PRESBYTERIAN UNIVERSITY COLLEGE, GHANA

FACULTY OF DEVELOPMENT STUDIES

DEPARTMENT OF ENVIRONMENTAL AND NATURAL RESOURCES MANAGEMENT

CHARACTERISTICS OF SOLID WASTE GENERATED IN TECHIMAN, GHANA

BY

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SEPTEMBER, 2020

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A project work (Dissertation) Submitted to the Department of Environment and Natural Resources of the Faculty of Development Studies, Presbyterian University College, Ghana in partial fulfilment of the requirement for the award of Master of Science degree in Environmental Health and Sanitation.

BY

GYIMAH YAW AGYEI

SEPTEMBER, 2020

DECLARATIONS

Candidate's Declaration

I hereby declare that this Dissertation is my own original research and that no part of it has been presented for another degree in this University or elsewhere. Work of other people cited in this dissertation have been duly referenced.

Candidate's Signature:……………………. Date:………………………………

Name: Gyimah Yaw Agyei

Supervisor's Declaration

I hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of dissertation laid down by the Presbyterian University College, Ghana.

Supervisor's Signature:…………………………. Date:……………..………...

Name: Richard Amfo-Otu (PhD)

ABSTRACT

Waste collection and disposal has been a challenge for many metropolitan and municipal assemblies in Ghana including the Techiman Municipal Assembly. The study focused on the characteristics (the physical composition and the per capita waste generated per each household) of solid waste within the Techiman Municipal were studied over a four-week period. Questionnaire survey and interviews with key stakeholders were also carried out. The results show a solid waste composition of 69.34% organic, 18.50% plastic, 5.48% paper and cardboard, 1.78% metals, 3.45% glass, 1.45% leather and Textiles. The average per capita waste generated was 0.71 kg/ca/day. The data generated on the quantity and composition of the waste stream in the municipality would play a positive role in solid waste management and help solid waste managers make informed decisions on waste management option. Household waste within Techiman were mainly food, yard waste, wood, paper and plastics, glass, textiles and Leather, rubber and metals. The majority of the waste generated by the households were the organic waste (69%) followed by plastic (19%). Efforts should be devoted to obtain better estimates of the generation rates and composition of non-household waste. In this study, an adequate and statistically valid characterization of household waste was made.

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And to everybody who directly or indirectly contributed to this work. I say thank you and may God richly bless you.

DEDICATION

To my wife, Mrs. Juliana Oduro Gyimah and all my children for supporting me through this course and my Siblings.

TABLE OF CONTENT

CONTENT **PAGES**

LIST OF TABLES

LIST OF FIGURES

Figures **Page**

LIST OF ABBREVIATIONS AND ACRONYMS

MSW - Municipal Solid Waste

MSWM- Municipal Solid Waste Management

TMA- Techiman Municipal Assembly

SPSS – Statistical Package for Social Sciences

CHAPTER ONE

INTRODUCTION

1.0 Background to the Study

Municipal or household wastes are often generated from several sources where variable human activities are encountered. Several studies indicate that much of the municipal solid waste from developing countries are generated from households (55–80%), followed by commercial or market areas (10–30%) with varying quantities from streets, industries, institutions among others (Nabegu, 2010; Nagabooshnam, 2011; Okot-Okumu, 2012). Waste from these sources are highly heterogeneous in nature (Valkenburg *et al.*, 2008) and have variable physical characteristics depending on their sources; notably in their composition are food waste, yard waste, wood, plastics, papers, metals, leather, rubbers, inert materials, batteries, paint containers, textiles, construction and demolishing materials and many others which would be difficult to classify.

The heterogeneity of the generated waste is a major setback in its utilization as a raw material. There is therefore the need for fractionation of the waste before they can be subjected to any meaningful treatment process. Source sorting and separation of waste is one of the traditional fractionation methods and fundamental steps in an integrated waste management system with the potential to provide data on waste generation and the quality of the fractions. However, the success of any designed waste segregation system will depend largely on the active participation of the waste generators in the various communities and how they comply with the principles of sorting and separation of the waste. Generation of waste from commercial outfits in Ghana is difficult to quantify on per capita basis since all the generators are not known. Assessment is mostly done on bulk of the waste collected. The composition may depend on the business activities; hence the household is the right source to obtain correct data for managing waste.

Waste management being a major environmental and health challenge around the world today is more pronounced in developing countries (Ejaro & Jiya, 2013). Reliable waste management data provides an all-inclusive resource for a comprehensive, critical and informative evaluation of waste management options in all waste management programmes (Chang & Davila, 2008; Hancs *et al*., 2011; Qdais *et al*., 1997). Unfortunately, these required fundamental statistics are lacking in many developing countries (Buenrostro *et al*., 2001) and where they are available, they are inconsistent because they come from many sources which cannot be validated and are sometimes based on assumptions but not scientific measurements (Couth & Trois, 2011; IPCC, 2006; Ranjith, 2012). The net effect of these misleading data are often a source of confusion and doubt in the minds of investors who may want to do business or services in the waste management sector. Ghana is no exception of this data deficit problem and Techiman is not an exception.

Data on municipal solid waste generation and composition are available in only few selected cities, most of which are over a decade old. A nationwide-waste statistic in general is lacking; field study on household waste composition and generation has not been conducted holistically in the sixteen regions of the country, hence lack of reliable data which could provide information to the local and national waste management authorities for decision making. Waste collection is a merit good – a good (service) deemed so important that the law requires that it is provided for the benefit of the entire society, regardless of the interest of the market to supply it or the users' ability (or willingness) to pay for it. The key indicator here is collection coverage or the percentage of the population that has access to waste collection services – in principle, this should be 100%. The World Bank website stated that it is 'common that 30–60% of all the urban solid waste in developing countries is uncollected and less than 50% of the population is served' (World Bank, 2012)

Over the last decade, cities have made considerable efforts to increase service coverage when it comes to was collection: almost half of the reference cities, including all but two of the cities with a human development index (HDI) of 0.75 or more (or a gross national income (GNI)/cap above $1600 (Wilson et al., 2012). report coverage rates of 99–100%. The poorest performing of the middle-income cities have collection coverage in the range of 70–90% population served, while all six of the low-income reference cities show collection coverage in the range 45–60%. World Bank report (Hoornweg & Hada-Tata, 2012) average collection coverage of 86% in upper-middle, 68% in lower-middle and 41% in low-income countries. Within many cities, the central business district and affluent neighbourhoods have near 100% coverage, while low-income and illegal settlements often have none.

Identification of these valuables in the solid waste stream and their quantities has called for the development of important recovery and recycling technologies and designs for treatment to extract the exact economic benefit of these materials (Pichtel, 2005; Gawaikar & Deshpande, 2006; Ahmad & Jehad, 2012). In most developing economies, biodegradables are the highest fraction; hence the strategic development of bioconversion processes to reduce the quantities of the generated waste and consequent benefit over mere disposal. Biogas and compost production from such a renewable source offer an advantage because of its continual and sustainable supply provided their production cost are minimized.

Accra, Kumasi and other Major cities in Africa generate 80% organic waste, 10% plastic, glass and metal waste and less than 1% paper waste per day (Gawaikar & Deshpande, 2006). But most of these wastes are not properly collected and disposed of in a safe and healthy manner. This situation is not limited to Accra and Kumasi but may be applicable to all the major cities in Ghana. The Techiman as one of the big cities in Ghana has a major waste management and disposal problem which may be attributed to lack of understanding of the waste management system. Although many cities the world over use 20-50 percent of their budget in solid waste management, only 20-80 percent of the waste they produce is collected (Achankeng, 2003). The uncollected or illegally dumped waste constitutes danger to human health and is a recipe for environmental degradation. Not only are the quantities but also the variety of waste is increasing as consumption habits are fuelled by globalisation (Achankeng, 2003).

Zoomlion, a private waste management company who collects most of the waste from the communities within the Techiman has no data on waste generated and composition to help plan and design their waste management strategies which is most needed, therefore this research aimed at generating data on the waste produced in Techiman and its composition by quantifying and characterising it to help authorities to know the kind of the waste they are dealing with.

1.1 Statement of the Problem

In recent times solid waste management has become a major problem in Techiman due to the continuous urbanisation, industrialisation and lack of data. The municipal assembly is doing its best to manage solid waste with the aim of providing good quality sanitation services in order to keep the cities in the municipality clean and to enhance public health and safety. Evaluation of the resource requirement for regular collection, transportation and disposal as well as equipment for waste management requires a correct assessment of the quantity of waste generated per day from all waste generated sources especially domestic source and the characteristics of waste generated.

Techiman, as in other parts of Ghana, there is no data on waste generation and composition thus making planning difficult. All the mixed waste ends up in the landfill sites without recovering or recycling any of the valuable materials in them. The population Techiman keeps on increasing which has resulted in an increase in waste generation and therefore its management. In view of this, source specific quantification and characterization of the household waste is very much required to assess the quality and quantity of waste generated (Gawaikar & Deshpande, 2006) will lead to correct assessment of waste generated and make it easier for authorities to proper plan for solid waste management in the Techiman.

1.2 Research Objective

The main objective of the research is to identify the various characteristics solid waste for proper management of waste in the Techiman and to help make informed decisions on project planning for diversion of this waste from the final disposal sites.

The specific objectives of this research were to:

1. To find out, the physical composition of household waste within the Techiman;
2. Ascertain the per capita and quantity of the waste generation in Techiman;
3. Determine the potential for recycling of the solid waste generated in Techiman.

1.3. Research Question

1. What is the physical composition (characteristics) of household waste within the Techiman?
2. What is the per capita and quantity of the waste generation in Techiman?
3. What is the potential for recycling of the solid waste generated in Techiman?

1.4 Significance of the study

The main problem facing policy makers in the waste management sector in most urban areas is their inability to make appropriate future predictions of the amount and the composition of MSW likely to be generated over a period so as to devise the most appropriate treatment and disposal strategy. The importance of reliable information on both the quantity and composition of municipal solid waste for the effective planning of waste handling infrastructure underscore the role this study may play. With the data, hopefully, some model structure can be developed to reasonably manage Municipal Solid waste in the locality where this work is being undertaken.

1.5 Limitation of the study

Time constrain made extending this research made it impossible to other areas of the Municipality. Covid- 19, causing a halt in almost all the activities in the world therefore affecting this research. Some potential respondents wanted to be compensated for the time spent in responding to the questionnaire. This makes the administration of questionnaire quite difficult.

