Development of a Sustainable Solid Waste Management System for Kikuyu Municipality, Kiambu County, Kenya

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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This thesis has been submitted for examination with our approval as university supervisors

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DEDICATION

This thesis is dedicated to all the waste workers of Kikuyu Municipality, for their unseen, unheard, unacknowledged toil and dedication.

To my wife and children, without whose support this thesis would not have been written.

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I thank all the people who have contributed their valuable time and support during the course of this study.

No matter where I go or what I do, my family has always been there for me, prayed for me and have been my source of inspiration. Thank you for your patience, support, love, care, sacrifices and everything else. I am what I am today because of you. I thank my friends and for all your prayers and best wishes.

Last but not least, I thank God for all the blessings.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND ACRONYMS

CBD	Central Business District
CBOs	Community Based Organizations
GHGs	Greenhouse gases
GNP	Gross National Product
ISWM	integrated solid waste management
ISWMS	Integrated Solid Waste Management System
JICA	Japan International Cooperation Agency
LCA	Life Cycle Assessment
MSEs	Micro and Small Enterprises
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
NEMA	National Environmental Management Authority
NGOs	Non-Governmental Organizations
UN	United Nations
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
USEPA	United States Environmental Protection Agency
WM	Waste Management
WMZs	Waste Management Zones

ABSTRACT

Provision of sustainable waste management services is essential for the well being and development of most cities in the developing world. Improper waste management has led to substantial negative environmental, health and safety problems. This thesis evaluated the solid waste management system in Kikuyu Municipality, Kiambu County in order to develop a framework for sustainable solid waste management for the future. The study analyzed the current solid waste management system and identified its strengths and weaknesses. Understanding how a sustainable waste management system functions in a developing city is important for policy makers and investors. The study observed that the current solid waste management system practiced in Kikuyu was unsustainable because there were no provisions for the segregation of waste and also the collection and transportation of waste was inadequate and inappropriate. Majority of the waste collected is dumped in open landfill and along the roadside and stakeholders are not involved in solid waste management decision making process. Heavy metals were determined from selected dumpsites and statistical analysis of the results showed that the concentration of cobalt, nickel, copper and lead are comparatively less than those obtained for other metals. The descending average heavy metal contents was found to be Fe>Cr>Cd>Ag>Zn>Pb>Ni>Cu>Co. The study established that the current solid waste management system is not sustainable and can be improved following the recommendations provided. A model of solid waste management was developed and to help in future management software that estimates the quantities of solid waste was also developed. The study shows that the current solid waste management

system is unsustainable in the long run. The municipal council should come up with an integrated solid waste system that involves the private, informal and other stakeholders in waste management.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

Waste management has become a major public health and environmental concern in urban areas of many developing countries. The situation in Africa, particularly in the capital cities is severe. The public sector in many countries is unable to deliver services effectively. Furthermore, regulation of the private sector is limited and illegal dumping of domestic and industrial waste is a common practice. In general, waste management is given a very low priority in these countries. As a result, very limited funds are provided to the waste management sector by the governments, and the levels of services required for protection of public health and the environment are not attained (Zurbrugg, 2000). The problem is acute at the local government level where the local taxation system is inadequately developed and, therefore, the financial basis for public services, including solid waste management, is weak.

Improper waste management has led to substantial negative environmental, health and safety problems. Municipal (or local) authorities charged with the responsibility of providing municipal waste management services have found it increasingly difficult to play this role. The difficulty has been aggravated by lack of effective legislation, inadequate funds and services, and inability of municipal authorities to provide the services cost-efficiently (Zerbock, 2003).

Cities in both developed and developing countries generally spend less than 0.5 % of their per capita gross national product (GNP) on urban waste services, which covers only about one-third of overall cost (World Bank, 1999). The responsibility over

waste collection and disposal is thus well beyond the capacity of municipal governments. More than 80 per cent of the total waste management costs in low-income countries are collection costs (World Bank, 1999). Solid waste is broadly comprised of non-hazardous domestic, commercial and industrial refuse including household organic waste, hospital and institutional garbage, street sweepings, and construction wastes (Zerbock, 2003). A report prepared by World Bank (1999) lists eight major classifications of solid waste generators:

- **Residential**: Includes waste generated in household units, such as food and fruit peels, rubbish, ashes etc.
- **Industrial**: Have two components: hazardous, which is toxic; corrosive; flammable; a strong sensitizer or irritant and may pose a substantial present or potential danger to human health or the environment when improperly processed, stored, transported, or disposed of or otherwise managed. Non-hazardous which include inert and essentially insoluble industrial solid waste, usually including, but not limited to, materials such as rock, brick, glass, dirt, and certain plastics and rubber, etc., that are not readily decomposable
- **Commercial**: Waste produced by wholesale, retail or service establishments, such as restaurants, stores, markets, theatres, hotels and warehouses.
- **Institutional**: Waste that originates in schools, hospitals, research institutions and public buildings.
- **Construction and demolition**: Waste building material and rubble resulting from construction, remodeling, repair, and demolition operations on houses, commercial buildings, pavements and other structures

- **Municipal services**: Sludge from a sewage treatment plant which has been digested and dewatered and does not require liquid handling equipment etc.
- **Process**: Treatment plant wastes principally composed of residual sludge and
- **Agricultural**: Spoiled food wastes, agricultural wastes, rubbish, hazardous wastes, plant parts and residues.

In a developed country framework, the waste generated from different sectors are generally treated separately while, in developing countries separate treatment of wastes generated from different sectors is usually not undertaken (Chakrabarti and Sarkhel, 2003). Improper handling and disposal of solid waste has multi-dimensional impact on human and environmental well being. Improper dumping can lead to

- pollution of air, soil, and water,
- contamination of surface and ground water supplies,
- clogging of drains,
- creation of stagnant water for insect breeding,

Plate 1.1: Clogged drainage due to solid wastes

Improper incineration and burning of wastes contributes significantly to urban air pollution; greenhouse gases (GHGs) generated from the landfills and untreated leachate pose threat to human as well as environmental well being (Hoornweg *et al.*, 1999).

Plate 1.2: Soil pollution as a result of solid waste disposal

1.2 Waste Management in Kenya

There is not much literature on the Kenyan waste management (WM) sector with the exception of Nairobi. Even for Nairobi, the available literature dwells largely on performance description and its causes, household waste generation behavior, and waste characteristics (Ikiara *et al.*, 2004). While poor management of waste is a general problem in Kenya, it is probably worst in Nairobi because of the lack of consistent data in other parts of the country.

Solid waste is of major concern since it constitutes of the bulky waste. There are no proper waste management systems in place for many of the local municipalities. This

research is therefore proposing to develop an integrated Solid Waste Management System (ISWMS) that can be used in Kikuyu town and can also be adopted in different municipalities, industries, town centers in rural areas and institutions in management of the solid waste**.**

1.3 Study Area

Kikuyu municipality covers an area of 136 km^2 and has 5 wards, and 13 sub locations as shown in figure 1.1.

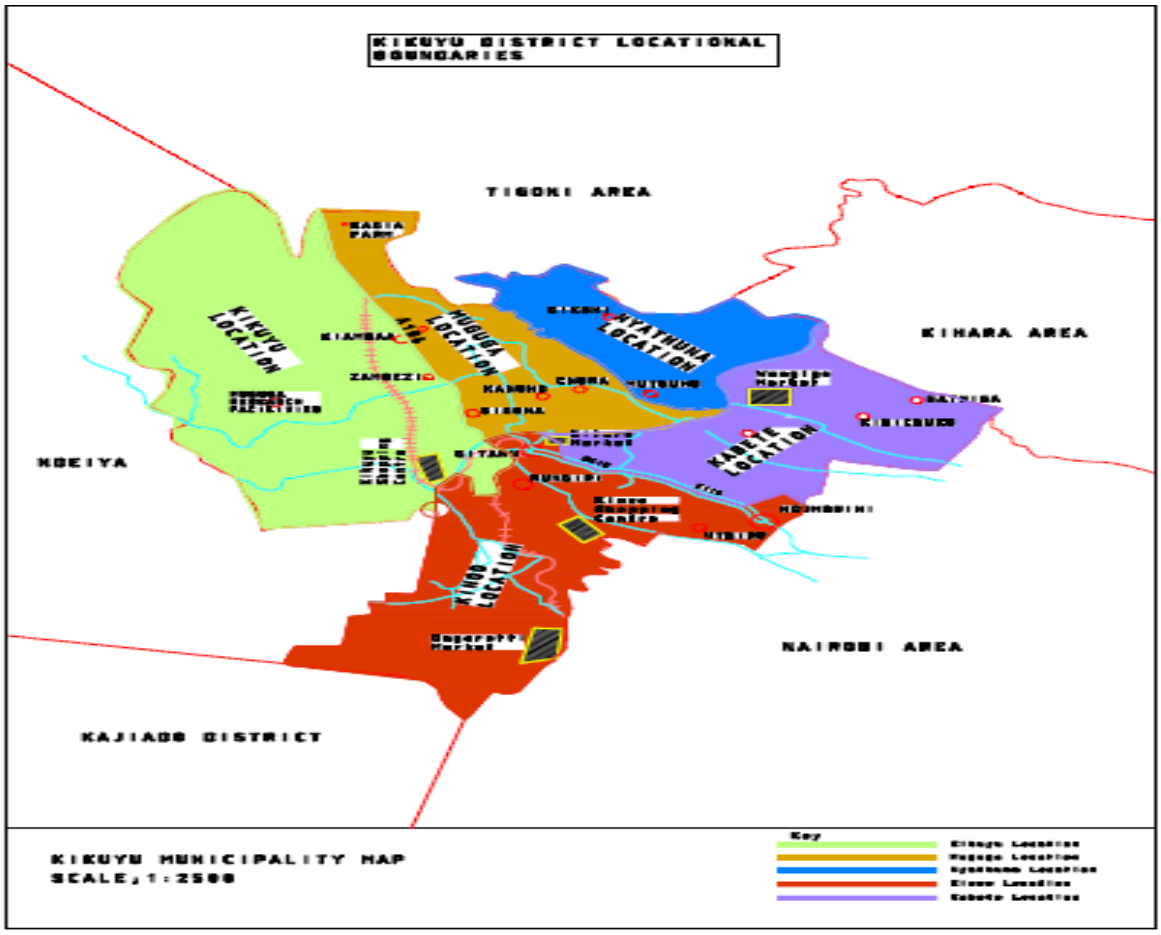


Figure 1.1: **Map of Kikuyu municipality.**

Source: Author, 2011

Kikuyu town is located in Kiambu County in the Central province. It is about 25 Km from Nairobi and 2 Km off Nairobi-Nakuru road, 45 Km to Kiambu county headquarters and 14 Km to Limuru town. It is bordered by Nairobi and Kajiado County to the South, Kiambu district on the North-East and Narok and Nakuru districts to the West. In 1989 Kikuyu Township had a total population of 86435. According to 2009 census the population rose to 265829 with 76794 households indicating a rapid growth.

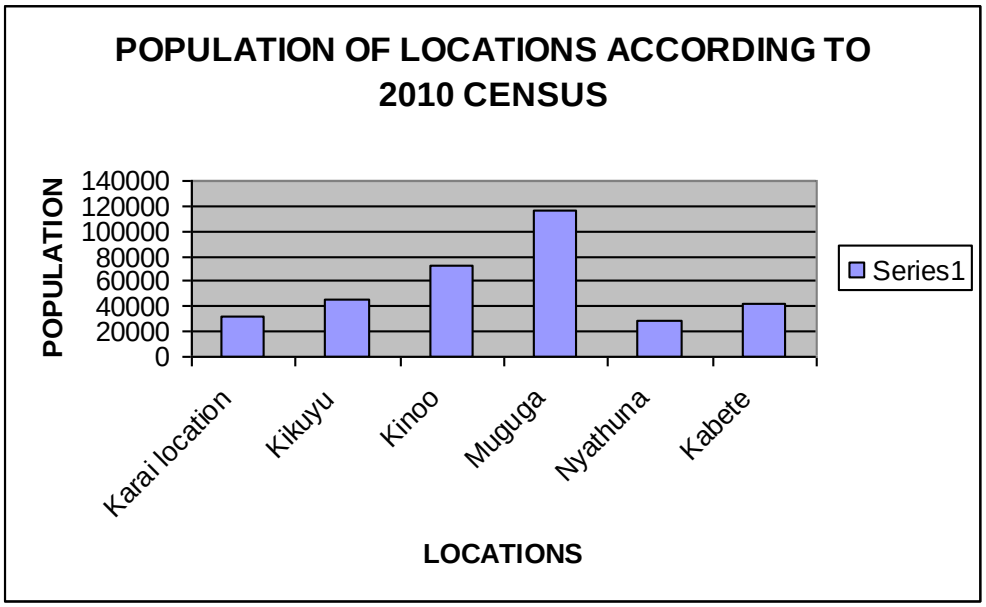


Figure 1.2: Population of locations

Source: KNBS-Population Census

Figure 1.2 displays a comparative analysis of urban growth in the neighborhood of Kikuyu Town.

There are no known mineral deposits in the municipality. However, the town has developed as an industrial base due to its closeness to Nairobi and good

communication links and ease of availability of materials. There are at least twenty industries located in the town and there is room for development of more industries.

Trade activities carried out in the town include retail and wholesale trade, sale of second hand clothes, kiosk operators, vegetables and fruits selling, stock sales and cereal produce. These are the major income generating activities to the council. These activities are carried out within the town centre and other small market centers.

The informal sector commonly referred to as *Jua Kali* is very crucial and forms a strategic base for industrial development in town. This sector supplies farm inputs to the agricultural sector, wares for domestic and industrial use and also creates substantial employment opportunities.

There has been a dominance of single storey buildings with the current trend being the construction of multi-storey complexes with intermix activities. The Central Business District (CBD) area is clearly demarcated and although the available public land is surrounded by private land, the council controls development on both leasehold and free hold land.

In addition to the CBD, there are other small nuclei centers which are a total of six markets. These centers are growing fast and there is high demand for services exerting pressure to the council to improve infrastructure such as water and energy supply in order to facilitate growth of the townships.

