

CHARACTERIZATION OF MUNICIPAL SOLID WASTE IN THREE  
SELECTED COMMUNITIES IN THE TARKWA TOWNSHIP OF TARKWA  
NSUAEM MUNICIPALITY IN GHANA

BY

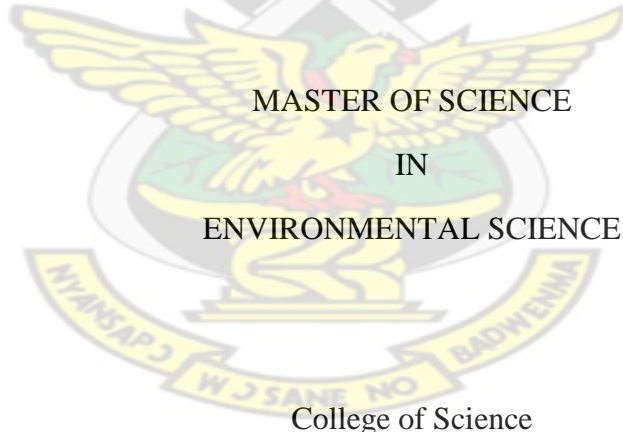
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IN  
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College of Science

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### Declaration

I, Benjamin Ansah, hereby declare that this is the result of my own work towards MSc. degree and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgment has been made in the text.

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## **Abstract**

Most municipal and metropolitan assemblies have identified disposal of solid waste as a major problem that has gotten to a stage which needs urgent workable solutions. Increase in volume of waste generated by municipal residents, change in the quality of waste composition and the treatment and disposal method of waste collected are of major concern. Change in generation rate and quality of solid waste composition in municipalities coupled with ineffective management has led to serious environmental problems. Success of solid waste management plans stems on accurate and up to date data on quality and quantity of generated solid waste. This thesis presents the characterization of municipal solid waste (MSW) in the Tarkwa Nsuaem municipality, whose population is growing by an average of 3% per annum. Extensive field investigation was used for quantification and analysis of composition of MSW in selected residential areas. Field observations, secondary data and key informant interviews were also used. Simple random sampling and analysis of solid waste from specific sources were used for waste characterization whereas house-to-house weight analysis method was used for waste quantification. It was estimated that the average per capita daily generation rate was 0.92 kg per capita per day and average daily generation rate per household of average size 4.27 persons was 3.93 kg per household per day. The dominant solid waste of the municipality was organic waste and accounts for 68.56%, followed by plastics/rubber at 16.02%, paper and cardboard at 4.87%, ash/sand at 4.15%, textiles at 3.23%, non-ferrous metal at 1.65%, glass/ceramics at 0.92%, ferrous metals at 0.31% and potentially hazardous 0.29%. Recommendations were made on how to improve effectiveness,

efficiency, integration and accountability and optimize municipal solid waste management.

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### **Dedication**

I dedicate this work to the Almighty God for His wisdom, protection, provision, care and guidance, to my lovely daughter, Manuel Efua Otewewa Ansah and her mother, Felicia Odai for their motivation and to my parents, Mr. Moses Ansah and Mrs. Rose Nyarkoh for their tremendous spiritual and material contribution that have brought me this far in my educational ladder.

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## List of Abbreviations/Acronyms

Abbreviations/Acronyms	Meaning
TNA	Technology Needs and Needs Assessment
EPA	Environmental Protection Agency
EST	Environmental Sound Technology
GHC	Ghana Cedis
GSS	Ghana Statistical Service
ISWM	Integrated Solid Waste Management
IWM	Integrated Waste Management
Kg	Kilogram
MMDAs	Metropolitan, Municipal and District Assembly's
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
No.	Number
NYC	New York City
TNMA	Tarkwa Nsuaem Municipal Assembly
UMaT	University of Mines and Technology
UNEP	United Nations Environmental Programme
USA	United States of America
USEPA	United States Environmental Protection Agency
WTE	Waste-To-Energy

## CHAPTER ONE

### INTRODUCTION

#### 1.1 Background of the Study

Municipal Solid Waste (MSW) management, the discipline associated with the control of generation, storage, collection, transfer, processing and disposal of solid waste, in a way which is governed by the best principles of public health, economics, engineering, aesthetics and other environmental considerations (Daskalopoulos *et al.*, 1997). In spite of the improved development of science and technology, solid waste management is still a serious environmental problem for most communities all over the world (Su *et al.*, 2008). Municipal Solid Waste management is one of the most vital issues in the contemporary urban environments; particularly in developing countries (Swati and Vikram, 2010) like Ghana and is one of the challenging issues in the cities, which are continually facing a serious pollution problem due to the generation of huge quantities of unmanageable solid waste (Kumar *et al.*, 2009).

Rapid upward changes in urbanization, population growth and lifestyles in developing countries contribute to increasing the per capita municipal waste generation. Keeping pace with these developments require commensurate growth in schemes to protecting the environment, to improving public health and accomplishing effective and efficient municipal solid waste (MSW) management. This should be a priority particularly for cities in developing countries (Bartelings

and Sterner, 1999; Jin *et al.*, 2006). According to Bartelings and Sterner (1999), the management of solid waste from households is important for two reasons.

- 1) Landfill space is becoming a scarce resource in many countries.
- 2) More profound is perhaps the concern that ecological damage from hazardous components even in the efficiently collected waste by the municipality will not automatically alleviate the concern about the spread of hazardous waste into the environment. Inappropriate waste handling, storage, collection and disposal practices pose environmental and public health risks. In heavily populated urban centres, appropriate and safe MSW management is of utmost importance to create a healthy environment for the people. Usually, however, in most places, the collected waste is generally dumped on land in a more or less uncontrolled manner (Mosler *et al.*, 2006).

Improper management of solid waste in most cities of developing countries leads to problems that impair human and animal health and ultimately result in economic, environmental and biological losses (Sharholy *et al.*, 2007; 2008) since landfill disposal and waste-to-energy (WTE) incineration remains the two principal options for managing municipal solid waste in most parts of the world (Moy *et al.*, 2008). Leachate from municipalities' landfills represents a potential health risk to both surrounding ecosystems and human populations (Salem *et al.*, 2008).

Furthermore, waste management activities are said to contribute to global greenhouse gas emissions by approximately 4%. In particular, the disposal of



waste in landfills generates methane that has high global warming potential (Papageorgiou *et al.*, 2009).

Effective management of municipal solid waste is very important and could provide environmental benefits and sustainable development, as well as reduce adverse impacts on public health.

To address both the earth's dwindling resources and the growing mountains of waste, many countries have introduced statutory waste minimization and recovery targets to ensure judicious use of these resources. The general public usually does not make the link between the two and tend to be generally more concerned with the effects that waste has on the environment (Emery *et al.*, 2007).

For effective waste management system for sustainable development, centers on waste characterization studies, the need to carry out this research work in the Tarkwa Nsuaem municipality.

## **1.2 Main Objectives of Study**

The main aim of this study is to characterize the municipal solid waste and set the basis for implementation of a recovery, reduction and recycling waste management programme at the municipality to address some of the inefficiencies in solid waste management for sustainable development.

### **1.2.1 Specific Objectives**

Specifically the study seeks to achieve the objectives below.

- To estimate the average daily generation rate (kg/cap/day)
- To identify and categorise, in a systematic way, the waste fractions involved
- To determine whether social class of household influences the quantum and type of waste generated.
- To suggest practices that will improve effectiveness, efficiency, integration and accountability and optimize municipal solid waste management

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### **1.3 Problem Statement**

The main problem facing policy makers in the waste management sector in the municipality is how to project and therefore fairly predict the amount and the composition of MSW that is likely to be generated in the near future in order to devise the most appropriate treatment and disposal strategy. The present scenario in which waste collection and management is from a central collection point to the main dumping site is inefficient and not reliable.

### **1.4 Justification of Study**

The main problem facing policy makers in the waste management sector in most urban areas is their inability to make appropriate future predictions of the amount and the composition of MSW likely to be generated over a period so as to devise the most appropriate treatment and disposal strategy. The importance of reliable

information on both the quantity and composition of municipal solid waste for the effective planning of waste handling infrastructure underscore the role this study may play. With the data, hopefully, some model structure can be developed to reasonably manage MSW in the locality where this work is being undertaken.

### **1.5 Scope of Study**

The study centres on solid waste generation and characterization in three selected communities in the Tarkwa Township of the Tarkwa Nsuaem Municipality and would give an in-depth characterization of the waste from various households and their current solid waste generation rate. The characterization involves the composition of solid waste in three different communities for seven days each. The research questions of the study are:

1. What is the average daily generation rate of solid waste (kg/cap/day)?
2. How efficient is the waste management system in the municipality?
3. How can municipal solid waste management be improved in the municipality?
4. Which of the socioeconomic classes have the highest solid waste generation rate?

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1 Solid Waste**

According to the Environmental Protection Agency of Ghana (EPA) of 1999, solid wastes comprise all such non-flowing materials generated by households, institutions, commercial establishments and industries, and discharged from their premises for collection; all litter and clandestine piles of such wastes; street sweepings, drain cleanings, construction/demolition waste, dead animals and all such waste materials.

##### **2.1.1 Municipal Solid Waste Management**

Solid waste management chain requires intensive use of Environmental Sound Technology (EST) for its activities which could be as simple as containers for primary collection to as complicated as incinerators for disposal of hazardous waste (UNEP, 2009). To Daskalopoulos *et al.*, (1997), Municipal Solid Waste (MSW) management is said to be the discipline associated with the control of generation, storage, collection, transfer, processing and disposal of MSW, in a way which is governed by the best principles of public health, economics, engineering, aesthetics and other environmental considerations. This definition of MSW management is the ideal that most metropolitan, municipal and district assemblies are struggling to achieve. In most countries, local governments are responsible for municipal solid waste management (UNEP, 2009). Solid waste management has become a serious environmental problem for most communities

all over the world (Su *et al.*, 2008). Inappropriate waste handling, storage, collection and disposal practices pose environmental and public health risks (Bartelings and Sterner, 1999).

### **2.1.2 Waste Generation**

Anthropogenic activities in society generate large quantities of wastes posing a problem for their disposal (Chandra and Devi, 2009). Almost all such human activities generate some amount of waste. Rapid increase in volume and types of solid and hazardous waste as a result of continuous economic growth, urbanization and industrialization, is an up-and-coming problem for national and local governments to ensure effective and sustainable management of waste. It was estimated that in 2006 the total amount of municipal solid waste (MSW) generated globally reached 2.02 billion tones, representing a 7% annual increase since 2003 (Global Waste Management Market Report, 2007). It was further estimated that between 2007 and 2011, global generation of municipal waste will rise to 37.3%; equivalent to roughly 8% increase per year. To Asase *et al.*, (2009), the estimated daily municipal waste generation rate in Kumasi is 0.6 kg per capita. According to Collivignarelli *et al.* (2004), waste production and composition depend on many factors, such as the stage of development; socio-economic, climatic and geographical conditions and collection frequency (Sharholy *et al.*, 2008). With its resultant exponential growth coupled with insufficient data for planning, it does not enhance effective waste management besides, increasing population levels, rapid economic growth and rise in

community living standards accelerate the generation rate of municipal solid waste in cities (Bartelings and Sterner, 1999). According to UNEP (2005) the rate of waste generation generally increases in direct proportion to that of a nation's advance in development and failure to provide a management system could result in greater environmental degradation with increase health risk to the urban population. To provide effective management system, there is the need for data on quantity variation and generation to plan for collection and disposal systems (Sharholly *et al.*, 2008).

### **2.1.3 Waste Minimization**

In recent years, the burdens that waste puts on the environment has been widely publicized, To address both the earth's dwindling resources and the growing mountains of waste many countries have introduced statutory waste minimization and recovery targets (Emery *et al.*, 2007). Minimization of municipal solid waste and diversion from landfill to derived raw materials are necessary to manage waste sustainably and achieve legislative compliance (Bench *et al.*, 2005). Public participation in Local Authority schemes is key to increasing household recycling levels; however, the most effective way to reduce waste is to deal with it at source, through waste minimization (Tonglet *et al.*, 2004).

#### **2.1.3.1 Reuse**

A publication on solid waste management by UNEP (2005) indicates that the informal recovery and reuse of materials from the waste stream occurs at several

levels in Africa; moreover, scavengers also recover materials for personal and commercial purposes. However, the extent of commercial recycling of paper, metals, glass, and plastic depends on the presence of industrial or other end uses for these materials.