1.6 Scope of the study

The study area covered the Techiman Township in the Techiman Municipal of the Bone East Region. The study will focus on characteristics of solid waste generated in Techiman. The scope will also cover the composition of the waste which is generated Techiman Municipal Assembly and how this has affected wasted management in the Municipality

1.7 Organisation of the Study

This work was organized into five chapters. Chapter One contains the general introduction for the study, the scope, objectives, research questions, justification, and organization of the work. The Chapter Two deal with the review of related literature on the subject of solid waste management. Chapter Three makes up the research methods used for the study. Chapter Four presents the findings and discussion of the processed data collected from the field. Chapter Five summarises the key findings for the study and also the recommendations and the general conclusion of the study.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.0 Introduction

This chapter deals with review of relevant literature related to the subject matter understudy. Areas covered are Concept of Municipal Solid Waste and Sources, Characteristics of Solid waste, Physical Characteristic of Solid waste, Chemical Characteristics of Solid waste, Approach to Solid waste Characterisation, Municipal Solid Waste Management, Source Separation and willingness to separate waste and Quantity and Composition of Solid Waste.

2.1 The Concept of Municipal Solid Waste

There is no such thing as waste in natural systems. Everything flows in a natural cycle of use and reuse. Living organisms consume materials and eventually return them to the environment, usually in a different form for reuse (University of California, 2009). Solid waste is material, which is not in liquid form, and has no value to the person who is responsible for it, Synonyms to solid waste are terms such as "garbage", "trash", "refuse" and "rubbish (Zurbrugg, 2003). Waste is more easily recognised than defined. Something can become waste when it is no longer useful to the owner or it is used and fails to fulfil its purpose (Freduah, 2004). Municipal waste is defined by Hogan et al. (2006) as household waste as well as commercial and other waste which because of its nature and composition are similar to household waste. Household waste is waste produced within a building or self-contained part of a building used for the purpose of living or residential accommodation. Municipal waste may therefore be considered to be coming from three different sources: household, commercial and other waste but this research would be devoted to household waste because municipal waste analysis is better carried out using household waste. Municipal Solid Waste includes durable goods, non-durable goods, containers and packaging wastes, food wastes and yard trimmings, and miscellaneous inorganic wastes. This information is of great importance to the research in helping categorise the waste into the right components. Thus, municipal waste is an accumulation of rejects from households, markets, traders, shops and other commercial activities in the areas (Bichi & Amatobi, 2013).

2.2 Sources and types waste

There are two basic sources of solid wastes: non-municipal and municipal as discussed below (UCCP & California University, 2009). Non-municipal solid waste is the discarded solid material from industry, agriculture, mining, and oil and gas production. Some common items that are classified as non-municipal waste are: construction materials (roofing shingles, electrical fixtures, bricks); wastewater sludge; incinerator residues; ash; scrubber sludge; oil/gas/mining waste; railroad ties, and pesticide containers (UCCP & California University, 2009). Municipal solid waste is made up of discarded solid materials from residences, businesses, and city buildings. Other common components are: yard waste (green waste), plastics, metals, wood, glass and food waste. The composition of the municipal wastes can vary from region to region and from season to season. Food waste, which includes animal and vegetable wastes resulting from the preparation and consumption of food, is commonly known as garbage (UCCP & California University, 2009).

Some solid wastes are detrimental to the health and well-being of humans. These materials are classified as hazardous wastes. Hazardous wastes are defined as materials which are toxic, carcinogenic (cause cancer), mutagenic (cause DNA mutations), teratogenic (cause birth defects), highly flammable, Categorization of solid waste generators are linked to zoning and land use. They are; Residential, Industrial, Commercial, Institutional, Construction and demolition, Municipal services, process and Agriculture. The term solid waste is all inclusive and encompasses all the source, types of classification, composition and properties (Peavey *et al*., 1985) corrosive or explosive (University of California, 2009).

2.2.1 Industrial Waste

Industrial waste is a type of waste produced by industrial activity, such as that of factories, mills and mines. It has existed since the outset of the industrial revolution (USEPA, 2010). Much industrial waste is neither hazardous nor toxic, such as waste fibre produced by agriculture and logging. The typical waste generators are Light and heavy manufacturing, fabrication, construction sites, power and chemical plants and the type of wastes generated are packaging waste, food wastes, construction and demolition materials, hazardous wastes, ashes and special wastes (Hoornweg & Thomas, 1999).

2.2.2Construction and Demolition Debris

Uncontaminated solid waste results from the construction, remodelling, repair, demolition of utilities, structures roads and uncontaminated solid waste results from land clearing (USEPA, 1998). Construction and demolition waste includes, but is not limited to bricks, concrete and other masonry materials, soil, rock, wood (including painted, treated and coated wood and wood products), land clearing debris, wall coverings, plaster, drywall, plumbing fixtures, non-asbestos insulation, roofing shingles and other roof coverings, asphaltic pavement, glass, plastics that are not sealed in a manner that conceals other wastes, empty containers which are ten gallons or less in size and having no more than one inch of residue remaining on the bottom, electrical wiring and components containing no hazardous liquids (NYS Dept. of Environmental Conservation, 2010).

2.2.3 Institutional Waste

The waste generators in this category are Schools, hospitals, prisons, government centres, the wastes produced here are paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes (Hoornweg & Thomas, 1999).

2.2.4 Residential (Household) and Commercial Wastes

Usually residential waste consist of food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous wastes) and these are generated by single and multifamily dwellings whiles commercial wastes consist of paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes are generated by Stores, hotels, restaurants, markets, office buildings, etc (Hoornweg & Thomas, 1999).

2.2.5 Municipal Service Waste

Services such as street cleaning, landscaping, parks and beaches maintenance, upkeep of other recreational areas and water and wastewater treatment plants generate wastes such as street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas and sludge (Hoornweg & Thomas, 1999).

2.2.6 Process Waste

Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing are responsible for the generation of the following solid waste; industrial process wastes, scrap materials, off-specification products, slay, tailings (Hoornweg & Thomas, 1999).

2.2.7 Agricultural Waste

The cultivation of crops, tending of orchards, vineyards, dairies, feedlots and the running of farms in general contributes to the solid waste stream in the form of spoiled food wastes, agricultural wastes such as dung, animal carcass, husks of corn etc., hazardous wastes (e.g., pesticides) (Hoornweg & Thomas, 1999).

2.3 Characteristics of Solid Waste

Reliable waste management data provides an all-inclusive resource for a comprehensive, critical and informative evaluation of waste management options in all waste management programmes (Chang & Davila, 2008; Hancs *et al*., 2011; Qdais *et al*., 1997). Unfortunately, these required fundamental statistics are lacking in many developing countries (Buenrostro *et al*., 2001) and where they are available, they are inconsistent because they come from many sources which cannot be validated and are sometimes based on assumptions but not scientific measurements (Couth & Trois, 2011; IPCC, 2006; Ranjith, 2012). The net effect of these misleading data are often a source of confusion and doubt in the minds of investors who may want to do business or services in the waste management sector. Ghana is no exception of this data deficit problem. Data on municipal solid waste generation and composition are available in only few selected cities, most of which are over a decade old. A nationwide waste statistic in general is lacking; field study on household waste composition and generation has not been conducted holistically in the ten regions of the country, hence lack of reliable data which could provide information to the local and national waste management authorities for decision making. Human and resource capacity to carry out these studies which involves the collection of informative data on waste composition and quantity that is hauled to treatment sites or recycling centers or disposal sites is lacking (Kanat, 2010; Pichtel, 2005).

Municipal or household wastes are often generated from several sources where variable human activities are encountered. Several studies indicate that much of the municipal solid waste from developing countries are generated from households (55–80%), followed by commercial or market areas (10–30%) with varying quantities from streets, industries, institutions among others (Nabegu, 2010; Nagabooshnam, 2011; Okot-Okumu, 2012). Waste from these sources are highly heterogeneous in nature (Valkenburg *et al*., 2008) and have variable physical characteristics depending on their sources; notably in their composition are food waste, yard waste, wood, plastics, papers, metals, leather, rubbers, inert materials, batteries, paint containers, textiles, construction and demolishing materials and many others which would be difficult to classify. The heterogeneity of the generated waste is a major setback in its utilization as a raw material. There is therefore the need for fractionation of the waste before they can be subjected to any meaningful treatment process. Source sorting and separation of waste is one of the traditional fractionation methods and fundamental steps in an integrated waste management system with the potential to provide data on waste generation and the quality of the fractions.

However, the success of any designed waste segregation system will depend largely on the active participation of the waste generators in the various communities and how they comply with the principles of sorting and separation of the waste. Generation of waste from commercial outfits in Ghana is difficult to quantify on per capita basis since all the generators are not known. Assessment is mostly done on bulk of the waste collected. The composition may depend on the business activities; hence the household is the right source to obtain correct data for managing waste. The characteristics and quantity of the solid waste generated in a region is not only a function of the living standard and lifestyle of the region's inhabitants, but also of the abundance and type of the region's natural resources (Anon, 2005). To ensure the amount of waste that ends up at the final disposal site is minimum, and to determine the most sustainable waste management strategy, it is first necessary to identify the nature and composition of the city's urban waste (Gomez *et al*., 2009).

2.3.1 Quantity

There are very significant differences in quantity depending on many factors, such as: The size of the population living in the area; The source of the waste generated (commercial, residential, touristic, industrial, etc.); The number of public or private gardens; Whether the families living in the area are predominantly poor or rich; and The season of the year, and the cultural aspects of the area affecting the composition, quantity and peak-days of the solid waste produced (Medcities Network, 2003).

2.3.2 Composition

Knowing the composition of waste is important for deciding the treatment systems. Numerous factors have an influence on the composition and characteristics of solid waste (Medcities Network, 2003).

The area: residential, commercial, etc. The season and weather (differences in the amount of population during the year, tourist places).

The economic level (differences between high and low-income areas). High income areas usually produce more inorganic materials such as plastics and paper, while low-income areas produce relatively more organic waste.

The cultural aspects of the zone,

Urban waste is normally divided into three big groups (Medcities Network, 2003). Inert waste includes metals, glass, soil, slags and ashes. Putrescible are also made up of food waste, yard trimmings. The last but not the lease are the Combustibles waste which includes paper, cardboard, plastics, wood, tires, leather and textiles.

2.4Physical Characteristics of Solid Waste

There are four characteristics that are absolutely necessary when setting up the treatment/disposal system (Medcities Network, 2003).Moisture content of solid waste is the weight loss (expressed in percentage) when a sample of solid waste is dried to a constant weight at a temperature of 100 °c -105 °c . The percentage of moisture contained in a solid waste sample can be calculated on a dry or wet basis. Moisture content has a great influence on the heat of combustion as well as decomposition of organic matter. It depends on the organic content, as well as the source of waste and the weather (Medcities Network, 2003).