1.4 Problem Statement

In a developing country like Kenya, the problems associated with solid waste management are more acute than in a developed country (Zerbock, 2003). Lack of financial resources and infrastructure to deal with solid waste creates a vicious cycle; lack of resources leads to low quality of service provision which leads to fewer people willing to pay for the services, which in turn further erodes the resource base and so on (Kuniyal *et al.*, 1998; Zerbock, 2003). The problem is further complicated by rapid growth in population and urbanization, which adds greatly to the volume of waste being generated and to the demand for waste retrieval service in municipal areas. However, an increase in population is not matched with an equal increase in revenue for the local municipalities for waste management (Zerbock, 2003). Besides this, rapid urbanization means rapid growth of shanty dwelling units that are largely unplanned for, and add to the waste, health, and hygiene problems. Another significant factor that contributes to the problem of solid wastes in a developing country scenario is the lack of proper collection and transportation facilities. Improper planning coupled with rapid growth of population and urbanization serves to add congestion in streets, and as a result the waste collection vehicles cannot reach such places, thus allowing filth to build up over time. Lack of monetary resources, at times, results in improper or no transportation vehicles for waste disposal adding another dimension to the ever rising cycle of problems (Jain *et al.*, 1994; Zerbock, 2003).

In any developing country, the threats posed by improper handling and disposal of solid wastes (though often ignored) contribute to the high level of mortality and morbidity (Medina, 2002). Human and ecosystem health is also threatened due to

improper handling of solid wastes. In addition to all the problems mentioned above, Kikuyu municipality owing to its high altitude faces additional challenges in solid waste management, in terms of the highly fragile environment and terrain. The problems associated with solid waste in the high altitude areas have serious cascading effects on the lower valley.

1.5 Research Questions

In order to achieve the objectives of the study, various questions were noted i.e.

(i.) What are the waste streams generated by the residents of Kikuyu Municipality?

(ii.) How is solid waste being managed in Kikuyu Municipality?

(iii.) Is there a policy that guides the management of waste in Kikuyu Municipality?

(iv.) What is the extent of heavy metals pollution in selected dumpsites within kikuyu Municipality?

1.6 Null Hypothesis

The solid waste management system in Kikuyu Municipality, Kiambu County Kenya is not Sustainable.

1.7 Objectives

1.7.1 Main Objective

To develop a sustainable solid waste management system for Kikuyu municipality, Kiambu County, Kenya.

1.7.2 Specific Objectives

(i) To determine the current solid waste management system and practices in kikuyu Municipality.

(ii) To identify the factors that influence solid waste management in Kikuyu Municipality.

(iii) To identify policy gaps and enforcement in implementation of solid waste management systems in local municipalities.

(iv) To develop a sustainable solid waste management model.

1.8 Conceptual Framework

The conceptual framework for this study has been adopted from previous work done by Schübeler *et al.* (1996). It takes into account three important dimensions (Fig. 1.3);

- Scope of waste management activities i.e. what needs to be covered?
- Actors and development partners i.e. who can contribute for taking the system towards higher sustainability?
- How to address strategic objectives and issues i.e. what is the best course of action to take?

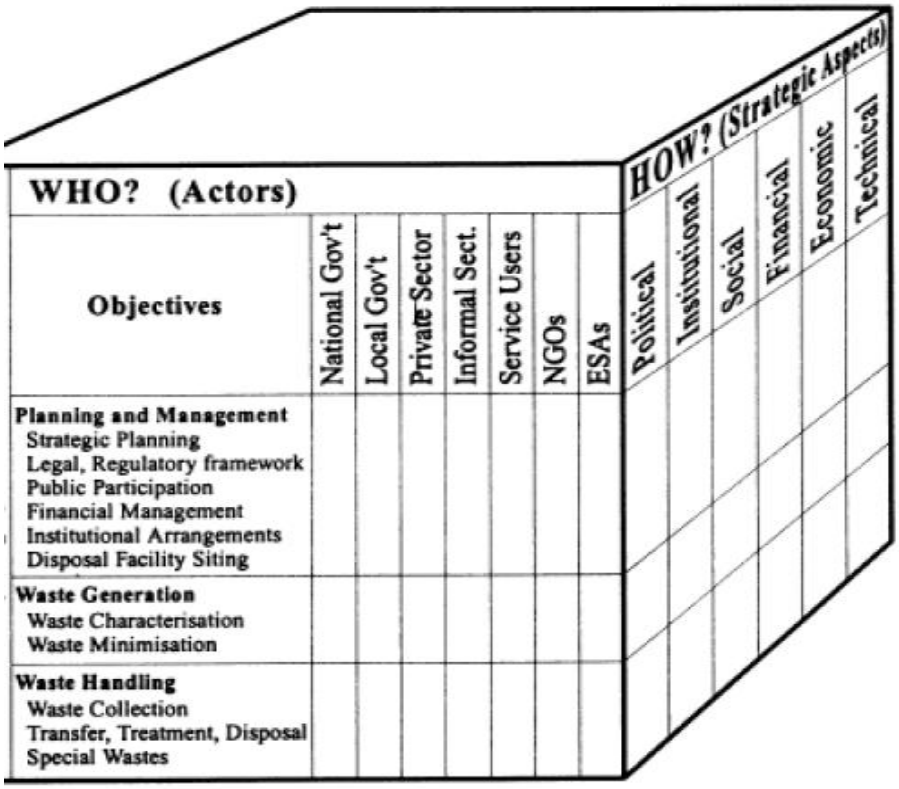


Figure 1.3: **Conceptual framework**

Source: Schübeler *et al.,* 1996

This framework is a modified version of the model described by Schübeler *et al.* (1996). The study used this framework to triangulate and conceptualize the data generated from the field study.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Global Solid Waste Management Practices

In urban areas, especially in the rapid urbanizing cities of the developing world, problems and issues of Municipal Solid Waste Management (MSWM) are of immediate importance (Ikiara *et al*., 2004). This has been acknowledged by most governments. However, rapid population growth overwhelms the capacity of most municipal authorities to provide even the most basic services (Zurbrugg, 2000). Municipal solid waste (MSW) management has become a major issue of concern for many developing nations where 30-50% of populations are urban (UNEP, 1996; Senkoro, 2003).

Solid waste management encompasses generation, collection, transportation and disposal of urban waste. Urban authorities have the responsibility to ensure safe, reliable and cost effective removal and disposal of solid waste, which takes up a large proportion of available resources which are not adequate to cope with the magnitude of the problem.

The management of solid waste is one of the challenges facing many urban areas in the world. Where there is an aggregation of human settlements with the potential to produce a large amount of solid waste; the collection, transfer and disposal of that waste has been generally assumed by municipal authorities in the developed world. The format varies, however in most urban areas. Garbage is collected either by a government agency or private contractor, and this constitutes a basic and expected government function in the developed world (Zerbock, 2003).

Indeed the overall problem of MSW is multi-faceted: many organizations, including the United Nations (UN) and various non-governmental organizations (NGOs) advocate for an integrated approach to MSW management by identifying key stakeholders, identifying specific issues which comprise important "stumbling blocks", and making recommendations based on appropriate technologies, local information, and pressing human and environmental health concerns (UNEP, 1996, Senkoro, 2003).

2.2 Impact of Solid Wastes on the Environment

Environmental quality is one of the nine public interest incorporated in land use planning. Others being health, safety, convenience, efficiency, energy conservation, social equity, social choice and amenity (Chapin and Kaiser, 1979). JICA (1998) acknowledged that key environmental problem facing human settlements in both urban and rural areas is mainly tied to urbanization. These include among others poor solid waste management, lack of sound legal framework to govern environmental management and failure to enforce existing environmental status by relevant public agencies and lack of community participation in environmental management.

Environmental problems associated with poor solid waste management are either related to generation, collection or disposal of solid waste. In most countries 30 to 50% of solid wastes generated are not collected (JICA, 1998). Such wastes generally accumulate on open spaces, wetlands and streets bringing with them serious health and environmental problems (UNCHS, 1996). JICA (1998) pointed out that poorly dumped and uncontrolled waste degrades urban environment, discourages efforts to keep streets and open spaces in clean and attractive conditions leading to reduced

aesthetic appearance and bad smells. Uncontrolled waste often ends up in drains leading to blockage of drainage channels resulting to floods and unsanitary conditions.

Since the mid-1980s municipal solid waste and the environmental consequences associated with its management have received a great deal of attention in industrialized countries. Research into the environmental effects of waste management practices show that the 'preferred' option(s) for waste management depends upon a number of site specific factors, including: characteristics of the waste, efficiency of the waste collection and processing systems required by different waste management practices, availability and proximity of markets for recovered materials, end use of the materials, recovered from the waste stream, emission standards to which waste management facilities are designed and operated, cost effectiveness of the environmental, protection obtained by different waste management practices and the social preferences of the community.

The recognition that there is no single practice that is preferred over others, has given rise to the concept of integrated solid waste management (ISWM). ISWM considers the full range of waste streams to be managed and views the available waste management practices as a menu of options from which waste managers can select the preferred option based on site specific environmental, economic and social considerations.

Life Cycle Assessment (LCA), which is used to assess the environmental impacts of products from cradle to grave, is increasingly being applied to the evaluation of waste management strategies. It should be noted however, that there is a fundamental difference between the life cycle boundaries of products and wastes. The life cycle of

a product starts with the extraction of raw materials (through activities such as mining, logging, etc) and ends with the final disposal of a product.

The life cycle of a waste on the other hand, starts when a material is discarded into the waste stream and ends when the waste material has either been converted into a resource (such as recycled material or recovered energy) or, when it has been finally disposed. Life cycle studies of waste materials cannot therefore be used as a basis for comparing products.

The environmental analysis model uses life cycle methodology to quantify the energy consumed and the emissions released from a user specified waste management system. The model has been structured so that it uses data specific to the user municipality to ensure applicability of the results and accuracy. At the same time, in order to allow the user the ability to undertake a 'first level' screening evaluation, default values have been provided, wherever possible.

2.3 Integrated Solid Waste Management

2.3.1 Landfills

Simply, solid waste is any unwanted or discarded solid item. Municipal solid waste (MSW) originates in homes, businesses, and other urban areas. There are several different ways to manage the solid waste but most can be categorized into two different approaches. The high-waste approach involves leaving it somewhere, burning it, or burying it (in a sanitary landfill or any excavation in the ground). The low-waste approach is twofold: attempting to produce as little solid waste as possible, and diverting as much solid waste away from landfills and incinerators (Miller and Tyler, 1995). Over the past few years, the former has been viewed as

cheap and irresponsible, and the latter has been viewed as initially expensive but morally gratifying.

2.3.2 Incineration

Burning solid waste in incinerators kills disease-carrying organisms and reduces the volume of waste by 90% and weight by 75%. In waste-to-energy incinerators, the heat released from the burning of solid waste can be used to heat nearby buildings, or sold to generate electricity. Unfortunately, the good news ends there. MSW incinerators emit small but noticeable amounts of lead, cadmium, mercury, and other toxic substances into the air we breathe (Miller and Tyler, 1995). Over 100 incinerators exist today in America, and over 250 are being planned for use (Contreau-Levine, 1982). The air is fragile enough as it is, and environmentalists are attempting to keep it as clean as possible.

2.3.3 Recycling

Recycling remains the most popular environmental activity among the peoples of industrialized nations, simply because it is done as often as we throw something away. These resource recovery programs extend the globe's mineral supply by reducing the amount of virgin materials that need to be removed from the globe to meet the demand. Resource recovery saves energy, causes minimal pollution and land disruption, cuts waste disposal costs, and extends the life of landfills by preventing waste from residing there.

The percentage of paper that is being recycled in other nations sends a clear message to Kenyans: we are not doing enough. Americans recycle 28% of the paper they use, although they lead the world in paper consumption and paper waste. France, Sweden,

Switzerland and Finland recycle at least one-third of their paper expenditures. Japan, Mexico, and the Netherlands are at a 44% rate, which is the highest in the world (Miller and Tyler, 1995).

2.3.4 Reducing and Reusing

To reduce solid wastes, people must reduce discarded products. We can cut back on the amount of trash we produce by buying things with changed product packaging and content. This is buying items from companies that use recycled products. It is called pre-cycling, and the whole process of recycling what you buy and buying recycled things is called completing the cycle. Reducing and reusing will not work unless a market exists for this material, and the consumers of these recycled goods should be the public (Young, 1995). Manufacturers who honestly deal with hazardous waste management can attempt to reduce the toxins and harsh chemicals in their products.

2.3.5 Composting

What do we do with all the food on our dinner plate that will go to waste? There are options: throw it way in the trash can, dump it down the sink via disposal systems in the plumbing, or compost it. Anything that is naturally degradable can be thrown into a compost bin. Food and organic waste created by food processing plants, kitchens, galleys, animal feedlots, yard work, and municipal sewage treatment plants. Paper, leaves, and grass clippings can be decomposed in this process in backyard compost bins, and the end result can be used in gardens and flower beds.

2.4 Challenges of Waste Management in Developing Countries

Major advances in the development of new materials and chemicals have increased the diversity and complexity of the waste streams. Consequently, wastes are taking on a new economic importance, not only in terms of revenues generated by the waste treatment and disposal industry, but also because wastes may have a residual value as a secondary raw material which can be recovered or reused.

2.4.1 Inadequate Coverage

Solid waste collection schemes of cities in the developing countries generally serve only a limited part of the urban population. Majority of the people especially in slum areas remain without waste collection services. These are usually the low-income earners living in poor conditions in peri-urban areas. One of the main causes of inadequate collection services is the lack of financial resources to cope with the increasing amount of wastes generated. (Zurbrugg, 2000)

2.4.2 Operational Inefficiencies

Operational inefficiencies are due to inefficient institutional structures, inefficient organizational procedures, or deficient management capacity of the institutions involved as well as the use of inappropriate technologies. The used vehicles are sophisticated, expensive and difficult to operate and maintain, thereby often inadequate for the conditions in developing countries. For example, UNEP (1996) estimated that in cities in West Africa, up to 70% of collection/transfer vehicles may be out of action at any one time.