UNEP (2005), further observed that the rate of reuse of materials is high in household with low-income, whereas in high-income areas, recovery is carried out by domestic servants and/or wardens. Reusing the materials directly, they rather sell bottles, plastics, cardboard, and paper to intermediaries or commercial centres that pay for these materials. This is confirmed by Chandra and Devi (2009), that high income group people throw away more plastic, metallic, glass waste and hazardous waste than the low income group.

#### **2.1.3.2 Aerobic Composting**

Composting, the bacterial conversion of the organics present in MSW in the presence of air under hot and moist conditions result in compost, the final product obtained after bacterial activity, which has very high agricultural value. It is used as organic fertilizer, is odourless and free of pathogens (Khan, 1994) though not totally free. Sharholly *et al.* (2008), stated that as a result of the composting process, the waste volume can be reduced to 50–85%. To Bundela *et al.* (2010), agricultural application of composted Municipal Solid Waste (MSW), as nutrient source for plants and as soil conditioner, is the most cost effective option of MSW management because of its advantages over traditional means such as landfilling or incineration. However, composting is likely to be a labour-intensive venture with unproven commercial viability (UNEP, 2005).



### **2.1.3.3 Incineration**

UNEP (2005) found that high capital and operating cost make controlled incineration and WTE inaccessible technologies for most African cities. Furthermore, incineration in Africa would be very difficult to put into practice if the waste stream is indeed 70% (wet basis) putrescible organic content. Residential domestic waste forms the bulk with high organic component of the municipality's solid waste. Another limiting factor is the lack of infrastructure to support these technologies. Aside infrastructure there is lack of human expertise and effective institutional control. Often in these developing countries, plastics are recycled by scavengers where markets exist. Some plastic recovery operations have modular pelletizers to process the material prior to sale. The processed material is then sold to local plastic product manufacturers. In some locations, rags are recovered, processed, and recycled by scavengers using rag-pulling equipment and other equipment to shred, clean, and re-knit the fibres into all-purpose utility cloths for resale (UNEP, 2005).

### **2.2.0 Collection and Segregation of MSW**

Collecting municipal solid waste (MSW) is a major and expensive task for local waste management authorities, thus efficient MSW collection is a necessity (You-Ti *et al.*, 2011).

#### **2.2.1 Segregation of Waste**

Solid wastes can be segregated at source, at transfer stations and at disposal area for subsequent use as secondary materials. More emphasis needs, however, to be



laid on segregation and collection of waste at door step- the source of generation (Chandra and Devi, 2009); as waste segregation at the household level is not widely practiced and waste recycling is minimal.

### **2.2.2 Collection of Solid Waste**

Principally, there are two solid waste collection systems in Ghana - door to door collection system which takes place in the low density areas of the urban centres, and communal collection system in the high density areas (Agyepong, 2011).

Collection is a key link in the chain of MSW management from the point of generation to ultimate disposal and in any initiative to upgrade waste management service, sustainable, contextually appropriate collection should be a major focus of attention. Where collection is performed by non-mechanical means, the volume of material to be collected often exceeds the capacity of the collection system (UNEP, 2005); in other words manual collection system is inefficient. In most cities, a fraction of MSW generated remains uncollected on streets, and what is collected is transported to processing or disposal sites (Sharholly *et al.*, 2008).

Waste collections generally occur at dawn before the commercial centres open and at dusk after these centres have closed for the day. Waste collection from market places and commercial centres tend to be made in the evening while waste collection from residential areas and of street sweepings is made at dawn (UNEP, 2005). The collection service shall be rendered on the basis of cost recovery (EPA, 1999). Most of the waste could be diverted for material and resource recovery, then a substantial reduction in final volumes of waste could be achieved and the recovered material and resources could be utilized to generate revenue to

fund waste management. In most municipalities, collection is provided by the municipality; what is more, private operators also provide service on a fee basis to households and commercial establishments (UNEP, 2005).

### **2.2.3 Methods of Waste Storage**

Storage of MSW at the source of generation is substantially lacking in most of the urban areas. Storage bins are common for both decomposable and non-decomposable waste (no separation of waste is performed) and the waste is subsequently disposed at a communal disposal centre (Sharholly *et al.*, 2008). In Ghana with regards to the EPA (1999) the Assembly requires all premises to have primary storage facilities (bins) which shall meet the approval of the Assembly with regard to size, material it is made of and capacity. Furthermore, in communities where house-to-house collection is not appropriate, the Assembly shall designate communal storage sites where solid waste can be discharged into a fixed or moveable container. The containers should be readily accessible to those dumping wastes, including children.

### **2.2.4 Transport and Transfer of Solid Waste**

Transport covers all types of vehicles under operation to transport solid waste from its generation point to the transfer station and from there to the treatment and disposal site (UNEP, 2009). The construction and location of transfer station is crucial to avoid adverse effects due to odour, breeding of disease vectors such as flies and mosquitoes, and the foraging of domestic birds and pets that may inadvertently carry disease agents back to their homes.

To UNEP (2005) transfer stations are not common in MSW management in African cities. In almost all cases, the point of disposal of the MSW is located on the perimeter of the city, within easy reach of vehicles and collection crews. The solid waste is stored temporarily in the dust bins and then transported to the disposal site (Chandra and Devi, 2009). It has been observed that many municipalities have employed private contractors for secondary transportation from the communal bins or collection points to the disposal sites (Sharholly *et al.*, 2008). To Chandra and Devi (2009), transporting vehicles carrying waste are not covered or partially covered during the journey and waste tends to spill on the roads.

### **2.3 Characteristics of Solid Waste**

A team of researchers are of the view that the composition and the quantity of MSW generated form the basis on which the management system needs to be planned, designed and operated (Sharholly *et al.*, 2008). According to Ghana's Climate Change Technology Needs and Needs Assessment (TNA) Report (2003) a study on the composition of MSW conducted in 1997 by the Accra Metropolitan Assembly showed that about 65% of the waste stream consists of organics and inert material arising from the practice of hand- sweeping sand constituted about 17.1% of the waste stream. Together, both organics and inert material accounted for about 82% of the waste.

A study reveals that the composition of solid waste in Mysore city in India has 40 % organic matter followed by 45 % earthen materials and 1.5 % as wooden materials, suggesting the city's waste has a large amount of biodegradable

materials. Though the percentage of non-biodegradable waste like metals and plastics is relatively not very high, substantial percentage of it made up of concrete / pebbles / silts / sands etc was observed: which is indicative of large scale building construction and other development activities (Chandra and Devi 2009).

### **2.3.1 Method of Solid Waste Characterization**

According to Brunner and Ernst (1986) there are three methods for determining the composition of urban solid waste streams and these are i) Waste Product Analysis, ii) Market Product Analysis and iii) Direct Sampling and Analysis

#### **2.3.1.1 Waste Product Analysis**

In this method, the products of treatment processes such as incinerator bottom ash and fly ash are analyzed for various chemical elements. From knowledge of the partition coefficients for these elements through the process, it is possible to infer the chemical composition of the raw waste stream. It is necessary to have a waste processing facility available, and to know the details of materials balances passing through it in order to apply this technique. It offers a reliable and cost effective alternative to conventional direct methods where a suitable treatment process is available. Using the incinerator as an analytical tool to prepare a waste sample of some hundreds of tonnes for elemental analysis is cheaper, and far more reliable, than selecting a one kilogram sample for grinding and sub-sampling down to 1-3 grams for analysis in the conventional direct method (Brunner and Ernst, 1986).

### **2.3.2 Market Product Analysis**

In this approach, a materials balance is undertaken in a region to derive the quantity of that material that would be expected to report to the waste stream. The method is quick and can be undertaken at little cost where the data is available. Normally, this is limited to regions as defined by country borders, where the data is collected by a Statistics Bureau. For example if the amount of paper in the municipal waste stream is reasonably well known, with a calculated total amount of paper expected in all waste streams, it should be possible to derive an expected amount in the commercial and industrial waste stream. In so doing one provide useful information on where paper recycling efforts should be placed. The method is also likely to be of use for materials which make up a small percentage of the waste stream. Determining say the amount of dry cell batteries, for instance, in direct sampling and analysis studies is either very unreliable or very expensive. Under such circumstances market product analysis, if possible at a regional level would give a quicker, cheaper and more reliable result.

#### **2.3.1.3 Direct Waste Sampling and Analysis**

In this conventional approach, sampling from a particular waste stream in a region is undertaken before manually sorting it into its material types. Subsequently, additional physical and chemical analysis such as moisture content, density under standard pressures, specific energy (calorific value) and elemental analysis may be undertaken. This is the most common method employed in Australia, and may be the only method practically available for determining the material composition in some regions. Its relative disadvantages in relation to determining elemental

concentrations, and the amount of small percentage components in the waste stream should be borne in mind (Brunner and Ernst, 1986).

#### **2.4.0 Disposal of MSW**

According to Agyepong, (2011), waste disposal in Ghana is mainly by landfilling. Currently the country can boast of only two Sanitary Landfill facilities located in Kumasi and Tamale. Two others are under construction in Sekondi-Takoradi and Tema. The other cities and towns depend on dumpsites for their waste disposal. Other systems such as incineration, waste to energy and anaerobic digestion have so far remained at exploratory stages, with the exception of composting which is at the implementation stage at Zoomlion.

Inappropriate waste handling, storage, collection and disposal practices pose environmental and public health risks. In heavily populated urban centres, appropriate and safe MSW management is of utmost importance to create a healthy environment for the people. However, the practice has been that the collected waste is generally dumped on land in a more or less uncontrolled manner (Mosler *et al.*, 2006).

In many metropolitan cities, open, uncontrolled and poorly managed dumping is commonly practiced, giving rise to serious environmental degradation. Improper management of solid waste in most cities of developing countries leads to problems that impair human and animal health and ultimately result in economic, environmental and biological losses ( Sharholly *et al.*, 2007; 2008). Unscientific disposal cause an adverse impact on all components of the environment and human health (Chandra and Devi, 2009). Moreover, landfill disposal and waste-



to-energy (WTE) incineration remains the two principal options for managing municipal solid waste (Moy *et al.*, 2008). Sanitary landfilling is an acceptable and recommended method for ultimate disposal of MSW. It is a necessary component of MSW management, since all other options produce some residue that must be disposed of through landfilling. However, despite the importance of landfill in solid waste management to the municipality, the uncontrolled leachate from the landfill leaves much to be desired (Sharholly *et al.*, 2008). According to Salem *et al.* (2008), leachate from municipalities' landfills represents a potential health risk to both surrounding ecosystems and human populations.

#### **2.5.0 Strategies and Guidelines for Formulation of MSW Management Action Plan**

Waste management planning requires reliable data concerning waste generation, influencing factors on waste generation and forecasts of waste quantities based on facts (Lebersorger and Beigl, 2011).

##### **2.5.1 Solid Waste Management Strategic Plan**

According to Asase *et al.* (2009), there is no single approach to waste management that makes it sustainable; however, the principles of integrated waste management could be followed to guide the development of site-specific MSW system that will be sustainable as demonstrated in the city of London. To Thorneloe *et al.* (2005), at the 10th International Waste Management and Landfill Symposium in Cagliari Italy, the determination of the best means to manage solid waste is not straightforward; nevertheless, solid waste management is characterized by ready-made prescribed answers, with single-issue interest groups

promoting a single solution, at the expense of others (Read, 2003). The truth, he argued, is that no single solution can manage society's waste adequately. Thus it is proposed that in practice, solid waste management must combine many different methods based on an integrated system.

Disposal of waste freely into the biosphere has now given way to think about and try to implement, an integrated waste management approach. The United Nations Environmental Programme (UNEP) defined 'integrated waste management' as '*a framework of reference for designing and implementing new waste management systems and for analysing and optimising existing systems*'. To incorporate a long-term and viable solid waste management system into a societal context requires that all of the elements in 6-tier waste management hierarchy be addressed in an integrated approach, this hierarchy is defined as: "reduction, reuse, recycling, recovery, treatment and disposal" (Seadon, 2006).

In preparing a strategic integrated solid waste management plan for a municipality, such plan should be drawn taking into account the waste generation sources, quantity, characteristics and the socio-economic and cultural structure of the city (Asase *et al.*, 2009).