This is a physical property and a measure of the energy released when waste is burnt. A heating value of about 11.6x106 J/Kg is needed to sustain combustion (Lee, 2005). Waste with lower heat value can be burnt, but it will not maintain adequate temperatures without addition of auxiliary fuel. Calorific values increase when there is more paper, card board and plastics because they have a high heating value, and decreases when there is a high content of organic matter, and therefore of moisture (Medcities Network, 2003; Fobi *et al*., 2001)

Density varies depending on the composition of waste. It is normally higher in residential areas where organic matter makes up a large proportion of the waste, and lower in commercial districts where waste contains more paper and cardboard. It also varies with the economic level, being less dense in high income areas where there is a higher percentage of packaging waste; the density of waste may also change during waste transportation (Medcities Network, 2003; Fobi *et al*., 2001).

Therefore, it is essential to indicate where density has been measured (at the point of generation, in the container, or at the disposal site), usually the density increases by 20%-25% during transport in a non-compaction truck. The density is important for the selection of waste collection equipment. For example, compactor trucks, which press the waste together, are most effective if the waste has a low density, for example, if it has a high proportion of paper, cardboard and plastics (Medcities Network, 2003; Fobi *et al*., 2001).

Information on the chemical configuration of solid wastes is important in appraising, processing and recovery alternatives. In addition, the analysis helps in adopting and utilizing proper equipment and techniques for collection and transportation. The chemical characteristics like pH, chemical constituents like carbon content, nitrogen, phosphorus, potassium, micronutrients etc. are to be analysed for the selection of proper waste management technology (Yousof & Rahman, 2007). It is the ratio of the weight of carbon to the weight of nitrogen present in the waste. It is an important parameter in composting processes and should always be between 20 and 35. Lower ratios indicate the loss of nitrogen as ammonia gas and render composting impractical (Medcities Network, 2003; Fobi *et al*., 2001).

2.6 Solid Waste Characterization

Yu and Maclaren (1995) described waste characterization as the examination of the composition of waste stream by material types (such as paper, glass, metal, etc.) or by product types (such as cans, magazines, glass containers, etc.). Knowledge of the quantity and composition of municipal solid waste is important for the planning and management of municipal solid wastes (Fobil *et al*., 2001). Such knowledge is important to direct waste policy and to plan for waste management options such as composting, recycling, recovery, transportation and disposal of solid wastes. In order to describe waste, two concepts are required: waste stream amounts and the composition of the waste streams (Moore *et al*., 1998). Residential waste can be segregated into eight (8) components based on intrinsic material properties (Fobil, 2001). Solid waste is generally composed of organic, paper, glass, plastic, metal, textile, residues or inert wastes as well as miscellaneous or other wastes (Government of Tamil Nadu, Department of Environment, 2007).

Organic waste or biodegradable includes largely putrescible components such as food materials, leaves, garden trimmings, grasses and other easily decomposable waste. Paper waste includes newsprint paper, scrap paper, and cardboard, waste paper, paper products and packaging materials (Ontario Ministry of environment, 2010). Glass waste consists of broken glassware, used and/or broken bottles, broken light bulbs and other glass products (Waste Watch, 2011). Plastic wastes comprise waste plastic products such as polyethylene products and other types of plastics used as packaging material (wienaah, 2007). Metal waste includes tin cans, both ferrous and non-ferrous scrap metal (Zero Waste America, 2010).

2.7 Approaches to Urban Solid Waste Characterization

There are three methods for determining the composition of urban solid waste streams (Brunner & Ernst, 1986): Waste Product Analysis; Market Product Analysis; and Direct Sampling and Analysis an outline of each of these methods, and an indication of when they should be used, is provided in this section.

2.7.1 Waste Product Analysis

In this method, the products of treatment processes such as incinerator bottom ash and fly ash are analysed for various chemical elements. From knowledge of the partition coefficients for these elements through the process, it is possible to infer the chemical composition of the raw waste stream (Brunner & Ernst, 1986). It is necessary to have a waste processing facility available, and to know the details of materials balances through it in order to apply this technique. Development of the technique is on-going (Brunner & Schackermayer, 1994), and it offers a reliable and cost-effective alternative to conventional direct methods where a suitable treatment process is available.

2.7.2 Market Product Analysis

In this approach, a materials balance is undertaken for a material in a region to derive the quantity of that material that would be expected to report to the waste stream (Brunner & Ernst, 1986). Extensive studies by Franklin Associates have been undertaken in the USA; the method is quick and can be undertaken at little cost where the data is available. Normally, this is limited to regions as defined by country borders, where the data is collected by a Statistics Bureau. This method is also likely to be of use for materials which make up a small percentage of the waste stream. For instance, determining the amount of dry cell batteries in direct sampling and analysis studies is either very unreliable or very expensive. Market product analysis, if possible at a regional level would give a quicker, cheaper and more reliable result (Moore *et al*., 1998).

2.7.3 Direct Waste Sampling and Analysis

In this conventional approach, sampling from a particular waste stream in a region is undertaken before manually sorting it into its material types. Subsequently, additional physical and chemical analysis such as moisture content, density under standard pressures, specific energy (calorific value) and elemental analysis may be undertaken (Moore *et al*., 1998).

2.7.4 Waste Quantification Methods

According to the USEPA, (1999), there are two basic approaches to estimating quantities of municipal solid waste. The first method, which is site-specific, involves sampling, sorting, and weighing the individual components of the waste stream.

This method is useful in defining a local waste stream, especially if large numbers of samples are taken over several seasons. The second approach to quantifying and characterizing the municipal solid waste stream utilizes a material flow approach to estimate the waste stream on a nationwide basis. The material flows methodology produces an estimate of total municipal solid waste generated, by material categories and by product categories. Sampling to quantify waste could either be done at the point of generation or at the point of disposal. However, most previous studies considered the characteristics of municipal wastes at final disposal sites (Blight et al., 1999). Because of the shift in focus of waste management strategies towards more recycling and resource recovery, determining the quantity and composition of waste at the point of generation is getting more attention (Qdais *et al*., 1997).

2.8 Municipal Solid Waste Management (MSWM)

In developing countries, solid waste management is faced with challenges including low collection coverage and irregular collection coverage and irregular collection services, insufficient refuse dumps as well as crude open dump sites, burning without air and water pollution control the breeding of flies and vermin and the handling and control of informal waste picking or scavenging activities (Ejaro & Jiya, 2013). This is very pertinent in Ghana and Techiman in particular where waste management services are largely inefficient and ineffective. According to Freduah (2004), one third to one-half of solid waste generated within most of these cities in low- and middle income countries, of which Ghana is no exception, are not collected. Generation and composition of solid waste is key in planning for the long-term solid waste management in an efficient and economical manner (Aguilar-

Virgen *et al*., 2010). Such management includes the selection and operation of equipment for the treatment and handling of waste, and the types of disposal facilities that will allow for energy generation and resource recovery.

MSW composition studies are essential to proper management of waste for a variety of reasons including a need to estimate potential materials recovery, to identify sources of component generation, to facilitate design of processing equipment, to estimate physical, chemical, and thermal properties of the wastes, and to maintain compliance with regulations (Ahmad & Jehad, 2012; Fakare *et al*., 2012). Waste management is an important element of environmental protection. Proper characterization of MSW is fundamental for the planning of municipal waste management services (Oyelola & Babatunde, 2008). Both planning and design of municipal waste management (MWM) systems require accurate prediction of solid waste generation (Dyson and Chang, 2005).

If solid waste management is to be accomplished in an efficient and orderly approach, the fundamental aspects and relationships involved must be identified and understood clearly (Puopiel, 2010). Fakare *et al*. (2012) describe MSWM as activities that deal with waste before and after it is produced, including its minimisation, transfer, storage, separation, recovery, recycling and final disposal. MSWM refers to the collection, transfer, treatment, recycling, resource recovery and disposal of solid waste in urban areas (Schubeler *et al*., 1996). MSWM incorporates the following: source separation, minimisation, collection, transfer, treatment, recovery, recycling and final disposal in an environmentally sustainable manner.

2.8.1 Municipal Waste Management Hierarchy

Waste Management Hierarchy (WMH) is a widespread element of national and regional policy and is often considered the most fundamental basis of modern MSWM practice. The hierarchy ranks waste management operations according to their environmental or energy benefits (Anon, 2005). Africa has concluded that the most sustainable way to manage waste in the majority of urban communities, like the Techiman, is to use the municipal solid waste hierarchy. It will require limited capital investment in comparison to complex and expensive waste treatment and landfill disposal systems which are typically used in developed countries. It will also require less technology and complexity (sustainable). The hierarchy is a useful policy tool for conserving resources, for dealing with landfill shortages, for minimising air and water pollution, and for protecting public health and safety (Anon, 2005).

2.8.1.1 Waste Reduction

Waste reduction is made up of all waste management methods – source reduction, recycling, and composting – that result in reduction of waste going to a landfill or combustion facility (Post, 2007). As part of the aims of this research, reducing the amount of waste that ends up in the final disposal site to efficiently manage the waste being generated and the logical starting point for the proper management of solid waste is to reduce the amounts of waste that must be managed (Hogan et al., 2006). Thus, the reduced waste quantities do not have to be collected or otherwise managed. The reduction of waste is a primary element of solid waste management hierarchies. A good number of economically developing countries have solid waste management hierarchies that list reduction of waste as the highest priority among the generic methods to manage solid waste. A current trend for minimising the amount of waste destined for final disposal is prompted, in large part, by the rapid diminishing of available landfill capacity (Hogan *et al.*, 2006).

From the definition above the three components of waste reduction are recycling, composting, and source reduction. Significant waste reduction could be accomplished through source reduction with increased backyard composting (Post, 2007). This suggestion is significant to the research as composting would result in diverting greater quantities of waste from the final disposal site since more than 50% of waste generated in developing countries in Africa like Ghana is organic (Mancini et al., 2007). Previous studies of urban waste streams have indicated that much can be recovered, reused and recycled from the waste. MSW has 40% recyclable, 29% compostable, 12% potentially compostable and 19% others (Kazimbaya-Senkwe & Mwale, 2001).

2.8.1.2 Re-use and Recovery

Achankeng (2003), has shown that there are a few formal systems of material recovery in Africa; however, there is a wide reuse of plastics, bottles, paper, cardboard, cans for domestic purposes. The practice is highly common among the poor in the city. The element of processing and recovery includes all the technology, equipment, and facilities used both to improve the efficiency of other functional elements and to recover usable materials, conversion products or energy from solid wastes (Puopiel, 2010). Some of the wastes are recovered through recycling and composting, and others converted into energy in the form of electricity, energy pellets or steam (Chowdhury, 2009). Recycling can divert a major portion of the waste stream from disposal site and recycling should be a fundamental part of the integrated solid waste management.

Reuse and recovery of the inorganic components of the waste stream is an important aspect of waste management but special attention is given to organic (biodegradable) residues because in majority of developing countries, these residues constitute at least 50% of the waste (by weight). Many authors and researchers suggest compositing could be a very viable recovery alternative (Achankeng, 2003). The resource recovery aspect regarding the biodegradable component is in threefold: used in agriculture as a soil amendment through composting, its energy content can be recovered and the organic content can be hydrolysed (Anon, 2005). The disposal site is the final ending place of all municipal solid wastes whether they are residential or any other wastes collected.