2.4.3 Hazardous Wastes

Some waste materials need special treatment because their properties make them more hazardous chemicals not only a matter of technology and legislation, but also of enforcement, funding and financial instruments. Changing processes to use less hazardous substitutes and minimizing hazardous waste quantities that are discarded can be seen as preferred options in dealing with any toxic waste.

2.4.4 Human Health Risks Issues

There are some human health risks associated with solid waste handling and disposal in all countries to some degree, but certain problems are more acute and widespread in underdeveloped nations. Cointreau-Levine (1982) has classified these into four main categories:

- Presence of human fecal matter,
- Presence of potentially hazardous industrial waste,
- The decomposition of solids into constituent chemicals which contaminate air and water systems,
- The air pollution caused by consistently burning, dumps and methane release.

Waste pickers are highly susceptible to disease, and it has been proposed to provide low-cost or free protective gear, such as gloves, boots, and clothing, to prevent contact injuries and reduce pathogens (UNEP, 1996).

2.4.5 Environmental Issues

The decomposition of waste into constituent chemicals is a common source of local environmental pollution. This problem is especially acute in developing nations where very few landfills meet acceptable environmental standards, due to limited budgets. As land becomes scarce, human settlements encroach upon landfill space, and local governments in some cases encourage new development directly on top of operating or recently closed landfills. A major environmental concern is gas release by decomposing garbage. Methane is a by-product of the anaerobic respiration of bacteria, and these bacteria thrive in landfills with high amounts of moisture. Methane concentrations can reach up to 50% of the composition of landfill gas at maximum anaerobic decomposition (Cointreau-Levine, 1982).

2.4.6 Factors Influencing Solid Waste Management

There are many factors that vary from place to place and that must be considered in the design of a solid waste management system (Zurbrugg, 2000). These include waste amounts and composition, access to waste for collection, awareness and attitudes. Domestic waste from industrialized countries has a high content of packaging materials made of paper, plastic, glass and metal, and so the waste has a low density. These factors make the waste very dense (high weight per unit volume). The consequences of this high density are that vehicles and systems that operate well with low-density wastes in industrialized countries are not suitable or reliable when the wastes are heavy. The combination of extra weight and the corrosiveness caused by the water content can cause very rapid deterioration of equipment. If the waste

contains a high proportion of moisture, or is mostly inert material, it is not suitable for incineration.

Many sources of waste might only be reached by roads or alleys, which might be inaccessible to certain methods of transport because of their width, slope, congestion or surface. This is especially critical in unplanned settlements such as slums or low-income areas and thus largely affects the selection of equipment.

Public awareness and attitudes to waste can affect the whole solid waste management system. All steps in solid waste management services, the opposition to the citing of waste treatment and disposal facilities, all depend on public awareness and participation.

Thus this is also a crucial issue, which determines the success or failure of a solid waste management system. Institution issues including the current and intended legislation and the extent to which it is enforced may limit the technology options that can be considered. The policy of governments regarding the role of the private sector (formal and informal) should also be taken into account.

There are various approaches to addressing the SW problems and each country need to study its situation and adapt approaches that are appropriate to its situation.

2.5 Goals and Principles of MSWM

The goals of MSWM are:

- To protect environmental health,
- To promote the quality of the urban environment,
- To support the efficiency and productivity of the economy
- To generate employment and income.

To achieve the above goals, it is necessary to establish sustainable systems of solid waste management which meet the needs of the entire population. The essential condition of sustainability implies that waste management systems must be absorbed and carried by the society and its local communities.

Waste management should be approached from the perspective of the entire cycle of material use, which includes production, distribution and consumption as well as waste collection and disposal. Whilst immediate priority must be given to effective collection and disposal, waste reduction and recycling should be pursued as equally important, longer-term objectives.

The principles of sustainable waste management strategies are thus to:

- Minimize waste generation
- Maximize waste recycling and reuse, and
- Ensure the safe and environmentally sound disposal of waste.

Solid waste management goals cannot be achieved through isolated or sectoral approaches. Sustainable waste management depends on the overall effectiveness and efficiency of urban management, and the capacity of responsible municipal authorities.

2.6 Municipal Solid Waste Management in Kenya

In Kenya local authorities are charged with the responsibility of collecting and disposing of solid and liquid municipal wastes within their areas of jurisdiction. Centralized MSW management systems are used by most local authorities in Kenya. According to estimates from the World Resources Institute and United States Agency for International Development (USAID), many local authorities in developing

countries spend over 30% of their budgets on refuse collection and disposal but can only collect at most 50 – 70% MSW (Matrix, 1993). Most local authorities do not meet environmentally safe MSW disposal levels because of lack of sanitary landfills.

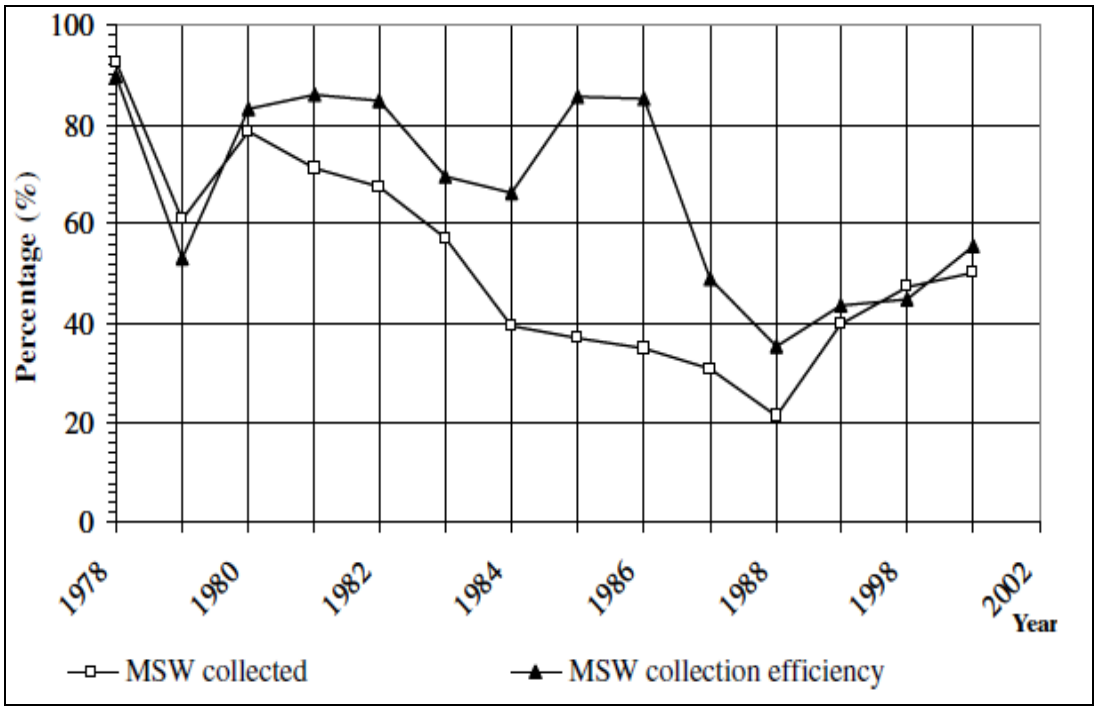


Figure 2.1: Comparison of percentage of MSW collected and the efficiency of collection in Kenya.

Source: JICA, 1998

Fig. 2.1 shows the variation of municipal solid waste collected and its efficiency from 1972 to 2002. A clear indication of a reduction tread of the amount of the solid waste collected. Strategies used can have dramatic impacts on the effectiveness and quality of service delivery.

Most local authorities have become economically constrained in offering efficient management of MSW, and are now more willing to embrace new ideas that can

improve the management of MSW. Although there is sufficient legislation covering waste management, local authorities lack the capacity to implement them.

2.7 MSW Collection and Problems Facing Local Authorities in Kenya

The waste management issues in Kenya are as a result of many interconnected factors. These are:- inadequate infrastructural waste management facilities such as treatment and disposal infrastructure, unreliable and irregular waste collection patterns lead to littering and physical accumulation of solid waste. The absence of modern waste management facilities such as sanitary landfills as left open dumping as the only means of disposal for solid wastes and lack of garbage segregation at the source worsens the situation. This poses great risks to human health while reducing recycling potentials to generate by-products. Solid wastes have become a public irritant due to emission of foul smell, presence of scavengers and rodents. This damages the aesthetic value of the affected areas and properties thus reducing their value. However, in the discarded wastes lie treasures yet to be exploited through recycling.

Local authorities in Kenya are faced with a myriad of problems that have greatly constrained provision of services and these include:

- Political interference
- Environmental pollution due to poor disposal
- Economic constraints

2.8 Actors in Solid Waste Management

2.8.1 Municipal Governments

Local municipal governments have a role in the set-up and operation of waste management systems. Most urban authorities in both industrialized and developing countries receive their powers and obligations from a central government, with allocation of powers and responsibilities to protect the rights of the citizens, to provide services, and to serve the common good (Mungai, 1998). On the one hand, they have to implement laws and regulations in order to fulfill their statutory obligations. On the other, a failure to provide a public service can result in those in power risking the wrath of their constituents, the ridicule of the international community, and (at least in the case of democratically elected officials) ultimately their ability to get elected and enjoy the privileges of public office.

2.8.2 The Formal Private Sector

The `formal private sector' refer to private sector corporations, institutions, firms and individuals, operating registered and/or incorporated businesses with official business licenses, an organized labour force governed by labour laws, some degree of capital investment, and generally modern technology (Furedy, 1990). In general, the defining characteristic of the formal private sector is that its main objective is to generate a profit on investments. Formal private companies are involved in wide-ranging activities in waste management systems, varying from waste collection, resource recovery, incineration and landfill management. They may participate in the waste management system in a number of ways, such as: entering into contracts paid

by the municipality to perform collection, processing, disposal or cleaning services for compensation, purchasing the right to perform services and keep (all or part of) the income generated, entering into contracts with individuals or businesses for collection services, functioning as a purchaser of recovered materials from the municipality or the collector.

2.9 The Informal Private Sector

The term `informal private sector' refers to unregistered, unregulated, or casual activities carried out by individuals and/or family or community enterprises, that engage in value-adding activities on a small-scale with minimal capital input, using local materials and labour-intensive techniques (Furedy, 1990).

Informal activities, in contrast with the formal sector in waste collecting and recycling, are often driven by poverty, and are initiated personally and spontaneously (and sometimes haphazardly) in the struggle for survival (although some enterprises, especially the ones engaged in recycling activities, manage to make considerable profits). Consequently, the choice of materials to collect is in the first place determined by the value of the waste materials and their ease of extraction, handling, and transport.

2.9.1 Community Based Organizations (CBOs)

The community sector needs to be included in waste management efforts as both private and public sector actors are unable to provide waste services to low-income areas of the city. Syagga (1992) supports the involvement of the community sector as an effective way of increasing access of the poor to urban services, including waste management.

Mungai (1998) observed that in Nairobi, organizations in the community sector, such as charitable organizations, ethnic associations, professional "support" NGOs, welfare societies, village committees, self-help groups, and security committees are already providing many of these services. Zerbock (2003) further supports this; any potential change to the waste disposal framework must take into account the urban poor, many of whom dependent on waste scavenging for their entire subsistence.

Micro-enterprises, or community based organizations can be effective in addressing the garbage problem (Zurbrugg, 2000). They often use simple equipment and labor-intensive methods, and therefore can collect waste in places where the conventional trucks of large companies cannot access. The Micro and Small Enterprises (MSEs) may be started as a business, to create income and employment, or they may be initiated by community members who wish to improve the immediate environment of their homes. Their shortcoming is that such, collection schemes that these systems generally collect and transport the waste a relatively short distance up to a transfer point, from where the waste should be collected by another organization.

Furthermore, community participation may involve making material, financial or physical contributions to activities of solid waste management, for instance working as cart operator or sweeper, and paying fees for waste collection (Bulle, 1999).

Often community management is carried out by a smaller group within the community, through for example a newly established committee or an existing community-based organization (Anschütz, 1996; Bulle, 1999).

Religious barriers, traditions, social hierarchy, low rate of literacy, or the burden of domestic tasks may impede their participation in such projects (Bulle, 1999).

Community Based Organizations (CBOs) active in solid waste management can be involved in various activities such as promoting re-use and recycling of materials, hiring waste collectors, collecting fees for waste removal and making arrangements with local authorities (Pfammatter and Schertenleib, 1996; Van de Klundert *et al*., 2001).

2.9.2 Non-Governmental Organizations (NGOs)

The term NGO can refer to such diverse organizations as churches, universities, labour organizations, environmental organizations and lobbies. Sometimes even donor organizations can fall under this heading. Generally; Non-Governmental Organizations (NGOs) are intermediate organizations which are not directly and continuously involved in community projects. NGOs not only advocate, they can also be involved in awareness-raising, advocacy, and decision-making. NGOs can act as intermediaries between grassroots initiatives (CBOs) and municipal governments, or serve the ideological, political, or altruistic interests of international organizations. They can advocate interests on a larger scale than the single community and provide support and advice to CBOs, but also to marginal groups in the society, such as waste pickers at dump sites and street children.

2.10 Challenges Faced by the Actors in SWM

The key constraints in terms of the development of integrated, sustainable, partnership-based solid waste management systems in developing countries, and the issues that underlie these constraints are discussed below.

2.10.1 Financial Constraints

Few municipal governments have a dedicated income stream for solid waste services. The sources of financing which can be used for solid waste come either from the national government, from conservancy (environmental) fees, or from fees or charges for services (often combined with sewerage or water charges), or out of property taxes. All of these sources can be problematic for the financing of solid waste operations. Property taxes are often based on old, out of date or preferential assessments which under-tax the owners and provide insufficient revenues. While people are willing to pay for water and other services that are essential to their survival, solid waste removal does not always fall into this category.

