MUNICIPAL SOLID WASTE CHARACTERISATION AND QUANTIFICATION AS A MEASURE TOWARDS EFFECTIVE WASTE MANAGEMENT IN THE TAKORADI SUB-METRO (GHANA)

A THESIS SUBMITTED TO THE DEPARTMENT OF ENVIRONMENTAL SCIENCE OF THE COLLEGE OF SCIENCE, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILMENT FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN ENVIRONMENTAL SCIENCE

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DECLARATION AND CERTIFICATION

I hereby declare that this submission is my own work towards the Master of Science (MSc.) Degree, and that, to my best of knowledge it contains no material previously published by another person or material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

Waste collection and disposal is a challenge for many metropolitan and municipal assemblies in Ghana and the Takoradi metropolis is no exception. Currently, all the waste generated in Takoradi sub-metro ends up at the final disposal sites without any recovery of the valuables in the waste. Waste separation efficiency and willingness to separate waste at source, the physical composition and the per capita waste generated per each household within the Takoradi metropolis were studied over a five week period. Questionnaire survey and interviews with key stakeholders were also carried out. The results show a solid waste composition of 60.01% biodegradables, 11.47% plastic, 7.35% paper and cardboard, 2.38% metals, 1.51% glass, 1.22% leather and rubber, 2.91% textiles, 8.04% inert materials and 4.98% miscellaneous materials. Over 80% of the waste had the potential for reuse (potentially recyclable) and of the usable material, 22.67% can be recycled and 63.64% for composting. The average per capita waste generated was 0.70 kg/ca/day. The average moisture of biodegradables waste was 54.99%. The data generated on the quantity and composition of the waste stream in the metropolis would play a positive role in solid waste management and help solid waste managers make informed decisions on waste management options.

DEDICATION

This piece of work is exclusively dedicated to God the Father, the Son and the Holy Spirit for the gift of life and blessings bestowed on me and our blessed mother the Virgin Mary. Also to my nephews, Mark Elikem Esiape and Sesi Kwami Dzramedo and my family and friends for the help, care, moral guidance, encouragement and spiritual support given me.

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LIST OF ABBREVIATIONS AND ACRONYMS

TSM	Takoradi Sub-Metro
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
STMA	Sekondi-Takoradi Metropolitan Assembly
SAEMA	Shama Ahanta East Metropolitan Assembly
CBD	Commercial Business District
BIO	Biodegradable
NON-BIO	Non-Biodegradable
ASTM	American Society For Testing And Materials
PET	Polyethylene Terephthalate
HDPE	High Density Polyethylene
PVC	Polyvinyl Chroride
LDPE	Low Density Polyethylene
PP	Polypropylene
PS	Polystyrene
SPSS	Statistical Package For Social Sciences
ANOVA	Analysis Of Variance
HSW	Household Solid Waste
SWM	Solid Waste Management
SE	Separation Efficiency

CHAPTER ONE

INTRODUCTION

1.0 Background

Solid Waste generation within households, markets and communities is as a result of human activities (Zurbrugg, 2002; Gawaikar and Deshpande, 2006 and Ejaro and Jiya, 2013). These human activities which directly or indirectly produce waste could be agricultural, commercial, or domestic. These sources of waste are highly heterogeneous and are made up of important waste streams such as plastics, yard waste, food waste, papers, metals, glass, textiles, leather and other miscellaneous materials.

Waste management being a major environmental and health challenge around the world today is more pronounced in developing countries (Ejaro and Jiya, 2013). 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 and Deshpande, 2006; Ahmad and 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 offers an advantage because of its continual and sustainable supply provided their production cost are minimized.

Accra and other African cities generate 80% organic waste, 10% plastic, glass and metal waste and less than 1% paper waste per day (Gawaikar and Deshpande, 2006).

However, most of these wastes is not properly collected and disposed of in a safe and healthy manner. This situation is not limited to Accra and may be applicable to all the major cities in Ghana. The Takoradi Sub-Metro (TSM) like Accra 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).

The various classes of residential areas often have varying waste management challenges; first class residential areas enjoy a door- to -door waste collection, while the second and third class residential areas sometimes have door –to- door service, but the majority of the areas are under the "pay- as- you- dump" service where community bins are provided. However, there are other third class residential areas which do not have any of these services. Wastes from these less-privileged areas are mostly dumped indiscriminately in open places.

Zoomlion, a private waste management company, collects most of the waste from the communities within the TSM but does not have data on waste generated and composition to help plan and design their waste management strategies which is most needed (Oumarou *et al.*, 2012).

This research therefore aimed at generating data on the waste produced in the TSM and its composition by quantifying and characterising it to inform decisions on waste management project planning.

1.1 Problem Statement

Municipal Solid Waste (MSW) generation has increased significantly within the TSM due to increasing urbanisation and industralisation. The municipal assemblies manage solid waste with the aim of providing good quality sanitation services in order to keep the cities clean and to enhance public health and safety. Evaluation of the resource requirement for collection, transportation, processing and disposal as well as equipment for waste management requires a correct assessment of the quantity of waste generated per capita per day from direct residential areas and the characteristics of waste generated (Gawaikar and Deshpande, 2006).

In Takoradi, 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 of STMA coupled with the influx of hundreds of economic migrants into the city‟s oil industry has resulted in an increase in waste generation and therefore its management (Adu-Boahen, 2012). In view of this, source specific quantification and characterisation of the household waste is very much required to assess the quality and quantity of waste generated (Gawaikar and Deshpande, 2006) which will allow correct assessment of waste load and make it easier for proper planning of solid waste management in the TSM.

1.2 Justification

The characterization and quantification of household waste in Takoradi would bring together data on the generation rate and the composition of waste in the sub-metro. This will help the sub-metro to operate an efficient waste management system. An efficient solid waste management system for TSM will serve as a model for municipal waste management for the other sub-metros in the city as well as other cities in Ghana since the problems of waste management is similar and prevalent through Ghana.

1.3 Main Objective

The main objective of the research was to characterise and quantify household waste for proper management of waste in the TSM and to help make informed decisions on project planning for diversion of this waste from the final disposal sites.

1.4 Specific Objectives

The specific objectives of this research were to:

a. Determine the physical composition of household waste within the TSM;

b. Assess the separation efficiency and willingness of the people to separate waste;

c. Determine the per capita and quantity of the waste generation in TSM;

d. Determine the potential for recycling of the MSW and

e. Determine the moisture content of the separated biodegradable waste materials.

1.5 Scope of Study

The selected study is the Takoradi Sub-Metro which is one of the four sub-metros of the Sekondi-Takoradi Metropolitan Assembly. The research work is presented in Six (6) chapters. The chapter one (1) looks at the problem of waste management in the TSM. Chapter two examines existing literature on solid waste characterization and quantification as well as waste management. Chapter three (3) describes the materials and methods employed in gathering data from the field. These included field investigation, questionnaire and face-to-face interviews. Chapter four (4) analyses the findings from the fields and chapter five (5) summarises the key findings of the study. Chapter six (6) is the conclusion and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

Rapidly growing populations, rapid economic growth and rise in community living standards have accelerated the generation rate of Municipal Solid Waste (MSW) causing its management to be a major worldwide challenge (Aguilar-Virgen *et al.*, 2010; Al-khatib *et al.*, 2010; Nabegu, 2010 and Fakare *et al.*, 2012). Particularly in urban cities of developing countries like Ghana, MSW management (MSWM) is a highly neglected area. Fakare *et al*. (2012), showed that the rate of change in domestic waste quantification and composition in developed and developing countries is outstanding. Generally the greater the economic prosperity and higher percentage of urban population the greater the amount of solid waste generated.

A walk through the streets of towns and cities in the urban areas of Ghana show a clear breakdown in the waste management situation in the country. A study by Fakare *et al*. (2012) showed that the problem of waste generation, handling and disposal have reached a disturbing level in Nigerian urban centers and in most cities in Nigeria (which is the same situation as Ghana); waste management issues have become a glaring challenge. In recent years, there has been a phenomenal increase in the volume of wastes generated daily in Ghana. About 83% of the population dump their refuse in either authorised or unauthorised sites in their neighbourhood, and weak capacity to handle solid waste creates unsanitary conditions (Freduah, 2004). Waste is inseparable from man, he stores up, uses, and disposes of materials and the waste produced by modern civilization is directly related to the living standard, socioeconomic and cultural attributes of that particular environment Fakare *et al*. (2012). There is therefore the need for an efficient waste management strategy to be adopted to help improve the poor handling of waste.

Data pertaining to MSW vary greatly among waste studies. Usually waste management decisions are based on household waste, which constitutes a small portion of the total waste stream. Industries and commercial activity hide the information to avoid statutory obligations (Anon, 2005). The valuable materials in the waste stream can be recycled and reused therefore minimising the amount of waste that ends up at the final disposal sites. However due to the heterogeneous nature, it is very difficult (if not almost impossible) to make projections as those for recycling and reuse (Kui, 2007; Walling *et al*., 2004).This view expressed by Kui (2007) and Walling *et al*. (2004), is relevant to this research because the waste produced by the people of TSM is mixed without any form of separation. Al-Khatib *et al*. (2010) noted that the composition of solid waste is an important issue in waste management and ends up affecting the density of the waste, the proposed methodology of disposal and is necessary for examining reuse, reduction and recycle of waste. Oumarou *et al*. (2012) therefore believes a comprehensive characterisation of MSW is crucial to the long term efficient and economical planning for solid waste management.

Identification of waste composition is crucial for the selection of the most appropriate technology for treatment, taking essential health precautions and space needed for the treatment facilities (Nabegu, 2010). Despite this acknowledgment, there has been no study on the analysis of municipal waste composition in TSM even though a lot of work on waste management has been done on municipal waste management mostly in the big cities such as Accra, Kumasi and Tamale. This paper attempts to fill this gap by providing data on the composition, and sources of municipal waste in three different residential areas of the TSM for the purpose of understanding the type of waste generated to help in proper waste management.

2.1 Municipal Solid Waste

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 fulfill 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. MSW 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 and Amatobi, 2013).

2.1.1 Sources and types of Municipal Solid Waste

The knowledge of the sources and types of waste in an area is required in order to design and operate appropriate solid waste management systems (Oyelola and Babatunde, 2008). Fundamental understanding of the sources and types of solid wastes is key in evaluating the composition and generation rates of MSW sources in a community area related to many aspects of residential units. Classified of types of solid waste in relation to the sources and generation facilities, activities, or locations where wastes are generated associated with each type which is presented in table 1. Types of solid waste based on origin (food waste, rubbish, ashes and residues, demolition and construction, agriculture waste), based on characteristics (biodegradable and non-biodegradable), based on the risk potential (hazardous waste) is the classification of (Puopiel, 2010). And also sources of solid waste as residential, waste from shops, commercials establishment, hotels/restaurants/eating stalls, slaughter houses and others.

Table 1: Source and Types of Solid Waste

Sources	Typical facilities, activities, or locations where wastes are generated	Types of solid wastes
Residential	Single family and multifamily detached dwellings low-medium and high-rise apartments, etc	Food waste, paper, cardboard, plastics, textiles, leather, yard wastes, wood glass tin cans, aluminum, other metals ashes, street leaves, special wastes, household hazardous waste.
Commercial	Stores, restaurants markets, offices building, hotels, motel, print shops service, stations auto repair shops, etc.	Paper, cardboard, plastics, wood, food, waste, glass, metals, special wastes, hazardous wastes, etc
Institutional	Schools, hospitals, prisons, governmental centers	As above in Commercial
Municipal services	street cleaning, landscaping, catch basin cleaning, parks and beaches, other recreational area	Special wastes, rubbish, street sweepings, landscape and tree trimmings, catch basin debris, general wastes from parks, beaches, and recreational areas.

Sources of MSW within a community

2.1.2 Characteristics of Municipal Solid 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).

2.2 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 and Jiya, 2013). This is very pertinent in Ghana and Takoradi 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 middleincome 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. This explanation is very relevant to the research as there is no known data on the generation and composition of solid waste available at the TSM.