2.9 Quantity and Composition of Municipal Solid Waste

The composition of waste varies according to changes in consumer patterns and economic growth rates and depends upon standard of living, season of the year, day of the week, population habits and the geographical site of human settlement (AguilarVirgen *et al.*, 2010). This makes managing solid waste one of the most essential services. Managing waste is unsuccessful due to rapid urbanization together with changes in the waste quantity and composition which makes it difficult to adopt for waste management system which may be successful at other places. Thus, data on waste characterization cannot be used to make decision for any different location. It is therefore necessary to quantify and characterize the MSW of the TMA which is the subject of present investigation. The importance of the knowledge on quantity and composition survey on waste has an essential role in determining the dimensions of the key elements in solid waste management. These elements include method and crew size, type of storage, method of disposal, and type and frequency of collection, degree of resource recovery. The determinations help in the evaluation of present conditions, as well as predicting future trends of waste. One of the factors that contribute to the poor management of solid waste is the lack of consistent data on the composition and quantity of solid waste being produced. In order to implement an effective solid waste management program, quantitative data on the composition of waste being generated must be obtained (Ejaro & Jiya, 2013). A community needs to know how much solid waste is being generated and how fast the waste is generated so the current and future needs in budgeting, disposal facilities operation and processing can be assessed. The data on the characteristics can be used in designing processing equipment and disposal facilities. In the case of composting, information on the biodegradable fraction of the solid waste becomes important (Guangyu, 1999).

2.9.1 Quantity of Municipal Solid Waste

There are several methods available for determining the quantity of wastes that require disposal (Anon, 2005); however, accuracy of the results depends on the method followed. These methods include weighing each vehicle and its load of wastes as it enters the disposal site (the approach involves the use of a weighing scale sufficiently large to accommodate vehicles of all sizes), weighing few randomly selected incoming vehicles is an alternative and the third and final method which is the least accurate involves the collection of the following data: 1) average density of waste, 2) number of loads collected per day, and 3) average volume per load. A number of methods have been used to approximate the volume of waste generated in a given locality. These are the specific weight method, specific refuse volume and bulk density and of the three, the specific weight method gives the most reliable information on amounts of waste that can be obtained.

Waste characteristics and per capita generation rates are two important parameters in designing any effective solid waste management program. Cost of collection, treatment and disposal are rising year by year and often represent a high proportion of municipal budget therefore knowledge of these parameters help in improving the operations. These rises are as a result of the significant and disturbing changes in the characteristics and composition of wastes (Gilbertson, 1969). Normally developed countries produce more solid waste per capita (0.7 – 1.8 kg/d) compared to middle income (0.5 – 0.9 kg/d) and low-income countries (0.3 – 0.6 kg/d) (Anon, 1999). All communities, people produce domestic waste and urbanization and industrial development has rapidly increased the range and diversity, as well as quantity of wastes that require collection and disposal (Rushbrook & Pugh, 1999). In order to plan the development of a waste management facility therefore, the waste manager requires information about the quantities and types of waste that are generated within and around the municipality which may be included in the waste management plan and in addition, probable increases in quantities of each waste stream should be estimated in order to plan for future provision of facilities. Population growth is one of the major causes of increase in solid waste volume in many cities and higher living standard results in higher solid waste generation rate and change in waste characteristics (Hoornweg *et al*., 1999).

It is a serious problem in cities of developing countries, where about 0.76 million tons or approximately 2.7million cubic meters of municipal solid waste is produced per day. The presence of degradable organic compounds, moisture contents, particle size and composition, density and compressibility are some of the solid waste properties playing major role in degradation rate in dumpsites. For high degree of accuracy sampling must be done at the generation source where a modest program in which special sampling areas are selected and defined. In setting up areas, care is taken all socioeconomic groups are represented. The sub metro was stratified into first, second- and third-class residents so as to be representation of the whole sub metro. Each participating household in the sampling area was provided with a container of some sort, a plastic bag, in which the day's output of wastes is placed. The per capita generation and total waste generation can then be determined through the sampling which is sufficiently accurate to meet most needs, whether they are for facility and equipment design or for waste management planning. Both planning and design of municipal waste management systems require accurate prediction of solid waste generation and the lack of complete historical records of solid waste quantity and quality due to insufficient budget and unavailable managing capacity has resulted in a situation that makes the long-term system planning and /or short-term expansion programs intangible (Dyson & Chang, 2005).

Globally, the per capita amounts of municipal solid waste generated on a daily basis varies significantly and going to say economic standing is one primary determinant of how much solid waste a city produces (Zurbrugg, 2002). Estimates of MSW quantities are usually based on the amount of waste generated per person per day, kg/person and that in general weight is used for measurement of solid waste quantities. Also, in municipal environmental management, it is very important to be able to predict the amount of solid wastes generated. This information is needed not only to make environmental standards and assess environmental impacts of the wastes, but also to evaluate the potential quantities of solid waste generated and collected which are of critical importance in selecting specific equipment and in designing waste collection routes, materials recovery facilities and disposal facilities. The data can also be used for budget preparation and operation optimization as well as provide essential foundation for environmental economy programs and can greatly influence final environmental management target and strategy.

2.9.2 Composition of Municipal Solid Waste

Waste composition analyses are widely used in order to investigate the waste generated in a specific area, and also to evaluate and compare different waste collection systems. In order to make evaluations and comparisons relevant and just, evidence-based knowledge of the investigated system is required. It is also necessary to ensure that samples used for the waste composition analyses are representative of the population as a whole (Bernstad *et al*., 2012). Full knowledge of the composition of the wastes is an essential element in: 1) the selection of the type of storage and transport most appropriate to a given situation, 2) the determination of the potential for resource recovery, 3) the choice of an appropriate method of disposal, and 4) the determination of the environmental impact exerted by the wastes if they are improperly managed (Anon, 2005).

Composition is tending to vary and becoming an important factor which determines further process and end-pipe treatment and the composition determines different waste management processes. Some waste management systems are flexible and can be applied to treat solid waste with any composition mixed or not. No pre-treatment reduces the income from recyclable materials. Pre-treatment is crucial (by separating into the various compositions hence the recyclable materials are identified and separated), in recovering potential valuable products to be reused for the market (Kui, 2007). Therefore, to get most from waste stream and decrease the chances of residuals from ending up in the landfill, there is the need to know what is in the waste by carrying out proper and efficient separation at source of generation. One of the most accurate approaches for characterising waste composition consists of collecting waste at its generation source and directly sorting it out into types of materials (Bernache-Perez *et al*., 2001).

Oyelola and Babatunde (2008), say the main constituents of solid wastes are similar throughout the world but the proportions vary widely from country to country and even within a city, because the variations are very much related to income level. Waste generated in developing countries contains large percentage of organic materials, more often than not three times higher than that of industrialized countries (Oyelola & Babatunde, 2008). The waste is also denser and more humid, due to the prevalent consumption of fresh fruits and vegetables, as well as unpackaged food. However, first world residents consume more processed food and packaged in cans, bottles, jars and plastic containers than those in the developing world. As a result, waste generated in the former contains more packaging materials than in that of the latter. Although countries sometimes use different categories for the physical characterization of solid waste, the high content of biodegradable matter and inert material, results in high waste density (weight to volume ratio) and high moisture content (Zurbrugg, 2002). These physical characteristics significantly influence the feasibility of certain treatment options. Vehicles and systems working well with low density wastes such as in industrialised countries will not be suitable or reliable under such conditions. In addition to the added weight, abrasiveness of the inert material such as sand and stones, and the corrosiveness caused by the high-water content, may cause fast deterioration of equipment.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This Chapter looks at how data was gathered for the research, the research method employed in the study, the data collection techniques used and the target population, the sample size and the sampling technique and data analysis method used.

3.1 Profile of the Study Area

The population of the Techiman Municipality, according to the 2010 Population and Housing Census, is 147,788 with 52,137 household, representing 6.4 percent of the region's total population. Males constitute 48.5 percent and females represent 51.5 percent. A greater percentage of the population (64.5%) live in urban areas as compared with 35.5 percent in the rural areas. The Municipality has a sex ratio of 94.5. The population of the Municipality is youthful (13.6%) of the 0-4 age group, depicting a broad base population pyramid which tapers off with a small number of the 70 plus years (3.0%). The total age dependency ratio for the Municipality is 75.2, the age dependency ratio for males is higher (78.9) than that of females (71.9).

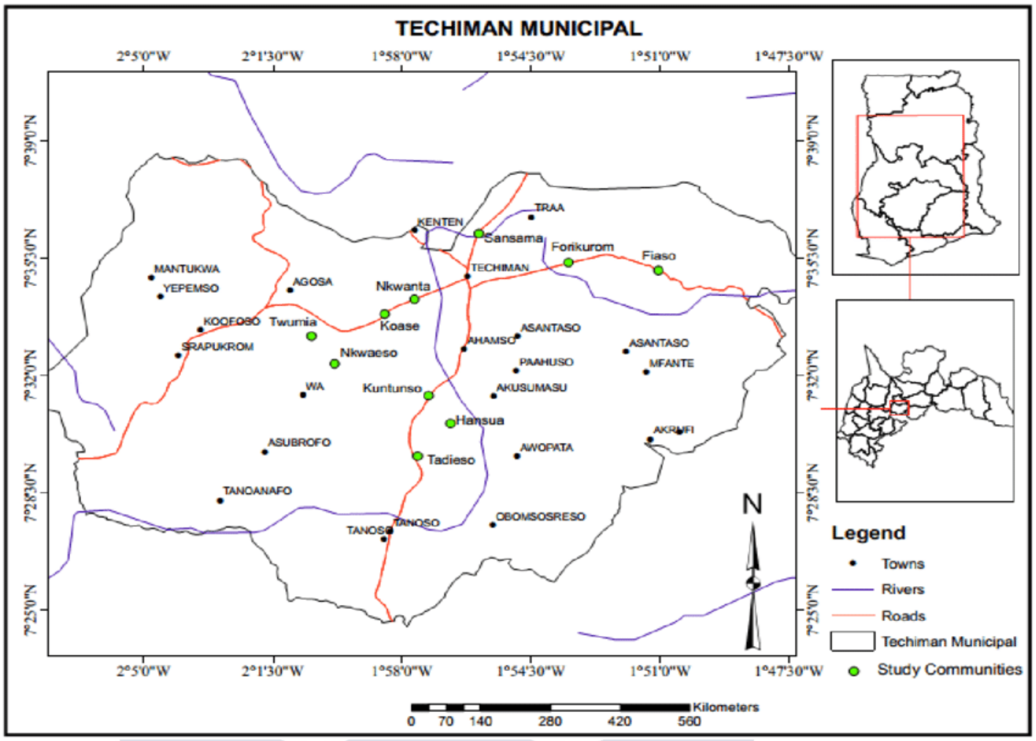

Figure 1: Map of Techiman Municipal showing the various communities

Source*:* Geographic and Information Services, University of Ghana

3.2 Research Design

The research approach that was used for this study is the case study approach. The case study is one of the approaches for research in the social sciences (Yin, 2003). In general, the case study approach is used when the researcher seeks to find the "how" and "why" of a real-life phenomenon (Yin, 2003). In this case to identify the various characteristics of the solid waste that is generated in Techiman Municipal. The case study was preferred here, because it answers questions that deal with operational links needing to be traced over time rather than mere frequencies or incidence (Yin, 2003) as happens in the other approaches.