Furthermore, for the plan to gain social acceptability public participation is vital and communication is a critical part to secure the public participation. The communities should be involved in making decisions concerning waste management strategies. There should be a method of communicating waste management system performance and proposed strategies with the community in order to get feedback and support from the community (Seadon, 2006; Asase *et*



*al.*, 2009). Community consultation and communication cannot be over looked in developing a sustainable waste management plan. For example, in New York City (NYC), an IWM plan that focused on the solid waste stream was adopted in 1988 (Clarke *et al.*, 1999). A 20-year plan worked on by 12 consultancies produced 12 different outcomes with two main general outlooks. Half called for a waste-to-energy plant with associated composting and landfill sites and the other half used a combination of material recovery facilities, processing plants, composting and landfills as their solutions. Interestingly, Citizen Advisory Boards rejected all 12 plans in 1992 and after meeting with communities, called for a plan that gave greater emphasis to source reduction and recycling. However, due to the overwhelming support of the Advisory Boards, NYC continued to support the programme and the process bore results (Seadon, 2006).

Therefore, what may make sense for one community may be very different for another depending upon existing infrastructure, policies, and environmental goals. This is why site-specific analyses are important in developing efficient and effective management plans (Thorneloe *et al.*, 2005).

The USA has made major progress in increasing recycling rates. However, the choices to be made in the future are becoming more complex and material specific such as waste conversion technologies and wet waste recycling programmes (Thorneloe *et al.*, 2005).

### **2.5.2 Government Laws and Regulations**

A wide range of policies could be available at international, national, and local level. At international level, various multilateral and bilateral treaties and

agreements, including Basel Convention, are available. National policies may have more than one perspective: they may help to improve SWM with respect to local conditions and/or they may assist to comply with international treaties and agreements. Furthermore, local policies could have an importance as in many countries, SWM is a local issue dealt by local governments (UNEP, 2009).

The Government of Ghana has adopted the EPA, (1999), which spells out the roles of the various stakeholders including the private sector. The purpose is to ensure sustainable collection, disposal and treatment of waste as well as improving planning, monitoring and enforcement of appropriate regulations at the local level.

According to Asase *et al.* (2009), there is no distinct law identified in Ghana for the management of solid waste; although, Ghana currently has no law for specific wastes, general waste regulations or hazardous waste regulations, nevertheless there is a policy framework that guides the management of hazardous, solid and radioactive wastes. Available are three key national policy documents relevant to solid waste management. These are the i) National Environmental Sanitation Policy (prepared by the Ministry of Local Government and Rural Development in 1999 to develop and maintain a clean, safe and pleasant environment for human settlements), ii) Guidelines for Landfills/Safe and Sound Management of the Bio-Medical Wastes in Ghana (drawn up by the Environmental Protection Agency to establish standards for design, construction and management of waste disposal systems to protect public health and the environment) and iii) Manual for the Preparation of District Waste Management Plans in Ghana.

The Tarkwa Nsuaem Municipal Assembly has bye-laws in relation to the handling of wastes, the local municipal government passes bye-laws, in pursuance of the powers conferred on the Assembly by some sections of the Local Government Act 1993, Act 462. These bye-laws indicate that solid and liquid waste made available by owners or occupiers of premises shall be collected, treated and disposed of at a designated site by the Assembly and its contractors or its agents (TNMA, 2004); moreover, the Assembly shall impose prescribed fees on an owner or occupier of premises where services are rendered for the disposal of liquid and solid waste and such fees shall be reviewed from time to time. To Asase *et al.* (2009), the flexibility of the legislation, especially in the case of the city bye-laws, makes it possible for the legislation to be in consonance with the strategy accepted for waste management in the city in consultation with the citizenry.

### **2.5.3 Challenges of MSW Management**

A lot has been said, written, and demonstrated about the inadequacies in solid waste management and its associated problems. In Africa a number of factors militating against effective solid waste management include a) poor administration b) limited funding and c) restrictions on raising or directly accessing user fee revenues (UNEP 2005).

To some researchers, the difficulties in providing the desired level of public service in the urban centres are often attributed to the poor financial status of managing municipal corporations (Ahsan, 1999). Also higher priority needs to be assigned to the management of municipal solid waste by the local authority and a

system approach needs to be adopted for optimizing the entire operation of SWM encompassing segregation at source, timely and proper collection, transportation routes and types of vehicles and development and proper operation of sanitary landfill site (Chandra and Devi, 2009).

Solid waste management systems in developing countries deals with many difficulties, including low technical experience and low financial resources which often cover only collection and transfer costs, leaving no resources for safe final disposal (Collivignarelli *et al.*, 2004). Agyepong (2011), estimated that a major urban planning challenge is the inability of city authorities to design our cities and settlements that will effectively deal with the issue of environmental sanitation, besides, the growth of towns and cities has resulted in increased population coupled with increased socio-economic activities; there has not been a commensurate increase in essential logistics for effective and efficient waste management services delivery.

Although the inefficiencies in waste management have been attributed to other factors such as management and funding but the wrong attitude of the general public to solid waste disposal should not be ignored. To Agyepong (2011), the lack of civic education, enforcement of regulations and low level of modern sanitation and minimal hygienic practices among the populace leads to faster and indiscriminate littering compared to the attempt to manage it. Majority of people are not willing to pay for collection and disposal of waste, nor separate and reuse waste.

#### 2.5.4 Education and Training

Asase *et al.* (2009), stated that intensive education of inhabitants of the city is required to ensure they fully understand the health hazards posed by inadequate MSW management which will motivate them to pay for MSW management services. Though education is not in itself alone sufficient to ensure improvements in environmental sanitation, neither is the provision of sanitary infrastructure nor services any better unless they are properly used. There is an unfortunate tradition in Ghana in which hygiene and environmental sanitation education is considered as a didactic one-way process in which the target group is considered as part of the problem rather than part of the solution (Asase *et al.*, 2009). Improved approaches based on problem-solving and active participation by the target groups must be developed and implemented (EPA, 1999). To UNEP (2005) an informed public can do much to improve the effectiveness of municipal waste management programmes. Also an educated public implies a MSW management system that is accountable to its constituents. This is likely to improve the service and performance of the system.

## **CHAPTER THREE**

### **MATERIALS AND METHODS**

#### **3.1 Location and Size**

The study was conducted in Tarkwa in the Tarkwa Nsuaem Municipality, one of the municipalities in the Western Region of Ghana. Tarkwa Nsuaem Municipality is located between Latitude 4°00'N and 5°00'40'N and Longitudes 1°04'5' W and 2°01'10'W. Geographically Tarkwa is bounded to the north by the Wassa Amenfi East District, the south by the Ahanta West District, the West by the Nzema East Municipal and the East by Mponohor Wassa East District. The Municipality has a total land area of 2354 sq. km (<http://www.ghanadistricts.com/districts/>). The main occupation of the people is gold mining. Tarkwa has a main Municipal Environmental Health Department that is responsible for all aspects of solid waste management.

#### **3.2 Population Size and Growth Rate**

The population of the municipality was projected from the 2000 population and housing census. The projected population of the municipality was 145,396 with 3.0% population growth rate (personal communication with Ussher, the municipal statistical officer, 2011)

#### **3.3 Data Collection Methods**

For the purpose of this study data were gathered from primary and secondary sources using different methods.

### **3.3.1 Primary Data Collection**

Extensive field investigation was used for quantification, analysis of MSW composition in the selected residential areas. Field observation and key informant interviews were also used. Information collected were on weight of solid waste (SW) generated by household in a day, constituents of SW, types of waste containers, mode of transportation and disposal, cost of disposal, separation of SW and plates relevant to the study were taken. The number of persons in each household was recorded in the data sheets.

At the dump site, measurement on weight, separation of waste into different categories and measurement of sample of each category were made and recorded.

#### **3.3.1.1 Advance Field Investigation and Preparation**

The advance field observation involved exploration through the study area to assess communal waste collection bins at central collection points, household dustbins and the municipal dumping site.

Preparations made for the collection of data include:

Equipment used:

- Plastic bags for each sampling site – for 7(days) for the 30 sample units (number of households)
- Weighing scale – one scale to weigh the waste
- Bucket – used as a container for weighing
- Plastic sheet – to spread waste over it for sorting, once collected and labelled from sampling site
- Gloves – for field volunteers to handle waste



- Nose masks – to protect workers from respiratory infections

Households were given numbers for purpose of data recording and analysis, plastic bags were corded by marker according to the numbers assigned to households and data sheets were also prepared for recording of data.

Leaflets which explain the study and requests for cooperation, together with 7 plastic bags were distributed to each household.

Two workers were required for the transportation of the waste. In addition, one worker was required for each sample area to collect and load the waste on a truck, the ideal means to transport the waste collected to the dump site where all the measurements were taken.

### **3.3.2 Secondary Data**

TNMA, 2004, which projected population figures and an overview of SWM, and the working in the operational areas, were collected in that order from Environmental Health Department, Ghana Statistical Service, Tarkwa and Private waste management companies respectively.

### **3.4 Sampled Areas and Techniques Used**

The criteria used to establish the zoning of the residential areas for the study were based on minimum wage, roofing and wall materials, and available public services, such as sewage infrastructure, running water and electricity.

The low socioeconomic status was those where inhabitants' income was less than twice the prevailing daily minimum wage at the start of the data collection in 2011 (GHC 3.73). Most of the houses in this category walls and roofs were of



cheap light, often natural material and in a precarious state needing repair. The households have limited access to sewage infrastructure, running water and electricity.

Where inhabitants' daily income was just over twice and up to five times the daily minimum wage, these were included in the middle socioeconomic status. Most of the housing materials were of concrete floor, brick, block, and cement mortar and most of the households had access to sewage infrastructure, running water and electricity.

Where inhabitants' income was more than five times the daily minimum wage, these were included in the high socioeconomic status and the construction materials used in these households were high quality concrete, bricks, sandcrete blocks and mortar with consistent access to public services.

Three residential areas sampled and representing the three different socioeconomic statuses of low, middle and high income groups are New Atuabo, Nurses Quarters and Apinto Midland Estate respectively. Thirty households were sampled for each of the three categories yielding a total of 90 households that were sampled. Simple random sampling technique was used for all the three categories. Wastes generated in these areas were collected once a day every morning for seven successive days, that is 630 sampling units were used. The collected wastes were weighed and weights recorded in the data sheet according to the numbers assigned to households. The plastic bags from those collected in each sample area were opened onto the plastic sheet and a representation were separated into different types: 1) Organic Waste, 2) Ferrous Metals, 3) Non-

ferrous Metals, 4) Glass / Ceramics, 5) Plastics / Rubber, 6) Textile, 7) Ash / Sand, 8) Paper /Cardboard and 9) Miscellaneous materials. The separated wastes were placed into different buckets and weighed. Each category of the separated wastes were weighed and recorded in the data sheet. Subsequently all wastes were dumped and equipment used cleaned.

### **3.5.0 Method of Solid Waste Characterization**

According to Brunner and Ernst (1986) there are three methods for determining the composition of urban solid waste streams. They are i) waste product analysis, ii) market product analysis and iii) direct sampling analysis.

The method chosen for this study involved the third option of direct sampling analysis of solid waste from specific sources, a labour-intensive manual process of sorting, classifying and weighing all items in each sampling unit and a detailed recording of the data.

Each of the waste samples from the source of generation were emptied on a black polythene sheet laid on a bare floor for sorting, the collected wastes were dumped together and mixed thoroughly and a representative sample was taken to comprise the composite sample (Soncuya and Vilorio, 1992).

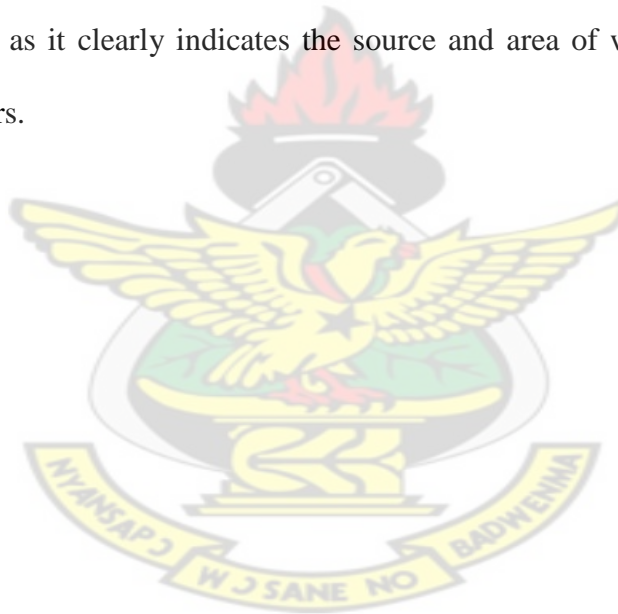
The total wet weight of each waste category was determined and expressed in kilogram and the percentage of each constituent was calculated. The whole process of sorting and weighing was carried out seven times a week for three weeks.