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 and 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 and 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 minnimisation, 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.

2.2.1 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 TSM, 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).

2.2.1.1 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). The view expressed by Hogan *et al*. (2006), is very relevant to the current research as the current tipping site in the Takoradi sub metro has almost reached its full capacity and therefore a new site for final disposal is sought.

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 and Mwale, 2001).

2.2.1.2 Re-use

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.

2.2.1.3 Recovery

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).

2.2.1.4 Disposal

The disposal site is the final ending place of all municipal solid wastes whether they are residential or any other wastes collected.

2.3 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 TSM 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 and 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).

2.3.1 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 and 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 2.7 million 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 and 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.

2.3.2 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 a 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 pretreatment 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 and Babatunde, 2008). The waste is also more dense and 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 lowdensity 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.

2.4 Municipal Solid Waste Characterisation, Quantification and Generation

Waste characteristics are essential data for waste disposal facilities planning and waste management policy formulation (Chung and Poon, 2001). TSM lacks data on quantity of waste generated and their characteristics which are some of the factors that contribute to the poor management of solid waste and in order to implement efficient and sustainable waste management program, quantitative data on the composition of the waste being generated within the sub metro must be obtained. The amount of waste generated by majority of Municipal Corporations / Councils are not weighed but the quantities are estimated on the basis of number of trips of trucks which carry the waste to disposal site (Gawaikar and Deshpande, 2006) and this is not different from the situation in the TSM. The amount of waste that does not get to the disposal site is therefore not accounted for. Specific source quantification and characterization is significant to achieve the aim of the investigation therefore waste for the study was taken directly from the households.

2.4.1 Municipal Solid Waste Characterisation

Developed countries utilize various methods for waste management which give way to renewable energy forms and the emergence of new products such as compost (Topanou *et al*, 2011). In these countries, considerable investment is made to recycle waste for the benefit of agriculture; on the other hand, waste management in developing countries remains an additional weakness which continues to hinder their emergence. Insufficient studies focused on waste characterisation in waste management planning in African cities hinder the decision-making in regards to adapting waste management as a tool of environmental protection. Waste
characterisation is identified as one of the factors influencing sustainable recycling collection in developing countries (Troschinetz, 2005).

2.4.1.1 Waste characterisation study

Sampling

The process for sampling of solid waste depends on the motivation of the waste investigation and testing. It is necessary to obtain a sample that represents the whole of the population or the enterprise to be investigated. Some important aspects have to be determined when sampling waste:

- Sampling area or enterprise; describe key parameters such as number of households.
- Sampling date(s)
- Sampling period (waste collected over a day, a week, etc.)
- Sampling: Directly from the waste producer, At the collecting or transport vehicle and At the treatment plant
- Sample size (nordtest, 1995)

Different methodologies of sampling are available to determine the generation and composition of MSW. Sampling can be through door-to-door waste collection or directly from waste collection trucks (Aguilar-Virgen et al., 2010).

Sampling was conducted according to methods used by Bernache-Perez et al. (2001) where stratified random sampling was performed as well as study area stratified into three distinct

levels of standard of living called: high standing, medium standing and low standing (Topanou *et al.*, 2011).

2.4.1.2 Number of Households and size of sample

In literature, there is no one specific method used for specifying the number of samples for solid waste characterization. According to the methodology recommended for solid waste characterization by Al-Khatib *et al.* (2010), thirty samples were adequate. The number of samples obtained from each site is representative of the respective populations in each area. For each category of the stratified standard of living, twenty (20) households were selected at random which makes it 60 selected households to be collected and weighed (Topanou *et al.*, 2011).

Representative number of household of the population can be deduced from the following formulae

1. n = Z * Z [P (1-P)/(D*D)] –formula for infinite population sample size determination (50,000 people and above)

SS = n / [1 + (n/population)] –For correction of the infinite population where

P = True proportion of factor in the population, or the expected frequency value

D = Maximum difference between the sample mean and the population mean,

Or Expected Frequency Value minus (-) Worst Acceptable Value

Z = Area under normal curve corresponding to the desired confidence level

n= number of samples of infinite population

SS= number of samples for corrected infinite population.

2. Sloven‟s formula in statistics

$SS=N/1+N(e)^2$

Where

SS=Sample size N=population

size e= margin of error/error

tolerance

3. The SWA-tool (European Commission, 2004) and other sources such as Nordtest (1995) and ASTM (2003) referred to this formula for sample size determination for waste analysis n= $\frac{(s*t)^2}{(e*x)^2}$

The three formulae above gave number of household of 100-150 as sample for population of between 50,000 and 10 million people.

1. For waste characterization analysis, Nordtest (1995) reported that 100-200 households are required in a defined community per week analysis. Where there are variations based on the type of houses, type of municipality, social and economic groups and others, the representative sample should be 30-100 households per the study area (Nordtest, 1995).

2. Sloven‟s formula in statistics was adopted to determine the number of households selected for this research.2.4.2 Municipal Solid Waste Quantification by Weight

Weight is the most simplest and efficient measurement for quantification in many waste management programs (Felder et al., 2001) and to help examine the current waste management operations, weight quantification and category classifications is selected. Quantification by weight also allows for the estimation of final design accuracy, in that records of waste sent to landfill are recorded by weight. This research is quantifying the household waste based on the weight of the waste generated which is in agreement with the views expressed by Felder et al., (2001).

2.4.3 Municipal solid waste Generation

Waste generation are those activities that encompasses materials which are identified as no longer being of value and are either thrown away or gathered together for disposal (Momoh and Oladebeye, 2010). In 2006 the total amount of MSW generated reached 2.02 billion tones globally, that is, a 7 per cent annual increase since 2003 (Anon, 2009). It is estimated that between 2007 and 2011, municipal waste will rise globally by 37.3 per cent, corresponding to roughly 8 per cent increase per year (Anon, 2009). It is accepted that Solid waste generation is increasing at a faster rate globally as indicated by Anon, (2009); Mensah and Larbi (2005).

2.5 Source Separation and Willingness to separate waste

Source separation of solid waste is the setting aside compostable and recyclable material from the waste stream before they are collected with other MSW, to make possible reuse, recycling and composting Anon (2005). This practice does not exist in the solid waste management practice of most developing countries like Ghana but has long been practiced in developed countries.

Source separation of MSW into various components is an important option towards achieving a sustainable and integrated sole waste management system in Ghana and in Takoradi in particular. It is better to separate recyclable materials at source rather than mixed waste recovery as cleaner and higher quality materials are produced through source separation (Anarfi, 2013). Source separated materials readily make available the necessary raw materials for recycling and composting plants. Relatively small portions of solid waste in additions to the inevitable by-products of composting and recycling

will end up in landfills. Separation of organic waste from the MSW stream represents an opportunity to reduce the quantity of waste entering landfills in developing countries by more than 50% by weight (Oduro-Appiah and Aggrey, 2013). Source separation increases the value of MSW and prolongs the lifespan of
landfills.

Introduction of source separation of waste as part of integrated solid waste management would thus require knowledge on the extent and category of separation in addition to the willingness and ability of the masses to effectively carry out the separation process. This will help develope alternative waste management strategies that will help diverse the waste that will end up in landfills.

In a study by Oduro-Appiah and Aggrey (2013), 75.3% of households would separate their waste only if they are given free bins, 72.3% were willing to separate their waste if the waste collection fee will be reduced and only 21.9% were willing to separate their waste with no incentive. Asase and Oduro-Kwarteng (2010) reported that over 70% of households were willing to separate waste so far as motivations such as free bins were in place.

2.6 Problems of managing Municipal Solid Waste

Some of the challenges facing solid waste management in developing countries (and for that matter Ghana) includes: collection and disposal, low collection coverage and irregular collection services, inadequate funds to support waste management, inadequate equipment to support waste storage, crude open dumping and burning without air and water pollution control (Puopiel, 2010).

The „blind technology transfer" of machinery from developed countries to developing countries contributes to the problems of managing MSW (Nabegu ,2010) and its subsequent failure has brought attention to the need for appropriate technology to suit the conditions in developing countries in terms of type of waste, composition, quantity of waste etc. Therefore the lack of data on the type of waste, its composition and the quantity pose a challenge to the selection of the right technology for treatment. Identification of waste composition is thus, critical for the selection of the most suitable technology for treatment, taking vital health precautions and space needed for the treatment facilities (Nabegu, 2010).

Waste characterization is the prerequisite for developing management strategies and/or for maintaining up to date data. The lack of data is due to the very high cost of the methodologies coming from developed countries, and on their inappropriate transfer to less developed countries. These two aspects prevent effective and sustainable waste management in developing countries (Topanou *et al*, 2011)

The main problem facing Ghana in managing waste is the lack of suitable sites for disposal of solid waste (Freduah, 2004). Reduction of the amount of waste that ends up at the final disposal site will help improve the waste management as the valuable materials will be recycled due to natural population increase and rural-urban migration. This is an undeniable fact, because the oil find in the region has increased the number of people migrating into the TSM for various economic reasons which in turn increased the amount of waste being generated.

A typical solid waste management system in a developing country shows a range of problems, including low collection coverage and irregular collection services, crude open dumping and burning without air and water pollution control (Puopiel, 2010).

2.7 Municipal Solid Waste Management in Ghana and TSM

Solid waste management in Ghana by law, is the responsibility of the Ministry of

Local Government and Rural Development, which supervises the decentralized Metropolitan, Municipal and District Assemblies that is, the responsibility for waste management by MMDAs is mandated by the local Government Act (1993), Act 462 section 10 subsection 3 (d and e). The Act was developed to mandate MMDAs to initiate programmes for the development of basic infrastructure and provide municipal works and services and also to develop, enhance and manage human settlements and the environment in the district. The MMDAs are also in charge for the collection and final disposal of solid waste through their waste management departments. (WMDs) and their Environmental Health and sanitation departments. This means that the MMDAs like the Takoradi sub metro need to find the most effective and feasible collection and disposal system that is sustainable because, solid waste disposal in Ghana has become a major challenge to MMDAs as a result of urbanisation and increasing densities over the years. Metropolitan Assemblies find it difficult to deal with the large quantities of solid waste generated. This is due to the fact that, people resort to indiscriminate dumping as the only means to managing their domestic solid waste thus resulting in littering and heaping of waste (Puopiel, 2010).

2.7.1 Municipal Solid Waste Generation in Ghana

Low-income countries‟ solid waste generation rates average only 0.4 to 0.6 kg/person/day, as opposed to 0.7 to 1.8 kg/person/day in fully industrialized countries (Tia, 2012).

Ghana‟s five largest cities (Accra, Kumasi, Sekondi-Takoradi, Tamale and Tema) account for about 19% of the total population and their residents generate an estimated 3,200 tonnes of solid waste per day (Anon, 2010). The waste management department of STMA has estimated the city‟s daily output of solid waste to be 285 metric tonnes based on the per capita waste generation given by the Ghana Statistical Service in the year 2000 (Adu-Boahen, 2012). The waste management department of the assembly collects 8,040 tonnes of the waste a month (Adams, 2011). The amount of municipal waste generated by the STMA in 2004 and 2010 are 0.68 kg/capita/day and 0.70 kg/capita/day for 2004 and 2010 respectively and 236 tons/day and 283 tons/day 2004 and 2010 respectively (Anon, 2010)

In Ghana, unlike other developed countries, there are no relevant waste stream data on waste generation. Waste management policies are therefore produced based on assumptions and not on any hard empirical data. But it is very difficult to establish the accuracy of the per capita daily waste output calculated by the Ghana Statistical Service and the subsequent waste generation estimate made by the city authorities. Urban residents generate more waste than their rural counterparts due to their high consumption of products (Adu-Boahen, 2012). Therefore the per capita daily waste generation in the STMA could vary and probably higher than the national average of 0.5 kg. The TSM generates 202 tonnes of waste per day and 73730 tonnes per year (Aryee *et al*, 2014). The estimated waste generated is based on the amount of that is about to be collected without accounting for those that are not collected. Thus carrying out a source specific analysis of the waste stream and calculating the per capita waste generation will help in the efficient management of waste in the sub metro.