2.10.2 General Institutional Constraints

The lack of critical thinking in relation to solid waste systems is often a barrier to innovative solutions. Even in developed countries, the intellectual framework for understanding the relationships between consumption, disposal, and recycling, industrial activity and natural resource exploitation is seldom complete or adequate. The lack of political will to make solid waste a priority means that it is usually lacking both talented personnel, adequate facilities, and the commitment of senior officials. Furthermore, the anachronistic organization of municipal government departments and traditional divisions of labour in both developed and developing countries are often inherited from 19^{th} century ideas about city government and sanitation, and do not lend themselves well to innovative problem-solving or to the needs of large cities.

Many cities already have master plans or comprehensive waste management plans, which characterize the solid waste problem as one of `technology'. These all too frequently fail to take unique features of the local system adequately into account, and imply that the solution to the problems can be achieved through the acquisition of large facilities. Once these plans are written and approved by the municipal government, they give rise to bureaucratic claims and privileges, and it can be difficult or even impossible to introduce innovative proposals in relation to current or potential activities of the community and the private formal or informal sector. Confusing and fragmented divisions of labour and responsibility may mean that activities which could be contracted out are administratively inseparable from each other, making it effectively impossible to split them off for a contractor. Shared responsibility and jurisdictional disputes between municipal departments and a lack of clarity in the division of responsibilities, tasks and resources between central and local government may make clear articulation of policy or an unambiguous needs analysis impossible.

2.10.3 Legislation and Regulations

Legislation and regulations are set up for particular purposes, and are often difficult to adapt to new circumstances. In particular, the legislative and regulatory context for solid waste management is dispersed, fragmented, and incomplete, and so does not tend to facilitate the formation of cross-sectoral partnerships. If such partnerships nevertheless come into being, existing legislation normally provides few tools for coordinating or managing them.

2.11 Markets and Technologies

Informal sector waste entrepreneurs and individuals are connected to the international commodities marketplace through the materials they collect. Ultimately, the economic value and profit potential of the waste materials is connected to international commodity prices, global trade, and industrial policy. Partnerships involving informal sector operators depend on their ability either to use the collected materials for their own manufacturing, or to prepare materials for commercial use.

2.12 Donor Influence

In contrast, donor biases towards particular technical approaches or insistence on supplying equipment which supports their own interest can also result in a situation where new arrangements disrupt existing informal sector waste handling systems. Donor interventions may also be motivated by the goals and/or bureaucratic procedures of the home office, rather than on a full understanding and appreciation of local nuances.

2.13 Strategies and Options for Solid Waste Management

Given the large number of individual issues and specific problems in various municipal solid waste management systems, it would seem tempting to address individual issues as they arise and apply local fixes, so as to keep collection and disposal services operating continuously as efficiently as possible. Indeed, in the short term, this is likely to be a good approach. In considering the long term, however, it is apparent from the scope of problems and the external factors brought to bear upon municipalities that a broader, more integrated set of solutions will be

necessary in order to adequately address MSW systems in the future. UNEP calls this sound practices. Sound practices function together to achieve defined solid waste policy goals, while appropriately responding to the entire set of conditions that constrain the choices available in specific MSWM decisions (UNEP, 1996)

This means, that a sound practice not only achieves a specific goal in MSWM, but that, to the extent possible, it takes into account the demands of the specific situation where a proposed solution is to be implemented.

2.14 Waste Reduction

It would seem that the easiest and most effective way to manage solid waste is to reduce the amount of waste to be disposed. However the amount of waste produced, even in developed countries, is often a function of culture and affluence. An emphasis on mass production and the development of cheap consumer goods has caused quality and longevity of goods to be sacrificed in the name of lowest market price, causing people to be more likely to simply throw away and replace items instead of repairing or maintaining them (Zerbock, 2003).

2.15 Integrated Approach

An integrated approach to waste management will have to take into account community and area-specific issues and needs an appropriate set of solutions unique to each context (Van de Klundert *et al.*, 2001; Schübeler, 1996; Senkoro 2003; UNEP, 1996). As with any issue in developing nations, solutions which work for some countries or areas will be inappropriate for others. Specific environmental conditions will dictate the appropriateness of various technologies, and the level of industrialization and technical knowledge present in various countries and cities will

constrain solutions. Studies on MSW issues however repeatedly discuss certain approaches as being at least adaptable to many developing nation scenarios.

USEPA, (United States Environmental Protection Agency, 2002), notes that sound environmental management is achieved when the 3Rs approaches are implemented according to the order, first source reduction, second recycling and composting and third disposal to the landfill or waste combustors. These approaches emphasize waste reduction and appropriate disposal options as part of an integrated evaluation of conditions.

2.16 Recycling

As noted, one of the approaches to waste management is by separating or sorting waste generated and eventually using it for other form of production. Separating waste materials at the household level occurs to some extent almost universally, and prevents the most valuable and reusable materials from being discarded. Following in-home retention of valuable material, waste-pickers currently remove most valuable materials either before garbage enters the waste stream or on route, especially in the lower and middle-income areas of many municipalities.

2.17 Composting

A somewhat more low-technology approach to waste management is composting. The waste of many developing nations would theoretically be ideal for reduction through composting, having a much higher composition of organic material than industrialized countries. For example, in developing countries, the average city's municipal waste stream is over 50% organic material (Hoornweg *et al.,* 1999). Studies in Bandung, Indonesia and Colombo, Sri Lanka have revealed that residential

waste composed of 78% and 81% compostable material, and market waste 89% and 90% compostable, respectively (Cointreau-Levine, 1982).

2.18 Dumping

The dumping of solid waste in landfills is the probably the oldest and definitely the most prevalent form of ultimate garbage disposal. In an examination of landfills throughout the developing world in 1997-1998, Johannessen (1999) found varying amounts of planning and engineering in MSW dumping; among the various regions visited, African nations (with the exception of South Africa) had the fewest engineered landfills, with most nations practicing open dumping for waste disposal.

2.19 Incineration

Incineration which is considered a 'disposal' option, since following incineration there is still some quantity of ash to be disposed of (probably in a landfill), as well as the dispersal of some ash and constituent chemicals into the atmosphere. However, it is important in terms of its waste-reduction potential, which can be 80 - 95% in terms of waste volume (Rand *et al.*, 2000). The high financial start-up and operational capital required to implement incineration facilities is a major barrier to successful adoption in developing countries (Rand *et al.*, 2000; UNEP, 1996).

Reduction of volume by incineration, along with sanitary disposal of the residue, has proven useful in Island nations such as Bermuda and the British Virgin Islands (Lettsome, 1998).

Negative environmental consequences of incineration mostly revolve around airborne emissions and should not be located where prevailing wind patterns would carry emissions over densely settled areas (UNEP, 1996).

2.20 Policies Relating To Sustainable Solid Waste Management

The conditions that govern access to and quality of urban infrastructure and basic services include: appropriate policies to enable provision and management of services, institutional framework, and availability of land, efficient community participation, condition of resource use and range of actors and affordability and cost recovery (Matrix, 1993)

The Session paper No. 1 of 1994 provide a reaffirmation of Kenya's medium to long term strategy to maintain measures for socio-economic stability which will lead to sustained development. It notices that it is only through sustainable economic growth that the national wealth can be created to support measures to alleviate poverty, protect vulnerable groups and provide rising standards of living for our people. It notes that physical sustainability requires conscious planning to husband the environment.

The physical planning subsidiary legislation provides that solid waste system is to be based on a bulk container of 15 m^3 and individual receptacles provided of 0.4 m^3 on the plot. The average daily refuse per plot is assumed to be 8.2 Kg (1 Kg per person per day). Each plot holder is required to have a small receptacle for storage (standard dustbin). Hard standing container should be provided at a ratio of 1 per 100 plots.

Table 2.1: Disposal System Standards

Disposal	No. of inhabitants	Location	Protection area
Garbage collection and burial	50 000 in one settlement or more with a radius of 25 Km	Outside residential settlement	Not less than 1 Km for urban areas
Incineration of hospitals and slaughter houses	50 000 in one settlement or more with a radius of 25 Km	Outside settlement in industrial zones	Industrial standards adopted effective or heavy
Collection	100 000 or more	Outside settlement in industrial zones	Industrial standards adopted effective or heavy

Source: GoK, 2002

According to the physical planning act, chapter 286, 1996, "Development" refers to the making of any material change in the use and the density of any buildings or land or the subdivision of any land which for the purpose of the act is classified as class A (Section 3(a)). Section 30(1), states that no person shall carry out development within the area of a local authority without a development permission granted by the local authority.

The environmental management and co-ordination act, of 1999 provide a legal and institutional framework for the management of the environmental related matters, it is the framework law of environment which was enacted on the 14th of January 1999 and its implementation commenced in January 2002.

CHAPTER THREE

3.0 METHODOLOGY

The field study was undertaken from May 2010 to December 2010. The study was developed to understand the solid waste management system in Kikuyu municipality in a developing country framework in order to suggest ways the system might achieve higher level of sustainability. It examined in depth the nature and features of the system and problems associated with it. In order to gain knowledge of the system being studied, interviews were conducted in conjunction with other methods for obtaining qualitative data. This research is based on the paradigm of critical social science. The main approach employed for this study was a qualitative case-study of Kikuyu municipality, Kiambu County of Kenya. The case study approach allowed use of inductive methods, such as interviews, focus group discussions, which allows for general conclusions to be drawn from particular facts.

3.1 Data Collection Methods

The methods used in data collection involved semi-structured interviews, mapping, trend and change analysis and non-participant observations (Chambers, 1994). Besides these, reports, published information were reviewed, and interviews conducted with key informants and participation of local community, community groups and non-governmental organizations.

The objective and essence of this study necessitated me to spend a relatively long period of time within the study area (Kikuyu), and allowed me to be part of the community and culture where the study took place. However, owing to prevailing

ground situations, the research opted for non-participant observation to study the system and the people. As a non-participant observer, the research studied various aspects of the present waste management system, for instance the waste collection system, waste disposal site, recycling system, etc. Non-participant observation helped to visualize and verify the response of various participants; and was used to compare and analyze the existing system. It enabled the researcher to understand the role of the ecological and cultural setting of the study area, and also the socio-cultural context of the community. Besides this, talking to the community people and observing the ground realities, further enhanced the understanding and helped in forming strategies or developing policy recommendations with the help of community members.

3.2 Review of Secondary Data

The research involved collecting data from numerous sources, community members, waste workers and administrators among others. Besides collecting primary data, the research also looked into data available in books, publications, reports, local news papers, and data from NGOs such as practical Action Eastern Africa and Green Loop among others. The secondary data obtained from various sources were used to enhance the understanding of the problems, rules and laws pertaining to waste management and also for triangulation and verification of the primary data collected. It helped in ascertaining the reliability of the data collected and thus, the study.

3.3 Sample size determination

Approximately 400 questionnaires were administered within a sample size of 10000 residents, business communities, industries, institutions. The sample size was obtained using the Fischer *et al., 1998* formula:

$$N = \frac{Z^2 pq}{d^2}$$

Where:

N- Desired sample size

Z – The standard Normal deviation at the required confidence level

P – The proportion in the target population estimated to have the characteristics being measured

Q – Q = 1-P

D - The level of statistics significance tests

P = 0.5

Z = 1.96

Q = 1- 0.5 = 0.5

D = 0.05

$$N = \frac{1.96^2 X 0.5 \; X \; 0.5}{0.05^2}$$

= 384 Questionnaires

3.4 Semi-structured Interviews

The research relied on semi-structured interviews to gain individual perspective of the community members and local administration in terms of waste management, how they perceived the problems associated with the current waste management system, what they felt were major areas of concern and the impediments to sustainable solid waste management and their aspirations for a future system.

Semi-structured interviews allowed the research to gain individual perspectives of the different stakeholders while open-ended questions allowed for enough flexibility to keep the flow of interview going according to the comfort level of the interviewee (Chambers, 1994) and helped to understand the problems in the existing system from different perspectives.

3.5 Sampling Techniques of Soil and Water Samples

As mentioned earlier, Kikuyu town lies at a higher altitude. Most rivers from Kikuyu flow towards the city and they are tributaries of Nairobi River. In developing a solid waste management system, illegal dumpsites located along rivers were studied to determine whether leaches increased the pollution levels of the river. In order to establish the presence of heavy metals, 15 soil samples and 100 water samples were collected from selected locations and analyzed.

3.5.1 Soil Samples

Fifteen (15) soil samples (3 replicates) were collected from exposed dumpsites. In each case the soil (9 - 10 cm depth) were put into a plastic bag using a stainless steel spoon. The collected samples were air dried and sieved into coarse and fine fractions. Well mixed samples of 1 g each were digested using analytical grade reagents

comprising of 5 ml of concentrated nitric acid, concentrated sulphuric acid and perchloric acid (3:1:1). Digestion of samples for determination of lead was achieved using nitric and perchloric acids only so as to avoid precipitation of lead ions by sulphuric acid. After digestion the samples were dissolved in 50 ml of distilled water, filtered and then diluted to 100 ml with distilled water. Heavy metal concentration of Cadmium (Cd), Cobalt (Co), Copper (Cu), Iron (Fe), Silver (Ag), Nickel (Ni), Zinc (Zn), Lead (Pb) and Chromium (Cr) of each fraction were analyzed by Atomic Absorption Spectrophotometer.

3.5.2 Water Samples

Water samples were collected in selected rivers and boreholes in 100 plastic bottles with screw caps. Each sample was analyzed for heavy metals i.e. Cd, Co, Cu, Fe, Ag, Ni, Zn and Pb and Cr using Atomic Absorption Spectrophotometer.

3.6 Development of Kikuyu waste management system (KIWAMAS)

Kikuyu waste management system software was developed to help manage waste produced in Kikuyu municipality. The system was able to estimate the waste generated in a given period of time with population given. If population increases or decreases the system will be able to tell the amount of waste to be expected in a given period of time and estimate the landfill in hectares required to dispose the waste. The system was developed and compiled using Visual Basic 6.0, with windows xp as the operating system.