### **3.5.1 Analyzing MSW**

The data was analyzed by Microsoft excel software. The raw data was fed into the programme and related charts were generated and calculations done.

### **3.6.0 Determination of the Generation of MSW**

There are two known methods to determine the per capita generation rate of solid waste for a study area. They are (a) determining the number, sizes and volumes of solid waste collection systems and (b) house-to-house, weight analysis methods and the latter of the two was used for this study. This approach allowed for high accuracy as it clearly indicates the source and area of waste and the number of generators.



## **CHAPTER FOUR**

### **RESULTS**

#### **4.1 Assessment of Solid Waste Management**

This study established that though solid waste management in the municipality is being reasonably managed, there is still a lot of room for improvement to reach the standard for effective solid waste management. Standards are not met in the following categories a) The collection efficiency is low, b) waste are not separated into needed fractions and c) the methods of disposal are not environmentally friendly.

##### **4.1.1 Availability, Enforcement and Impact of Solid Waste Regulations**

There are bye-laws in the Tarkwa Nsuaem municipality (TNM) governing solid waste management and penalty for people who flout it; however, enforcement is chronically weak.

##### **4.1.2 Financial Mechanism of Solid Waste**

All the financial activities of Solid Waste Management (SWM) in the municipality a) annual budget, b) subsidies from national government c) local financial input and d) revenue from penalties are taken care of by the local municipal government. Waste generators in the municipality do not pay for the solid waste, irrespective of the quantity generated.

#### **4.1.3 Separation of Solid Waste**

The study showed there is hardly any separation of waste among the sampled households. Most households did not consider cleanliness and the environment outside their home stands as primary concerns for engaging in waste management activities.

#### **4.1.4 Storage of Solid Waste in the Home**

The study also revealed that there were variations in the temporary storage of solid waste at home, based on their socioeconomic status. Out of the 30 sampled households of the low income earners 18 used polythene bags, 11 used broken buckets (Plate 1B) and 1 used a wooden basket in storing waste at home. Twenty three (23) members of the middle income class used small bins manufactured purposely for waste storage as 7 of them used rubber bucket with cover. All the 30 households of the high income earners sampled used purposely manufactured large volume poly bins (Plate 1A) in storing their solid waste and 15 of the 30 bins located in a well constructed waste bay outside their immediate surroundings reducing spillage to a minimum. The mechanised trucks collected the waste directly and emptied them in its hold at this high income neighbourhood. Even at this level separation of waste is not done.



A

B

Plate 1: Solid Waste Storage Bins

#### **4.1.5 Treatment of Municipal Solid Waste**

Municipal solid wastes were collected from several places in the municipality and simply dumped at a designated site untreated. There are no records to suggest the municipality had ever purposely treated; if there was any such treatment, it was what was done by nature.

#### **4.1.6 Transfer and Transportation of Municipal Solid Waste**

The solid waste of the low and middle class households was stored temporarily in the communal bins and then transported to the designated-disposal site by mechanized trucks. There were eight of such trucks in the whole municipality. Three of these trucks belong to the municipal assembly and managed by the Environmental Health Department of the municipality. Four of the trucks belong to two private stakeholders of whom two belong to Treds Envitech Limited and the other two to Zoomlion Ghana Limited. The eighth one belongs to the University of Mines and Technology (UMaT), Tarkwa and therefore managed by



the institution. Seven of the vehicles owned by the assembly and private stakeholders, transport waste from the centralised collection points in their zones of operation in the municipality to the main dumping site. Apart from these mechanized trucks, there were tricycle carriers owned by Zoomlion Ghana Limited which were also used to transport waste from some middle and low income houses and some commercial areas to their central collection point. Two workers of the Environmental Health Department use wheel barrow in transporting solid waste from homes and stores at a fee to the central collection point to be transported to the main dumping site. It was observed that trucks of the Municipal Assembly were often not covered with net during transporting of waste and waste tended to spill on the roads. Most often workers generally were not fully provided with personal protective clothing leading to direct exposure to waste. There is no transfer station in the municipality.







Plate 2: Solid Waste Transport Trucks

#### 4.1.7 Final Disposal of Municipal Solid Waste

The conventional and environmentally unfriendly methods including open-burning, open-dumping (plate 3) and non-sanitary landfill are practised in the municipality. Transported solid waste was dumped on an open area at Tarkwa Aboso. There are no drains on the site to regulate the movement of leachate and runoff water. Also vectors of diseases such as mosquitoes and flies are not systematically controlled. The waste deposited at the dump site was generally neither spread nor compacted on a regular basis. It was also not covered with inert material. Thus, very unhygienic conditions prevail at the dump sites.



Plate 3: Municipal Solid Wastes Dumped At Dumping Site



Plate 4: Mixture of Runoff Water and Leachate on the Dumping Site

#### **4.1.8 The Role of Stakeholders at Different Levels of Solid Waste Management**

Almost all stakeholders in the waste management sector perform all the requisite functions in the solid waste management chain except separation and treatment of solid waste end of chain which receives little attention if any at all from stakeholder. The chunk of the activities in the chain was performed by private

stakeholders and supported by the Environmental Health Department of the municipal assembly.

#### **4.1.9 Challenges and Opportunities in the Quest to Improve SWM**

Challenges faced in managing solid waste in the municipality were: 1) minimal determination of waste generation rate, 2) limited financing to provide for adequate waste disposal, 3) limited technical institutional capabilities, 4) lack of support for research and development, 5) inadequate community participation and education, 6) inadequate private sector financial participation, 7) problems of social acceptance of bin placement and 8) land acquisition problems for solid waste dumping site.

#### **4.2.0 Solid Waste Composition**

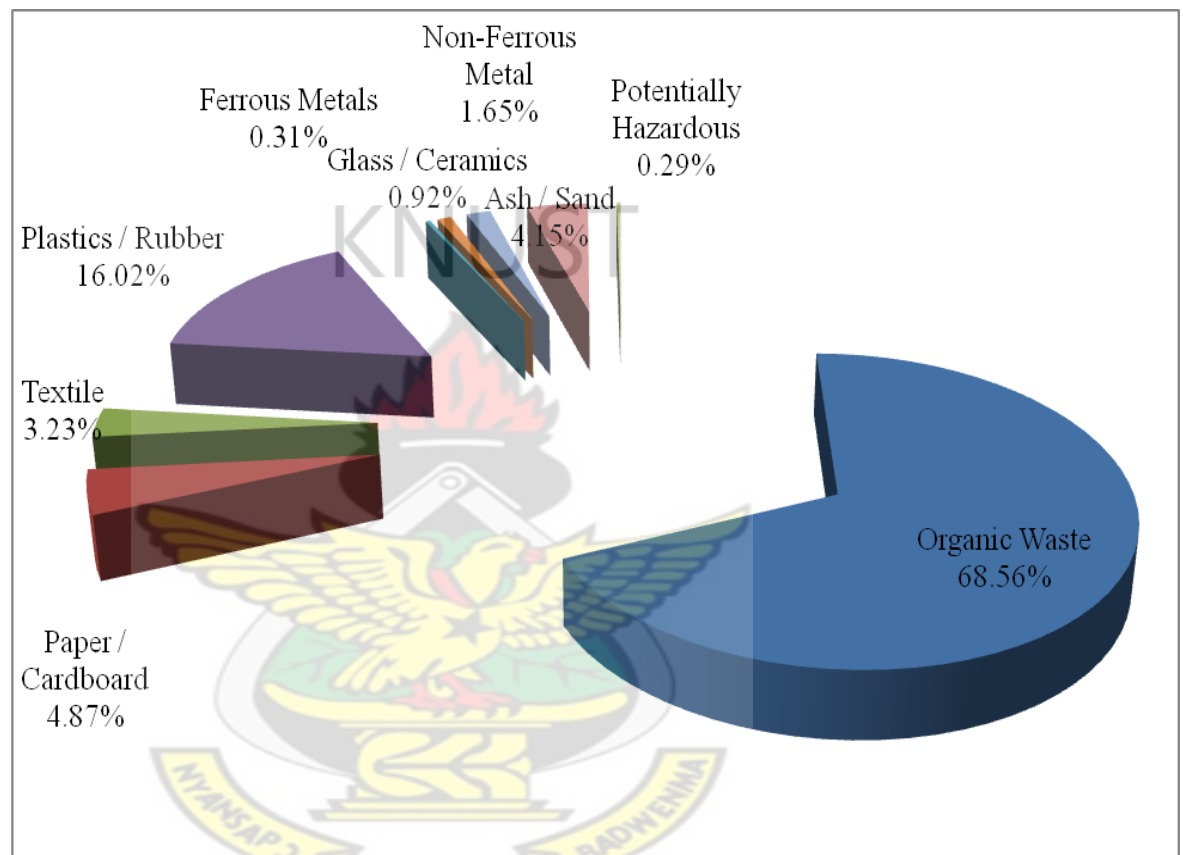
Constituents of solid waste in the municipality range from organic solid waste to potentially hazardous (miscellaneous) waste with their various quantities. The study revealed that the proportions of waste constituent generated in the defined three socio-economic strata differed (25.22% for low income class, 22.71% for middle income class and 20.63% for the high income class); though in all three the ratio of the organic content was highest (68.56%).

#### **4.2.1 Analyses of Municipal Solid Waste Stream**

In view of the fact that municipal solid waste is analyzed by material, such as paper and paperboard, yard trimmings, food scraps, plastics, furniture and clothing (USEPA, 2009), the municipal solid waste (MSW) collected in the study

was analyzed as shown in figure 1. The municipal solid waste was made up of the things that are commonly used and then thrown away in the municipality, which explain the lifestyles of the generators.

#### Composition of Municipal Solid Waste



**Figure 1: Composition of Municipal Solid Waste**

A total sample waste load of 633.67 Kg was weighed, out of which 454.95 Kg was organic waste and textiles and therefore belonged to the energy recovery category, 150.59 Kg to the recyclable category (paper/cardboard, plastics/rubber, ferrous metals, non ferrous metals such as aluminum, copper, lead and glass/ceramics) 28.12 Kg to the non-recyclables category such as (sand/ash and hazardous materials such as dry cell). Figure 1 provides details regarding the



composition of household solid waste sampled over the study period. From the computation of the primary data gathered on the sample solid waste, the ratio of the broad composition in descending order are organic waste accounts for 68.56%, followed by plastics/rubber at 16.02%, paper and cardboard at 4.87%, ash/sand at 4.15%, textiles at 3.23%, non-ferrous metal at 1.65%, glass/ceramics at 0.92%, ferrous metals at 0.31% and potentially hazardous 0.29%. Out of the total waste stream that was sampled, 95.85% could be reused and just 4.15% may not have clear use and may be discarded or used as soil conditioner. Out of the 100%, 23.77% is potentially recyclable with financial and environmental benefits, and 71.79% of the waste stream could be reused to generate energy. Out of the 434.45 Kg of the energy recovery waste, organic waste formed 426.38 Kg which involved food and vegetable waste and 8.07 Kg was plant waste of grass, leaves and wood waste including twigs wood shavings and saw dust. However, this potential source of energy in the municipality is not separated for later reuse; therefore the waste is disposed of as a wasted energy source.