Nationwide estimates of the rate at which municipal solid waste is generated have been developed by public and private organizations. These estimates are simply average generation rates and they fail to account for local variations in income level and the types of businesses and institutions in a particular community (Puopiel, 2010).

2.7.2 Municipal Solid Waste Collection in Ghana

One of the mandates of the Assembly and the Takoradi Sub Metro in particular are to collect and dispose of waste in the Sub Metro but this has posed a great challenge (Aryee *et al.,* 2014). The STMA has a difficulty in the collection and the disposal of solid waste (Adams, 2011) and the major challenges confronting the assembly in waste is the inability of private service providers to deliver efficient services due to the frequent breakdown of equipment and vehicles as well as inability of Ministry of Local Government and Rural Development to pay the service providers.

The practice of involving private sector has seen the demarcation of cities into zones, engagement of companies through competitive bidding or no bidding and rendering of service with or without signed contractual agreements between companies and Local Governments (Oduro-Kwarteng, 2011).

For the purpose of effective waste collection, the city of Accra was demarcated into waste collection districts where a company was contracted by AMA to collect waste in one district or two (Anomanyo, 2004). For easy and efficient collection and disposal of municipal solid waste, the Sekondi-Takoradi metropolitan assembly has been zoned into four Sub Metros. The Sekondi, Takoradi, Essikado-Ketan and Effia Kwesimintim Sub metros (Aryee *et al*., 2014). Different private waste collection service providers are responsible for collecting waste within each zone. Zoomlion Ghana limited is the waste collection companies assigned to the TSM. Beach road enjoy full coverage of door-to-door services while part of the second class residents,

Essikafoambatem No 1 enjoy door-to-door services and the third class residents, Adakope have to find ways of disposing of their waste and New Takoradi residents depend on the communal lifting system. The main types of vehicles used by Zoomlion were compaction and skip trucks.

MSW collection is carried out on both franchise and contract basis in the TSM. On the franchise basis, a house-to-house collection in high income areas for a fee with weekly collection frequency. These areas are well-planned residential areas with access roads described as first and second class areas. In the Takoradi sub metro, the fees charged for collecting waste from the first class and second class vary with the first class paying more than the first where the frequency with which the waste is collected is higher. The communal lifting system in the third class residents operates on the pay-as-you-dump term.

From the above assessment, it can be deduced that there are basically, two main modes of waste collection in AMA and KMA as well as Takoradi sub metro. These are door-to-door or house-to-house collection and communal collection which are carried out in the high class and low class residential areas respectively. The door-todoor collection may not favour the poor or low income areas and therefore there is the likelihood of poor waste collection services in these areas. Attention on collecting solid waste in these areas will be less. So there is the tendency for residents to dump waste any how because of poor collection service as well as those communities without any of the services.

2.7.3 Municipal Solid Waste Disposal in Ghana

There are several methods for the final disposal of municipal solid that have evolved over the years. These methods vary greatly with types of wastes and local conditions (Puopiel, 2010). The most commonly recognized methods for the final disposal of solid wastes in early practices of managing solid waste were dumping on land, canyons and mining pits; dumping in water; feeding livestock; ploughing into the soil and reduction and incineration. Some of these unwholesome practices of solid waste identified during the early disposal practices still exist in cities, towns and villages today which is evident in the TSM walking through the town. Indiscriminate dumping on opened land and dumping in gutters particularly are clearly evident in towns and cities, while dumping in water especially people living in coastal towns is common.

A study carried out in Ado-Akiti in Nigeria showed that, the methods of solid waste disposal include dumping of waste in gutters, drains, by roadside, unauthorized dumping sites and stream channels during raining season and burning of wastes on unapproved dumping sites during the dry season (Momoh and Oladebeye , 2010). This has gone to confirm that the practices of solid waste disposal in the 1950s still exist today.

Increasing amount of solid waste arising from municipalities and other sources and its consequent disposal make solid waste disposal in Ghana and for that matter TSM a grave cause of concern and the main area of problems are indiscriminate dumping, lack of fitting disposal sites, troubles with proper solid waste disposal due to deterioration of road ways and escalating traffic woes. The problem relating to the capacity of dump site has also become a challenge to the various municipalities of which the TSM is a part. Anomanyo (2004) says, from the 1991 till date AMA had to shift the dumping site from one location to another due to the dump capacity, which usually gets filled in a short time. Between 1991 and late 2001 the dumping site had to be move from Mallam to Djanman which unfortunately could not last as it was filled to capacity in just three months. The dump site was again shifted to an old stone quarry at Oblogo in the McCarthy Hills of Accra. The STMA with Takoradi sub metro inclusive send all waste collected to a tipping site (Aryee *et al*., 2014) which is almost filled to capacity therefore a new dumping site needs to be moved to.

Since the formal systems of solid waste disposal cannot cope with the ever-increasing volume of solid waste being generated, waste is dispose of indiscriminately especially in watercourses and drainage channels and also through burning (Puopiel, 2010). Gilbertson (1969), however, maintained that open dumping of solid wastes on land, though considered unsanitary and unaesthetic, is still the most common disposal practice.

2.8 Private Sector Involvement in Waste Management

In many cities of Asia, deficiencies in the provision of waste services are the result of inadequate financial resources, lacking management, and technical skills of municipalities and government authorities to deal with the rapid growth in demand for service. Although budgets are limited, the willingness to pay for well rendered services is high thus giving an opportunity for appropriate approaches (Zurbrugg, 2002). Solid waste collection in developing countries especially in Africa is a real challenge to the public sector. Given the level of investment the running cost of solid waste management and the competing priorities (water, health, education, road and energy) of national governments the public sector alone could not deliver the solid waste services. The private sector is partnering with the public sector to give the needed resources for the solid waste service delivery (Oduro-Kwarteng, 2011).

Pressures on government to reduce taxes, while increasing and improving levels of service are leading to an exploration of privatisation as an option for waste management functions.

Privatisation can take various forms. A government can award a contract to a private firm for specified MSWM services; it can contract with a private firm to construct a waste management facility, which the firm may subsequently own or operate; it can license a private firm to carry out MSWM activities and recover its costs directly from those served; or it can allow qualified firms to participate in open competition. Informal waste recovery and scavenging may be rendered more productive through support measures and appropriate technical design of the waste management systems. Public sector involvement in waste recovery and/or leasing of waste recovery rights to private sector enterprise may be considered (Adu-Boahen, 2012).

CHAPTER THREE

MATERIALS AND METHODS

3.0 Study Area

The study was carried out in the (Takoradi sub-metro) TSM which is under the Sekondi-Takoradi Metropolitan Assembly (STMA) of the Western Region of Ghana. The STMA has undergone several changes in status and change in name. It started as Sekondi Town Council in 1903, under the Town Council Ordinance No 26. Takoradi then joined the administration in 1946. Sekondi-Takoradi was elevated to the status of a city in 1962. The Assembly was named as Shama Ahanta East Metropolitan Assembly (SAEMA) through an LI 13116. The assembly was renamed STMA in 2008 through an LI 1928 after Shama was carved out. The STMA is divided into four zones or sub-metropolitan councils namely: Sekondi sub-metro, Effia Kwesimintim Sub-metro, Essikado Ketan Sub-metro and the Takoradi sub-metro (Fig. 1). The division into zones was also to help enhance the effectiveness of collecting waste in the metropolis (Anon, 2012a).

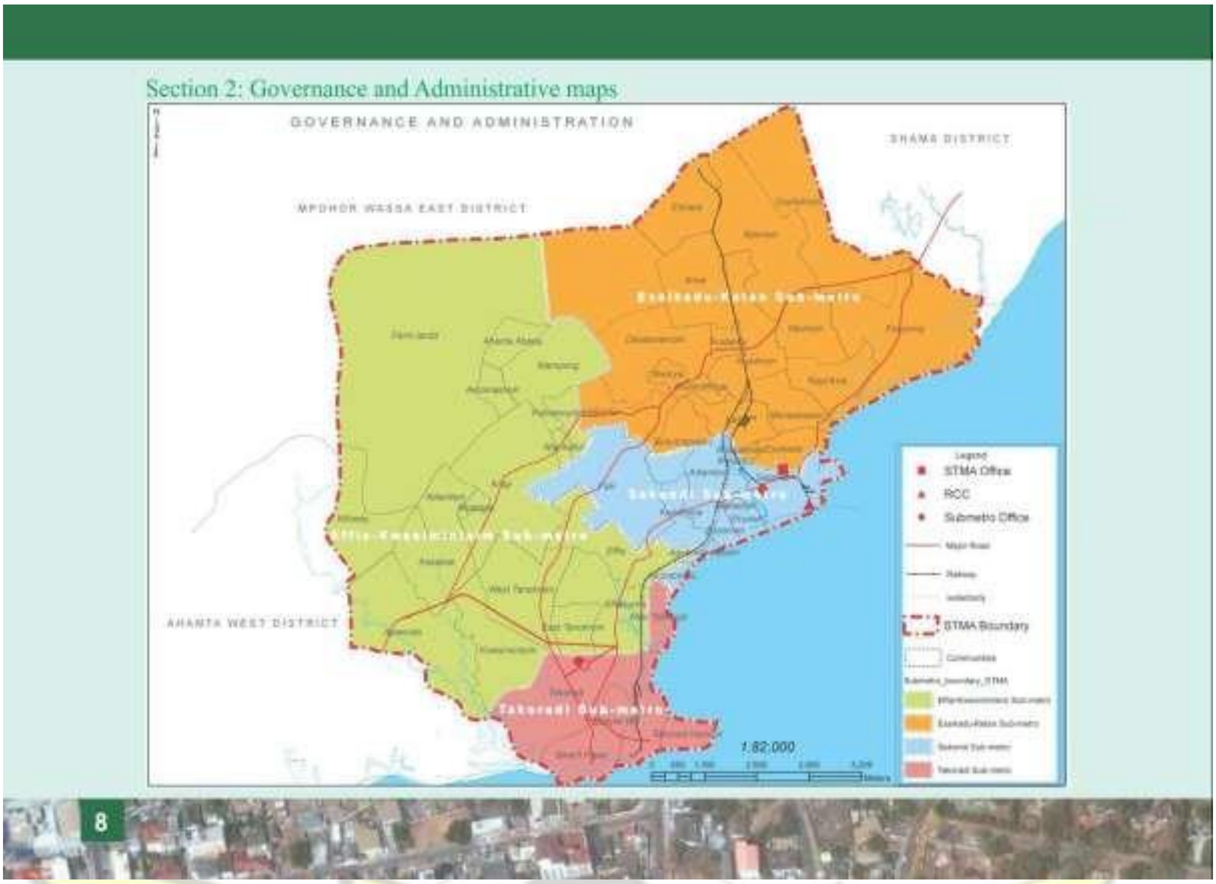

Fig 1: A map showing the four sub-metros under STMA

TSM is now widely believed to be absolutely the leading economic, commercial and industrial nerve centre of STMA due to the oil find. Oil has been mined in Ghana in a small way since the late nineteenth century, but Ghana joined the league of oil producing countries with the discovery of oil in commercial quantities at Cape Three point in the Western Region in June, 2007. Ghana"s new oil and gas industry"s positive impact are already being felt across the nation and employment is booming (Anon, 2011).

Findings indicate that Sekondi-Takoradi is evolving as a location for an oil industry cluster. Intense linkages between firms in the core oil industry and with other supporting businesses show characteristics of an industrial cluster (Quayson, 2012).Takoradi harbour for example which is the closest port to the Jubilee field, has thousands of new jobs being created and the flood of new workers has brought an instant turnaround in the fortunes of a town that had been in a state of decline. TSM is now the hub of the new industrial development in the region (Anon, 2011). The Western Region has experienced huge movements of in-migration in the last decade but more people have been attracted into the region especially the STMA probably more than it would have been without the oil find. It is in the hope of finding work in the oil related industries (Planitz and Kuzu, 2014).