3.3 Study Population

The study population included both males and females above 18 years of age who are staying in Techiman. This is because they are the age group relevant to this research.

3.4. Data sources

The sources of data for this study was from primary and secondary sources. The primary data was obtained from the field through various data collection techniques, including questionnaire survey, interviews, and field observation. The secondary data was also obtained from annual waste management reports from the Environmental and Health Sanitation Department of Techiman Municipal Assembly and reports on waste management from other private companies and it's financing in the Town.

3.4.1 Primary Data Collection

Primary data was collected through field survey, face-to-face interviews and Questionnaire survey. This helped us the get first-hand information from respondents during the research.

3.4.1.1 Field Survey

Field observation involved visiting randomly selected households to inform occupants about the survey work and to communicate the importance of the respondent's participation and how the respondents was involved. The field survey helped receive feedback on their willingness to participate in the programme. Participants was assured of the confidentiality of their responses. The suitability of the study area households as points for sorting at source was also assessed.

3.4.1.2 Face-to-face Interviews

Face-to-face interviews was conducted amongst a cross-section of persons working in the administration of the Techiman Municipal Assembly, Zoomlion Ghana Limited (District Manager and Assistant and some field supervisors) and Assemblymen in the study area. The face-to-face interviews at the Techiman Municipal Assembly was focused on the various stakeholders involved in waste management, data on the generation and composition of solid waste from the Municipality, collection and disposal Municipality, final disposal site and the availability of waste management logistics. At the Environmental and Sanitation Unit, information was sought on the available data on quantity of waste generation and its composition, solid waste management strategies in the Municipality and whether or not there is an engineered landfill site.

At the offices of the Zoomlion Ghana Limited the quantity of solid waste generated and it composition (based on the number of trips without weighing), method of solid waste collection, provision of dustbins and skips, adequacy and frequency of collection, availability of an engineered landfill site, and the availability of waste management equipment and logistics. Within the communities, the assembly men of the selected areas like Anyimana, Kenten, Wiaso, New krobo, Brigade, Diasempa and other areas introduced the research team and the scope of the research to the communities. From the assembly men also, the face to face interviews focuses on

Solid waste generation and composition, availability of disposal site for households, adequacy of community dustbins and skips, regularity of collection of waste, problems and challenges of waste management in the communities and methods of managing the waste.

3.4.1.3 Questionnaire Survey

Administration of questionnaires and direct field measurements, was two approaches was adopted in obtaining data relevant for the research. A well-structured questionnaire was developed and administered randomly to sample households for collection of relevant data relating to the research work. The household waste characterization survey questionnaire looked at solid waste management and the separation of waste at the household level. Also, information about each respondent, the household socioeconomic status, household waste disposal methods, knowledge on waste separation, knowledge on waste management and knowledge on the composition of their waste will be sought for in the questionnaire. The content of the questionnaire was based on five of the twelve factors influencing Separation of municipal solid waste in developing countries identified by Troschinetz (2005). The factors were waste collection and segregation, household economics, household education, local recycled-material market and Municipal solid waste management administration. The target groups for the questionnaire were women because they are the persons often in charge of cleaning, gathering and final disposal of household waste in the home.

3.4.2 Secondary Data Sources

Books, articles, newspapers, journals and internet sources are some of the secondary data that were used. Some other secondary data were also obtained from the

Techiman Municipal Assembly. The data includes: the assemblies waste management strategy, basic day to day information on waste generated and their composition, time taken in collecting waste to final disposal sites, implementing agencies within the assembly, collaborators and indicative cost.

3.6 Sampling

3.6.1 Sample frame and sample size determination

According to the 2010 population census, the population of Techiman was 147,788. Growth rate of 2.7, the projected population in 2013 was 182,810. Using also the household size of 7.9, the total number of households was 52,137. This represented the sample frame for the questionnaire survey. The sample size was 98 households.

From this, a total of 397 samples was needed as a representative sample. However, a total of 1393 samples was collected within the period of the survey which was far above what was statistically needed. This high sample size helped limit the margin of error and also close in with the mean, hence better accuracy. Also, following the procedure outlined by Nordtest (1995), household numbers of 50- 250 would be representative enough to undertake the survey. For the face-face interviews, 10 Assembly men were interviewed. One person each from the Waste Management Department/Zoomlion and Finance Department will also be interviewed.

3.6.2 Sampling of Household

Sampling of households was carried out randomly within the stratified classes of the three residential areas. The first-class residential areas are made up of single detached houses which are a well-planned community with serial numbers so households were sampled by selecting every Kth house starting from the direction of the first point of contact with any house in the selected area. The second-class residential area was made up of high-rise buildings or multiple occupancy properties and these buildings were given numbers and then randomly selected. The households in the randomly selected buildings were later given numbers to randomly select the households to be used in the research work. Because most of the third-class residential areas are made up of structures or housed in unplanned and squatter settlements winding movement was used to select every Kth house starting from direction of the first point of contact with any house in the area. After selecting the number of households for the research, a respondent was interviewed and the questionnaire given to each Kth household.

3.7.1 Collection of household data

The designed questionnaires were given to households to fill and those who could not fill on their own, were assisted to fill. Data obtained were on socio-economic standing, demographics, educational level, and knowledge on waste management among others. Data was also collected through observations and direct field data collection using a sheet to record waste weighed after sorting into various components.

3.7.2 Education of Households on the Survey

The randomly selected households were educated on sorting and separation of waste. This was done on one-on –one basis after the questionnaire administration. This was done for a period of two days. During the period, a one-way separation method was explained to them as to which materials were to be sorted into which colour of polythene bags that were provided. Also, the importance of the survey was explained to the respondents to encourage their full participation. Households were also allowed to ask questions and they were also tested for their understanding on the sorting and separation activities by asking them questions.

3.7.3 Distribution of Polythene Bags and Waste Bins

Two polythene bags were supplied to each of the randomly sampled households for the separation of their solid waste. Each household was given a blue polythene bag for biodegradables (BIO) and a black polythene bag for non-biodegradables (NON-BIO). In the case of the third-class residents, a waste bin each was distributed to them to keep the polythene in since they did not have proper waste bins. Collection of waste from Households and further sorting Waste from the households was collected three (3) times in a week (Mondays, Wednesday and Saturdays) over a period of four (4) weeks. The waste was sorted and separated in the two polythene bags. Biodegradables (food, yard and wood waste) was sorted into the blue polythene bag while the non-degradable waste (plastics, paper and cardboard, metal, glass, leather and rubber, inert and all other waste) was sorted into the black polythene bag. Further sorting and separation were carried out into various physical components and weighed and recorded.

3.8WasteQuantification

The per capita generation of the waste and the total waste generation were deduced from the waste components separated. The separated wastes were collected, weighed and recorded. The waste was then sorted further and separated into various components and reweighed. The per capita generation was determined as per the mixed and also the separated components using the formula:

$$\text{Cap waste (kg/day)} = \frac{\sum \text{HH Waste} / \text{HH}}{\text{HM}} \qquad \text{(UNESCAP, 2010)}$$

HH waste: Average waste generation of one household (kg/day)

HH: Number of households surveyed

HM: Average number of household members

The total Generation rate was obtained by multiplying the per capita generation by the total population.

3.9 Physical Composition of MSW Analysis

MSW from the households were segregated into the following compositions and analysed by weigh, as well as the percentage composition described by the ASTM (2003) method. By modification the following were adopted: Blue polythene bags for Biodegradables; Food waste, yard waste and wood Black polythene bags for non-biodegradables, except paper; Plastics and Metals; Papers (packaging/cardboard/office print/sheet/newsprint and tissue/diaper); Leather and Rubber; Textiles; Inert (sand, ceramic, rock, ash); and Miscellaneous (other materials which could not fit in the above).

3.10 Determination of Moisture Content

Following the method of Bryant *et al.* (2010), the moisture content of the biodegradable (food waste and yard trimmings) of the household waste was determined by heating the waste in an oven to a temperature of 10-[5 °C for 12 hr until it stabilized. The difference between the weight before oven drying and after oven drying gave the moisture content of the waste. The moisture content of the biodegradables of all the various classes was determined separately. The moisture content was measured immediately after sample collection to prevent drying out of the waste.

Determination of Moisture content:

The moisture content as a percentage was determined from the formula:

$$\text{Moisture content } (\%) = \frac{(a-b)}{a} \times 100$$

Where a = initial weight of sample as delivered

b = weight of sample after drying.

Analysis to establish the above was based on a 100-kg sample of waste (Kazimbaya Senkwe and Mwale, 2001 and Dyson and Chang, 2005). That is to determine the combined moisture content of the food waste and yard waste, the total dry mass of both was subtracted from the 100 kg sample.

3.11 Data Processing and Analysis

Since the research design was mixed approach, there was accommodation for qualitative and quantitative analyses. Qualitative information from interviews and observation will be transcribed and coded into themes. The qualitative data was not further analysed but rather they was serve as basis for validating the responses obtained quantitatively.

The researcher placed more emphasis on the quantitative data analysis. Quantitatively, responses from the pupils and key informants was coded and keyed into SPSS. Various statistical processes and measurements was then conducted in order to reveal the research findings. The analysed data was displayed in charts, tables, and other descriptive analyses.

3.12 Ethical consideration

Ethical consideration is a very important component of any research, this ensures reliability of data. Upon arrival, all chosen respondents were taken through the purpose, scope and objectives of the study. They were assured that their names and contact information was not going to be published and the study was going to be used for academic purposes only without any monetary benefits. The participants that obliged to partake in the study were made to understand the questionnaires and interviews posed to them. The researcher took time to explain into detail all information that needs clarification. They were also assured that they could opt-out of the research at any time without any reason.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.0 Introduction

In this chapter, the data collected from respondents was subjected to statistical analysis. The analysis of the data was based on the responses given to the questionnaires and the results obtained are presented in the form of tables and chats with the frequency counts and percentages where appropriate. The data have been divided into three main headings comprising of socio-demographic data, data on knowledge of respondents on the waste separation and recycling and characteristics of the waste generated in the study area.