Table 1: Composition of Sampled Municipal Solid Stream

Category / Component	Description	Low Income Earners	Middle Income Earners	High Income Earners	Total weight (Kg)	Percentage (%) values
Energy Recovery						
Organic waste	Kitchen/food waste, green waste, wood waste	159.84	143.90	130.71	434.45	68.56

Textile	Clothing, napkin, curtains, linens	10.77	6.93	2.80	20.50	3.23
Sub total		170.61	150.83	133.51	454.95	71.79
Recyclables						
Paper and cardboards	Newspaper and cardboard	15.36	11.20	4.28	30.84	4.87
Plastics / Rubber	Plastic chairs, bowls	40.80	29.83	30.88	101.51	16.02
Ferrous Metals	Metal products predominately made from steel	1.1	0.6	0.3	2.00	0.31
Non-ferrous metal	Aluminum, copper, lead	0.45	3.48	6.5	10.43	1.65
Glass / ceramics	Bottles, jars, light bulbs and broken bowls	0.98	0.93	3.90	5.81	0.92
Sub total		58.69	46.04	45.86	150.59	23.77
Non-Recyclables						
Ashes / sand	Sand from sweeping and ash from kitchen burnings	15.68	7.43	3.20	26.31	4.15
Potentially hazardous	Material requiring special	1.39	0.42	0	1.81	0.29

	disposal techniques (includes Dry cell)					
Sub total		17.07	7.85	3.20	28.12	4.44
Total sampled solid waste		246.37	204.47	182.57	633.66	100

Table 8 provides details regarding the composition of the households' sampled waste. The entries in table 8 are weights of randomly sampled waste in each category and their corresponding percentages.

#### 4.30 Daily Per Capita Generation

The tables 5, 6 and 7 in appendix B are the raw data collected from the socioeconomic classes (low, middle and high income earners) of selected residential areas in the municipality. New Atuabo, classified as a low income earners residential area in the municipality with sampled total household size of 165 and total waste generation of 920.57 Kg from a sampled size of 30 households (sample unit of 210). The waste generation rate for the low income earning residential area was 0.7969 Kg / person / day and an average household size of 5.5. Nurses Quarters were classified as a middle income earners residential area. It had sampled total household size of 119 and total waste generation of 826.36 Kg from sampled size of 30 households (sample unit of 210). The waste generation rate was 0.9920 Kg / person / day and an average household size of 3.96. The Apinto Midland estate was classified as a high income earners residential area. It had a total household size of 101 and total waste generation of 744.26 Kg from a sample size of 30 households (sample unit of 210). The waste

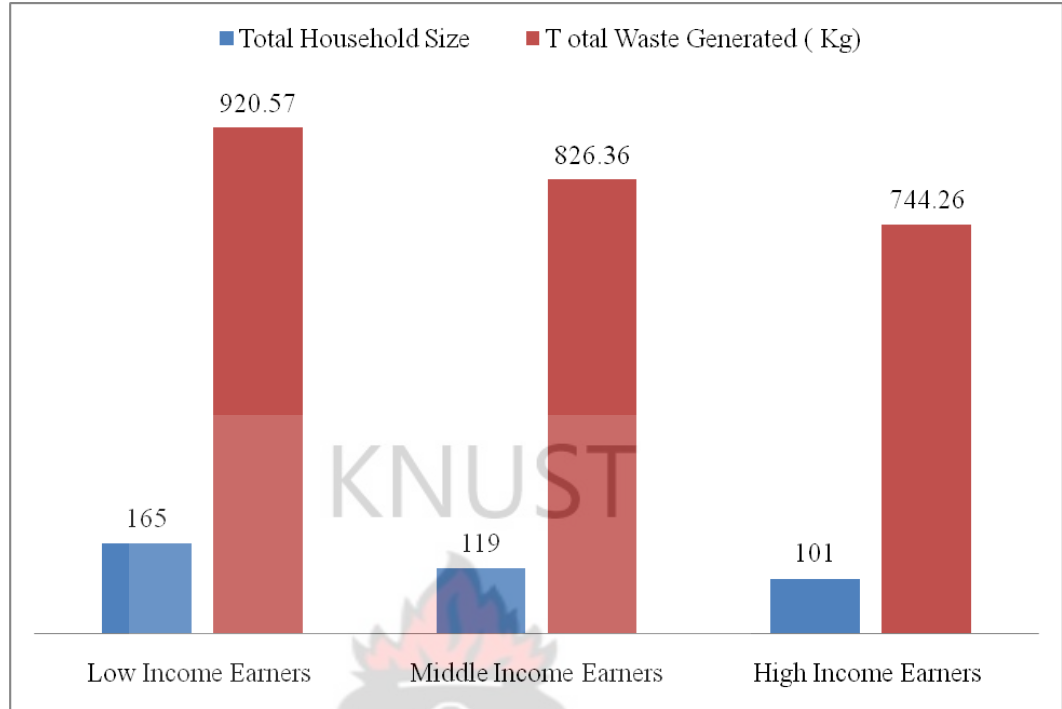


generation rate of this residential area was 1.05 Kg / person / day with an average household size of 3.36.

Table 2: Summary Sheet for Solid Waste Generation Rate in the Selected Communities.

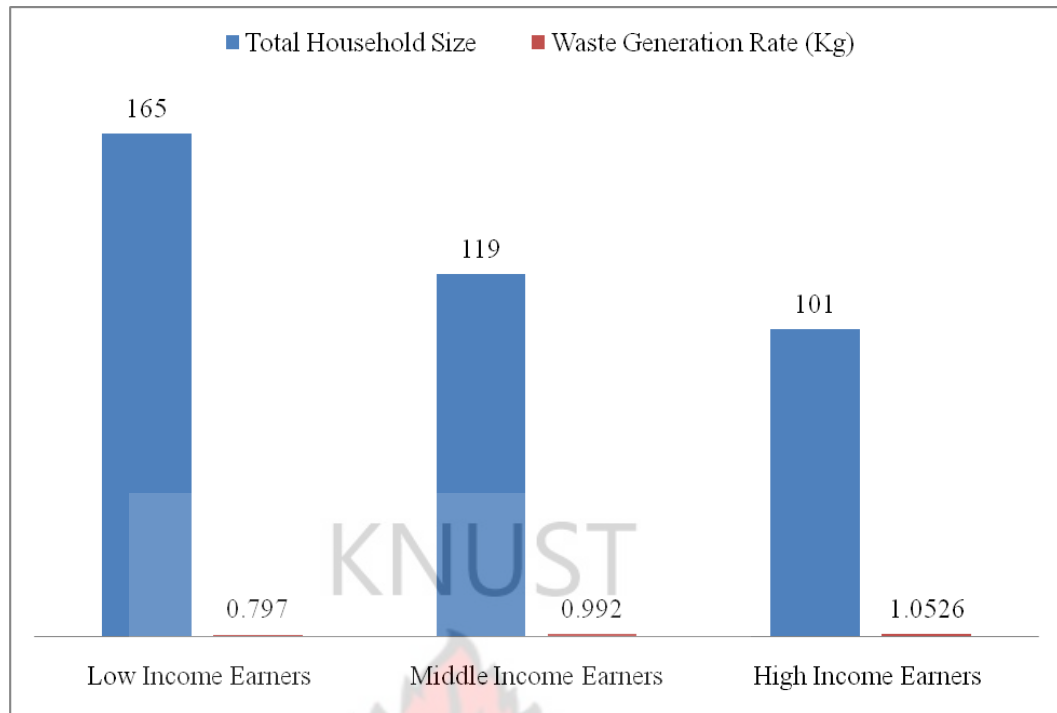
Description	Low Income Earners	Middle Income Earners	High Income Earners	Total
Waste Per Category Generated (Kg)	920.57	826.36	744.26	2491.18
Total Family Size	165	119	101	385
Generation Rate (Kg) Per Head	0.7970	0.9920	1.0527	0.92 (average)
Average House Hold Size	5.5	3.966	3.366	4.2777 (average)
Mean	30.69	27.55	24.81	27.68

Per head waste generation rate, total household size and total waste generated varied between different localities based on the socioeconomic classifications although trends were similar. The relationship between total waste generated, total household size and generation rate is shown in the figures 2 and 3.



**Figure 2: Population and Waste Generation Relation**

From the figure 2 the socioeconomic class with the highest population (total household size) generated the highest waste by weight. This clearly shows as written by many researchers that increase in population of an area cause an increase in waste generation in that community.



**Figure 3: Population and Waste Generation Rate Relation**

Considering the figure above the high income earners class had the lowest population (101) from thirty households but yet had the highest generation rate (1.05 kg / person / day) and also the low income earners class had the highest population (165) from thirty households and had the lowest generation rate (0.797 kg / person / day).

#### 4.4.0 Waste Management Strategy

Apart from the collection, transporting and open dumping in the municipality, scavenging activities was also carried out in the municipality. There was a proper use of environmentally sound technology in the municipality by an entrepreneur, in the form of plastic waste recycling to reduce and divert plastic waste material from the dump site. As the small scale industry modifies waste as raw material and supply for the production of other secondary products.

#### **4.5.0 Recycle**

There was a small scale plastic/rubber recycling industry in the municipality.

Raw materials were bought from scavengers gleaning of supplies at the municipality's dump site. These plastic and rubber materials were classified into 1) plastic bowls, 2) sachet water plastic and 3) plastic chairs. About 60 broken chairs, 80-100 mini sacks of sachet water (5 kg per sack) and 500 kg rubber bowls were received fortnightly. The raw materials were mostly received during school holidays and on weekends since school children were the main scavengers of the raw materials. Thirty five (35) pesewas was paid per kilogram for sachet water rubbers, 60 pesewas for broken plastic bowls and GH¢ 2.00 per faulty plastic chairs from 50-100 pieces but if below the stated quantity GH¢ 1.80 per faulty chair. Eighty (80) pesewas per kilogram for severely damaged chairs. These materials were washed, milled into pellets, dried and sacked in mini sacks and stored (300-400 sacks) for later transportation to sales point. The pellets per sack for the categories weigh 3 kg for sachet water plastics, 45 kg for the plastic chairs

and 25 kg for plastic bowls. Plate 5 shows pellets in sacks



Plate 5: Pellets of plastics in sacks

#### 4.6 Projecting Municipal Solid Waste

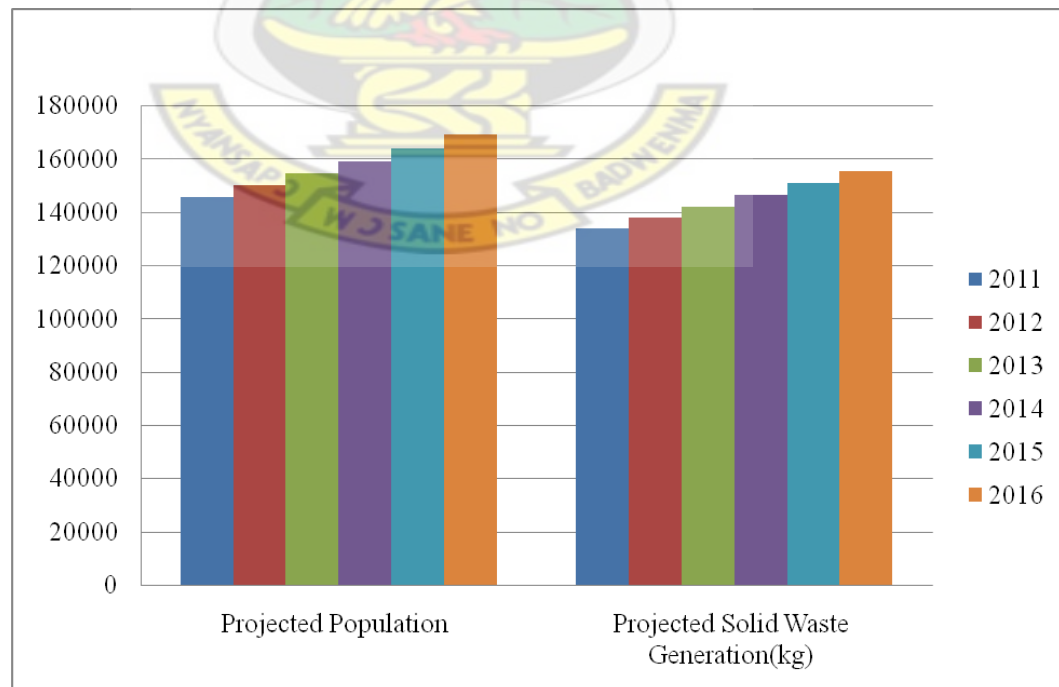
Waste projection informs waste policy making and is an indispensable process in waste management planning (Chung, 2010).