According to the 2010 population and housing census, the population of TSM is approximately 97,352 people with gender distribution as 48,470 males and 48,882 females. About 27,920 are between the ages of 0-14, 65,292 between 15-62 and 4,140 of the population are above 65 years (Anon, 2012c).The Metropolitan economy which is the local economy of the Metropolis and the socioeconomic activities of the STMA is classified into three major sectors; manufacturing, agriculture and the services. The manufacturing sector is made up of paper manufacturing, timber manufacturing, metal fabrication, micro enterprises and agro processing. Majority of the people engaged in agriculture are into crop farming and fishing. The service sector is made up of shipping/forwarding, hotel/hostel/restaurant, bulk oil storage and distribution, transport services, harbor and port services and commerce (Anon, 2012b). Twenty one percent of the population are engaged in agriculture and are into crop farming with 6% of this population also into fish farming. The service sector is the largest employer of the labour force in the Metropolis. It employs 59.9% of the labour force who are mostly employed in white-colour jobs in private and public institutions (Anon, 2012b).

3.1 Demarcation for the Survey

The sorting and separation was carried out at the household levels. Portions of the study area which have been divided already by the STMA into three basic socioeconomic classes of settlement (first, second and third class residential areas) were chosen for the survey. The areas selected within the TSM as a representative of each of the social classes, first class, second class and third class, were Beach road, Essikafoambatem Number One and Adakope, respectively. The STMA classification which is based on socioeconomic development takes into consideration the type of buildings, road network and other social amenities in the area (Anon, 2012a).

- First class residential areas are mostly made up of single detached houses outside the city centre with gardens/lawns. The first class residential areas are usually quiet neighbourhoods with various amenities and access to social services. Not only are those areas quiet, but are also very close to the commercial business district (CBD), making vehicular and pedestrian accessibility to the CBD very easy. Crime rate in such areas is very low with the presence of police patrols. Not surprisingly, the inhabitants are mostly politicians, top public service officials, the rich and the elite in society.

- Second class residential areas are made up of high rise buildings or multiple occupancy properties with no gardens/lawns and close to the central business district. The second class residential areas are characterised by mixed residential properties like semi-detached, flats, and multi-family properties usually referred to in Ghana as the "traditional compound houses". Such compound houses are typically two-storey with 10 to 15 bedrooms. In such areas, basic amenities like schools, hospitals are available and accessible.

- Third class residential areas are often made up of wooden or make shift structures. The communities are unplanned and have many squatters. Low income families dominate. The third class residential areas are normally condensed, overcrowded and noisy. The crime rate is high. The value of land is low

3.2 Data types and sources

Data used for the research were from both primary and secondary sources.

3.2.1 Primary Data Collection

Primary data were collected through field survey, face-to-face interviews and Questionnaire survey.

3.2.1.1 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 will be involved. The field survey was to help receive feedback on their willingness to participate in the programme. Participants were assured of the confidentiality of their responses. The suitability of the study area households as points for sorting at source was also assessed.

3.2.1.2 Face-to-face Interviews

Face-to-face interviews were conducted amongst a cross-section of persons working in the administration of the STMA, TSM (WMD), Zoomlion Company Limited (Regional Manager and Assistant and some field supervisors) and Assemblymen in the study area.

The face-to-face interviews at the STMA focused on the various stakeholders involved in waste management, MSWM options, data on the generation and composition of solid waste from the sub-metros, collection and disposal strategies in the metropolis, classification of areas into socioeconomic settlements, final disposal site and the availability of waste management logistics. At the TSM (WMD), information was sought on the available data on quantity of waste generation and its composition, solid waste management strategies in the sub-metro and whether or not there was an engineered landfill site.

At the offices of the Zoomlion Company Limited the quantity of solid waste generated (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 (3 assemblymen) introduced the research team and the scope of the research to the communities. From the assembly men also the face to face interviews focused on MSW collection and disposal, 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.

3.2.1.3 Questionnaire Survey

Administration of questionnaires and direct field measurements were the two approaches 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 minimisation of waste through recycling 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 recycling were sought for in the questionnaire. The content of the questionnaire was based on five of the twelve factors influencing sustainable recycling 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 MSWM 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.

3.2.2 Secondary Data Sources

Books, articles, newspapers, journals and internet sources were some of the secondary data used. Some other secondary data were obtained from the STMA. The data obtained include: the assemblies waste management strategy, basic day to day activities, time taken in collecting waste to final disposal sites, implementing agencies within the assembly, collaborators and indicative cost.

3.3 Sample Size Determination

The number of samples needed as a representative of the population and waste amount was deduced from the Sloven"s formula: $SS=N/1+N(e)^2$, (Puopiel, 2010; Ariola, 2006), where SS=Sample size, N=population size, e= margin of error/error tolerance. Also as a check other formula relating to the right sample size representative of the population, $n = Z * Z [P (1-P)/(D*D)]$ and $SS = n / [1 + (n/population)]$ for correction of the infinite population were assessed, where P = True proportion of factor in the population, or the expected frequency value, D = Maximum difference between the sample mean and the population mean, Or Expected

Frequency Value minus (-) Worst Acceptable Value, Z = Area under normal curve corresponding to the desired confidence level, n= number of samples of infinite population and SS=number of samples of finite population.

From this, a total of 400 samples were needed as a representative sample. However, a total of 1393 samples were collected within the period of the survey which was far above what was statistically needed. This high sample size was to help 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 50250 would be representative enough to undertake the survey. The household sampled as a function of the population size in each of the stratified class is as listed in Table 2.

Table 2: Number of households of the various classes

SN	CLASS OF RESIDENTIAL AREA	SAMPLE SIZE
1	Beach road	28
2	Essikafoambatem no 1	34
3	Adakope	31

3.4 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 is 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.

3.4.1 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.

3.4.2 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.

3.4.3 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.

3.5 Collection of waste from Households and further sorting

Waste from the households was collected three (3) times in a week (Mondays, Wednesday and Fridays) over a period of five (5) 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 was carried out into various physical components and weighed and recorded.

3.6 Waste Quantification

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 were 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:

$$\text{Per capita waste generation} = \frac{\text{weight of MSW generated at the household}}{\text{Total number of persons in the household} \times \text{total generation days}}$$

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

3.7 Physical Composition of MSW Analysis

MSW from the households were segregated into the following compositions and analysed by weight 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 (PET, HDPE, PVC, LDPE, PP, PS and Pure water sachet)
- Metals
- Papers (packaging/cardboard/office print/sheet/newsprint and tissue/diaper)
- Leather and Rubber
- Textiles
- Inert (sand, ceramic, rock, ash)
- Miscellaneous (other materials which could not fit in the above).

$$\%\ \text{omposition of separated waste} = \frac{\text{Weight of separated wast}}{\text{The total mixed weight sampled}} \times 100$$

3.8 Separation Efficiency

The efficiency of the separation was assessed by the weight of sorted waste in the designated polythene bag provided as a percentage over the total weight of waste in the same bin.

Example:

$$\text{Separation efficiency of IO} = \frac{\text{weight of IO in blue polythene bag}}{\text{total weight of all waste separated into blue bag}} \times 100$$

The administered questionnaire helped to determine the preparedness of the participants to separate their waste at any given period. This was compared with how best the separation was done and attributions to the level of separation achieved were assigned considering the background of the household.

3.9 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 105 ^{o}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 (KazimbayaSenkwe 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 substrated from the 100 kg sample.

Basis: 100 kg sample

$$\text{moisture content} = \frac{(100 - b) \times 100}{100}$$

where b = Total dry mass

3.10 Data Analysis

The statistical package for Social Sciences (SPSS) 16 for Windows and Microsoft Excel were used to analyse the data obtained. SPSS was used to establish if any correlations between income levels of the three socioeconomic classes and the per capita generation and household size as well as the percentage generation of the composition of the waste stream. One way ANOVA was used to test for significant difference between the three classes. The mean value in relation to the standard error of the separation effectiveness of the waste in the three classes was determined using the SPSS. The significance was at p=0.05 (95% confidence level).

CHAPTER FOUR

RESULTS

4.0 Background of Respondents

The survey shows that of the 93 respondents, 66% were females and 34% males (Table 3). Average household size was 6 for all the three socioeconomic groups. 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, 66.67% had their knowledge from one source and the rest from more than one source. Most (56.14%) of this knowledge was from newspapers, television news and radio (Table 4). They were again asked if they were willing to separate their waste on a daily basis. On willingness to separate waste at source, 72% were willing to separate their waste on a daily basis while 27.96% said they were not ready to separate their waste (Table 6). On recycling, 93% of the respondents had heard and read on recycling of waste materials and 7% had not. Similarly, 81.40% heard or read of recycling from newspapers, television or the radio, thus being an influential source of promoting environmental awareness (Table 5). More than 77% of the respondents were willing to send materials to recycling centres if these were established in their neighbourhoods (Table 6).

On home composting, 74% of the respondents were willing to adopt the concept and 46% were also willing to buy extra bins for this purpose.

Most of the respondents that were self-employed often worked from their homes or on the street in front of their houses especially those in the second and third class residential areas.

Table 3: Background characteristics of respondent

Item	Number of Respondent	Percentage %
Gender		
Male	32	34.41
female	61	65.59
Employment Status, Beach Road		
Formal	17	60.71
Informal	8	28.57
Unemployed	3	10.71
Employment status, Essikafoambatem No 1		
Formal	12	35.29
Informal	16	47.06
Unemployed	6	17.65
Employment Status, Adakope		
Formal	8	25.81
Informal	18	58.06
Unemployed	5	16.13

Table 4: Source of knowledge on Separation of waste

Answer	Number of respondent	Percentage %
News Paper	12	21.05
Television news	8	14.04
Radio	4	7.12
Both Radio and Tv news	5	8.77
News Paper, Tv news and Radio	3	5.26
Other Sources	25	43.86

Table 5: Source of knowledge on Recycling of waste

Answer	Number of respondent	Percentage %
News Paper	28	32.56
Television news	11	12.79
Radio	9	10.47
Both Radio and TV news	12	13.95
News Paper, TV news and Radio	10	11.63
Other Sources	16	18.6

** knowledge from newspapers, television news and radio is 81.4%

Table 6: Descriptive Statistics of Socioeconomic Characteristics of the Respondents

Item	Number of Respondent	Percentage %
Have You heard or seen waste separation?		
Yes	57	61.29
No	36	38.71
Are you willing to separate your waste?		
Yes	67	72.04
No	26	27.96
Have you heard or seen waste recycling?		
Yes	86	92.47
No	7	7.53
If recycling centre is established would send waste for recycling?		
Yes	72	77.42
No	21	22.58
Would you accept concept of home composting?		
Yes	69	74.19
No	24	25.81
Would you buy an extra bin for home composting?		
Yes	43	46.24
No	50	53.76

4.1 Physical Composition of Waste

Table 7: Physical Composition of MSW

PHYSICAL COMPOSITION OF WASTE	CLASS RESIDENTIAL SETTLEMENTS BEACH ROAD		SSIKAFOAMBATEM No		ADAKOPE	
BIODEGRADABLES	**Wt kg**	**Wt %**	**Wt kg**	**Wt %**	**Wt kg**	**Wt %**
Food Waste	1799.77	*42.47*	2255.93	*60.76*	1376.15	*36.62*
yard Waste	1109.29	*26.18*	44.3	*1.19*	317.5	*8.45*
Wood	97.8	*2.31*	34.9	*0.94*	42.1	*1.12*