3.7 Data Analysis

The data was divided into broad categories that were developed from the review of literature. Some of these categories were: waste generation, waste collection and transportation, waste decision making process, public involvement in the decision making process and so on. The emerging trends and patterns were further elaborated upon and the input of committee members and other experts was taken to formulate possible policy recommendations and strategies. The research heavily drew upon the expertise of National Environmental Management Authority (NEMA) members and NGOs while developing policy recommendations and strategies.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Solid Waste Management in Kikuyu Municipality

The Kikuyu municipality currently oversees a population of around 256,007 individuals (KNBS, 2009). It is interesting to note here that according to official figures (as provided by the Kikuyu Municipality), the number of registered households and other establishments (excluding institutions) are approximately half of the total figures stated above. This makes it particularly difficult for the municipality to implement solid waste management across all parts of the town. At the municipal level, the official planning and execution of solid waste management is based on a hierarchical system. Decisions are made by the Chairman of the Council and passed on to the three sanitary inspectors and the engineer, who are responsible for different sections.

Solid waste management is undertaken by the environmental committee, with the help of the town clerk and town engineer. Then there is environmental officer who acts as the supervisor of the waste collection and disposal. He supervises the cleaners, drivers and loaders.

The Kikuyu municipality has dustbins of which are central vats. Central vats refer to a centralized waste dropping point, centrally located within a particular area. These vats are located throughout the municipal area. The local sweepers and residents drop the waste in these vats and the municipal transportation vehicles ferry the waste from the vat to the dumping grounds in Limuru located 15 Km away. If an area is not accessible by municipal trucks or pick-up vans, the sweepers use hand carts to collect

the waste. In some areas, due to the terrain, even handcarts cannot be used; in such areas the waste is disposed in non designated areas such as road sides and river banks among others.

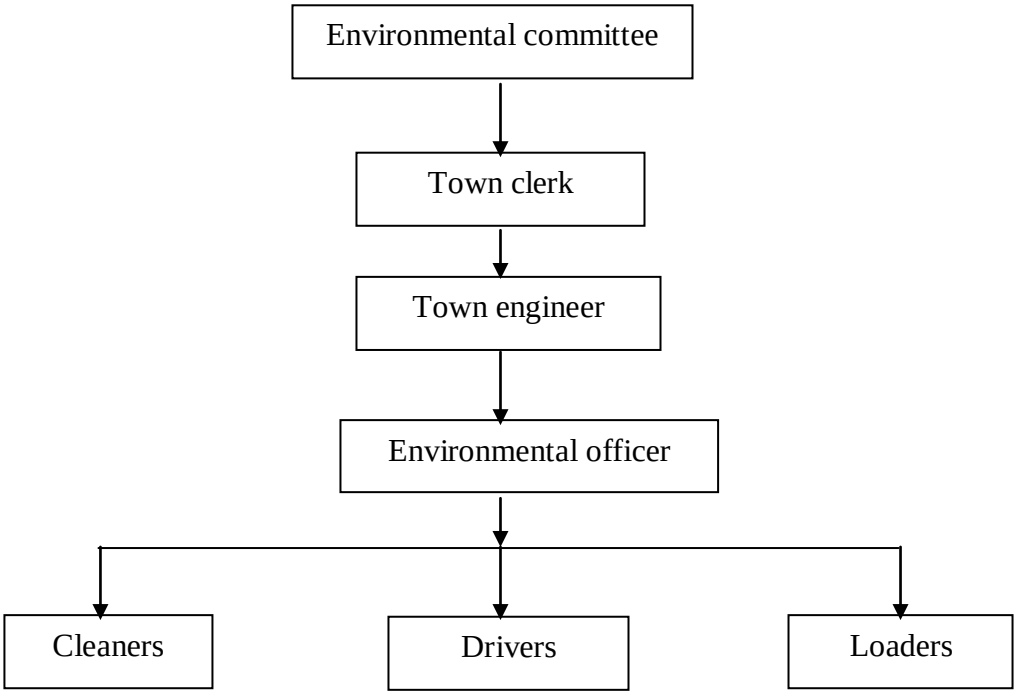


Figure 4.1: Organizational chart for solid waste management in the Kikuyu municipality

The Kikuyu municipality largely depends on its own sources of revenue for sustenance. However, it receives additional funding from the state government for various projects under special allocations. Information regarding the revenue generated for the municipality, and the expenditures incurred for the waste management department was provided to the researcher.

4.2 Collection and Transportation of Waste

The collection of waste is undertaken by the municipality. The issues related to the collection and transportation of the waste can be understood as follows:

4.3 Improper Disposal and Littering

Kikuyu still practices dumping of its waste irrespective of its nature and composition. Waste is put in a waste bin and either dumped in a transfer station. From there, the waste is either collected by municipal waste collection vehicles and taken to (and dumped at) the municipal dumping site near Limuru or it is washed away by the surface water.

4.4 Transfer Stations

The municipality has constructed transfer stations in different parts of the town where the residents from a particular locality are expected to dump wastes. The idea is to have a central point in the locality where people can dump their waste; from here the waste can be collected and moved to the dumping grounds. The majorities of these stations, however, are uncovered and open, which attracts many animal, flies, and insects of all kinds. The most worrisome aspect of these stations is that due to their proximity to population, they pose a serious health threat to the locals. More often than not, these stations are not serviced regularly, except for those that are along the main business district and this allows the garbage to accumulate over time leading to spill over.

The municipality has also placed garbage bins in various parts of the town. However, the concentration of these bins is limited along the main roads. Lack of garbage bins induces people to litter the town and throw garbage anywhere they see fit.

4.5 Transportation of Waste

It was observed that the waste is transported in open tractors or trucks and has the tendency to fall off at every bump or pothole on the road. According to the literature, this is a typical problem for developing nations around the world (Hoornweg *et al.*, 1999; Medina, 2002; Zerboc 2003; Zurbrugg, 2000). Flies cover the truck on its journey to the dumping ground (Medina, 2002). From transfer stations, collection of waste is undertaken by a fleet of vehicles which include open bodied trailers and tractors, trucks and a pick-up truck. The municipal supervisors decide which areas will be covered by whom. One truck is expected to collect the waste from Dagoretti, covering Kawangware and Naivasha road in one trip. Another truck covers Wangige area while a third vehicle covers Kinoo, Uthiru and surrounding areas and in and around the business center.

Plate 4.1: Loading of solid wastes into open bodied trailers

4.6 Landfill/open Dumping

During the field site assessment, seven open dumping sites located in Wangige, Dagoreti, Kikuyu town, Kinoo, ACK, Joy center and Uthiru were identified. The dumpsites were located in urban areas and some close to residential areas and thus exposing the population to great danger. This prompted the evaluation of the extent of heavy metal pollution in the dumpsite and the water points surrounding the dumpsite.

4.7 Heavy Metal Contents in Selected Dump Sites and Rivers in Kikuyu.

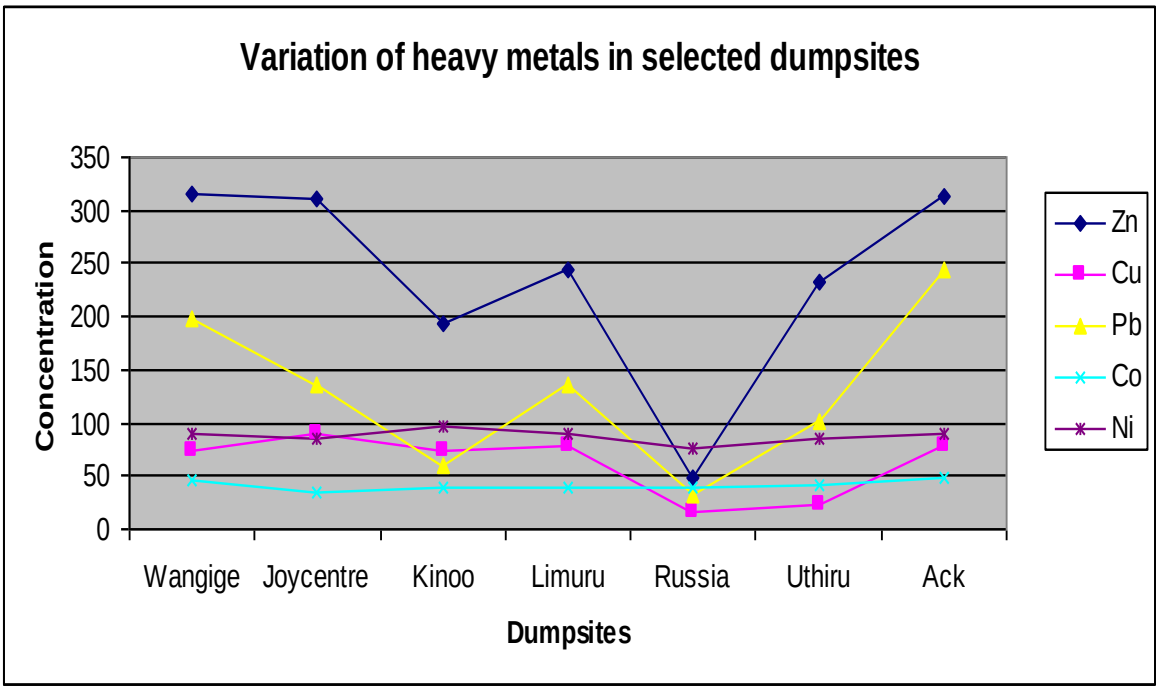


Figure 4.2: Variation of Heavy Metals (ppm) in Selected Dumpsites.

The statistical analysis of the results of heavy metal contents showed that the concentration of cobalt, nickel, copper and lead are comparatively less than those obtained for other metals. The descending average heavy metal contents is

Fe>Cr>Cd>Ag>Zn>Pb>Ni>Cu>Co. The detection of these metals is an indication of a greater mass of disposal of waste containing these metals. Comparison of these metal contents with USEPA limits showed that all the metals are under the specified limits. However, the content would increase with increase of the volume reduction during biodegradation (Das *et al.*, 1998; Das *et al.*, 2002), hence a long term environmental concern and a potential liability. This provides the basis for the defensive ways of pollution and calls for reasonable utilization and a long range plan of solid waste management.

In the water samples, metals differed in concentrations of a particular metal and were found to be within WHO standards. However, the high level of heavy metals in the dump sites can be a disaster in waiting. Some of the waste from the dumpsites may end up into the rivers thus extending environmental and health risks to the communities living within the vicinity as well as those living downstream who could be using the water for domestic and agricultural purposes like irrigation.

From the environmental evaluation conducted, it was determined that dumpsites expose the residents around it to unacceptable levels of environmental pollutants with adverse health impacts and if a conducive environment is to be obtained an urgent solution is needed in the management of the wastes.

4.8 Questionnaire Analysis and Discussion

1) **A general estimation of the volume of solid waste generated in a working day by commercial enterprises C, institutions I, industries D, and house holds H.**

Table 4.1: Descriptive Statistics

	N(Frequency)	Minimum	Maximum	Mean	Std. Deviation
C	4	3.00	131.00	22.15	61.23
I	4	1.00	11.00	18.17	4.12
H	4	31.00	86.00	14.39	26.77
D	4	1.00	5.00	30.33	1.89

From Table 4.1, it's clear that the arithmetic mean which is a single value that summarizes a set of data. It locates the centre of the values of the volume of solid waste generated in a working day from households in Kikuyu is the least with 14.39 units, followed by the mean from institution which amounts to 18.17 units, then followed by the mean from commercial enterprise with 22.15 units and finally the mean volume of the solid waste from industries is the highest 30.33 units. This could be as a result of high volume of solid waste produced by industries despite the small number of industries in kikuyu municipality.

Regression Analysis

Table 4.2: Regression coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	95.0% Confidence Interval for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
1	(Constant)	72.47	.000		5.97	35.03
	C	1.91	.000	1.03	-43.86	213.11
	I	0.14	.000	.66	3.46	57.038
	H	-1.74	.000	-.88	-1.95	31.28

Table 4.1 and 4.2 shows the regression analysis which considers the nature of the relationship between two or more variables. Taking D, which is the estimated volume of the solid waste generated from industries in a working day as a dependent variable, C, I and H which are the estimated volumes of the solid waste generated from commercial enterprise, institutions and households respectively in a working day as independent variables. We can come up with a regression line as follows:

D = 72.469+ 1.905C + 0.137I – 1.735H.

This indicates that an increase in the volume of the solid waste generated by the commercial enterprises by 1 unit causes an increase in volume from industries by 1.905 units, an increase in the volume generated by institutions by 1 unit causes an increase of volume produced by industries by 0.137 units and an increase in volume produced by house holds of 1 unit causes a decrease in volume produced by

industries by 1.74 units. Finally it indicates that, when there are no volumes of solid waste from the commercial enterprises, institutions and households, the volume of solid waste from the industries equals to 72.45 units. This can further be concluded that, the volume of the solid waste generated by industries from Kikuyu municipality is the highest with 72.45 units as compared to the volume generated by institutions, commercial enterprises and households. From the above regression analysis, industries could also be taken as the primary source of solid waste generated in Kikuyu municipality.

2) **Are there any particular problems you encounter while managing the waste generated by commercial enterprises C, institutions I, industries D, and house holds H?**

Table 4.3: Descriptive Statistics

	C	I	H	D
N	23	11	13	4
Mean	9.17	2.82	7.31	3.25
Std. Error of Mean	4.47	0.88	1.92	0.85
Mode	1.00	2.00	1.00	1.00
Std. Deviation	21.44	2.93	6.91	1.71
Variance	459.88	8.56	47.73	2.92
Skewness	3.62	2.03	0.76	-0.75

The mean of the particular problems while managing the waste from commercial enterprise is 9.17 which is the largest mean compared to institutions, households and industries. This showed that, there are more problems encountered while managing wastes in commercial enterprises than in the other three sources.

This standard error of the mean also showed that, there was much variations around the regression line which correspond with the problems encountered in the commercial enterprises which was 4.47 units than that of household which was 1.92 units and that of institutions and industries were almost the same with 0.88 units and 0.85 units, respectively. The larger the standard error the poor the goodness of fit and vice versa.

The issue of recycling the solid waste is not a problem to the households in Kikuyu, but other measures such as the introduction of tough measures on those who dump illegally, regular collection of solid wastes, improvement of disposal services, and availability of more trash bins and finally need for public awareness.