Table 3: Projection of Population in the Tarkwa Nsuaem Municipality by 2016

Year	Projected Population
2011	145,396
2012	149,824
2013	154,387
2014	159,089
2015	163,933
2016	168,926

Source: Ussher, municipal statistical officer (2011), Tarkwa Nsuaem Municipality, at growth rate of 3%.

The population figures for the next five years were sourced from the Ghana Statistical Service in the municipality, projected by a team of experts headed by the head of service (personal communication with Ussher, the municipal statistical officer, 2011). The projection was from the 2000 population and housing census with population growth rate of 3.0%, This was due to the unavailability of results of the 2010 population and housing census. These figures were used to predict the quantum of waste to be generated each day in accordance to their respective years with the solid waste generation rate (0.92 kg) computed from the study with an assumption. It was assumed that the solid waste generation rate remains the same over the projected period. This is shown in the figure below.



#### **Figure 4: Population and Corresponding Waste Generation per Day**

Figure 4 projects solid waste generation per day for 2011, 2012, 2013, 2014, 2015 and 2016 could be estimated as 133,764.32, 137,838.08, 142,036.04, 146,361.88, 150,818.36 and 155,411.92 respectively. Based on these estimated figures (with the assumption that the solid waste generation rate remains constant) could be used to predict the amount of MSW that is likely to be generated in the near future in order to devise the most appropriate solid waste management strategy to address some of the inefficiencies in solid waste management.





## CHAPTER FIVE

### DISCUSSIONS

The existing solid waste management system was evaluated to assess its adequacy to meet the goals and objectives of Tarkwa Nsuaem Municipal Assembly's (TNMA) Environmental Health Department. The state of waste management in the municipality may just be adequate but lacks the capacity to ensure efficient usage of resources to manage i) reducing the generation of waste, ii) increasing reuse of materials prior to their entering the waste stream, iii) recycle of generated waste, iv) waste use (composting and waste-to-energy) and v) landfilling of unusable waste (The United Nations Centre for Human Settlements, 1994).

Municipal solid wastes were collected from several places in the municipality and simply dumped at one place. There was no separation of waste among the sampled households. This was reaffirmed that Source separation, totally absent in the solid waste management practice of most developing countries. Source separation in addition to central sorting techniques has been the bedrock of successful materials recovery and recycling programmes in developed countries (Oduro-Appiah and Aggrey, 2013). For a successful household solid waste source separation programme, UNEP (2000) recommend frequent public education and convenient collection services.

.

Solid wastes were not purposely treated but simply dumped at selected sites in the municipality. If there was any treatment at all it was what was done by nature. This dumping practice contradicts the municipality's own provision made in the

bye-law that ‘ *solid and liquid waste made available by owners or occupiers of premises shall be collected, treated and disposed off at a designated site by the Assembly and its contractors or its agents* (TNMA, 2004). Thus the non-treatment of solid waste in the municipality, is not unique but akin to what happens elsewhere in the developing world as exemplified by what is practised in Philippines where dumping and burning of waste was the norm (Mirza, 2001). Consistent local, district, regional, national and global effort must be put in to control. Raw dumping of solid waste considering its seepage effect in polluting underground water, harmful effect on ozone layer depletion, spread of vector-borne diseases, their unsightly appearance and intolerable odour. It is documented that waste management activities is said to contribute to global greenhouse gas emissions by approximately 4%. In particular, the disposal of waste in landfills generates methane that has high global warming potential (Papageorgiou *et al.*, 2009).

Solid waste transportation in the municipality was done by privately-owned mechanized trucks to the central collection point. There was no transfer station in the municipality. Observation was not different from what Sharholy *et al.* (2008), noted that many municipalities have employed private contractors for secondary transportation from the communal bins or collection points to the disposal sites.

Though sanitary landfill is the most common technology around the world, the conventional and environmentally unfriendly methods including open-burning, open-dumping and non-sanitary landfill (UNEP, 2009) is what is practised in the Tarkwa Nsuaem municipality. There are no drains at the dump site to regulate the

movement of leachate and runoff water. However, unscientific disposal cause an adverse impact on all components of the environment and human health (Chandra and Devi, 2009).

Almost all service providers in the waste management sector in the municipality perform all the functions in the solid waste management chain except separation and treatment of solid waste of which no service provider performs. The chunk of the activity was performed by private service providers with minimal support from the assembly's own equipment. It therefore stands to reason that the municipal assembly alone cannot effectively manage solid waste. With regards to the rapid changes in quantity and composition of solid waste, this study supports observation that governments have to be in continuous dialogue with service providers to improve efficiency to regularly introduce appropriate regulations which can help bring the required improvements in Solid Waste Management (SWM) system (UNEP, 2009). It was realised from this study that since most of the activities of SWM were done by service providers whose emphasis may be on maximizing profits, their output if not monitored regularly to ensure the municipality is receiving value for money, these providers end up with ineffective waste management. The flip side of the coin is also whether the private providers are receiving payment for the job done and on time. This transition from public to private institutions undertaking the running of various public utilities and services make it imperative for governments to establish strong regulatory institutions to make sure that the service providers deliver effective and efficient services (UNEP, 2009).

The waste composition at immediate source shows major categories that would aid in the effective source separation of waste material to enhance downstream material recovery and value generation in the development of the ISWM plan.

The primary data from the study revealed that, organic waste accounts for 68.56%, and of the total waste stream that was sampled, 95.85% could be reused.

Compared to the developed countries, wastes generated in the study area contain large volumes of organic matter. A comparative study by Asase *et al.*, (2009), on the waste stream in Kumasi, Ghana and that in London, Ontario, Canada, show the clear difference between the compositions of waste in the two cities, with organic materials accounting for 63% of waste in Kumasi but only 30% in Ontario.

The increase in food and vegetable waste may be due to the fact that the people of the municipality consume and dispose less inorganic food materials and confirms the observations of the study in the Tarkwa Nsuaem municipality. A study conducted by Alkhatib *et al.* (2010), in Palestine indicated that the bulk of waste was organic (65.1% by weight) and that conducted by Nabegu (2013) in Kano metropolis, Nigeria, also indicates a predominance of organic and biodegradable matter 66%, which were slightly lower than the result found (68.56%) in this study. In Karuvadikuppam in Puducherry in India, biodegradable waste comprising 65% and non biodegradable waste comprising 35% (Swati and Vikram, 2010). Thus the results from the work suggest a strong resource recovery potential for animal feed or compost in the municipality. Recyclable waste made up 16.7% by weight the waste composition in the study (Alkhatib *et al.*, 2010);

quite similar to the figure of 16% in this study. These plastic and rubber recyclables suggest there is incentive to introduce source separation.

The fact that this study showed the organic component of the waste stream formed highest percentage is not unique; many other studies back this trend (Sakawi, 2011; Okot-Okumu and Nyenje, 2011; Forouhar and Hristovski, 2012).

The need for waste separation and subsequent use of this organic component for compost and or animal feed or energy generation should not be preserve of the developing countries but such uses are more critical and beneficial to developing ones like Ghana. The composition of the waste stream may be influenced by the dynamics of their culture, the per capita income, the developmental changes in consumption patterns and waste disposal or recycling services in the municipality (Blight and Mbande, 1998).

Re-using organic waste in any of the transformed state described above would reduce what is left to open dumping site. Diverting organic waste from dumping could also reduce the amount of greenhouse gas emissions and leachate from the dump site. In view of the fact that leachate from municipalities' landfills represents a potential health risk to both surrounding ecosystems and human populations (Salem *et al.*, 2008). Also waste management activities is said to contribute to global greenhouse gas emissions by approximately 4%. In particular the disposal of waste in landfills generates methane that has high global warming potential (Papageorgiou *et al.*, 2009).

MSW was produced by consumption of consumer goods by residents in their daily activities such as 'Maintenance' (meeting the basic needs of food, housing

and personal care), 'Subsistence' (providing the financial requirements) and 'Leisure' (social and recreational pursuits) activities (Zhen-shan *et al.*, 2011).

Considering the figure 3 (Population and Waste Generation Rate Relation) the high income earners class had the lowest population (101) but yet had the highest generation rate (1.05 kg / person / day) and also the low income earners class had the highest population (165) and had the lowest generation rate (0.797 kg / person / day). This observation may be attributed to the fact that there may be no or little reuse of used material at the high income earners residential area whereas there is reuse at the low income earners residential area thereby extending the useful life of the used materials. This is confirmed by UNEP (2005), that the rate of reuse of materials is high in household with low-income, whereas in high-income areas, rather reusing the materials directly, households sell bottles, plastics, cardboard, and paper to intermediaries or commercial centres that pay for these materials. Chandra and Devi (2009) also had the same view that high income group people throw away more plastic, metallic and glass waste and also hazardous waste than the low income group. This reuse by selling phenomenon may also be due to activities of scavengers. There may be significantly more scavenging activities at the residence of the low income earners while there may be little or no scavenging activities at the residence of the high income earners. Scavenging is high since there is uncontrolled picking through waste to recover useful items in loose security community. The end product of scavenging could be raw materials for several downstream industries. The lack of significant scavenging activities in the municipality is a clear indication that the presence and full operation of



commercial recycling businesses is lacking. The extent of commercial recycling of paper, metals, glass, and plastic depends on the presence of industrial or other end uses for these materials (UNEP, 2005). Such downstream industries do not exist in the municipality.

The assertion made by Bartelings and Sterner (1999) that increasing population levels, rapid economic growth and rise in community living standards accelerate the generation rate of municipal solid waste rings true here. Estimating the rate of solid waste generation in this study perhaps might be the first on record in the municipality. More often than not 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) (The United Nations Centre for Human Settlements, 1994). This might be due to rapid economic development, rapid population growth resulting from the influx of Ghanaians from other regions and foreigners from neighboring countries due to the great boom of economic activities, which originated from gold mining activities both legal and illegal and their associated ancillary business activities, higher consumption lifestyles. However, the changes were not accompanied with improved efficiency of solid waste collection. This observation in this study is confirmed by Hoornweg and Thomas (1999), who observed that urban generated solid waste crises are highly attributed to three factors: rapid increase in population, heavy consumption pattern of urban dwellers and inefficiency of the authorities whose statutory roles include efficient refuse management.



Solid waste management deserves a better consideration TNMA than what is given now by management. From the study the daily generation rate of the municipality lies above the 0.6 kg per capita estimated daily municipal waste generation rate in the larger metropolitan city Kumasi (Asase *et al.*, 2009). Hristovski *et al.* (2007), reported that the daily per capita generation in the municipality of Veles, Macedonia in 2002 was  $1.06 \pm 0.56$  kg per person per day; a figure higher than what was found in this study.

On average, waste generation of USA is 4.34 pounds per person per day (2.0 kg/cap/day) (USEPA, 2009) which is much higher than figures found elsewhere; an observation may be attributed to their very advance development as a nation.

The rate of solid waste generation of the study of TNM may have a direct link to recent rapid increase of population arising from the booming mining activity in the municipality. Thus there is urgent need for the municipality to institute host of preventive measures to reduce solid waste output and these should include reuse, recycling, and composting of biodegradable materials. If this is not done, the purpose of solid waste management would always be a dream.

Although considerable efforts have been made by successive governments and other entities in tackling waste-related problems in the municipality, there are still major gaps. The most pressing of these gaps have been 1) limited financing and 2) determination of generation rate for future forecast of MSW. These are some of the challenges of Solid Waste Management (SWM) but the chief of which have been confirmed by a number of researchers is the amount of waste generated by households. This figure once calculated is key establishing the appropriate waste

management systems. The figure should allow a municipality to charge rates compatible with the principle applied worldwide, and design a fair payment system for households according to the amount of residential solid waste they generate (Ahsan, 1999; UNEP, 2005; Benítez *et al.*, 2008).

Higher priority needs to be assigned to the management of MSW by local authority and a system approach needs to be adopted for separation at source, timely and proper collection, transportation routes and types of vehicles and development and proper operation of sanitary landfill site (Chandra and Devi, 2009). Wrong attitude of the public to solid waste disposal should not be forgotten as it might lead to faster and indiscriminate littering compared to the attempt to manage it (Agyepong, 2011).

