The environment would be clean and free from diseases thereby promoting the culture of hygiene among the citizens.

- It would lead to conducive and safe environment.

- It would create room for the gathering of all waste at a required place hence ensuring proper disposal which would be used for biogas.

- It would give way for the provision of sufficient logistics for the collection and treatment of human waste, as well as make room for the enactment of more bye-laws and ensuring that the provision of toilets by landlords among others are strictly adhered to.

5.3 Conclusions

From the forgone discussion, one can say that, the rising cost of LPG, the indiscriminate felling and use of firewood/charcoal can be minimised if the use of bio gas could be vigorously promoted. LPG which is widely and commonly used by many homes, hotels and industries as a source of fuel is very scarce and difficult to come by. Imports of crude oil is on the high side. It is, therefore, imperative to appreciate the use of biogas as a permanent domestic source of energy. Human waste can, therefore, be converted into biogas or ethanol and used to power vehicles, domestic and industrial electrical generators, stoves and boilers for the timber industries, thereby making the society not totally dependent on energy from the national grid. It is, therefore, proper to ascertain whether it will be economically viable to add value to the "useless" human and animal wastes in the form of obtaining biogas and also the possibility of using the sludge from the waste to develop bio-fertilizer (natural manure) for the benefit of farmers. This will enhance the use of clean energy, make energy available and affordable to all, irrespective of location of community and weather conditions. This is essential for minimizing climate risk, for reducing poverty and improving global health, for empowering women and meeting the MDGs, for

global economic growth, peace and security, and health of the planet (Moon, 2011). It will also make our cities clean and reduce our health bills.

5.4 Recommendations

The study recommends the following:

- There is the need for self-help by community residents by making them co-owners of the waste treatment facility in order to beef up the labour and logistics needs for collection of human waste.
- The waste treatment facility for a community should be located at a strategic place in order to beef up the labour and logistics needs for collection of human waste in the study area.
- It is important to consider the economic situation of the residents, the condition of roads and topography of the study area in setting up the waste treatment plant.
- It should be made compulsory for every landlord in the study area to provide toilets in their homes and also encourage residents to avoid creating "flying toilets" in the area.
- The government should seek funds with the involvement of the private sector to convert landfill waste to gas and manure which would be an economically viable project.
- The government and other non-governmental organizations should source for funds to implement the biogas project on large scale basis in the study area and beyond.
- There is the need for the KMA to enact strong and enforceable legislations

5.5 Suggestions for Further Research

The research findings gave me an insight to suggest the following topics to be considered for further research:

- The degree of environmental pollution created by the activities at the landfill must be further studied.
- What can be done to reduce the huge water bills associated with this current design of WCs should be looked at.
- The correlation between the income of a community and their waste generation partterns should be studied.
- The effects of providing more and accessible toilets on the cleanliness and health of a community should be studied.
- What should the KMA do to enforce its legislations on the disposal of human waste?

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APPENDIXES

1 INTERVIEW *(with Mr. Ato Fanyin-Martin Osei)*

This is a brief interview granted by the researcher to a worker of the pilot biodiesel project located at the Kumasi (Dompoase) Landfill on 2nd Nov., 2013

Q: Is biogas environmentally friendly concerning the emission of GHGs?

A; Methane gas when released into the atmosphere is very harmful. Methane is not environmentally friendly when released into the atmosphere. It seeks to deplete the ozone layer therefore it is not advisable to release it in its raw state into the atmosphere. So methane gas should be burnt to change its constituents to carbon dioxide (CO_2) which is more GHG friendly, for it is better to emit CO_2 into the environment than to emit methane gas because the methane gas will deplete the ozone layer. So The pollution might not be all that strong. Fortunately methane is an inflammable gas. In order to reduce its effect on the ozone layer, it is good to burn it in order to change it to CO_2 for CO_2 is a lesser evil thane methane gas should both gases be released into the atmosphere.

Q: What is the composition of gases present in the bio-digester?

A: The gases present in the biogas comprises CO_2, methane, hydrogen sulphide and some other gases such as oxygen. But the oxygen content should be zero.

Q: What is the percentage of methane present in each bio-digester?

A: The quantity of methane gas present in each bio-digester is averagely 65% of $30m^3$. So the quantity of methane present among the other gases is 60%.

Q: Will it be sensible/advisable to invest in biogas production considering the quantity and quality of FS?