4.1 Socio-Demographic Characteristics

From Table 1, it can be seen that the age of respondents falls between the categories of 30 to 40 years forming 41 percent of the sample size. A few of the respondents were also in the age category of 18 to 30 years, and 40 to 60 years with the percentages of 28% and 30% respectively. This indicates that majority of the people living within the sampled area are in the ages of 30 to 60 years. This means that these age groups are the once who generate most of the most.

Table 1: Age of respondents

Ages	Frequency	Percent
18-30	28	28.57
30-40	40	40.82
40-60	30	30.61
Total	**98**	**100.0**

Source: Field Survey, 2020

With respect to the gender of the 98 respondents, 64% were females and 36% males. From table 2, the female are more than the males, this is because the females are those who does most of the cleaning in the house.

Table 2: Gender of respondents

	Frequency	Percent
Male	35	35.71
Female	63	64.29
Total	98	100.0

Source: Field Survey, 2020

For that of level of education, 18.36% indicated their level of education to be at the tertiary level. Those with secondary level of education were 20.41%. Also 40% indicated to have gotten basic school education and 20% also have other forms of education. This is presented in the Table Below.

Table 3: Educational level of respondents

Education level	Frequency	Percent
Basic	40	40.81
Secondary	20	20.41
Tertiary	18	18.36
Others	20	20.41
Total	98	100.0

Source: Field Survey, 2020

Employment status

From Table 4, majority of the respondents (44%) were found at the informal. 37% found at the formal sector and 18% not doing any form of work.

Table 4: Respondent's employment status

Employment Status	Percentage
Formal	37.8
Informal	43.9
Unemployed	18.4
Total	100.0

Source: Field Survey, 2020

Marital Status

With respect to marital status, 55% of the sample size of 98 are married as shown in Table 5. Those singles were a percentage of 40 and also 5% of the respondents indicated being separated. This shows that majority of the respondents are married as indicated on the Table 5.

Table 5: Respondents Marital Status

Marital Status	**Percentage**
Single	40.0
Married	55.0
Separated	5.0
Total	100.0

Source: Field Survey, 2020

Source of Knowledge on Waste Separation

On waste separation activities, 61% had heard or seen waste separation activities while 39% had neither heard nor seen any separation activities. On their source of knowledge on waste separation, 22% had their knowledge from newspapers, 10% from Television, 6% from radio, 8.77 from both radio and Television, 5.26 from both newspapers, Television and radio and lastly 48% from other sources. Most (52. %) of this knowledge was from newspapers, television news and radio (Table 6)

Table 6:Respondents Source of Knowledge

Source of Knowledge	Percentage
News Paper	22
Television	10
Radio	5.9
Both Radio and Tv News	8.8
News Paper, Tv news and Radio	5.3
Other Sources	48.0
Total	100.0

Source: Field Survey, 2020.

Source of knowledge on recycling of waste

On their knowledge source with respect to Waste recycling, radio, Newspaper and Television had the large percentage (88.82) with 11.18% being from other sources

Table 7:Respondents Source of Knowledge on waste recycling

Source of Knowledge	Percentage
News Paper	10
Television	13
Radio	33
Both Radio and Tv News	13.0
News Paper, Tv news and Radio	20.0
Other Sources	11
Total	100.0

Source: Field Survey, 2020

Descriptive Statistics of Socioeconomic Characteristics of the Respondents

They were again asked if they have heard about waste separation, 68.37% of the respondents answered yes and 31.63 said no. On willingness to separate waste at source, 71.43% were willing to separate their waste on a daily basis while 28.57% said they were not ready to separate their waste. On recycling, 75.51% of the respondents had heard and read on recycling of waste materials and 24.48% had not. More than 73.46% of the respondents were willing to send materials to recycling centres if these were established in their neighbourhoods, whiles 26.53 were not.

Table 8: Respondents reactions about waste separation and recycling

Item	Frequency	Percent
Have you heard or seen waste separation		
YES	67	68.37
NO	31	31.63
Are you willing to separate your waste		
YES	70	71.43
NO	28	28.57
Have you heard or seen waste Recycling		
YES	74	75.51
NO	24	24.48
If Recycling centres are established will you send your waste there		
YES	72	73.46
NO	26	26.53

Source: Field Survey, 2020

4.2 Waste characterisation

4.1.1 Physical Composition of Waste

From the pie chart below, largest quantity of waste generated in Techiman was organic waste (69%), followed by plastic waste at 19% then next in line was paper waste at 6% followed by glass waste at 3%, metal waste 2% and Textiles and leather being 1%.

Table 9:Percentages of the various waste types

Waste Type	Percentage
Organic	69
Plastics	19
Papers	6
Glass	3.0
Metal	2.0
Textiles and Leather	1
Total	100.0

Source: Field Survey, 2020

The mean amounts of waste types generated daily per household

The waste type that was generated the most per household per day was organic waste (0.516 kg) followed by plastic waste (0.117 kg) and then paper at (0.056 kg) and glass waste (0.047 kg) and with metal waste trailing at 0.026 kg.

Table 10:Mean weight (kg) of various waste types per household

Waste Type	Mean weight(kg)
Organic	0.516
Plastics	0.117
Papers	0.056
Glass	0.047
Metal	0.026
Total	**0.8**

Source: Field Survey, 2020

The per capita generation of the various waste types

From the Table below, every individual in each of the households generates a mean of 0.072 kg/day of organic waste followed by plastic waste with 0.016 kg/day then paper waste with 0.006 kg/day followed by glass waste at 0.006 kg/day with metal waste trailing with 0.004 kg/day.

Table 11. Per capita generation of waste of Techiman

Waste Type	Mean person kg/week
Organic Waste	0.07187
Plastic Waste	0.01626
Metal Waste	0.00355
Paper Waste	0.00622
Glass Waste	0.00555

Source: Field Survey, 2020

Solid waste generated per day by the entire population (kg)

Daily the entire population generates more organic waste than any other waste type (1327.94 kg) followed by plastic waste (300.44 kg) and then paper (114.93 kg) followed by glass waste (102.55 kg) and with metal waste trailing at 65.59 kg.

Table 12:Mean weight (kg) of various waste types by the entire population

Waste Type	Mean weight(kg)
Organic	1327.94
Plastics	300.44
Papers	102.55
Glass	65.6
Metal	114.9
Total	**1911.5**

Source: Field Survey, 2020

Daily production of waste to be generated in the short, medium and long term.

In the next five years the largest amount of waste to be generated by the entire population daily would be organic waste with an amount of 1423.53 kg followed by plastic waste with an amount of 322.06 kg then paper waste with an amount of 114.93 kg followed by glass waste with an amount of 102.55 kg and metal waste trailing with 65.59 kg. The amount of waste to be generated in the medium term by the entire population daily would be organic waste with an amount of 1635.83 kg followed by plastic waste with an amount of 370.094 kg then paper waste with an amount of 141.57 kg followed by glass waste with an amount of 126.32 kg and metal waste trailing with 80.80 kg. The amount of waste to be generated in the long term by the entire population daily would be organic waste with an amount of 1879.83 kg followed by plastic waste with an amount of 425.30 kg then paper waste with an amount of 162.69 kg followed by glass waste with an amount of 145.17 kg and metal waste trailing with 92.85 kg.

Table 13: Waste to be generated in the short, medium and long term

Waste Type	Mean Weight (kg)			
	Now	Short Term	Medium Term	Long Term
Organics	1327.94	1423.33	1635.83	1879.83
Plastics	300.44	322.06	370.094	425.3
Metals	114.93	114.93	141.57	162.69
Papers	102.55	102.55	126.32	145.19
Glasses	65.59	65.59	80.8	92.85
Totals	**1911.45**	**2028.46**	**2354.614**	**2705.86**

Source: Field Survey, 2020

DISCUSSIONS

4.3 Waste Characterization

4.3.1 Organic Waste (food waste)

Organic waste was the largest fraction of the sampled household waste generated daily (69%).This is also the case in many developing countries where buying of unprocessed food to be cooked at home seems to be the norm. This generates significant amounts of organic waste. In contrast, in developed countries, buying of processed and ready to-eat foods seems to be the norm, thus leading to a lower representation of food waste in household waste but a higher percentage of packaging materials. Al-khatib et al. (2010) and Gomez et al. (2009), reported of garden and food waste as contributing to 65.1% of the total waste stream in most developing countries. The percentage of organic waste reported in this study is similar (69%). The percentages of organic waste in municipal solid waste in selected African cities were recorded as 56% in Ibadan, 75% in Kampala, 85% in Accra, 94% in Kigali and 51% in Nairobi (Oyelola & Babatunde, 2008).

4.3.2 Plastic & Paper

Plastics waste (19%) was the second largest waste form generated after organic waste; this is not consistent with the trend in countries within the West African Region. According to Silva, et al. (2006) in West Africa plastic waste usually comes third to organic waste. Paper makes up 6% of the household garbage generated; this is not consistent with the trend that the West African Region generates a higher percentage of paper waste **Silva, et al**. (2006). Also, it can be noted that the percentage of paper in the waste (6%) is relatively low compared with plastic waste

(19%), this is due to the fact that plastics rather than paper is widely used in packaging. It is less likely that residential solid waste contains significant proportions of office/commercial waste that consists almost entirely of paper and cardboard**.** Paper waste included all paper products (printed or plain paper, newspapers and notebooks), all types of corrugated and non-corrugated carton boxes and packages, etc. Plastic waste was composed mainly of packaging, plastic products, hard and flexible plastic household items, PET bottles.

4.3.3 Metal

Metals formed 3% of household garbage generated; this agrees with the work done by Silva Alves, et al. 2006 which indicated that the West African Region has metal being the least of the MSW generated. Most of the waste consisted of tin-cans used to package processed foods which were not much because in developing countries the buying of unprocessed food to be prepared at home is a common practice as pointed out by Bernache-Pérez et al. (2001).

4. 3.4 Glass

The glass waste mainly consisted of beer bottles, liquor bottles, medicine, and other beverage and juice bottles. Although broken glass bottles were also observed, most of the glass bottles were not broken. Even though households were specifically asked not to refuse to give any recyclable waste materials at home during the survey period; few unbroken bottles were observed in the samples suggesting that recyclables were in fact removed from the sample waste stream for reuse or for sale. This may account for the amount of glass waste. The articles of glass collected over the 4 weeks were not many but it weighed more because the density of glass is high and according to the laws of physics the density of a material is directly proportional to its mass hence the reason for the weight of glass collected during the survey.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Introduction

Chapter five summarizes the whole work and concludes the study. It gives some policy recommendations. The first part focuses on summary of the findings of this study; the second part also provides the conclusions of the study. Finally, the last part presents recommendations.