The situation of inadequate central government funding as gleaned from this study, seems poignantly put to be aggravated by a publication in the national Daily Graphic, Friday, May 20, 2011, by Ofosu-Ampofo (2011) captioned “*MMDAs to pay own waste management bill*”, This in effect meant the Ministry of Local Government and Rural Development would no longer accept waste management bills passed to it from the metropolitan, municipal and district assemblies (MMDAs). The public, who disobeyed the bye-laws governing solid waste in the municipality, was to pay a fine, as a means to contribute to ways of raising revenue to pay waste bills, the fines might not have been enough to deter them from disobeying the laws. In my considered opinion, more should be invested in education on the need for the citizenry to obey the laws governing waste management for effective management. Personnel from Environmental

Health Department of TNMA periodically went on radio to educate the populace about proper storage and disposal of solid waste and pointed out the effects on public health, land use, and the environment if poorly handled. Periodic clean-up exercises in the municipality were also organized. Education through the electronic media has helped in reaching thousands of individuals to educate them on safe management of solid waste.

KNUST



## **CHAPTER SIX**

### **CONCLUSION, RECOMMENDATION AND LIMITATIONS**

#### **6.1 Conclusion**

In this study several important parameters of the municipal waste stream were assessed. It was estimated that the average daily generation rate is 0.92kg per capita per day. It was also estimated that the average daily generation rate per household was 3.93kg per household of 4.27 persons per day. The dominant solid waste of the municipality is organic waste including food and vegetable waste and other organic materials with 68.56%, followed by plastics and rubber with 16% and paper and cardboard with 5%.

#### **6.2 Recommendations**

- 1) Further studies should be made to analyze the various chemical elements of the waste. From knowledge of the partition coefficients for these elements through Waste Product Analysis, it is possible to infer the chemical composition of the raw waste stream and used as raw material for some agro industries than as a discarded material.
- 2) Local authorities should be resourced to develop institutional framework to ensure effective waste management: The environmental health officials of the municipality must be well informed through training, seminars, workshops and related activities to enable them function more effectively with respect of waste management issues.

3) Stakeholders should be involved in the planning, operation and maintenance of waste management facilities to ensure their improved performance and sustainability. Not forgetting the general public in the municipality

4) The management of the municipal environmental department must undertake public education and promote waste separation at source for better treatment and also encourage the general public to use compost. A curriculum should also be developed and implemented to teach students and the public about environmental management. Transfer station and an engineered sanitary landfill should be established in the municipality to ease transportation and disposal of solid waste concerns.

### **6.3 Limitations**

Due to time and financial constraints it was necessary to limit the sampling to households for the study without including the commercial, industrial, agricultural, construction and demolition waste and institutional waste since they generate solid waste and forms part of the MSW but not the bulk or greater part of the waste due to financial constraints

There was no adequate data at the local level in aspects such as weight of waste generated and composition and others.

## References

**Agyepong, J. S.** (2011). Presentation at the UN Conference on Building Partnerships for Moving Towards Zero Waste, Zoomlion Ghana Limited

**Ahsan, N.** (1999). Solid waste management plan for Indian megacities. *Indian Journal of Environmental Protection* 19 (2), 90–95.

**Alkhatib, I. A., Monou, M., Abdul S. F., Zahra, A., Hafez Q. S. and Despo, K.** (2010). Solid Waste Characterization, Quantification and Management Practices in Developing Countries, a Case Study: Nablus District- Palestine. *Journal of Environmental Management*, Volume 91. Issue 5, Pages 1131-1138

**Asase, M., Yanful, E. K., Mensah, M., Stanford, J. and Amponsah, S.** (2009). Comparison of Municipal Solid Waste Management Systems in Canada and Ghana: A Case Study of the Cities of London, Ontario, and Kumasi, Ghana Waste Management 29 (2009) Pages 2779-2786

**Bartelings, H. and Sterner, T.** (1999). Household Waste Management in a Swedish Municipality: Determinants of Waste Disposal, Recycling and Composting. *Environment and Resource Economics* Volume 13, Number 4, 473-491, DOI: 10. 1023/a: 1008214417099

**Bench, M. L., Woodard, R., Harder, M. K. and Stantzos, N.** (2005). Waste Minimisation: Home Digestion Trials of Biodegradable Waste. *Resources, Conservation and Recycling*. Volume 45, Issue 1, September 2005, Pages 84–94

**Benítez, S. O., Lozano-Olvera, G., Morelos, R.A., and Vega C.A.** (2008). Mathematical Modeling to Predict Residential Solid Waste Generation. *Waste Management*. Volume 28, Supplement 1, 2008, Pages S7–S13

**Blight, G. & Mbande, C.** (1998). *Waste Management Problems in Developing Countries. Solid Waste Management: Critical Issues for Developing Countries*. Kingston: Canoe, pp. 11-26.

**Brunner, P. H. and Ernst, W. R.** (1986). Alternative Methods for the Analysis of MSW. *Waste Management and Research*; Vol4, pp 147 160. <http://wmr.sagepub.com/content/4/1/147.abstract> (accessed 5 June 2011)

**Bundela, P. S., Gautam, S. P., Pandey, A. K., Awasthi, M. K. and Sarsaiya, S.** (2010). Municipal solid waste management in Indian cities – A review *International Journal of Environmental Sciences* Volume 1, No 4, 2010 Pp 591-606

[http://210.212.96.131/rpcb/ReportsAndPaper/MSWM\\_Amit\\_Singh.PDF](http://210.212.96.131/rpcb/ReportsAndPaper/MSWM_Amit_Singh.PDF)  
(Retrieved April, 2011)



**Chandra, Y. I. and Devi, N. L.** (2009) Studies on Municipal Solid Waste Management in Mysore City- A case study pp 15-21

**Chung, S.S.** (2010). Projecting Municipal Solid Waste: The Case of Hong Kong SAR Resources. *Conservation and Recycling* Volume 54, Issue 11, September 2010, Pages 759–768

**Clarke, M. J., Read, A. D. and Phillips, P. S.** (1999). Integrated Waste Management Planning in New York City. *Resources, Conservation and Recycling* 26, 125–141.

**Collivignarelli, C., Sorlini, S. and Vaccari, M.** (2004) “Solid Wastes Management in Developing Countries”, CD-ROM of ISWA 2004 World Congress, Rome, Italy October 17–21, 2004.

**Daskalopoulos, E., Badr, O. and Probert, S. D.** (1997). Economic and Environmental Evaluation of Waste Treatment and Disposal Technologies for Municipal Solid Waste. *Applied Energy*, Volume 58, Issue 4, December 1997, Page 209-255

**Emery, A., Davies A., Griffiths, A. and Williams, K.** (2007). Environmental and Economic Modelling: A Case Study of Municipal Solid Waste Management Scenarios in Wales. *Resources, Conservation and Recycling* Volume 49, Issue 3, January 2007, Pages 244–263

Environmental Protection Agency, Ghana, (1999). Ministry of Local Government and Rural Development, Environmental Sanitation Policy (1999), Re-Printed November 2001 Pp 1-51

**Forouhar, A. and Hristovski, K. D.** (2012). Characterization of the Municipal Solid Waste Stream in Kabul, Afghanistan. *Habitat International* Volume 36, Issue 3, Pages 406–413

Ghana's Climate Change Technology Needs and Needs Assessment Report, January 2003 Under the United Nations Framework Convention on Climate Change. Version 1. Page 1-110

Ghana Districts. [http://www.ghanadistricts.com/districts/?news&r=5&\\_id=141](http://www.ghanadistricts.com/districts/?news&r=5&_id=141) (accessed 10 September 2010).

Global Waste Management Market Assessment, 2007 Key Note Publications Ltd, July 2008, Pages: 166

[http://www.researchandmarkets.com/reports/461875/global\\_waste\\_management\\_market\\_assessment\\_2007](http://www.researchandmarkets.com/reports/461875/global_waste_management_market_assessment_2007) (accessed 16 July 2010).

**Hoornweg, D. and Thomas, L.** (1999). What a Waste: Solid Waste Management in Asia. *Urban Development Division*. The World Bank, Washington DC. USA.

**Hristovski, K., Olson, L., Hild, N., Peterson, D. and Scott Burge, S. (2007).**

The Municipal Solid Waste System and Solid Waste Characterization at the Municipality at Veles, Macedonia. *Waste Management* Volume 27, Issue 11, 2007, Pages 1680-1689

**Jin, J., Wang, Z. and Ran, S. (2006).** Solid Waste Management in Macao: Practices and Challenges. *Waste Management* 26 (9), 1045–1051.

**Khan, R. R. (1994).** Environmental Management of Municipal solid Wastes. *Indian Journal of Environmental Protection* 14 (1), 26–30.

**Kumar, S., Bhattacharyya, J. K., Vaidya, A. N., Chakrabarti, T., Devotta, S. and Akolkar, A. B. (2009).** Assessment Of The Status Of Municipal Solid Waste Management In Metro Cities, States Capitals, Class I Cities, and Class II Towns In India. *Waste Management* Volume 29, Issue 2, February 2009. Page 883-895

**Lebersorger, S. and Beigl, P. (2011).** Municipal Solid Waste Generation in Municipalities: Quantifying Impacts of Household Structure, Commercial Waste and Domestic Fuel. *Waste Management* Volume 31, Issues 9–10, September–October 2011, Pages 1907–191.

**Mirza, S. A. (2001).** Assessment of Solid Waste Management Practices of Households: A Case Study of Two Selected Coastal Barangays of Catanauan Municipality, Quezon Province, Philipines

**Mosler, H. J., Drescher, S., Zurbrugg, C., Rodriguez, T. C. and Miranda, O. G.** (2006). Formulating Waste Management Strategies Based on Waste Management Practices of Households In Santiago De Cuba, Cuba. *Habitat International* 30 (4), 849–862.

**Moy, P., Krishnan, N., Ulloa, P., Cohen, S. and Brandt-Rauf, P. W.** (2008). Options for Management of Municipal Solid Waste in New York City: A Preliminary Comparison of Health Risks and Policy Implications. *Journal of Environmental Management* Volume 87, Issue 1, April 2008, Pages 73-79

**Nabegu B. A.** (2013) Application of One Way Analysis of Variance (ANOVA) in Exploring Municipal Solid Waste Characteristics in Kano Metropolis, Northwestern Nigeria. *Greener Journal of Science, Engineering and Technology Research* ISSN: 2276-7835 Vol. 3 (2), pp. 062-067, February 2013

**Oduro-Appiah K. and Aggrey B. E.** (2013). Determinants of Source Separation of Municipal Solid Waste in Developing Countries: The Case of Ghana. *Journal of Sustainable Development in Africa* (Volume 15, No.3, 2013) ISSN: 1520-5509  
*Clarion University of Pennsylvania, Clarion, Pennsylvania*

**Okot-Okumu, J. and Nyenje, R.** (2011). Municipal Solid Waste Management under Decentralisation in Uganda. *Habitat International* Volume 35, Issue 4, October 2011, Pages 537–543

**Ofosu-Ampofo, S.** (2011) Daily Graphic, Friday, May 20, 2011, MMDAs to Pay Own Waste Management Bills, page 23

**Papageorgiou, A., Barton, J.R. and Karagiannidis, A.** (2009). Assessment of the Greenhouse Effect Impact of Technologies Used for Energy Recovery From Municipal Waste: A case for *England Journal of Environmental Management* Volume 90, Issue 10, July 2009, Pages 2999-3012

**Read, D. A.** (2003). What Is Integrated Waste Management (IWM)? Energy from Waste Foundation Project – A draft project report prepared on behalf of Kingston University; Waste and Environmental Management Research Unit, School of Earth Science and Geography

**Sakawi, Z.** (2011). Municipal Solid Waste Management in Malaysia: Solution for Sustainable Waste Management. *Journal of Applied Sciences in Environmental Sanitation*, Volume (6) 1: 29-38, March, 2011

**Salem, Z., Hamouri, K., Djemaa, R. and Allia, K.** (2008). Evaluation of Landfill Leachate Pollution and Treatment Desalination. Volume 220, Issues 1-3, 1 March 2008, Pages 108-114

**Seadon, J. K.** (2006). Integrated Waste Management – Looking Beyond the Solid Waste Horizon School of Geography And Environmental Sciences, University of Auckland, Private Bag 92019, Auckland, New Zealand School of the Built Environment, Unitec New Zealand, Private Bag 92025, Auckland, New Zealand.