A: The Bill Gate pilot project at the Dompoase Landfill is principally to trap biodiesel through the collection of fatty acids to produce lipids though almost the same processes are used to produce both biogas and biodiesel. In producing biogas we depend on what the biogas is to be used for and the amount of biogas to be produced. All that you need to produce biogas is a digester, FS and ruminants (almost free from the abattoir) for inoculation. If you combine the two in a digester in the right

proportions you get your biogas. If you want to use the FS then you must consider other forms of inoculation. Inoculation is important to enrich the FS. We use rumen for the inoculants. Considering the quantity of FS that comes to the site every day, I think it is and would be sensible and prudent to tap the energy contained there in the FS into biogas production. For what happens now is that the FS is just deposited into the settling pound and that is all. The faecal sludge is brought to the landfill any way and allowed to go through the normal anaerobic digestion without any other use. Nothing happens to it again. So why can't we use them to produce biogas? What is there to lose if we have both the faecal sludge and the ruminants dumped at the landfill? If we can have digesters to help produce biogas, what are we loosing? Ruminants are got from the abattoir and can be used to enrich the FS. Combining these two we can get methane. So what is there to lose? What is there to lose? It will be economically viable to use the faecal sludge and the waste from the abattoir to produce methane gas instead of flaring it into the environment.

2 QUESTIONNAIRE

PREAMBLE

This researcher is a final year Masters student at COLTEK embarking upon a research work on the assessment of the economic viability of using human waste at the Kumasi Landfill site for generating biogas as a domestic fuel.

Waste management is of late becoming a major problem for the entire nation of Ghana to handle efficiently. Filth has engulfed most cities, towns and most especially the municipal and metropolitan areas. As evidence of this, both liquid and solid wastes could be seen at the market places, lorry parks, gutters, storm drains, homes and river bodies. The list goes on and on implying that the environment has been polluted with all sorts of waste including electronic waste.

This research is restricted to ascertain whether it is economically viable to use the human waste sludge at the Kumasi (Dompoase) Landfill to trap biogas for fuel, so that in the process it will turn waste into wealth. Does this wealth include reducing environmental pollution by this liquid waste and its related health effects as well as making our cities clean? Let the research tell.

Please, understand that all information provided here would be treated with the utmost confidentiality and that it is for academic purposes only. Thank you in advance for participating in the survey.

Introduction

Please, tick (in the bracket) one of the options or write a short answer to the following questions.

1. Please indicate your age.
   a. Less that 20 { } b. 20 -29 { }
   b. 30 - 39 { } d. 40 – 49 { }
   c. 50 and above { }
2. What is your educational level?
   a. No formal education { } b. Basic education { }
   c. Secondary education { } d. Technical education { }
   e. Tertiary education { }

3. How long have you been involved in this waste management work?
   a. 1 – 5 { } b. 6 – 10 { }
   c. 11 – 15 { } d. 16 – 20 { }
   e. Greater than 20 years { }
4. How long have you been working with your current employer?
   a. 1-5 years { } b. 6-10 years { }
   c. 11- 15 years { } d. 16-20 years { }
   e. Greater than 20 years { }

Possibility of turning human waste to wealth

5. Where do you dispose of the human waste produced from your homes?
   a. Into the drains { }
   b. Into a river or a stream { }
   c. Into a septic tank and transported to the landfill { }
   d. In a hole and covered or buried { }
   e. Others (Specify)……
6. Do you think methane gas could be trapped from the human waste discharged at the landfill? Yes { } No { } Not sure { }
7. Is it possible to replicate this project of converting waste to wealth elsewhere in Ghana? Yes { } No { } Not sure { }
8. Suggest one way to make effective use of animal waste from the abattoir. .....
9. Would you use "toilet gas" without further thoughts? Yes { } No { } Not sure { }
10. What do you think the sludge removed from the human waste dumped at the landfill be used for?.....
11. Would you apply fertilizer derived from the human waste on your farms?
    Yes { } No { } Not sure { }

Effect of the Fuel Produced on the Pollution of the Atmosphere (Cleaner Fuel)

12. Please, indicate the extent to which the following contribute to atmospheric pollution. Please, tick.

Statement	Not serious at all	Not serious	Serious	Very serious	Neither serious nor acceptable
a. Rate of collection of waste per week					
b. Number of toilets available in area					
c. Duration of opening and closing of public toilets					
d. Cleanliness at the toilets					
e. Scent/odour at public toilets					
f. Asking landlords to provide toilets in their homes					
g. Availability of "flying toilets" in your area					
h. Personal hygiene at the toilets (water to wash hands)					
i. Children's reaction to the toilet situation in your area					
j. Enough legislation					
k. Population density					
l. Waste from breweries,					

sawmills & fitting shops					
m. Lifestyle of residents					
n. Use of firewood					

13. In your opinion, what is the most probable and common cause of cholera outbreak in your community?.....
14. Is biogas environmentally friendly (i.e. no emission of greenhouse gas)?
    Yes { } No { } Not Sure { }
15. Do you think biogas is cheaper than crude oil products? Yes{ } No{ } Not sure{ }

Does the collection and processing of human waste affect the cleanliness of the city?

16. To what extent does the collection and processing of human waste from the city centre affect the cleanliness of the city? Please tick the appropriate space.