	3006.86	***70.95***	2335.13	***62.89***	**1735.75**	***46.19***
NON-BIODEGRADABLE						
Paper and Cardboard						
News/Office Print/ Cardboard	152.7	*3.6*	167.56	*4.52*	93.8	*2.49*
Tissue Paper/Diaper	217.9	*5.14*	141.3	*3.81*	93.5	*2.49*
	370.6	***8.74***	**308.86**	***8.32***	**187.3**	***4.98***
Plastics						
Plastic Film/LDPE	146.4	*3.45*	249.02	*6.71*	219.6	*5.84*
PET	85.7	*2.02*	50.91	*1.37*	29.9	*0.8*
HDPE	45.5	*1.07*	36.2	*0.97*	24.5	*0.65*
Pure water sachet	54.65	*1.29*	125.31	*3.38*	65.5	*1.74*
PP	33.5	*0.79*	28.51	*0.77*	17.7	*0.47*
PS	32.95	*0.78*	15.32	*0.41*	4.2	*0.11*
PVC	11.1	*0.26*	6.7	*0.18*	8.8	*0.23*
Other Plastics	13.5	*0.32*	20.6	*0.55*	8.91	*0.24*
	423.3	***9.99***	**532.58**	***14.34***	**379.11**	***10.09***
Metal	**132.9**	***3.14***	**93.25**	***2.51***	**55.6**	***1.48***
Glass	**116.4**	***2.75***	**45.7**	***1.23***	**20.6**	***0.55***
leather and Rubber	**27.1**	***0.64***	**83**	***2.24***	**29.8**	***0.79***
Textiles	**79.8**	***1.88***	**181.22**	***4.88***	**73.6**	***1.96***
Inert	**33.2**	***0.78***	**55.5**	***1.49***	**820.8**	***21.84***
Miscellaneous	**46.7**	***1.1***	**68.3**	***1.84***	**450.7**	***11.99***
TOTAL	**4237.96**	***100***	**3712.94**	***100***	**3757.46**	***100***

**Percentages of waste composition in italics*

The percentage by weight of the physical waste composition from the waste stream from all the randomly selected households combined over the entire period of the survey from the various classes of residential areas is shown in Table 7. The waste stream from the Beach Road had 70.95% biodegradable waste, 8.74% paper and cardboard, 9.99% plastics, 3.14% metals, 2.75% glass, 0.64% leather and rubber, 1.88% textile, 0.78% inert and 1.10% miscellaneous (Table 7). Essikafoambatem No 1 had 62.89% biodegradable waste, 8.32% paper and cardboard, 14.34% plastics, 2.51% metals, 1.23% glass, 2.24% leather and rubber, 4.88% Textile, 1.49% inert and

1.84% Miscellaneous. Adakope has 46.19% biodegradable waste, 4.98% paper and cardboard, 10.09% plastics, 1.48% metals, 0.55% glass, 0.79% leather and rubber, 1.96% textile, 21.84% inert and 11.99% miscellaneous.

The percentage composition of biodegradables were highest for all three areas and Leather and rubber had the lowest composition for Beach road while glass had the lowest by weight for both Essikafoambatem No 1 and Adakope. The figures shown in the table are averages of all the samples taken. Averagely the study area (TSM) has 60.01% biodegradables, 11.47% plastic, 7.35% paper and cardboard, 2.38% metals, 1.51% glass, 1.22% leather and rubber, 2.91% textiles, 8.04% inert materials and 4.98% miscellaneous materials.

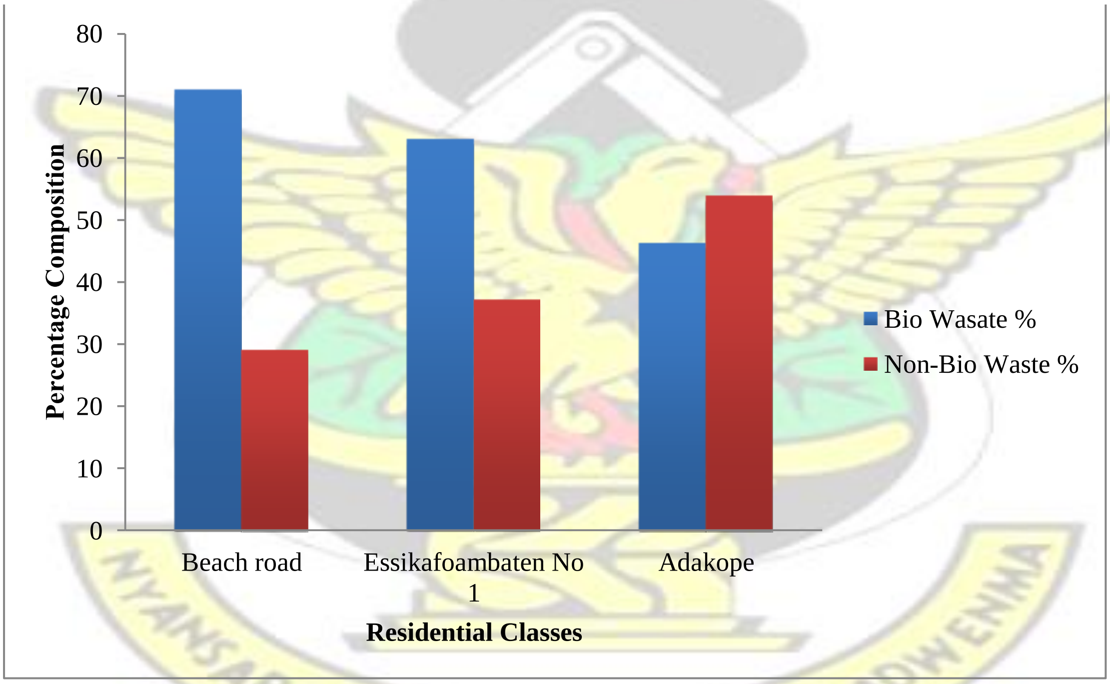

Fig. 2: Categorisation of Waste stream into Bio and Non-Bio

A total waste load of 11,708.36 kg was weighed, out of which 3757.46 kg belonged to the low socioeconomic status, 3712.94 kg to the medium status and 4237.96 kg to the high status (Table 7). It can be seen that biodegradable waste generated by the three classes decreased steadily and the non-biodegradable waste increased steadily from the first to the third class. One-way ANOVA test indicates that there is no significant difference in the quantity of waste generated among the three residential classes (Appendix). The ANOVA produce a test statistic of 0.05 and a p-value of 0.96 which is greater than any significance level.

Of the three socioeconomic groupings; biodegradables (food, yard and wood waste) accounted for more than half of the total except for the third class area which has high amount of Inert and miscellaneous materials (Table 7) accounting for the high amount of non-biodegradable waste generated compared to the other residential areas.

The first and second classes had their waste stream made up of more biodegradables than non-biodegradables (Fig. 3). The independent t-test for Beach Road, Essikafoambatem No1 and Adakope residential classes between Bio waste and Nonbio waste shows that, there is a significant difference between the two groups of waste generated by the various classes.

4.2 Separation Efficiency and Willingness to Separate Waste

Table 8 shows the mean values of how well the various classes of residents separated (separation efficiency) waste into the right polythene bags provided for the survey. From the table, the heading " io" represents amount of biodegradable waste in the right polythene bag given the selected households and the heading "Non- io" represents the amount of waste in the right polythene bag that is, the polythene bag that is to contain only non-biodegradables waste.

Table 8: Mean ± standard error of the Separation Efficiency of the various classes of Residents

SEPARATION EFFICIENCY (MEAN±SE)

Class of Residents	WK1	WK2	WK3	WK4	WK5
BIO					
1st C lass	6.82±0.6	6.87±0.6	6.81±0.6	6.47±0.6	5.44±0.6
2nd Class	4.21±0.2	4.32±0.3	4.12±0.2	4.07±0.2	3.95±0.3
3rd Class	3.10±0.2	2.67±0.2	2.95±0.2	2.74±0.2	4.09±0.4
NON-BIO					
1st C lass	1.04±0.4	1.70±0.2	0.60±0.1	1.03±0.2	0.66±0.1
2nd Class	3.20±0.6	2.00±0.5	0.80±0.3	1.74±0.4	1.50±0.3
3rd Class	3.13±0.4	2.43±0.4	0.80±0.2	0.34±0.1	4.37±0.2