As for the industries, transport, bad odors and smoke are the major problems encountered while managing the wastes. However, mixing recyclables and non recyclables, uncollected bins, council reluctance, cost, dust and improper recycling are not major problems. In commercial enterprises, hazardous waste and lack of space are the most problems encountered while managing the waste. Finally in institutions, lack of space, incinerators, shortage of staffs and rodents and insects are the major problems encountered.

The variance is used to compare the variability in two or more sets of data. The variability of problems encountered in industry as a source of waste is less as

compared to the other sources. This shows that the problems are more uniform in industry as a source than in the other three sources.

From Table 4.3, the standard deviation which provides a great deal of information on whether the population is normally distributed or not, is highest in problems encountered in managing the waste in commercial enterprises with 21.44 units, followed by that of households with 6.91 units, then the standard deviation of problems encountered in institutions follows with 2.93 units and finally the standard deviation of problems from industries is the lowest with 1.71 units. This also corresponds with the skewness where the value descends from those of commercial enterprises which are 3.62 units to those of industries which are – 0.75 units. The higher the standard deviation, the normal the population is distributed.

Table 4.4: Correlations

Table 4.1: Coefficients of correlation					
		C	I	H	D
C	Pearson Correlation	1	.97**	-.073	.67
	Sig. (2-tailed)		.00	.81	.33
	N	23	11	13	4
Problems encountered	Pearson Correlation	.97**	1	.00	.62
	Sig. (2-tailed)	.000		.99	.38
	N	11	11	11	4
H	Pearson Correlation	-.07	.00	1	-.11
	Sig. (2-tailed)	.81	.99		.89
	N	13	11	13	4
D	Pearson Correlation	.67	.62	-.11	1
	Sig. (2-tailed)	.33	.38	.89	
	N	4	4	4	4
**. Correlation is significant at the 0.01 level (-tailed).					

The relationship between problems encountered in commercial enterprise and in institution is 0.97 which is very close to 1 which means that the problems

encountered from the two sources is almost the same at 0.01 level of significance. This is the same case in relationship between the problems encountered in the institution and the households. But in the case of relationship between the commercial enterprise and the households, there is a total difference since the coefficient is -0.07 which is very small.

Hypothesis Testing

Table 4.5: One-tail t-Test

					95% Confidence Interval of the Difference
	T	Df	Mean Difference	Lower	Upper
C	2.05	22	9.17	-.10	18.45
I	3.19	10	2.82	.85	4.78
H	3.81	12	7.31	3.13	11.48
D	3.81	3	3.25	.53	5.97

In the present study, we tested a hypothesis whether the Independent variables D, I and H had any impact on dependent variable C or test whether the problems encountered in managing the waste from industries, institutions and households had any impact on the problems encountered in managing waste from commercial enterprises.

From the regression line: **C = - 7.21+ 9.861I -0.989 H + 1.319D.**

$$\mathbf{C = \alpha + \beta_1 I + \beta_2 H + \beta_3 D}$$

1. We set a null hypothesis $H_{0,}$ $\beta_1 = 9.861 = 0$ Against an alternative that H_a $\boldsymbol{\beta 1} = 0.003 \neq 0$.

Using test of significance approach,

The critical t, or t_α = 2.2281 at 10 degrees of freedom (from a normal distribution tables)

The calculated t, t_{cal} = 3.194 (the single tail t value of problem encountered in managing the waste in institutions. from the table above)

Since $t_{cal} > t_\alpha$, we rejected H_0 and accepted $H_{a.}$ this means that, $\beta_1 = 0.003 \neq 0$ which further showed that the problems encountered in managing the waste in institutions have an impact to problems encountered in managing the waste in commercial enterprises.

2. We set a null hypothesis $H_{0,}$ $\beta_2 = -0.989 = 0$ against an alternative $H_{a,}$ $\beta 2 = -0.989 \neq 0$.

Using of significance approach, test

The critical t, or t_α = 3.814 at 12 degrees of freedom (from a normal distribution tables)

The calculated t, t_{cal} = 2.1788 (the single tail t value of problem encountered in managing the waste in households. from the table above)

Since $t_{cal} < t_\alpha$, we rejected H_a and accepted $H_{o,}$this means that $\beta 2 = -0.989 = 0$ which further showed that the problems encountered in managing the waste in households had no any impact to problems encountered in managing the waste in commercial enterprises.

(i) We set a null hypothesis $H_{0,}$ $\boldsymbol{\beta_3 = 1.319 = 0}$ against an alternative that $H_{a,}$ $\boldsymbol{\beta 3 = 1.319 \neq 0.}$

Using test of significance approach,

The critical t, or t_α = 3.182 at 3 degrees of freedom (from a normal distribution tables). The calculated value of t, t_{cal} = 3.806 (the single tail t value of problem encountered in managing the waste in industries. from the table above)

Since $t_{cal} > t_\alpha$, we rejected H_0 and accepted $H_{a.}$ this means that, $\boldsymbol{\beta_3 = 0.003 \neq 0}$ which further showed that the problems encountered in managing the waste in industries have an impact to problems encountered in managing the waste in commercial enterprises.

Chi-Square Test

A measure of discrepancy existing between the observed frequencies and the expected frequencies of independent variables can be obtained by calculating the χ^2. If the value of χ^2 is zero, then the observed and the expected frequencies agree exactly. The greater the difference between χ^2 - value and zero, the greater the discrepancy between the observed and the expected frequencies

Table 4.6: Sum of Observed and Expected frequencies

	∑ of Observed N	∑ of Expected N	∑ of Residuals
Commercial Enterprises	23	23.4	- 0.4
Industries	11	11	0
Households	13	11.2	0.2
Institutions	4	4	0

From the Table 4.6, there is a discrepancy between the observed and the expected frequencies of the problems you encounter while managing the waste from commercial enterprises although it's not large since the value of the chi- square is - 0.4 which is not much smaller from zero.

The value of χ^2 is zero as far as the problems encountered industries are concerned. This shows that, the observed and the expected frequencies of the problems encountered while managing the waste from industries agrees exactly and thus there is no discrepancy between the frequencies.

Furthermore, there is a discrepancy between the observed and the expected frequencies of the problems you encounter while managing the waste from house holds although it's not big since the value of the χ^2 is 0.20 which is not much bigger from zero.

Finally, the value of χ^2 of the problems encountered while managing the waste from institutions is zero, then the observed and the expected frequencies agree exactly.

This means that the observed and the expected frequencies of the problems encountered while managing the waste from industries agrees exactly. No discrepancy that exists. It's also important to note that the chi square value decreases as the degree of freedom increases in the table above.

3) What solid waste services, if any, would you like to be made available to you as per commercial enterprises C, institutions I, industries D, and house holds H?

Table 4.7: Descriptive Statistics

	C	I	H	D
Mean	11.08	4.43	17.17	3.33
Std. Error of Mean	3.35	1.72	3.90	0.33
Median	10.00	2.00	16.00	3.00
Mode	1.00	1.00	2.00	3.00
Std. Deviation	12.07	4.54	13.52	0.58
Variance	145.74	20.62	182.88	0.33
Skewness	1.60	1.14	.72	1.73

From the statistics of the data, the mean of the waste services, if any, would be recommended to be made available to you in commercial enterprise is 11.08 units which is the second largest mean compared in institutions which is 4.43 units, households which has the largest mean of 17.12 units and industries has the smallest

mean of 3.33 units. This shows that, there are more waste services recommended to be made available to households than in the other three sectors.

The most common waste services that would be recommended to be made available as far as commercial enterprises want are; burning plastic, improved dumpsite, good transport materials and sewerage to be made available to them as solid waste services.

Few households in Kikuyu municipality want public awareness, pit latrines and good drainage to be made available to them as solid waste services. An average number of industries in Kikuyu municipality need recycling and advanced technology to be made available to them as solid waste services while few institutions in Kikuyu municipality want transfer stations and incinerators to be made available to them as solid waste services.

The variance is used to compare the variability in two or more sets of data. The variability of waste services recommended to be made available in industry as a source of waste is less with 0.33 units as compared to the other sectors which are 20.62, 145.74 and 182.88 units for institutions, commercial enterprises and households respectively. This shows that the waste services recommended to be made available are more uniform in industry as a source than in the other three sectors.

From the above standard deviation which provides a great deal of information on whether the population is a normal distribution or not, its lowest in industries with 0.58 units , followed by institutions with 4.54 units, then commercial enterprises which is 12.07 units and finally household is the highest with 13.52 units. The higher the standard deviation, the normal the population is distributed. The distribution of

the waste services recommended to be made available in the industrial sector is normally distributed as compared to ones recommended in the other sectors.

Correlations

Table 4.8: Coefficients of correlation

		C	I	H	D
C	Pearson Correlation	1	.67	.81**	-.34
	Sig. (2-tailed)		.10	.00	.78
	N	13	7	12	3
I	Pearson Correlation	.67	1	.65	-1.00**
	Sig. (2-tailed)	.10		.12	.00
	N	7	7	7	3
H	Pearson Correlation	.81**	.65	1	.00
	Sig. (2-tailed)	.002	.12		1.00
	N	12	7	12	3
D	Pearson Correlation	-.34	-1.00**	.00	1
	Sig. (2-tailed)	.78	.00	1.00	
	N	3	3	3	3

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

The table above shows the correlations which are the relationship between two or more variables. It's clear from the table that, the correlation of a similar variable is

equal to one. The correlation coefficient of commercial enterprises and the institutions equals to 0.67 which means that the solid waste services if any, that would be recommended in the institutions are closely related to those recommended in the commercial enterprises. Further, the correlation between the waste services recommended to be made available in commercial enterprises and waste services recommended to be made available in industries is - 0.34 which indicates that there is a negative relationship between the recommended solid waste services in both sectors in consideration. The correlation coefficient between the waste services recommended to be made available in industries and the waste services recommended to be made available in institutions is -1.00 which means that there is no any relationship at all between the solid waste services if any ,that would be recommended in the institutions and the ones in industries.

Regression Analysis

Table 4.9: Coefficients of linear regression

Model		Unstandardized Coefficients		Standardized Coefficients
		B	Std. Error	Beta
	(Constant)	3.41	0.00	
	H	6.21	0.00	
	C	0.59	0.00	1.06
	I	5.04	0.00	0.36

a. Dependent Variable: D

When we take the variable D, the solid waste services if any ,that would be recommended in industrial sector as a dependent variable and the other three variables I, H and C , the problems encountered in institutions, households and commercial enterprises respectively as the independent variables, we come up with a regression functions as follows **:**

D = 3.407+ 5.037I + 0.621 H + 0.593C.

The above result from the regression line shows that, when there is no solid waste services if any that would be recommended in, institution, households and commercial enterprises, the amount of solid waste services if any, that would be recommended in industries amounts to 3.41 units.

Its also clear that when solid waste services if any, that would be recommended institutions is increased by 1 unit, the increase in solid waste services if any ,that would be recommended in industrial sector increases by 5.04 units. Further more, an increase in the solid waste services if any that would be recommended in household by 1 unit increases the ones in industrial sector by 0.62 units. Like wise an increase in solid waste services if any that would be recommended in commercial enterprises by 1 unit causes an increase in solid waste services if any that would be recommended in industrial sector by 0.59 units.

Table 4.10: Coefficient of determination (R square)

Model	R	R Square	Change Statistics		Durbin-Watson
			R Square Change	Df	
1	1.000	1.000	1.000 .	2	.100

a. Predictors: (Constant)I, D and C

b. Dependent Variable: H

The R^2 (coefficient of determination) measures the proportion in variation in D that can be attributed to the variations in I, H and C. Since in the above regression line the coefficient of determination, R^2 is equal to 1. This shows that the there is a perfect fit and the entire variation in D are explained by the regression. Else 100% of D is explained by the I, H and C.

This further shows that, the solid waste services recommended in industrial sector as a source solid waste in Kikuyu municipality are perfectly explained by the solid waste services recommended in the other sectors i.e. institutions , commercial enterprises and households. So they are similar in nature.

4.9 Burning

It was observed that some residents opt to burn their solid waste. However, this method is not appropriate on hazardous waste. This contrary creates adverse environmental impacts and is known to producing gaseous pollutants.

Figure 4.3: **Response on Solid Waste Disposal**

During the survey results it was established that those who burn do it as a method to make their environment clean. They cite the method as cheap, convenient and have no other alternative. The results of the respondents showed that a good number of residents are not aware of the dangers that are associated with burning unsorted solid waste.

4.10 Informal Recycling and reusing

Whereas most people acknowledged reusing and recycling some solid waste such as plastics, metals, papers , stones, timbers, tires, the study showed that the waste finally end up in unorganized dumping.

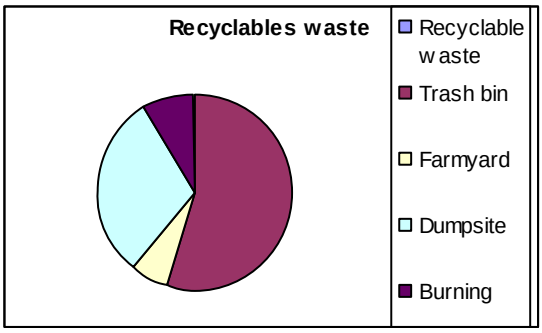


Figure 4.4: Recyclable Waste disposal

A more reasonable approach would be to collect and sell for recycling in industries to make such items like toilet paper, plastic poles, floor tile and many more economically and environmentally sustainable resources.

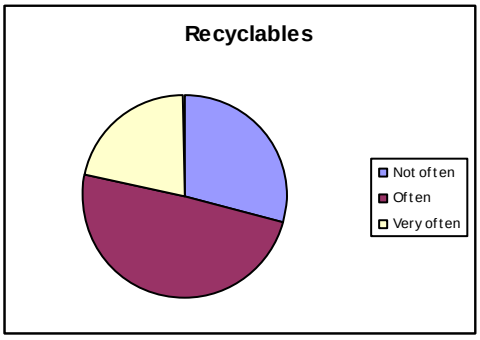


Figure 4.5: Frequency of Production Recyclable

Metallic waste can be reused in the *Jua Kali* Industries to fabricate metal items or taken back to the industry for smelting and made into other value added metallic waste. Glasses can be recycled in the industry to make some glassware. In Kikuyu, these techniques have not been adequately adopted and its integration in the waste management will be a great score.