Situation	Not serious at all	Not serious	Serious	Very serious	Neither serious nor acceptable
a. Rate of collection of waste per week					
b. Number of toilets available in area					
c. Fear of outbreak of cholera?					
d. Duration of opening and closing of public toilets					
e. Scent/odour at the public toilets					
f. Availability of "flying toilets" in your area					

g. Children's reaction to the toilet situation in your area					
h. Enough legislation					
i. Lifestyle of residents					
j. Volume of waste generated					
k. Willingness of locals to help maintain sanitary conditions					

17. What kind of toilet facility do you have in your house?
    a. Bomber (aqua privy) { } b. Water closet (WC) { }
    c. KVIP { } d. Bucket (head pan) { }
    e. Others (specify)……
18. While using a WC in your house and the tap is not flowing, where do you attend natures call? In a...
    a. Container and poured into the drains { }
    b. Gutter { }
    c. Wrapper and thrown away anywhere { }
    d. Secret pit { }
    e. Container and thrown into a rubbish bin { }
19. Do you fear the outbreak of any epidemic in relation to the haphazard disposal of human waste in your area? Yes { } No { } Not Sure { }
20. What do you suggest should be done to keep the environment clean?
    a. More education { }
    b. Provision of more public toilet facilities { }
    c. Reduction in rates of waste charged at the commercial toilets { }
    d. Provision of strong legislation to punish offenders { }
    e. Others (specify) ……
21. What is your view on educating the public on keeping a clean "toilet free" environment?
    a. Education is enough { } b. Education is not needed { }

c. Little education so far { } d. Needs more education { }

e. Education should be suspended { }

Labour and Logistics for collection of human waste

22. To what extent does labour and logistics affect the effective collection of human waste in your area? Please, tick the appropriate space.

Situation	Not important at all	Not important	Important	Very important	Neither important nor unimportant
a. Zoning collection of waste in the area					
b. Is government intervention needed?					
c. Asking landlords to provide more toilets					
d. Biogas project for the metropolis					
e. Relationship between government and local authority					
f. Enough educative programmes					
g. Residents being co-owners of facility					
h. Location of facility					
i. Conditions of road and topography					
j. Density of population					
k. Willingness to pay					

for services					
l. Residents' attitude towards waste as a 'throwaway'					

23. Are there enough logistics e.g. septic tankers, to collect human waste from your locality? Yes { } No { } Not Sure { }
24. What do you think about bye-laws for handling human waste?
    a. Non-existent { }
    b. Very weak { }
    c. Weak { }
    d. Good { }
    e. Excellent { }
25. How would you rate the performance of Kumasi Waste Management Limited (KWML) so far as handling human waste in your community is concerned?
    a. Excellent { }
    b. Good { }
    c. Poor { }
    d. Very poor { }
    e. Lackadaisical { }
26. Who do you think should provide vehicles for the collection of human waste in your locality? Government { } Private companies { } Others (specify) ……
27. Are you satisfied with the current arrangement? Yes{ } No{ } Not sure { }
28. Do you think the KWML has the human resource and logistics to do effective collection of human waste? Yes { } No { } Not sure { }

Enough funds to undertake the project

29. Is it prudent to diversify into other sources of energy?
    Yes { } No { } Not sure { }
30. Which energy source given would you consider appropriate for your locality?
    a. Solar { }

b. Mini hydro dam { }

c. Biogas { }

d. Biomass { }

e. Others (specify).....

31. Would you contribute positively towards establishing such an energy source in your locality? Yes { } No { } Not sure { }
32. Considering the present day of huge water bills is W/C relevant?
    Yes { } No { } Not sure { }
33. Would you want an improved version of a WC which uses less water?
    Yes { } No { } Not sure { }
34. Should government seek funds to convert landfill waste to gas and manure?
    Yes { } No { } Not sure { }
35. Will the above project in (34) be economically viable? Yes { } No { }Not sure { }
36. Is it prudent for government to source funds to implement the biogas project on large scale? Yes { } No { } Not sure { }

Benefits of the biogas project to the citizens

37. Indicate how much benefit you think you will achieve from the following? Please tick.

Situation	No benefit at all	No benefit	Few benefits	Much benefits	Neither benefits nor loss
a. Rate of collection of waste per week					
b. Reducing the rate of firewood collection					
c. Amount of time spent in collecting firewood					
d. Outbreak of cholera					
e. Times of opening and closing of public toilets					

f. Scent/odour at the public toilets					
g. Asking landlords to provide toilets in their homes					
h. Availability of "flying toilets" in your area					
i. Enough education					
j. Biogas to power plants for electricity					
k. Biogas good for off-grid applications					
l. Biogas for rural farmers for drying farm produce					
m. Biogas for irrigation in rural areas					

38. If the "toilet-to-gas" project is implemented on large scale, do you think it will solve the haphazard disposal of human waste in the metropolis?

    Yes { } No { } Not sure { }

39. Do you prefer manure fertilizer to chemical fertilizer? Yes { } No { } Not sure{ }

40. Would the environment be safe if it is free from human waste?

    Yes { } No { } Not sure { }

THANK YOU VERY MUCH!