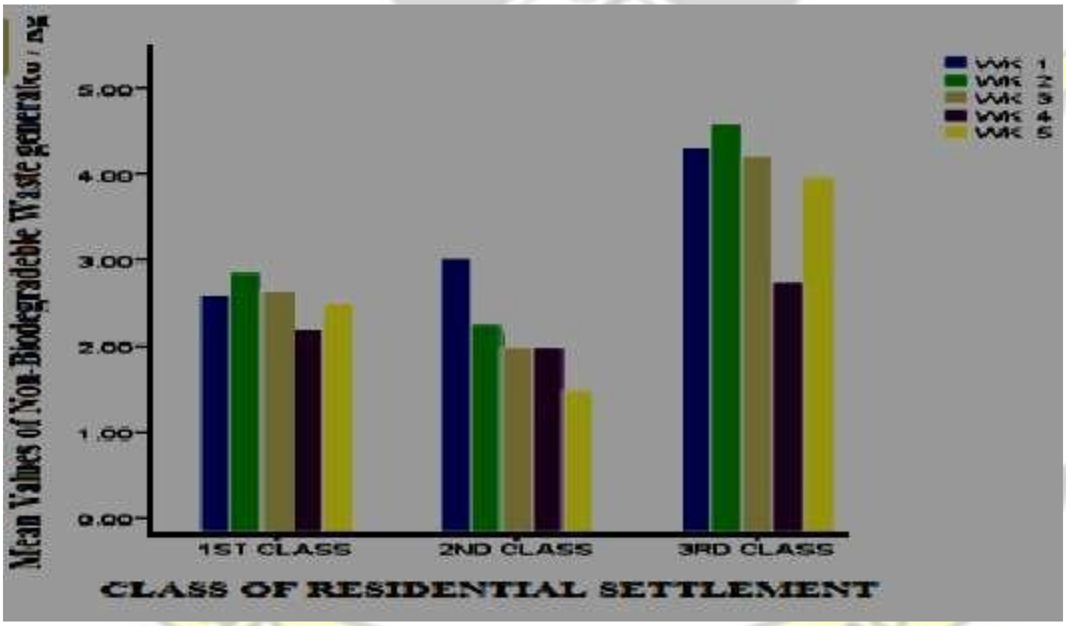

Fig. 3: Amount of Non-Bio in the Non-Biodegradable Polythene Bag

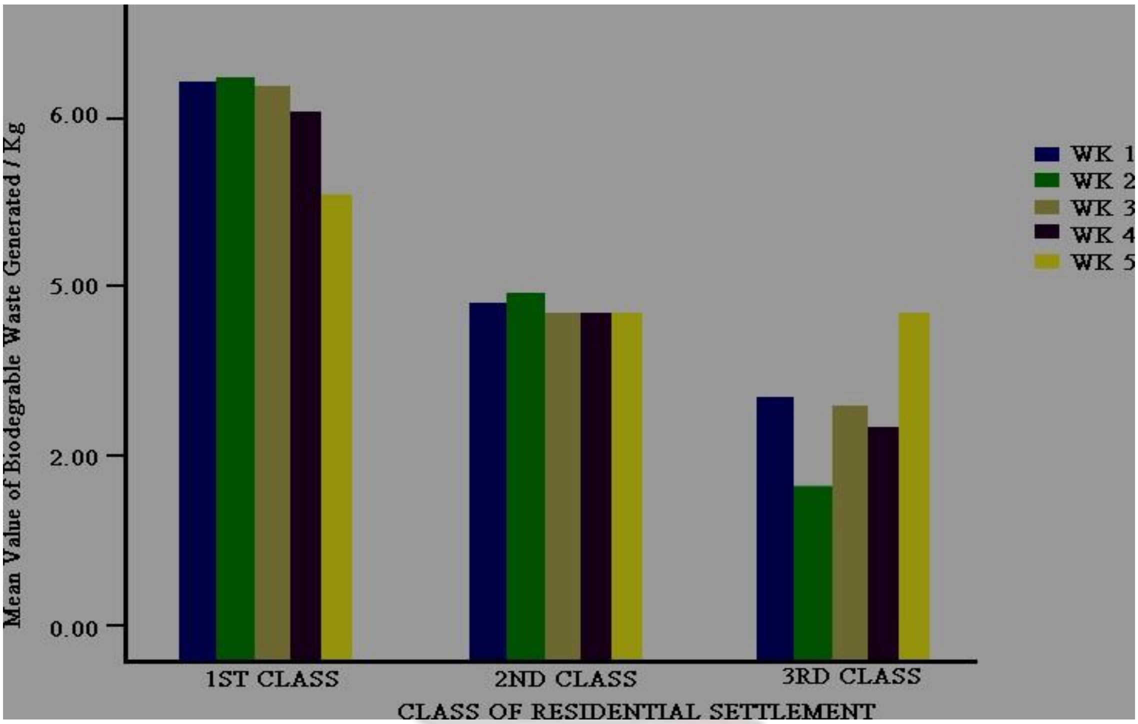

Fig. 4: The Amount of Bio in the Biodegradable Polythene Bag

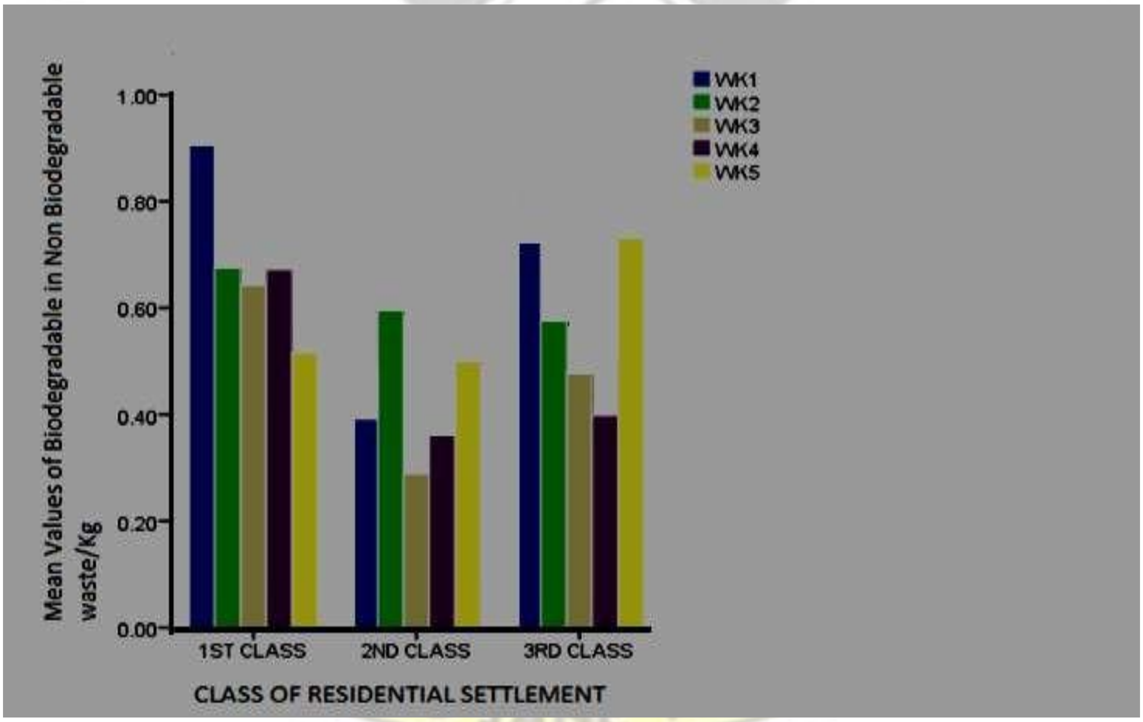

Fig. 5: The Amount of Bio in Non-Biodegradable Polythene Bag

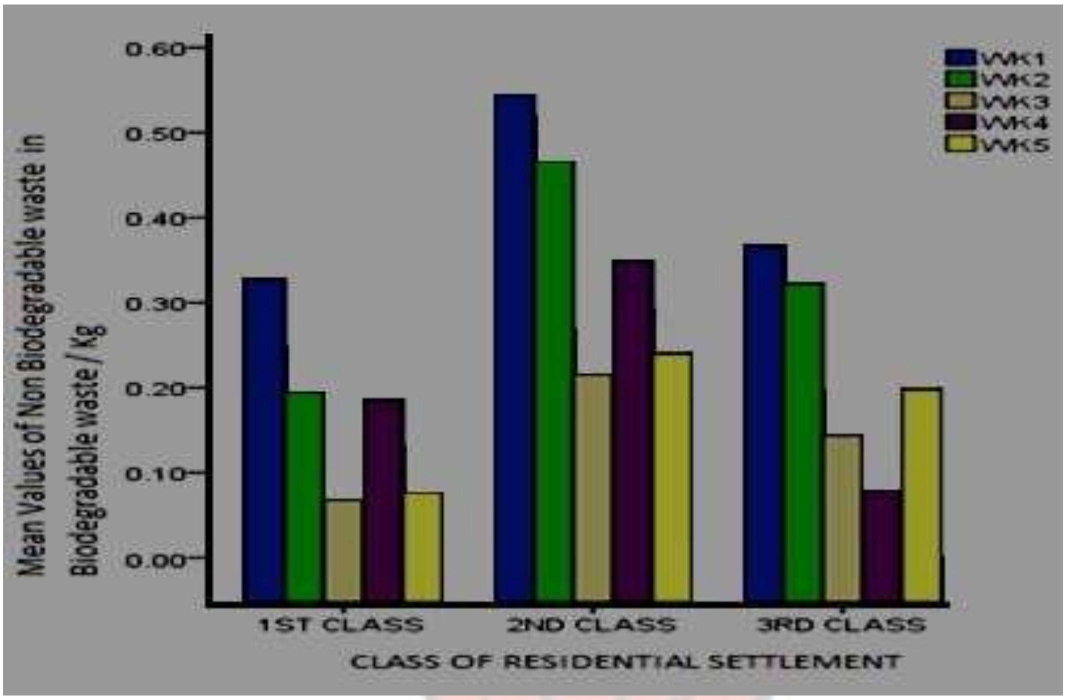

Fig. 6: Amount of Non-Bio in Biodegradable Polythene Bag

There were various degrees of separation efficiency into the designated polythene bags provided for the study. In the polythene bag designated for biodegradable in the first class residential area, 18.57% of the respondents had 100% separation efficiency, 79.29% had 80% to 99.99% separation efficiency and 1.76% had 50% to 79.99% separation efficiency. However, in the second class, 6.50% of the respondents had 100% separation efficiency, 83.53% had 80% to 99.99% separation efficiency and 9.64% had 50% to 79.99% separation efficiency. In the third class areas, 14.77% of the respondents had 100% separation efficiency, 76.13% had 80% to 99.99% separation efficiency, 7.10% had 50% to 79.99% separation efficiency and 1.94% had less than 50% separation efficiency. For the waste in the polythene bag designated for non-biodegradable in the first class residential area, 4.50% of the respondent had 100% separation efficiency, 51.43% had 80% to 99.99% separation efficiency, 39.29% had 50% to 79.99% separation efficiency and 4.28% had less than 50% separation efficiency. In the second class, 16.47% of the respondent had 100% separation efficiency, 53.53% had 80% to 99.99% separation efficiency, 26.47% had 50% to 79.99% separation efficiency and 3.53% had less than 50% separation efficiency. In the third class, 3.23% of the respondent had 100% separation efficiency, 74.84% had 80% to 99.99% separation efficiency, 19.35% had 50% to 79.99% separation efficiency and 2.58% had less than 50% separation efficiency. From the result, it shows that less than 5% of the respondents had less than 50% separation efficiency.

4.3 Per Capita Waste Generation

Table 9: Relationship between Income Level and Per Capita Waste Generation

	INCOME LEVEL OF VARIOUS CLASS OF HOUSEHOLD		
AVERAGE WASTE PER CAPITA	1ST CLS INC	2ND CLS INC	3RD CLS INC
1ST CLS AVR	-0.0082	*	*
2ND CLS AVR	*	-0.1838	*
3RD CLS AVR	*	*	-0.0177

**. Correlation is significant at the 0.01 level (2-tailed).

The results show that the higher the income level the lower the per capita generation of waste per weight generated (Table 9). However, the correlation variables can be considered as a weak effect therefore no or negligible relationship or a non-significant correlation exist between the income level and per capita waste generation.

Table 10: Relationship of Per Capita Daily Waste Generation to Households size

	Household Size of the Various Households		
Average Waste per capita	**1st Class Hse size**	**2nd Class Hse size**	**3rd Class Hse size**
1st Class AVR	-0.711	*	*
2nd Class AVR	*	-0.825	*
3rd Class AVR	*	*	-0.706

The ANOVA (Table 10) shows there is a strong negative relationship between household size and per capita generation of waste in the area. This means that as household size increase the per capita (kg/day) waste generation decreases.

Table 11: Per Capita Waste Generation by Socioeconomic Status

Per Capita Waste Generation Per Day by Socioeconomic status (kg/ca/day)		
First Class	**Second Class**	**Third Class**
0.76	0.66	0.69

The total daily per capita generation rates show the first class areas having a higher rate of 0.76 compared to the second and third class which had a generation rate of 0.66 and 0.69 and the average for the three classes was 0.70 (Table 11). The ANOVA test of per capita waste generation rate among the three classes indicates that, there is significant difference among the three classes of per capita waste generated over the period. The ANOVA test produces an F-statistic of 5.91 and p-value 0.0, which means that the differences between the classes are significant at 5% significance level.

4.4 Potential for Recycling

Table 12: Composition of MSW Socioeconomic status

ITEM	Beach Road %	Essikafoambatem N0 1 %	Adakope%
Compostable	72	67	48
Recyclable	19	24	15
Residue	9	9	37

The higher socioeconomic status residential areas discard higher (73%) amount of waste with potential for composting compared to the lower status, which generates 48% (Table 12).

From the various waste streams, 91, 91 and 62% from the first, second and third class respectively can be reused additionally, 18, 23 and 14% had the potential of being recycled with financial and environmental benefits. Similarly, 73, 68 and 48% of the waste streams could be reused for composting.

The ANOVA test of compostable waste generated for the three residential classes shows that, there is no significant difference between the compostable wastes generated by the three residential classes. Also, the ANOVA test of recyclable wastes generated for the three residential classes shows that, there is no significant difference between the recyclable wastes generated by the three residential classes. For the residual waste generated by the three classes, it indicates that there is no significant difference between the residue wastes generated by the three residential classes.

4.5 Moisture Content of the Various Socioeconomic Classes of Solid Waste

Table 13: Moisture content of solid waste

Class/component	Beach Road/first class	Essikafoambatem No 1/ second class	Adakope/third class
Moisture%	59.05	61.87	44.06

The moisture content in the food and yard waste from all the three classes of residential areas ranged from 44.09% to 61.87%, with Adakope having the lowest moisture content and Essikafoambatem No 1 the highest.

CHAPTER FIVE

DISCUSSION

5.0 Physical Composition

Results from the study show that food residues were on average the most abundant (58.56% putrescible; food and yard) waste in all the three classes of residential areas. 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 putrescible waste. In contrast, in developed countries, buying of processed and readyto-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 putrescible reported in this study is similar (58.56%). 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 and Babatunde, 2008). The 58.56% organic waste in this study indicates that composting would be a good waste management option for the Takoradi metropolis.

Of the three classes of residential areas used for this study, food residues were the highest volumes of waste in the second socioeconomic class and this may be due to the large numbers of local restaurants “ hop bars” in that community. The third class areas had the lowest volumes of food residues as most of these food wastes were used as animal feed. Yard trimming formed the bulk of the waste in the first class residential areas.

Textiles, is another category of waste that stands out as it formed only 1.88% of the total waste generated within the high socioeconomic status area. This should have been higher considering their high purchasing power and the ever-changing fashion trends within such communities. However, this may be because they give out most of their unwanted clothes to their domestic workers before discarding the rest.