5.2 Summary of findings

The purpose of the study is to find out the various composition or characteristics of solid waste that is generated in Techiman Municipal. Based on the topic both quantitative and qualitative methods of data collection was also used for the study which involved collecting and analysing the data gathered in succession. The qualitative data was collected and analysed with in the sequence to help explain the quantitative results obtained in the first phase. The researcher used several methods under the qualitative method to collect information for the study. Under the qualitative methods of data collection, the following was used; field visits, observation and questionnaires. The researcher was keen on observing and taking notes of important issues on the topic under investigation. Field visits were embarked on to get the various solid waste for the study.

5.3 Conclusion

Household waste within Techiman were mainly food, yard waste, wood, paper and plastics, glass, textiles and Leather, rubber and metals. The majority of the waste generated by the households were the organic waste (69%) followed by plastic (19%). Waste separation was not being practiced in the Municipality. There was a general willingness among the inhabitants of the municipal to separate waste at source. The average per capita waste generation for Techiman was 0.072 kg/day looking at the available data, if proper waste separation and composting at source measures are put in place only small amount of waste will end up at the Landfill site.

5.4 Recommendations

- Education of people in Techiman Municipal on the need to separate waste through public enlightenment and awareness in the media (radio, television and newspaper since most of the respondents had heard about separation through these media), schools, churches, mosques, community associations, traders and transporters unions and use of traditional rulers should be carried out by the Techiman Municipality.
- With the purpose of improving the current waste management system and having the information presented here regarding the composition of HSW and MSW, it is recommended to conduct an analysis and assessment of the potential treatment options for the non-biodegradable in the waste stream of Techiman Municipal, with a market-oriented approach.

- Efforts should be devoted to obtain better estimates of the generation rates and composition of non-household waste (they do end up in the landfills as well and have valuable materials). In this study, an adequate and statistically valid characterization of HSW was made. However, the other sources contributing to MSW were not examined. Further studies particularly focusing on these aspects might be worthwhile to possibly increase the amount of recyclables.
- To enhance the sustainability of SWM, it is recommended that public awareness, funding, expertise; equipment and facilities as well as other provisions that are currently lacking or inappropriate must be provided. Furthermore, since the envisaged SWM practices call for some behavioural changes, there is a need for community participation on related issues.
- The segregation of the waste types at source using bin bags of different colours was a success hence it is recommended for waste to be segregated at source.
- If the above recommendations given are well taken and implemented, it will bring about effective solid waste management by reducing the amount of waste that ends up in the final disposal site in Techiman Municipal which is currently a very big canker.

REFERENCES

Achankeng, E. (2003). “Globalisation, Urbanization and Municipal Solid Waste Management in Africa*”, Proceedings of the Conference of African Studies Association of Australasia and the Pacific - African on a Global Stage*, University of Adelaide, Adelaide, Australia, pp. 1-22.

Adams, A. (2011). *Sekondi-Takoradi Metro Assembly in Focus*, Ghanaian Chronicle, Accra, Ghana.

Addo, E. A. (2009). “Economic Analysis of Household Source Separation of Solid Waste: The case of Kumasi Metropolis of the Ashanti region of Ghana”, *Unpublished MSc. Thesis Report*, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, 110 pp.

Adu-Boahen, A. (2012). “Management of the Kojorom Final Waste Disposal Site by the Secondi-Takoradi Metropolitan Assembly” *Unpublished MSc. thesis Report*, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, 99pp.

Aguilar-Virgen, Q., Armijo-de Vega, C., Taboada-Gonzalez, P. A., & Ojeda-enitez, S. (2010). “Municipal Solid Waste Generation and characterization in Ensenada, Mexico” *Open Waste Management Journal*, 3:140-145.

Ahmad, A., & Jehad, H. (2012). “Municipal Solid Waste Composition Determination Supporting the Integrated Solid Waste Management in Gaza Strip*”, International Journal Environmental Science and Development*, 3(2): 172-176.

Aisa, S. O. (2013). "Characterization of household waste in Kinondoni Municipality, Dar Essalaam" *Academic Journal of Interdisplinary Studies*, 2(13): 35-46 pp.

Al-khatib, I. A., Monou, M., Abdul Salam F., Abu, Z., Shaheen, H. Q., & Kassinos, D. (2010). "Solid Waste characterization, Quantification and Management Practises in Developing Countries, A case study: Nablus District – Palestine". *Journal of Environmental Management*, 9: 1131-1138.

Anarfi, K. P. (2013). "*Source Separation, Characterization and Recycling Potential of Household Solid Waste. A case study of Kumasi, Ghana", Unpublished MSc. Thesis Report*, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, 121 pp.

Anomanyo, E. D. (2004). "Integration of Municipal Solid Waste Management in Accra (Ghana): Bioreactor Treatment Technology as an Integral Part of the Management Process" *Unpublished MSc. Thesis Report*, Lund University, Lund, Sweden, 48 pp.

Anon (1999). "Effective Solid Waste Management With The Participation of Waste Producers, Report from Calcutta UNDP-World Bank Water and Sanitation programme and Seventh Meeting of The Urban Think Tank".

Anon (2009). "Developing Integrated Solid Waste Management Plan Training Manual", *Vol. 2. Assessment of Current Waste Management System and Gaps Therein*, Osaka/Shiga, Japan.

Anon (2010). "National Environmental Sanitation Strategy and Action Plan NESSAP: Materials in Transition MINT", *Ghana, Ministry of Local Government and Rural Development*, Accra, Ghana, 142pp.

Anon (2011). "Ghana: The New Land of Opportunity for Oil and Gas Investment: Overview of the Potential for Ghanaian Oil and Gas Investors"*http://maritimehubafrica.com/uploads/news_attachment/Report_Ghana_Oil_Opportunities.pdf*. Accra, Ghana, 4pp. Accessed: March 15, 2014.

Ansah, B. (2008), "Characterisation of Municipal solid waste in three selected communities in the Tarkwa- township", Msc. Thesis, Kwame Nkrumah University of Science and Technology, Kumasi- Ghana.57pp.

Asamoah- Okyere E. (2011), "Characterisation and Composting of solid waste generated in the Aburi Township", Kwame Nkrumah University of Science and Technology, Kumasi- Ghana. 72pp.

ASTMD (2003). "Standard Test Method for Determination of the composition of Unprocessed Municipal Solid Waste", *American Society for Testing and Materials International*, USA, 6pp.

Bernache-Perez, G., Sanchez-Colon, S., Garmendia, A. M., Davila-Villareal, A. and Sanchez-Salazar, M. E. (2001), "Solid Waste haracterisation Study in the Guadalajara Metropolitan Zone, Mexico", *Waste Management Research*, 19(5): 413-424.

Bernstad, A., Jes la our, J. and Aspegren, H. (2012), "Local Strategies for Efficient Management of Solid Household Waste – The Full-Scale Augustenbong Experiment*", wmr.sagepub.com*, pp. 200-212.Accessed: August 20, 2020.

Brunner, P., & Ernst, W. (1986). "Alternative Methods for the Analysis of MSW. Waste Management & Research", 4, 147-160.

Chung S. and Poon, C., (2001). "Characterization of Municipal Solid Waste and its Recyclable contents of Guangzhou", *Waste Management Research*, 19: 473-485.

Dyson & Hang, N, (2005), "Forecasting Municipal Solid Waste Generation in a Fast-Growing Urban Area with System Dynamics Modelling". *Waste Management Journal*, 25: 669-679.

Ejaro, S. P. & Jiya, S. N. (2013), "Source Specific Quantification characterization and Management of Solid Waste in Lapai, Nigeria State, Nigeria", *Ethiopian Journal Environmental Studies and Management,* 6(5): 561-569.

Fobil, J. (2001). "Factors to be considered in the Design of an Integrated Municipal Solid Waste Management in the Accra Metropolis". M Phil Thesis, University of Ghana.

Gawaikar, V. & Deshpande,V. P. (2006), "Source Specific Quantification and Characterisation of Municipal Solid Waste – a Review", *Solid Waste Management Division, National Environmental Engineering Research Institute (NEERI)*, Nagpur, India, 86: 33-38.

Gilbertson, W. E. (1969), "Present and Future Trends in Municipal Disposal of Solid Waste", In chap. 1 of Problems in community Waste Management, World Health Organisation Public Health Papers No. 38, 9-20 pp.

Gomez, G., Meneses, M., Ballinas, L. & Castells, F. (2009), "Seasonal Characterization of Municipal Solid Waste (MSW) in the city of Chihuahua", *International Journal of Waste Management*, 29(9): 2018-2024 pp.

Guangyu, Y. (1999), "Amounts and composition of Municipal solid wastes, Point sources of pollution: local effects and its control", *Encyclopaedia of Life Support Systems (EOLSS)*, 1-8 pp.

Hogan, A., Cunningham, D. and Finn, J. (2006), "Characterisation of Non-Household Municipal Waste in Ireland and the Development of an Approach to Tracking Municipal Waste Composition", *Final Report Prepared for the Environmental Protection Agency Environmental*, RTDI programme, Clean technology, Ireland, 129 pp.

Hoornweg, D., & Thomas, L. (1999). "What A Waste: Solid Waste Management in Asia". Working Paper Series Nr. 1. *Urban Development Sector Unit*. East Asia and Pacific Region, p. 5.

Hoornweg, D., Thomas, L. and Verma, K. (1999), "What a Waste: Solid Waste Management in Asia", *Urban Development Sector Unit*, East Asia and Pacific Region, Washington D.C., USA.

Kazimbaya-Senkwe, & Mwale, A. H. (2001), "Solid Waste in Kitwe; Solid Waste Characterization Study for the City of Kitwe, Zambia: Phase 1", *His Sinpa Papers Sinpa Number 28/2001 Zambia*, Sinpa Programme, Institute for Housing and Urban Development Studies, Rotterdam, Netherlands in cooperation with Copper belt University, Kitwe, Zambia, 57pp.

Kui, L. (2007), "Study of Influence Factors in Municipal Solid Waste Management Decision-making*", Unpublished MSc. Thesis Report*, Industrial Ecology, Royal Institute of Technology, Stockholm, Sweden, pp. 1-43.

Lohani, B. N., & Hartono, D. M. (1985). "Estimation of Solid Waste Generation Rates in the City of Bandung, Indonesia". *Waste Management & Research* (3), 103-117.

Nabegu, A. (2010), "An analysis of Municipal Solid Waste in Kano Metropolis, Nigeria*", Journal of Human Ecology*, 31(2): 111-119.

NYS Dept. of Environmental Conservation. (2010). "NYS Dept. of Environmental Conservation", from NYS Dept. of Environmental Conservation web site: http://www.dec.ny.gov/chemical/8732.html, Retrieved August 8, 2020.

Oduro-Appiah, K.& Aggrey, B.E. (2013), "*Determinants of Source Separation of Municipal and Solid Waste in Developing Countries: The Case of Ghana", Journal of Sustainable Development in Africa*, 15(3): 47-60.