4.11 Composting

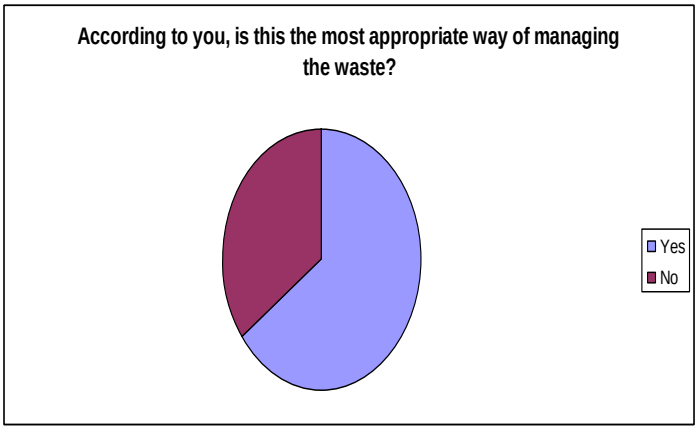


Figure 4.6: Response on Management of Waste

Biodegradable solid waste can be used as farm manure. Composting is not widely used in Kikuyu since majority are urban dwellers with no garden. Most use other method such as trash bins, burning along the streets and the bulk end up in dumpsite. Surprisingly, the majority are comfortable with the way they dump their waste, a phenomenon that needs to be reversed if a battle on solid waste is to be won.

Even to the waste collectors, the solid waste is dumped unsorted. Composting can reduce the amount of solid waste going into the refill.

4.12 Polythene bag ban

Though ban of polythene bags can be the best option in reducing non biodegradable waste, the laws that govern their use is out of the council jurisdiction.

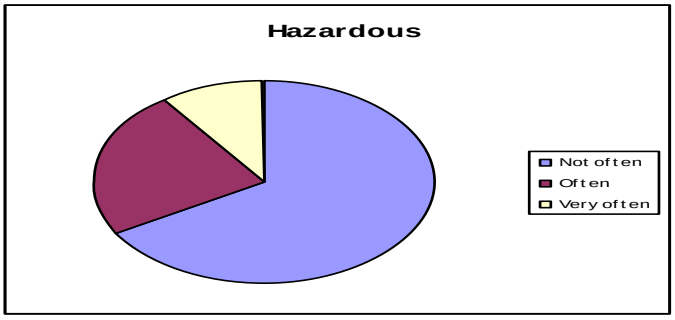


Figure 4.7: Hazardous Waste

4.12.1 The Ban

Recently NEMA banned the use of polythene bags and even the government imposed extra tax in polyethene. However, they have continued to be used by the public and even industries. Besides discouraging their use, collecting and reselling them to industries that recycle can be an alternative.

4.12.2 Public perception of the ban

Where as public desires to live in a clean environment, the study showed that most would be uncomfortable with the ban. Despite having no economic policy to regulate the waste, most still perceive this as the responsibility of the council to ensure cleanliness of the town. With the weak rules and un-organized council this has been an uphill task despite unaccomplished promises.

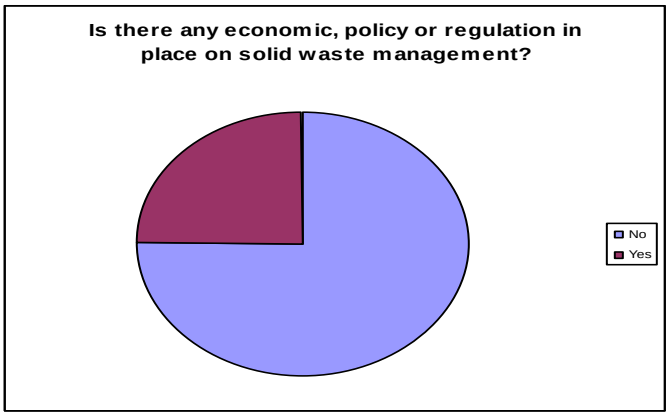


Figure 4.8: Regulation on Solid Waste Management

Public participation can be a viable way of reducing the waste since they are the source of the great menace that is witnessed in Kikuyu municipality. Where as most thought tough measures should be imposed, without the willingness of the residents and necessary legislation it is hard to implement.

Of great concern is that the population is aware of the loopholes that make it a challenge to have a clean environment as outlined by the suggestions they were giving (graph below).

4.13 Governance

As a management there is need to monitor solid waste generation, method of collection and disposal in order to give informed decisions that aids in planning. The

council should provide an administration system and stipulate the functions, work, proceedings and powers.

4.14 Public Consultation and Involvement

Policy development in Kikuyu has always been the prerogative of those who are in power. Given the complexity of issues and problems, it is apparent that the top-down solutions and management strategy for solid waste management will not be sustainable, because sustainable solid waste management depends on the participation of citizens in the system. For any future solid waste management system public consultation should be made a prerequisite. By doing so, the Kikuyu municipality stands to gain on many different fronts. Foremost, public involvement in decision making may help the Kikuyu municipality to bring the issue at hand to the people. This may in turn help in informing the people and making them aware of the existing problems or solutions proposed. People may be able to share their ideas, thoughts and concerns regarding various aspects of solid waste management in Kikuyu. This may make the system transparent and efficient, as decisions once taken with general consensus will be easier to execute and people will be hopefully more willing to help to execute the plan by reducing their waste, segregating their waste and so on.

Consultation can be achieved through participation of the general public or through a body selected, elected, or appointed by the people at the ward level. The idea of a ward committee as is one such body. However, care should be taken that the ward committee is composed of people from all sections of the society. Another way to ensure participation may be through community based organization. These grass-

roots level organizations already have an existing structure of their own and a widespread reach in the community, and since these organizations work purely on voluntary non-profit basis, consultation can be undertaken at the CBO level. Social organizations and institutions such as schools and colleges should be used in spreading awareness and information transformation. This will save time and valuable resources for the municipal authorities. Regular ward level meetings should be organized to keep the people involved and informed. Baseline data on the status of waste - generated, collected, properly disposed, recycled, composted and thrown in the street etc - should be generated. For this, too, local bodies and institutions can play a substantial and an active role. Research and development should be promoted and encouraged.

This research responds to the need for an assessment of Solid Waste Management in Kikuyu. Analysis of collected data was undertaken and emerging trends and patterns provided critical insight into the solid waste management scenario in Kikuyu. Keeping in view the trends and patterns, a short-term plan of action was developed.

The short-term plan of action developed in this study will complement the proposed solid waste management system and recommends the development of a comprehensive sustainable solid waste management plan in the future.

Solid waste management system as currently practiced is unsustainable in the long run. Waste is not segregated, and the collection and transportation of waste is basic and inadequate. Collection and transport methods are rudimentary and pose both human and environmental risk. People, in general, indulge in dumping waste in street corners, municipal transfer stations, which are open and often overflowing. Collection services were found to be infrequent and inadequate. Recycling and

composting of the waste is undertaken by individuals with interest, however, there is no provision for composting or recycling of solid waste by the municipality. Recycling is completely undertaken by the informal sector, which is inefficient, hazardous and risky. Kikuyu lacks a sanitary landfill and the municipality practices open dumping. The dumping ground is near the fringes of Limuru town, thus posing a health threat to the people living near the dumping ground, and an environmental risk to the entire area. There are no safety measures in place for waste workers; immunization and basic services such as the provision of safe clothing and proper equipments are not provided by the municipality. The enforcement of waste management regulation is limited and in most cases perpetrators of illegal dumping are not found.

4.15 Creation of Three Stream Waste System

Long-term sustainability of the solid waste management system also depends on the level of segregation of waste. Segregation of waste should be three stream i.e. bio-degradable, recyclables and garbage/waste; this will also help in finding appropriate disposal options. Segregation of waste should be done at the source itself. Segregated waste can be collected on a weekly basis from households and on a daily basis from business establishments.

4.16 Promotion of Reduction, Reuse, and Recycle

Emphasis should be placed on the three R's – reduction, reuse, and recycle. This will help in creating of less waste and in increased material recovery. Reduction can be achieved by starting a deposit-refund system, i.e. it should be made compulsory for certain types of waste to be taken care of by the company producing them under

extended producer's responsibilities. In order to ensure that these particular wastes go back to the producers, an extra deposit could be charged when someone purchases these items, and this deposit should be recoverable on return of the items (say cover/foil/plastic bottles etc.). This may reduce the burden of waste to a great extent. Wastes such as chip packages, wrappings, drinking water bottles, soft-drink bottles, etc. should be included in this system.

The recycling of waste is another important requirement for sustainable waste management practices. In the case of the Kikuyu municipality a formalized waste recycling or recovery system, should be undertaken by the municipality. NGOs or private firms may be enlisted in organizing and including the non-formal recycling sector as part of the formal system.

4.17 Composting

Large scale composting can be expensive and may not work in Kikuyu; hence the focus should be on developing ward level, or preferably community level, small-scale composting processes. Community-based composting helps in diverting a major portion of the waste generated close to the source of generation, thereby, significantly reducing transportation costs and prolonging the life span of landfills. Furthermore, community-based composting may enhance recycling activities, and facilitate the final disposal of waste in a proper manner. People who are from economically backward categories may be employed for composting schemes. This can be a source of employment and income generation for both the people employed for composting and the municipality as well. Community level composting may be

efficient and easier to manage. Community level composting can be undertaken at the local level, thus, it will save money and resources for the municipality.

4.19 Collection of Waste

Collection of the waste should be undertaken at the doorstep level and people from economically backward sections may be employed for the same. These people should be properly trained and equipped. The collected non-degradable materials should be removed using covered trucks and trailers. Care should be taken not to spill the waste during transportation. All the collection workers should be provided with proper handling equipments and their safety should be ensured by the municipality.

4.19 Waste Disposal

Disposal of the waste should be undertaken in a prescribed scientific manner. A sanitary landfill designed specifically for the final disposal of wastes should be built. Sanitary landfills minimize the risks to human health and the environment associated with solid wastes. Formal engineering preparations with an examination of geological and hydrological features and related environmental impact analysis should be carried out before a sanitary landfill is built. Staff working in the sanitary landfill should be properly equipped and trained. Kikuyu municipality should find a proper location for a sanitary landfill. Disposal of hazardous waste such as medical or toxic waste should be undertaken with the help of the central government. Special provisions should be made to adequately deal with these wastes, and special transportation facilities and specially trained staff should be employed for dealing

with hazardous wastes. The municipality should immediately seek help from the State and the Central government in this regard.

4.20 Responsible Bureaucracy

Bureaucrats are the back bone of any civil organization. In case of volatile and continuously changing political situations, the bureaucrats ought to play a pro-active role in ensuring that the projects and plans and processes are not affected by the prevalent political situation. In the case of a change in government at the municipal level, provisions should be made to grandfather the plans and processes, started by the previous board. Plans and processes ought not to be allowed to be abandoned midway, which results in loss of time and resources. Bureaucracy can play a dynamic role in ensuring the smooth functioning of the municipality and this mechanism should be included in the planning process itself.

The Kikuyu is at present capable of supplying waste management services to a very small part. The study showed that delegation of waste collection to an integrated system can result in a more efficient collection. Moreover, involving the private sector may result in a larger investment basis and therefore permit investments in collection equipment, which the council cannot afford. For this reason, the council can decide to outsource a significant part of the waste collection services to private enterprises. However, the council can maintain a function in the provision of waste management services which is important to maintain waste collection and transportation capacity in order to be able take over the service provision from franchisees or contractors that do not fulfill their contract obligations.

As the Kikuyu in itself is too big for any individual waste collector, the council should establish a number of Waste Management Zones (WMZs) within the council limits. Franchising and contracting seems to be the best option to cover even peri-urban areas. The former will cover the conventional areas whereas the latter comprises secondary waste collection in a number of peri-urban areas. The primary waste collection, if any, within the peri-urban area will be the responsibility of the communities themselves.

In the present context, franchising means that a franchise contract is established between council and a franchise contractor. Under the franchise contract, the contractor will collect and transport waste to the landfill, pay the set landfill fee and collect fees from the households and enterprises for the service. Contracting means that council will enter into a direct contract with a transport contractor and pay him for his services. In this case the council will collect the fees to pay for the contractor's services at household or enterprise level through the Waste Management Committee for each area.

In establishing WMZs, should be put into consideration

- The WMZs must cover the entire jurisdiction of Kikuyu municipality so that each and every household, institution, enterprise, industries etc has access to a defined waste management service
- The WMZs must be of a manageable size.
- The WMZs must involve the residents in their decision making.

In having a bureaucracy that integrates the waste collectors, waste management council, residents and various institutions proper waste management can be achieved.

4.21 Integrated Waste System

An integrated waste re-arranged system of plan must place an emphasis not only on which specific waste management option are to be chosen, but on the scheduling of these location of facilities and equipment (Tippers, Bull dozer, Pail loaders).

A more flexible choice and scheduling programme for waste management options which must be able to adopt to changing conditions need to be considered in the plan. The basic aim here is to allow decision makers to be able to determine the optimal times to implement and discontinue or close the waste management programme and facilities. Throughout the planning period, this should include a determinist schedule plan of when and what recycling programme to implement the dump site is to be opened or filled in a given planning period. Also the schedule option should minimize the overall cost associated with the solid system for a defined planning period. This is achieved by integrating a cost minimization e.g. minimizing the cost of equipment maintenance (bull dozers, pail loaders and tippers).

Some operation research model is particularly well suitable for the description of a complex task. Method involving some variables as constraints (equipment: bull dozer, pail loader and tippers). This model may be used to help understand the complexity of the system as well as assessing the long term role and impact of the new technology option. In his integrated model of waste optimization proposed a network model which would help decision makers in the waste management and facility sitting decision. Kaila (1986) developed a model for the strategic evaluation of municipal solid waste management system.