The "paper" waste was mainly disposal tissues and diapers in all the three socioeconomic classes. Of the plastics, it was highest in the second class socioeconomic status and lowest (9.99%) in the high socioeconomic class. The contribution of paper to household waste (HSW) was lower in the Takoradi area compared to that in developed cities/countries. Plastics, especially LDPE and pure water sachets were higher among the other types of plastics produced in the waste stream. This may be due to the fact that, although no formal recycling programs have been implemented in TSM, most paper waste generated in households (e.g. newspapers, magazines) are sold to food vendors who use them in wrapping food and other items, whereas most plastic items enter the waste stream and end up in the landfills. However, the amount of recyclable plastics produced could supply small recycling plants considering the per capita generation of waste. The first class generates more packaging waste in total (paper, metals, plastics and glass) than the second class, and the third class generates the least of this type of waste. The highest percentage of packaging waste generated by the high income population indicates its greater purchasing power, reflected in its consumption pattern. Oyelola and Babatunde (2008), reported that the packaging fractions of household waste have a direct relationship with household income; the wealthier households produce significantly higher percentages of paper, plastic, metal and glass wastes, mostly from packaging materials. The composition of packaging materials from this study confirms it. The lowest production packaging in the Low income neighbourhoods produced the lowest packaging indicates low consumption, given the lower purchasing power and greater tendency to profitable recycling, given the population‟s greater need for supplementary income.

Over 5.14% of disposable tissues and diapers were generated in the high socioeconomic areas followed by the second class areas (3.81%) and the low income areas, 2.49 . The low status areas generated the highest (21.84) amount of "inert"
(sand and dirt) waste. Of the "miscellaneous" items, a greater amount was found in the low socioeconomic status, 11.99%. This may be due to the patronage in secondhand electronic items and disposable batteries compared to only 1.15% in the high socioeconomic status areas.

From the study, biodegradable waste constituted 60.01% and non-biodegradable waste 39.34%. Differences in waste composition between the various socioeconomic classes were not statistically significant on the basis of weight, confirming the similarity in the waste variation across the different socioeconomic classes.

5.1 Separation Efficiency and Willingness to Separate Waste

Source separation programs need high participation rate of the people and a guaranteed participation is difficult to measure since what people say they will do and what they actually do may not be the same. The willingness to separate waste at source may not reflect in the actual separation of the waste at source. The willingness of households to separate waste at source on average was 71.4%, 79.4% and 64.5% for first, second and third class areas respectively. This is consistent with research by Anarfi (2013), who recorded 73.3% and 86.7% for the low and middle income groups, respectively. It is also consistent with work by Asase and Oduro-Kwarteng (2010), who reported that over 70% of respondents in their study area were willing to separate their household waste at source. The results from other researchers have also confirmed the high willingness to separate household waste in Ghana (Asase and Oduro-Kwarteng, 2010). Respondents from the third class had the lowest response in terms of willingness to separate waste at source and the explanation may be because they did not believe initially the collection and disposal of their waste from their residence will totally come at no cost to them.

The separation efficiency achieved for separating waste at source for the study was 95.70%, 90.86% and 91.32% for the first, second and third class respectively for the polythene bag designated for biodegradable while that for the non-biodegradables was 79.76%, 84.65% and 85.85%. This indicates that the numbers of households who were willing to separate at source and actually participated in the source separation were different. The willingness was much lower than what was actually separated at source. The high percentage of people achieving a good separation was probably due to the explanation given to them on the benefits of source separation to the existing solid waste management system in the sub-metro. People wanted to say if source separation is the solution to the solid waste challenges facing the metropolis and the country then they were willing to help solve the problem. The level of separation efficiency achieved by the third class residents considering their prior knowledge of separation (41.9%) and their willingness to separate waste (64.5%) may be because they have problems with managing their waste especially disposal. The much lower separation efficiency achieved in the bag designated for non-biodegradable may be because some amount of food waste was left in the packaging.

The results from the questionnaire and field survey suggest that a culture of waste segregation does not exist in the study area. However, there were a high number of residents (72.04%) who were willing to separate their waste. This indicates a desire for access to other disposal options in the community, like recycling (77.42% of respondents are willing to send waste for recycling) and composting (74.19% of respondents are willing to accept the concept of home composting).

5.2 Daily Per Capita Generation

From the study, the average TSM"s municipal solid waste generated was 0.70 kg per person per day which is similar to the per capita generation of 0.75 kg/ca for metropolitan and municipal areas (Anon, 2010). This is above the estimated national average of 0.5 kg per capita per day (Mensah and Larbi, 2005). This result is in line with global trends for developing countries which also indicate an increase in MSW generation rate with improving economic conditions (Gomez *et al.*, 2009). In the city of Kitwe, Zambia, the daily per capita generation in the year 2003 for low, medium and high income areas was 0.40, 0.60 and 0.68 kg per day respectively but our present study was 0.69, 0.66 and 0.76 for low, medium and high income areas respectively. This result on average was higher than the 0.68 kg/ca/day for 2004 but same as the 0.70 kg/ca/day for STMA in 2010 (Anon, 2010). Daily per capita generation in TSM falls within the range of per capita generation rates (Anon, 1999). Developed countries normally produce more solid waste per capita (0.7 – 1.8 kg/d) compared to middle income or developing countries (0.5 – 0.9 kg/d). Ghana and for that matter TSM falls in the middle income category. This rate is much lower than those reported for some developed or high income countries like the US (1.98 kg), Canada (1.64 kg), Japan (1.22 kg) and Germany (1.15 kg), but slightly higher than those found in developing economies like India (0.41 kg) and Yemen (0.45 kg). This data confirms that, in general, a direct correlation exists between the economic status of a country and its HSW generation rate in urban areas (Bernache-Perez *et al.*, 2001). In this study, the per capita waste generation was negatively correlated with income levels, that is, as income levels rise, the amount of waste generated reduces (Aisa, 2013). This is because most households purchase cheap inferior items that do not last and have to be discarded in a relatively shorter time. If the income levels are high, people tend to buy quality and durable products that last long. It might also have happened due to number of households, getting food items from outside and reusing some types of waste. Most of the people living in the study area especially those in the first class are government servants/ employees in private company or NGO/ labours/ students. These people have their breakfast/lunch outside the home. This activity reduces waste generation in their homes, therefore reducing waste generation.

Dauda and Osita (2003) obtained 0.25 kg/ca/day for Maiduguri and 0.51 kg for Guadalajara, -Mexico. The amount of waste generated in Kumasi, Accra, Tamale, Tema and all the major cities in Ghana in 2004 and 2010 showed a slight change in the per capita generation which was not more than 0.04 kg increment or reduction with the exception of Tema which had a higher increase in the per capita generation difference of 0.11 kg (Anon, 2010).

Again, there was a very strong negative correlation between the household size and the per capita waste generation. Jenkins (1993), Qdais *et al.* (1997), Bolaane and Ali, (2004) and Ojeda-Benitez *et al.* (2008), have shown that as the number of household members increases, waste generation per capita decreases. Thus, the larger the household size, the smaller the daily per capita waste generation. The reason for this may be attributed to households‟ social and economic activities. In the household survey it was observed that, waste from business activities taking place at households were mixed with the waste produced from domestic activities. Per capita daily waste generation may not be dependent on household‟s size as there were variations in household size during the study period. Relatives and friends moved in and out during the study period, January and February which were just after the Christmas festivities.

5.3 Recycling Potential

On the average, of the total waste generated in the three socioeconomic classes, 81.65% had reuse potential. Additionally, out of the useful percentage, 22.67% could be recycled and 77.33% could be composted or used for energy generation. Of the total waste generated, 63.39% was compostable, 18.58% recyclable and only 18.35% for landfilling. According to Anon (1999), generally, all low and middle income countries have a high percentage of compostable organic matter in the urban waste stream ranging from 40 to 85% of the total waste. The high organic matter content (50%-90%) makes the waste suitable for composting (Oyelola and Babatunde, 2008).

In Ensenada, Mexico, 86.36% of the waste generated had the potential to be reused with only 13.65% ending up at the final disposal site which compares fairly with our study in TSM (Aguilar-Virgen *et al*., 2010).

5.4 Moisture Content

Food and yard waste contributed higher amounts of moisture to the waste stream. Although moisture content is important in composting to obtain quality compost; the moisture in organic matter impregnates other waste when mixed. Often, moisture content in waste increases the weight of waste that gets to the landfill sites and therefore increases the leachates at the landfill site. The optimum moisture content often ranges from 50 to 60% for optimal metabolic activity to occur (Lopez Zavala and Funamizu, 2005). From the study, two residential areas had ideal moisture contents in their waste; Beach Road; 59.05% and Essikafoambatem No 1, 61.87%.

Below the above range, microbial activity decreases and composting process slows.

The moisture contents compare fairly with work by Kazimbaya-Senkwe and Mwale (2001).

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.0 Conclusion

Household waste within the Takoradi sub-metro were mainly food, yard waste, wood, paper and cardboard, plastics, glass, textiles, Leather and rubber and metals. Biodegradables from all the three socio economic groups were over 60% and plastics 11.74%.

Solid waste within the TSM had an average recyclable and compostable content of 81.65%. Only 18.35% of the waste may end up at the final disposal site if appropriate recycling and composting measures are instituted. Waste separation was not being practiced in the metropolis. There was a general willingness among the inhabitants of the metropolis to separate waste at source. The average per capita waste generation for TSM was 0.70 kg/ca/day, at all the three socio-economic levels with the highest waste generation being in households in first class residential areas. Moisture content of the waste stream in TSM was 54.99%.

6.1 Recommendation

- Education of people in TSM 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 Takoradi submetro.

- It is recommended that home composting facilities (with low or no cost to the household as only 46.24% of the respondents were willing to buy bin for composting) be established for households to encourage home composting within the community, and private firms should be involved for efficient and effective solid waste management in the area.

- 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 TSM, 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 behavioral changes, there is a need for community participation on related issues.

- Other chemical analysis such as C, N and O should be determined through laboratory analysis to give much more detail information on the quality of compost that could be produced from the biodegradables. The quality of the compost produced yields a better return.

- 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 TSM

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APPENDICES

APPENDIX 1

HOUSEHOLD WASTE CHARACTERIZATION SURVEY ity/ Town/ Village

……………………….. Location……..……………………

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

PART 1 - ABOUT YOURSELF

Age group

Under 20yrs [ ] 20-30yrs [ ] 31-40yrs [ ]

41-50yrs [ ] 51--59 yrs [ ] 60 yrs and above [ ]

Gender Male [ ] Female [ ]

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

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

Marital Status Single [ ] Married [ ]

Status in the household

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

PART 2 - ABOUT YOUR HOUSEHOLD

Which of the following best describe your home?

Single Family Detached [ ] Duplex or Townhouse

[ ] Multifamily Unit/ Compound House[ ] Storey building [ ]

How many people live in your house? ……………………………………………..

How many households are in your house? ....

How many of your household members fall within the following age groups?

0-12 ……………….

13-19 ……………….

20-30 ……………….

31-40 ……………….

41-50 ……………….
71 and above ……………….

How much is your household‟s average monthly expenditure?

Less than GH¢ 200 [ ] 1   GH¢ 200-500 [ ] 3   above GH¢ 2000 [ ] 5

GH¢ 500-1000 [ ] 2   GH¢ 1000-2000 [ ] 4

How many of your household are in the following levels of education?
Primary/JHS ……………….

Secondary / Technical ……………….

Vocational ……………….

Tertiary/Professional ……………….

None ……………….

Others (specify) ……………….

Part 3 Household Waste Disposal

How do you dispose your household wastes?

Buried [ ] Burned [ ] Individual Bin (House to house Collection) [ ] Communal dumpsite [ ]

How many refuse bins do you have in your household?

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

How often is your bin lifted?

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

Which Company services your household?

Zoomlion [ ] Informal Waste Collectors [ ] others (specify) ……………………….