Oduro-Kwarteng, S. (2011), "Private Sector Involvement in Urban Solid Waste collection: Performance, capacity and Regulation in five cities in Ghana" *Unpublished PhD. Thesis Report*, CRC Press, Belkema, Rotterdam, Netherlands, 378 pp.

Oyelola, O. T. & Abatunde, A.I. (2008), "Characterization of Domestic and Market Solid Wastes at Sources in Lagos Metropolis, Lagos, Nigeria", *African Journal of Environmental Science and Technology*, 3(12): 430-437.

Peavy, H., Rowe, D., & Tchobanoglous, G. (1985). "Environmental Engineering, McGraw-Hill series in water resources and environmental management". In H. Peavy, D. Rowe, & G. Tchobanoglous, Environmental Engineering (pp. 573-592). McGraw-Hill.

Pitchel, J. (2005), "Waste Management Principles: Municipal Hazardous, Special Waste", *CRC Press*, Boca Raton, Florida.

Puopiel, F. (2010), "Solid Waste Management in Ghana: the case of Tamale Metropolitan Area", *Unpublished MSc. Thesis Report*, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, 93 pp.

Qdais, A., Hamonda, M., & Newham, J. (1997). "Analysis of Residential Solid *Wastes at Generation Sites". Waste Management and Research*, 15, 395-406.

Rushbrook, P. & Pugh, M. (1999), "Solid Waste Landfills in Middle-and Lower Income ountries", *Urban Development Division Waste Management*, The World Bank, Washington, USA.

Seshie V. Isabella (2009), "Municipal solid waste characterisation and Quantification as a measures towards effective waste management in the Takoradi sub-metro", Kwame Nkrumah University of Science and Technology, Kumasi- Ghana.63pp.

Silva Alves, J. W., Gao, Q., Guendehou, G. S., Koch, M., Cabrera, C. L., Mareckova, K., *et al.* (2006). "Waste generation, composition and management data. 2006 IPCC Guidelines for National Greenhouse Gas Inventories".

Tasantab J Chadi (2011). "Solid waste management in Ghanaian towns, a case study of Saboba", Msc. Thesis, Kwame Nkrumah University of Science and Technology, Kumasi- Ghana. 66 pp.

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) (2010). "United Nations Economic and Social Commission for Asia and the Pacific", from United Nations Economic and Social Commission for Asia and the Pacific Web site:

http://www.unescap.org/esd/sudu/swm/workshop/2010/dhaka/Resources/02-SW M-Interact Manual/source/ Retrieved July 1, 2020.

USEPA (1998). "U.S Environmental Protection Agency, Municipal and Industrial Solid Waste Division office of solid waste". Characterization of building related construction and demolition debris in the United States., from USEPA Website: http://www.epa.gov/osw/hazard/generation/sqg/c%26d-rpt.pdf Retrieved July 16, 2020.

USEPA (1998, June). "U.S. Environmental Protection Agency, Municipal and Industrial Solid Waste Division office of solid waste". Characterization of building related construction and demolition debris in the United States., from USEPA Website: http://www.epa.gov/osw/hazard/generation/sqg/c%26d-rpt.pdf Retrieved August 16, 2020.

Yousof, R., & Rahman, M. (2007). "Monitoring Quantity and Characteristics of Municipal Solid Waste in Dhaka City". Environmental Monitoring Assessment. Springer Netherlands, 35, 3-11.

Zero Waste America (ZWA). (2010). "Zero Waste America.", from Zero Waste America Web site: http://www.zerowasteamerica.org/WhatIsWaste.htm Retrieved August 17, 2020.

Zurbrugg, C. (2003). "Basics of solid waste management in developing countries".

Zurbrugg, K. (2002), "Urban Solid Waste Management in Low-Income Countries of Asia. How to cope with the crisis", Scientific Committee on Problems of the Environment (SCOPE) Urban Solid Waste Management Review Session, Durban, South Africa, pp. 1-13pp.

APPENDICES

APPENDIX 1

PRESBYTERIAN UNIVERSITYCOLLEGE, GHANA

DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

B.Sc. Environmental Health and Sanitation

Characteristics of solid waste generated in Techiman Municipal

HOUSEHOLD WASTE CHARACTERIZATION SURVEY

City/ Town/ Village ………………………..

Location……..…………………

House Number………….…… Name of Respondent…………………………..

PART 1 - ABOUT YOURSELF

1. Age group

a. Under 20yrs [ ] b. 20-30yrs [ ] c.31-40yrs [ ]

d. 41-50yrs [ ] f.51--59 yrs [ ] g. 60 yrs and above [ ]

2. Gender: a. Male [ ] b. Female [ ]

3. What is your highest level of education?………………….………………..…

4. What is your Occupation? …………………………………………………….

5. Marital Status: a.Single [ ] b.Married [ ]

6. Status in the household

a. Father/Mother [ ] b.Child [ ] c. Other [ ](Specify)………………..

PART 2 - ABOUT YOUR HOUSEHOLD

1. Which of the following best describe your home?

a.Single Family Detached [ ] b.Duplex or Townhouse [ ]

c.Multifamily Unit/ Compound House [ ] d.Storey building [ ]

2. How many people live in your house?…………………………………..
3. How many households are in your house? ....
4. How many of your household members fall within the following age groups?

a. 0-12 ………………. b. 13-19 ……………….

c. 20-30 ………………. d.31-40 ……………….

e . 41-50 ………………. f.71 and above ……………….

5. How much is your household's average monthly expenditure?

a. Less than GH¢ 200 [ ] b. GH¢ 200-500 [ ]

c. GH¢ 500-1000 [ ] d, GH¢ 1000-2000 [ ]

e. above GH¢ 2000 [ ]

6. How many of your household are in the following levels of education?

a. Primary/JHS ………………. b .Secondary / Technical ……………….

c. Vocational ………………. d. Tertiary/Professional …………….

F .None ………………. g. Others (specify) ……………….

Part 3 Household Waste Disposal

1. How do you dispose your household wastes?

   a. Buried [ ] b. Burned [ ]

   c. Individual Bin (House to house Collection) [ ] d. Communal dumpsite [

2. How many refuse bins do you have in your household?

One [ ] Two [ ] Three [ ] Four [ ]

Five [ ]

3. How often is your bin lifted?

Once a week [ ] Twice a week [ ] Thrice a week [ ]

4. Which Company services your household?

a. Zoomlion [ ] b. Informal Waste Collectors [ ]

c.others (specify)…………

5. Do you sell or give out items to itinerant buyers?

Yes [ ] No [ ]

If Yes specify the item…………………………………

Part 4: Knowledge on Waste Separation

1. Have you ever heard or seen waste separation activities?

   Yes [ ] No [ ]

2. If Yes, from where :

a. Foreign Countries [ ] b. other parts of Ghana/Different communities [ ] c.In movies [ ] d.Television news [ ]

e.Radio [ ] f. Newspapers [ ]

g.Magazines [ ] h.others nspecify)…………………………………….

3. Are you willing to separate your waste on daily basis, even after this exercise?

Yes [ ] No [ ] If No why ……………………

4. If Yes what will be your driving force:

a. When motivated [ ] b. Clean Environment [ ]

c. Resource [ ] d. Best practice and example from other Countries for recycling [ ] f. others (specify) …………………………………..

Part 5: Knowledge on Environmental Management

1. Do you often read about or listen to environmental issues?

Yes [ ] No [ ]

2. If Yes from which source:

a.Newspaper [ ] b. Television [ ]

c. Radio Station [ ] d. Magazines [ ]

e. Billboards [ ] f. Fliers [ ] g.Others (specify)………………

3. How has this changed your perception about the environment?

a. Advocate for clean environment [ ]

b. Neighbourhood environmental cleanliness advocate [ ]

c. Household environmental advocate [ ]

4. Which of the following will you recommend for a clean environment at your neighbourhood?

a. Constant environmental education at the neighbourhood [ ]

b. Regular clean up [ ]

c. Sanitary Inspection activities [ ]

d. Persecution of offenders (polluters) [ ]

Part 6: Knowledge on Recycling

1. Have you heard or read anything about recycling of waste materials?

Yes [ ] No [ ]

If Yes from which source?

a.Television [ ] b.Radio [ ] c.Magazines/Newsletters [ ]

d.Newspaper [ ] e.Billboards [ ] f. others (specify) …………………

2. Do you know any company engaged in recycling of waste?

Yes [ ] No [ ] If Yes, name any ……………………………

3. Do you recycle any of the following materials?

a. Newspapers [ ] b. other papers and Cardboards [ ] c.Glass [ ]

d. Metal & Cans [ ] e .Plastics [ ] f. Leaves/Food waste/ Yard waste [ ] g. others (specify) ………………………………..

4. If you do recycle, what is the principal reason for your action?

a. Concern for the environment [ ] b. Concern about the availability of landfill space [ ] c. My children encourage me to recycle [ ] d. Get paid for recycling material [ ]

Others (specify)…………………………………………………………

5. If you do not recycle what would be your principal reason?

a. Inconvenience [ ] b. Believes there are better ways to handle my waste /garbage [ ] c, believes it's the responsibility of government/ Waste management company [ ]

d. Do not have the necessary facilities and skills to recycle [ ]

e. Others (specify) …………………………

6. If you do recycle, how long have you been recycling?

a. Less than 1 year [ ] b.1-2 yrs [ ] c.3-5 yrs [ ]

d. more than 5 yrs [ ]

7. If a recycling Centre is established at your neighbourhoods, would you be willing to bring materials for recycling? Yes [ ] No [ ] If No why …

If Yes explain ……………………………………………………………

8.Are you willing to buy two household waste plastic bags? (One waste plastic bag for recyclables and one for non-recyclables) Yes [ ] No [ ]

If No why ……………………………………………………………………

APPENDIX II

DATA COLLECTION SHEET (WEEK ONE)

WASTE COMPOSITION	MONDAYS	WEDNESDAYS	SATURDAYS
ORGANIC			
PLASTICS			
PAPERS			
TEXTILES AND LEATHER			
METALS			

DATA COLLECTION SHEET (WEEK TWO)

WASTE COMPOSITION	MONDAYS	WEDNESDAYS	SATURDAYS
ORGANIC			
PLASTICS			
PAPERS			
TEXTILES AND LEATHER			
METALS			

DATA COLLECTION SHEET (WEEK THREE)

WASTE COMPOSITION	MONDAYS	WEDNESDAYS	SATURDAYS
ORGANIC			
PLASTICS			
PAPERS			
TEXTILES AND LEATHER			
METALS			

DATA COLLECTION SHEET (WEEK FOUR)

WASTE COMPOSITION	MONDAYS	WEDNESDAYS	SATURDAYS
ORGANIC			
PLASTICS			
PAPERS			
TEXTILES AND LEATHER			
METALS			

APPENDIX III