**Sharholy, M., Ahmad K., Vaishya, R. C. and Gupta, R. D.** (2007). Municipal Solid Waste Characteristics and Management in Allahabad, India. *Waste Management* Volume 27, Issue 4, 2007, Page 490-496

**Sharholy, M., Ahmad, K., Mahmood, G. and Trivedi, R. C.** (2008). Municipal Solid Waste Management in Indian Cities – A Review. *Waste Management* 28 (2), 459– 467.

**Soncuya, R.T. and L.A. Vilorio.** 1992. Solid Waste Study of Mandaluyong and San Juan. Prepared for the MEIP Project in Metro Manila on Integrated Waste Resource Recovery and Reuse. Manila.

**Su, J., Xi, B. D., Liu, H. L., Jiang, Y. H. and Warith, M. A.** ( 2008). An Inexact Multi-Objective Dynamic Model and Its Application in China for the

Management of Municipal Solid Waste. *Waste Management*, Volume 28, Issue 12, December 2008, Pages 2532-2541.

**Swati, P. and Vikram, R. M.** (2010). Assessment of Municipal Solid Waste management in Puducherry, India. *Resources, Conservation and Recycling*, Volume 54, Issues 8, June 2010, Pages 512- 520

Tarkwa Nsuaem Municipal Assembly Bye-Law (2004)

**Thorneloe, S. A., Weitz, K. A. and Jambeck, J.** (2005). Moving from Solid Waste Disposal to Materials Management in the United States

**Tonglet, M., Phillips, P. S. and Bates, M. P.** (2004). Determining the Drivers for Householder Pro-Environmental Behaviour: Waste Minimisation Compared to Recycling. *Resources, Conservation and Recycling*, Volume 42, Issue 1, August 2004, Pages 27–48

United Nations Center for Human Settlements (Habitat) UNCHS, (1994). A reference handbook for trainers on Promotion of Solid Waste Recycling and Reuse in Developing Countries of Asia., Nairobi, Kenya



United Nation Environmental Programme (UNEP). (2000). International Source Book on Environmentally Sound Technologies for Municipal Solid Waste Management. USA: UNEP.

United Nations Environment Programme (UNEP) (2005). Solid Waste Management (Volume II: Regional Overviews and Information Sources) December 2005

United Nations Environment Programme (2009). Developing Integrated Solid Waste Management Plan Training Manual: Assessment of Current Waste Management System and Gaps therein, Volume 2

United State Environmental Protection Agency (2009). Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2009

**You-Ti, H., Tze-Chin, P. and Jehng-Jung, K.** (2011). Performance Assessment for Municipal Solid Waste Collection in Taiwan. *Journal of Environmental Management* Volume 92, Issue 4, April 2011. Pages 1277–1283

**Zhen-shan, L., Hui-zhen, F. and Xiao-yan, Q.** (2011). Estimating Municipal Solid Waste Generation by Different Activities and Various Resident Groups: A Case Study of Beijing. *Science of the Total Environment* Volume 409, Issue 20, 15 September 2011, Pages 4406–4414

## Appendix A

### House-to-house, volume-weight analysis methods

Table 4: Data Sheet for Daily Generation Rate

Community .....

Date.....

House No.	Family size	Days							Total
		1	2	3	4	5	6	7	
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									

Computation: Mean; daily generation rate = (B) / (A) / 7 (kg/person/day)

Table 5: Data Sheet for Composition

Category / Component	Low Income Earners	Middle Income Earners	High Income Earners	Total Weight	Percentage (%)
Organic Waste				(a)	$(a)/(A)*100$
Paper /Cardboard				(b)	
Textile					
Plastics / Rubber					
Ferrous Metals					
Glass / Ceramics					
Non-ferrous Metals					
Ashes / Sand					
Miscellaneous					
Total				(A)	100

The entries in this table are weights of waste in each category.

#### Computation

Total weight in each category, such as (a), (b), etc., is addition of all entries across the row.

$$\text{Grand total weight} = (a) + (b) + \dots (j) = (A)$$

The computation formula for the percent composition of each category is shown in the last column of the table.

## Appendix B

Table 6: Daily Generation Rate of Low Income Residential Area

Household size	Days							Total
	1	2	3	4	5	6	7	
12	8.39	8.16	8.16	2.95	2.27	4.99	8.62	43.54
3	2.49	0	3.31	3.18	7.26	4.22	5.67	26.13
5	2.72	2.72	3.18	2.95	2.72	4.54	4.08	22.91
4	7.03	6.58	3.18	2.04	2.49	3.18	2.27	26.77
10	5.9	16.78	8.16	7.26	2.72	4.99	5.44	51.25
6	2.27	2.72	0.45	1.36	6.8	4.54	5.22	23.36
5	1.36	3.17	2.72	4.08	2.27	3.18	6.12	22.9
5	1.59	1.13	3.18	4.08	2.04	3.18	4.99	20.19
1	3.63	2.26	5.9	3.18	3.63	2.27	1.36	22.23
4	2.04	2.72	1.81	3.4	2.72	2.72	2.27	17.68
15	10.89	5.9	9.52	3.63	4.08	6.8	4.99	45.81
3	3.4	2.72	2.27	4.08	4.99	4.99	3.99	26.44
6	7.26	4.54	4.08	3.18	4.31	2.72	4.08	30.17
6	6.35	10.21	2.49	5.44	3.86	4.54	5.44	38.33
1	2.49	5.44	1.81	4.54	3.54	2.27	4.54	24.63
6	4.3	7.48	8.62	3.63	3.17	5.44	6.17	38.81
2	3.4	3.63	2.72	1.36	3.86	2.49	3.62	21.08
1	2.27	1.36	1.13	0.91	2.72	2.04	2.72	13.15
3	0.91	15.88	5.21	6.58	1.81	5.22	6.8	42.41
4	4.31	4.08	4.64	3.18	3.63	2.72	4.54	27.1
8	4.54	3.86	4.08	3.18	2.27	2.72	4.54	25.19
4	2.94	2.26	5.44	1.81	5.44	2.49	3.62	24
5	4.31	4.08	3.63	4.99	2.72	3.86	4.08	27.67
8	4.35	11.11	3.63	4.31	3.17	4.54	4.31	35.42
5	2.49	3.86	8.39	3.18	2.72	5.44	4.08	30.16
4	2.94	14.06	3.86	3.18	3.31	2.72	4.54	34.61
5	3.86	5.21	4.08	10.89	2	4.54	2.27	32.85
6	5.17	9.98	7.03	4.76	3.4	8.85	16.06	55.25
10	6.12	4.99	3.63	4.08	6.8	5.44	6.8	37.86
8	7.71	3.63	6.35	2.27	3.86	3.86	4.99	32.67
Total household size = 165				Total waste generated = 920.57				

Daily generation rate =  $(920.57 / 165) / 7 = 0.7970 \text{ Kg / person / day}$

Average household size =  $165 / 30 = 5.5$

Table 7: Daily Generation Rate for Middle Income Earners Residential Area

Household Size	Days							Total
	1	2	3	4	5	6	7	
4	3.4	2.95	3.63	4.54	3.18	2.94	4.99	25.63
5	2.72	1.82	5.9	3.4	2.27	3.63	4.99	24.73
7	4.08	5.9	5.9	5.22	3.86	6.35	2.27	33.58
7	5.22	4.76	2.27	1.36	3.18	4.08	2.49	23.36
6	4.54	4.08	4.54	4.99	4.31	6.35	4.54	33.35
3	4.08	3.86	1.81	2.27	3.18	4.99	2.04	22.23
5	4.31	2.72	2.27	2.72	2.27	2.36	2.18	18.83
4	1.81	2.27	2.95	4.08	2.72	3.4	4.99	22.22
4	5.9	3.63	3.63	3.18	2.27	2.95	4.08	25.64
5	7.71	5.44	3.08	2.72	4.54	3.18	4.31	30.98
2	4.54	2.95	3.18	4.08	3.63	2.04	3.63	24.05
4	3.63	3.18	2.72	2.27	1.36	3.18	4.08	20.42
4	4.54	4.99	4.08	4.54	2.9	3.63	5.44	30.12
5	7.26	4.54	3.86	3.18	6.35	7.25	4.08	36.52
3	3.63	3.86	4.31	2.72	4.99	3.63	3.18	26.32
4	4.99	4.08	2.27	2.95	2.27	2.27	4.54	23.37
5	5.67	5.44	2.04	1.36	2.95	4.54	7.26	29.26
6	6.35	3.86	3.18	4.08	5.44	3.18	3.18	29.27
3	5.44	5.44	2.27	1.81	4.99	4.08	5.9	29.93
4	2.72	4.08	2.63	2.27	3.18	1.36	1.18	17.42
1	0	0	2	0	0	0	0	2
2	3.18	3.86	3.64	3.63	2.04	3.63	3.18	23.16
7	18.14	14.51	1.81	2.27	4.31	5.99	8.16	55.19
3	9.07	4.76	4.54	4.31	6.8	4.44	5.9	39.82
3	4.54	3.86	4.31	4.99	4.44	4.99	3.63	30.76
4	6.35	4.54	6.8	6.35	4.99	4.08	5.67	38.78
2	4.99	4.54	5.9	5.44	6.8	4.26	6.8	38.73
3	3.18	3.63	2.27	2.49	2.18	3.18	4.08	21.01
1	1.81	1.36	3.18	3.18	2.95	2.63	5.44	20.55
3	4.54	3.18	4.08	4.54	4.17	3.63	4.99	29.13
Total household size = 119					Total waste generated = 826.36			

Daily generation rate =  $(826.36/119) / 7 = 0.9920\text{kg} / \text{person} / \text{day}$

Average household size =  $119/ 30 = 3.96666667$

Table 8: Daily Generation Rate for High Income Earners Residential Area

Household Size	Days							Total
	1	2	3	4	5	6	7	
1	1.81	2.72	2.27	0	1.36	2.27	0	10.43
1	1.36	1.36	2.72	0.91	3.18	1.81	2.27	13.61
1	1.13	2.04	1.36	2.72	0	2.18	0	9.43
4	5.9	5.44	2.49	2.72	1.36	3.4	4.53	25.84
1	2.45	3.45	1.72	0	2.49	1.36	2.54	14.01
1	1.27	1.81	2.27	0	1.13	1.81	0.52	8.81
2	1.59	1.36	1.81	2.27	1.81	2.27	3.86	14.97
1	1.81	2.27	4.31	2.27	2.72	3.18	2.72	19.28
4	4.44	5.53	3.63	1.81	4.08	1.81	0.91	22.21
2	2.04	1.36	3.54	0.91	2.27	1.81	0.91	12.84
8	7.48	8.44	4.08	4.54	5.44	5.67	3.18	38.83
2	1.36	2.04	2.27	1.36	2.27	1.81	2.72	13.83
5	3.63	8.62	1.81	4.08	3.18	3.99	5.08	30.39
6	6.58	6.8	3.63	3.4	4.53	3.63	4.53	33.1
5	3.04	1.99	2.27	4.08	3.63	3.18	3.86	22.05
3	6.35	5.9	3.18	1.36	3.18	4.53	3.63	28.13
2	1.27	1.81	2.72	2.04	3.4	1.81	1.36	14.41
5	15.42	18.14	2.27	2.27	9.07	2.72	3.4	53.29
7	3.86	4.08	1.81	4.08	3.18	3.63	4.77	25.41
7	5.9	6.8	8.16	4.54	5.9	6.8	4.53	42.63
4	4.99	7.94	2.27	3.63	4.08	3.63	3.63	30.17
4	10.66	12.25	3.18	3.18	6.35	4.53	4.53	44.68
1	0.9	1.36	2.27	0.45	2.27	1.81	0	9.06
6	2.27	2.49	1.81	3.63	2.72	5.44	4.53	22.89
2	1.95	1.81	2.27	0.91	1.81	2.27	0	11.02
2	8.16	5.9	5.9	5.44	3.63	6.8	4.99	40.82
4	7.71	9.07	2.27	4.54	6.35	5.9	7.03	42.87
7	3.86	2.72	4.08	6.8	3.4	9.07	9.98	39.91
1	2.04	1.36	4.08	2.72	1.81	2.27	0.45	14.73
2	9.07	7.71	2.63	4.54	1.59	5.44	3.63	34.61
Total household size = 101					Total waste generated = 744.26			

Daily generation rate =  $(744.26 / 101) / 7 = 1.0523 \text{ Kg / person / day}$

Average household size =  $101 / 30 = 3.36$