Do you sell or give out items to itinerant buyers? Yes [ ] No [ ]

If Yes specify the items …………………………………………………………

Part 4: Knowledge on Waste Separation

Have you ever heard or seen waste separation activities? Yes [ ] No [ ]

If Yes, from where:

Foreign Countries [ ] Other parts of Ghana/Different communities [ ] In movies [ ]

Television news [ ] Radio [ ] Newspapers [ ] Magazines [ ]

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

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

Yes [ ] No [ ]

If No why ……………………………………………………………………………

If Yes what will be your driving force:

When motivated [ ] Clean Environment [ ] Resource [ ] Best practice and example from other

Countries for recycling [ ] others (specify) …………………………………………..

Part 5: Knowledge on Environmental Management

Do you often read about or listen to environmental issues? Yes [ ] No [ ]

If Yes from which source:

Newspaper [ ] Television [ ] Radio Station [ ] Magazines [ ]

Billboards [ ] Fliers [ ]

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

How has this changed your perception about the environment?

Advocate for clean environment [ ] Neighbourhood environmental cleanliness advocate [ ] Household environmental advocate [ ]

Which of the following will you recommend for a clean environment at your neighbourhood? Constant environmental education at the neighbourhood [ ] Regular clean up [ ] Sanitary Inspection activities [ ] Persecution of offenders (polluters) [ ]

Part 6: Knowledge on Recycling

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

Yes [ ]   No [ ]

If Yes from which source?

Television [ ] Radio [ ] Magazines/Newsletters [ ] Newspaper [ ] Billboards [ ]

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

Do you know any company engaged in recycling of waste?   Yes [ ]   No [ ]

If Yes, name any ……………………………………………………………………………

Do you recycle any of the following materials?

Newspapers [ ]   other papers and Cardboards [ ]   Glass [ ]   Metal & Cans [ ]

Plastics [ ]

Leaves/Food waste/ Yard waste [ ] others (specify) ………………………………..

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

Concern for the environment [ ]   Concern about the availability of landfill space [ ]

My children encourage me to recycle [ ]   Get paid for recycling material [ ]

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

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

Inconvenience [ ] Believes there are better ways to handle my waste /garbage   [ ]

elieves it‟s the responsibility of government/ Waste management company [ ] Do not have the necessary facilities and skills to recycle   [ ]

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

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

Less than 1 year [ ] 1-2 yrs [ ] 3-5 yrs [ ] more than 5 yrs [ ]

Do you think residents should be required by law to recycle, or should be voluntary?

By Law [ ]   Voluntary [ ]   Not Sure [ ]

If a recycling centre is established at your neighbourhood, would you be willing to bring materials for recycling? Yes [ ] No [ ]

If No why ……………………………………………………..…………………

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

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 …………………………………………………………………………

How long will you be willing to spend to drive (one way) to a recycling centre? Less than 10 min [ ] 10 min [ ] 11-15 min [ ] 16-20 min [ ] More than 20 min [ ] should not be my responsibility [ ]

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

How much extra would you be willing to pay on your monthly waste collection bill/Container site fee for recycling?

Less than 10% [ ] 10 – 20% [ ] 20 – 30% [ ] 30 – 40% [ ] 50% [ ] above 50% [ ] If home Composting is to be introduced at your household would you be prepared to accept the concept?   Yes [ ]   No [ ]

If Yes what is your motivation---

If No why---

If a composting bin is designed for home composting would you be prepared to buy and use?   Yes [ ]   No [ ]

If Yes give reason ……………………………………………………………..

If No why………………………………………………………………………………..

Any comment/ suggestion ………………………………………………………

……………………………………………………………………………………………

APPENDIX 2

DATA COLLECTION SHEET

WASTE COMPOSITION	**MON.**	**WED.**	**FRI.**
BIODEGRADABLE			
Food waste			
Yard waste			
Wood			
PLASTICS			
PET			
HDPE			
Pure water Sachet			
PVC			
LDPE			
PP			
PS			
Other plastics			
METALS			
PAPERS			
Office/News Print/ Cardboard			
Tissue papers			
GLASS			
LEATHER & RUBBER			
TEXTILE			
INERT			
MISCELLANEOUS			

APPENDIX 3 CALCULATIONS OF MOISTURE CONTENT OF THE SAMPLES

Beach Road

Component	Weight kg	% by Mass	% Moisture	Dry Mass kg	% Dry Mass
Food	2.29	82.97	61.13	0.89	32.25
Yard	0.47	17.03	48.91	0.24	8.7
	2.76	100			40.95

Basis: 100 kg sample waste.

Percentage Moisture $\frac{100 - 49.95}{100} \times 100\% = 59.05\%$

Essikafoambatem

No 1

Component	Weight kg	% by Mass	% Moisture	Dry Mass kg	% Dry Mass
Food	2.7	84.38	62.97	1	31.25
Yard	0.5	15.63	55.98	0.22	6.88
	3.2	100.01			38.13

Basis: 100 kg sample waste.

Percentage Moisture $\frac{100 - 38.13}{100} \times 100\% = 61.87\%$

Adakope

Component	Weight kg	% by Mass	% Moisture	Dry Mass kg	% Dry Mass
Food	2	76.63	51	0.98	37.55
Yard	0.61	23.37	21.4	0.48	18.39
	2.61	100			55.94

Basis: 100 kg sample waste.

$$\text{Percentage Moisture} = \frac{100 - 55.94}{100} \times 100\%$$

$= 44.06\%$

APPENDIX 4 AVERAGE PER CAPITA GENERATION OF WASTE

SN	**SIZE**	**BEACH**	**SIZE**	**ESSIKAFOABATEM No. 1**	**SIZE**	**ADAKOPE**
		Average		**Average**		**Average**
1	6	1.12	7	0.38	9	0.56
2	6	1.14	3	0.82	6	0.82
3	4	0.97	6	0.54	6	0.74
4	6	0.71	5	0.54	10	0.26
5	3	1.02	3	0.9	10	0.26
6	5	0.60	5	0.5	5	0.62
7	6	0.75	9	0.34	6	0.4
8	5	1.33	10	0.14	4	0.82
9	8	0.38	4	1.08	3	1.12
10	4	1.29	5	0.8	4	0.78
11	8	0.39	3	1.1	5	0.74
12	6	0.80	8	0.32	5	0.58
13	7	0.53	4	0.68	4	0.68
14	6	0.73	4	0.78	2	1.44
15	8	0.63	6	0.58	8	0.48
16	14	0.21	5	0.76	5	0.68
17	9	0.61	11	0.26	6	0.36
18	9	0.39	4	0.84	4	0.56
19	6	0.84	4	0.78	3	0.94
20	5	0.60	5	0.74	6	0.58
21	5	0.61	5	0.56	5	1.02
22	4	1.19	2	1.48	4	0.86
23	4	0.88	6	0.74	6	0.56
24	6	0.52	4	0.76	8	0.56
25	7	0.46	8	0.34	2	2.1

26	7	0.86	5	0.48	6	0.52
27	5	1.35	2	1.36	12	0.36
28	9	0.74	6	0.58	7	
29		0.38	9	0.64	6	
30		0.68	5	0.22	16	
31		0.74	4	0.64	6	
32		0.36	10			
33		0.3	15			
34		0.74	4			
Average		**0.76**		**0.66**		**0.69**

APPENDIX 5 RESULT OF THE ANALYSIS OF VARIANCE (ANOVA)

The one-way ANOVA test shows that there is no significant difference among the three residential classes on quantity of waste generated.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	12599.69	2	6299.84	0.05	0.96	3.14
Within Groups	8669101.64	63	137604.79			
Total	8681701.33	65				

Per Capita Waste Generation per Day by Socioeconomic Status

Result of the Analysis of Variance (ANOVA) of the per capita generation

The ANOVA test of per capita waste generated among the three classes shows that, there was a significant difference among the three classes of per capita waste generated over the period.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.069865	2	0.534932	4.122794	0.019589	3.105156608
Within Groups	10.899	84	0.12975			

Total	11.96886	86

APPENDIX 6 BACKGROUND INFORMATION ABOUT RESPONDENTS

Descriptive Statistics of Socioeconomic Characteristics of the Respondents (FIRST CLASS)

Item	Number of Respondent	Percentage %
Sex		
Male	15	53.57
Female	13	46.43
Have You heard or seen waste separation		
Yes	25	89.3
No	3	10.7
Are you willing to separate your waste		
Yes	20	71.4
No	8	28.6
Have you heard or seen waste recycling		
Yes	28	100
No	0	0
If recycling centre is established would send waste for recycling?		
Yes	23	82.1
No	5	17.9
Would you accept concept of home composting		
Yes	20	71.4
No	8	28.6
Would you buy an extra bin for home composting		
Yes	18	64.3

No	10	35.7

Table: Descriptive Statistics of Socioeconomic Characteristics of the Respondents (SECOND CLASS)

Item	Number of Respondent	Percentage %
Sex		
Male	9	26.47
Female	25	73.53
Have You heard or seen waste separation		
Yes	19	55.9
No	15	44.1
Are you willing to separate your waste		
Yes	27	79.4
No	7	20.6
Have you heard or seen waste recycling		
Yes	32	94.1
No	2	5.9
If recycling centre is established would send waste for recycling?		
Yes	27	79.4
No	7	20.6
Would you accept concept of home composting		
Yes	25	73.5
No	9	26.6
Would you buy an extra bin for home composting		
Yes	17	50
No	17	50

Table: Descriptive Statistics of Socioeconomic Characteristics of the Respondents (THIRD CLASS)

Item	Number of Respondent	Percentage %
Sex		
Male	8	25.81
Female	23	74.19
Have You heard or seen waste separation		
Yes	13	41.9
No	18	58.1
Are you willing to separate your waste		
Yes	20	64.5
No	11	35.5
Have you heard or seen waste recycling		
Yes	26	83.9
No	5	16.1
If recycling centre is established would send waste for recycling?		
Yes	22	71
No	9	29
Would you accept concept of home composting		
Yes	24	77.4
No	7	20.6
Would you buy an extra bin for home composting		
Yes	8	25.8
No	23	74.2

APPENDIX 8

Composition of MSW Socioeconomic status

Type of Waste	Beach Road		Essikafoambatem No. 1		Adakope	
	kg	%	kg	%	kg	%

COMPOSTABLE						
Food waste	1799.8	42.47%	2255.9	60.76%	1376.1	36.62%
Yard waste	1109.29	26.18%	44.3	1.19%	317.5	8.45%
Wood	97.8	2.31%	34.9	0.94%	42.1	1.12%
Textile	79.8	1.88%	181.1	4.88%	73.6	1.96%
Total	**3086.7**	**72.84%**	**2516.2**	**67.77%**	**1809.3**	**48.15%**
RECYCLABLE						
News/ Office/ Cardboard	152.7	3.60%	167.56	4.52%	93.8	2.49%
Plastic Film/LDPE	146.4	3.45%	249	6.71%	219.6	5.84%
PET	85.7	2.02%	50.91	1.37%	29.9	0.80%
HDPE	45.5	1.07%	36.2	0.97%	24.5	0.65%
Pure Water Sachet	54.65	1.29%	125.3	3.38%	65.5	1.74%
PP	33.5	0.79%	28.5	0.77%	17.7	0.47%
Metal	132.9	3.13%	93.25	2.51%	55.6	1.48%
Glass	116.4	2.75%	45.7	1.23%	20.6	0.55%
Leather & Rubber	27.1	0.64%	83	2.24%	29.8	0.79%
Total	**799.35**	**18.74%**	**879.41**	**23.70%**	**557**	**14.81%**
RESIDUE						
PS	32.95	0.78%	15.3	0.41%	4.2	0.11%
PVC	11.1	0.26%	6.7	0.18%	8.8	0.23%
Other Plastics	13.5	0.32%	20.6	0.55%	8.9	0.24%
Tissue/Diaper	217.9	5.14%	141.3	3.81%	93.5	2.49%
Inert	33.2	0.78%	55.5	1.49%	820.8	21.84%
Miscellaneous	46.7	1.10%	68.3	1.84%	450.7	11.99%
Total	**377.45**	**8.90%**	**323**	**8.69%**	**1408.1**	**37.46%**

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