The material waste is modeled by a number of factions; personnel, purchase and maintenance of equipments. An example is where if the Kikuyu Town Council is to

make an effective use of the basic garbage collection equipments such as a pail loader, bulldozer and a tipper, an optimization model in form of liner programming model can be applied to maximize the benefits. The cost of purchasing one unit of pail loader, tipper and bull dozer are Kshs.20 M, 10 M and 30 M respectively.

The routine maintenance cost for the for each pail loader, tipper and bull dozer are Kshs. 600 000, Kshs. 400 000 and Kshs. 500 000 respectively. Personnel and sundry for running each respectively are Kshs.1 million, Kshs.1 million and Kshs. 2 million respectively. The maximum allowable budget by the Kikuyu Town Council for personnel and sundry, purchase and routine maintenance in terms of the benefits derived by managing the solid waste has been determined to be in the ratio of 6:4:7. Hence to maximize the benefits when managing the waste, the number of pail loaders, tipper and bulldozer should be determined by using linear programming.

The model takes into account the scheduling decision, benefit overtime, budget constraints and constraints on the number of the equipments available to effectively manage the project. More over decision making is very vital to the engineer during the planning and implementation of the projects.

3.22 Modelling for Sustainable Solid Waste Management

As discussed above, it is clear that a quick and an effective solution is needed if the war on solid waste is to be won. The unorganized and uncontrolled dumping is a major setback that calls for a proper management that takes care of the waste to its final disposal.

A system involving substantial content that is particularly set for actions which will best accomplish the overall objectives of the decision makers within constraints of

law, morality, economics resources, political and social pressure and which will govern the physical life and other natural sciences is of paramount importance. Any model developed to aid in sustainable solid waste management should therefore address the control of solid waste generation, storage, collection transfer and transport, processing and disposal in a manner that is in accord with the best principles of public health, economic engineering, conservation aesthetics and other environmental considerations that are also responsive to public attitudes.

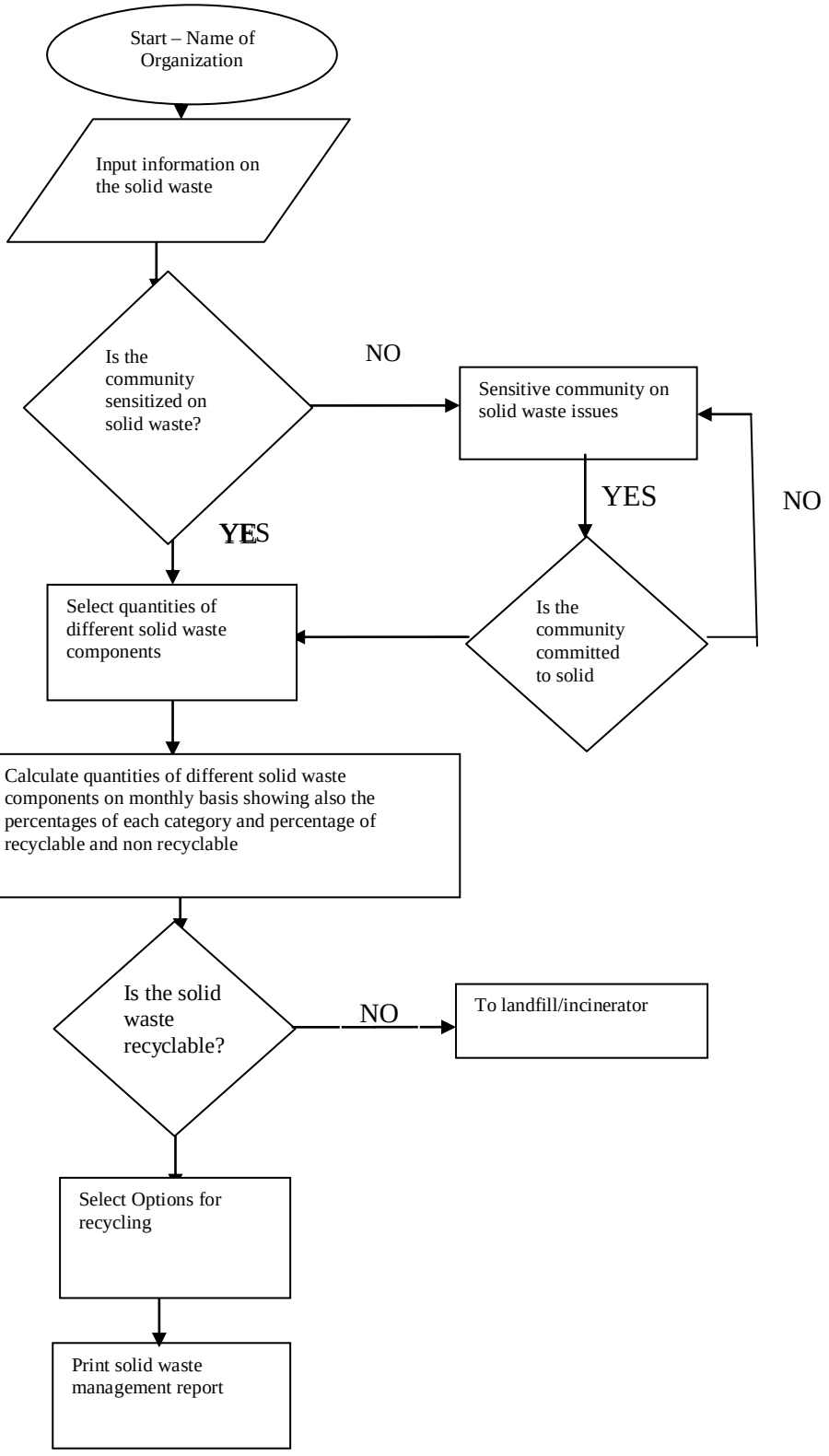


Figure 4.9: Flow Chart on Solid Waste management Model

To work towards a more effective management, long term planning and commitment through appropriate decisions is necessary. To facilitate this, the information on solid waste can facilitate the visions of the future since it can help to develop action plans and inform decision makers about future consequences. Development of a waste management strategy requires information on solid waste production and solid waste characteristics. Once the information is available, public sensitization is necessary since they are the bulk producers of solid waste. Public awareness is necessary and can make eventual methods of collection, reusing, recycling and disposal easier and effective.

Following collection and sorting, the recyclable waste is utilized in an economical and environmental friendly way. This can enable the municipality to schedule the collection of the garbage for dumping at the designated sites. In most cases the wastes were often discarded because they were all considered as negative value goods. The prevalent method of disposal of wastes have been to first collect them from their source and then burn them in a land fill site or throw them in surrounding deep erosion gullies within the municipality. However, this is a temporary solution which is a threat to future economy and environment

Different waste management option must be combined intelligently in a way as to reduce the environmental and social impact at an acceptable cost of the masses in the municipality.

To further enhance a quick decision the study developed Kikuyu Waste Management System (KIWAMAS).

4.23 Kikuyu Waste Management System (KIWAMAS) set up.

The model software was tested and validated using the data obtained from the study site. The model accepts data from various waste generators in a Municipality such as, domestic, agricultural, industry and institutions. The wastes was calculated and the gross amount given as an output. This further estimated the volume of landfill required for the disposal of waste.

To facilitate future plans, predictions can be made using the model based on the waste generation volume over time and the human population growth rate over a certain period.

The model can be applied in any council to predict future requirements like size of dumpsite, volume of waste, manpower or even technical equipments and development if the following parameters are known and quantified;

- Population.
- Waste generation per capital.
- Duration of waste generation.
- Waste generators.
- Waste classes and characteristics.
- Landfill area available and the hydrogeology of the area.

Other outputs that can be generated are;

- Percentage waste generations per sector.
- Overall waste class percentage e.g. percentage of glass from all hospitals in the study area.
- Summary bar and line graphs for all wastes.

- Comparative data from generators in the study location
- Percent of recyclable and non recyclable data from generators.
- Total hazardous waste per sector and overall hazardous wastes from all sources in the study location.

4.23.1 Procedures for installing the system

- Install the directory first – the directory enables the user to access the database and connect it to the system.
- Install KIWAMAS setup
- Once both are installed, run the directory and enter the database you are using and ensure by clicking the icon ‘see you’ then exit the directory.
- Open the KIWAMAS system. It has a trial period of thirty days and a key which has been given to the owner. Insert the key and click trial, exit and open it again.
- once the system has loaded it will ask you the password
- Type the password and in case you want to change the password, type allow me and a pop box will appear. In that pop up box type your new password and verify.
- After the password has loaded the system is ready for use.

1. Back office

Back office is used to input data once. The data given in the back office guides the user when using the front office. The subs of back office entail; county details, zone details, categories details and class details.

a) ***County details*** – in this level the user enters county name, size of the county, population and code that distinguish the county from others

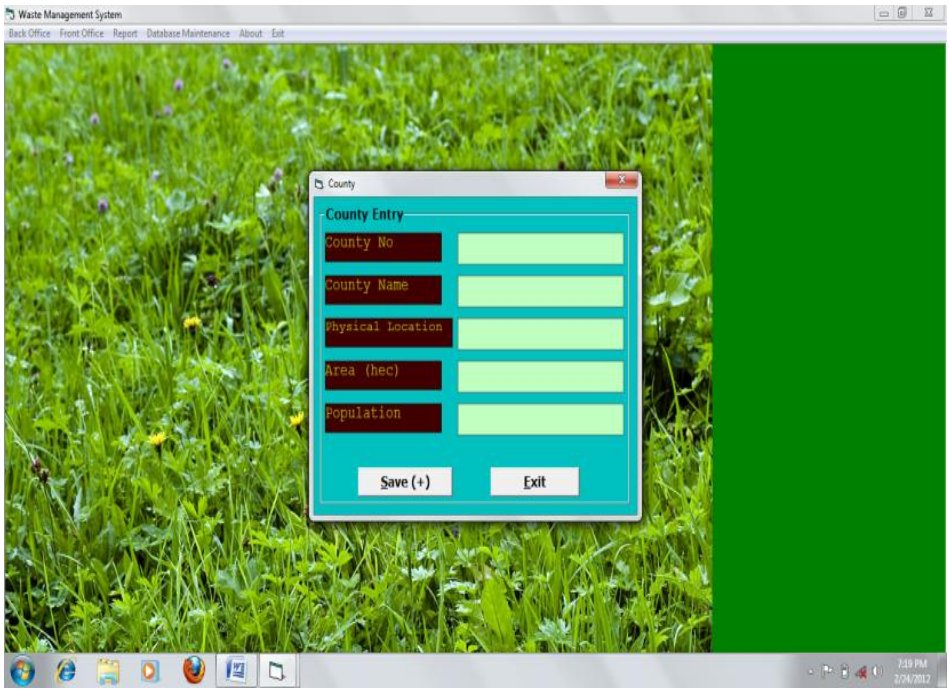


Figure 4.10: County details

b) ***Zone details*** – zones are areas within that county. The user gives the names of the zone, size in hectare, population and a code to differentiate it from others.

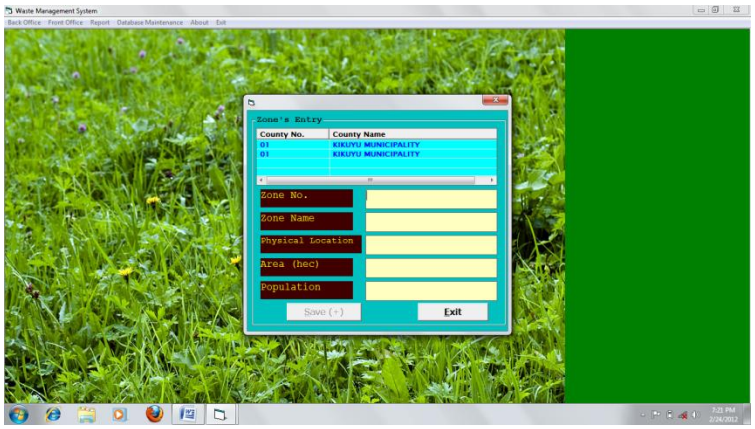


Figure 4.11: Zone details

c) ***Categories*** – the term category generalize all the industries, hospital, institution and domestic in a county.

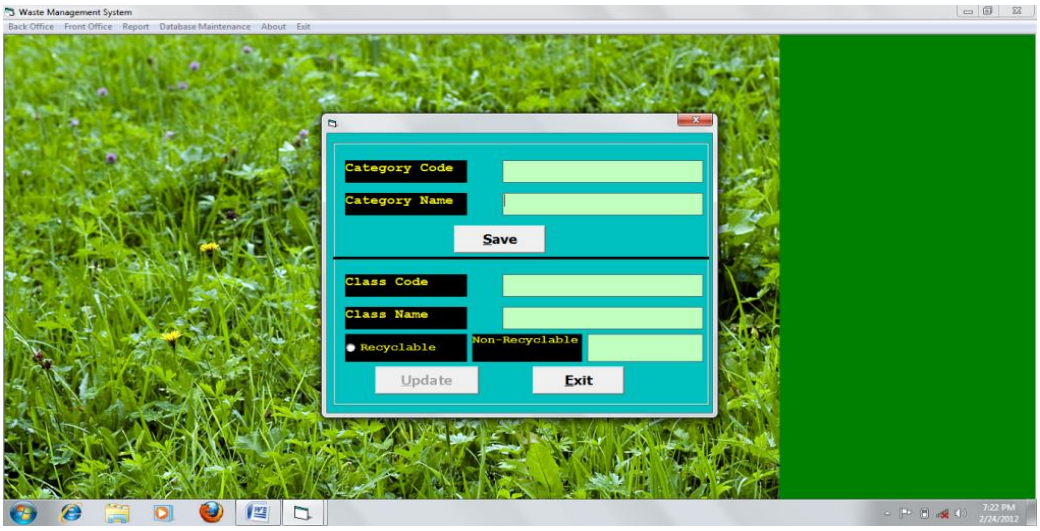


Figure 4.12: Categories

d) *Classes* – this is a term used to generalize types of materials used in the County. These types are plastic, metals, glass, textile, hazardous, papers and others.

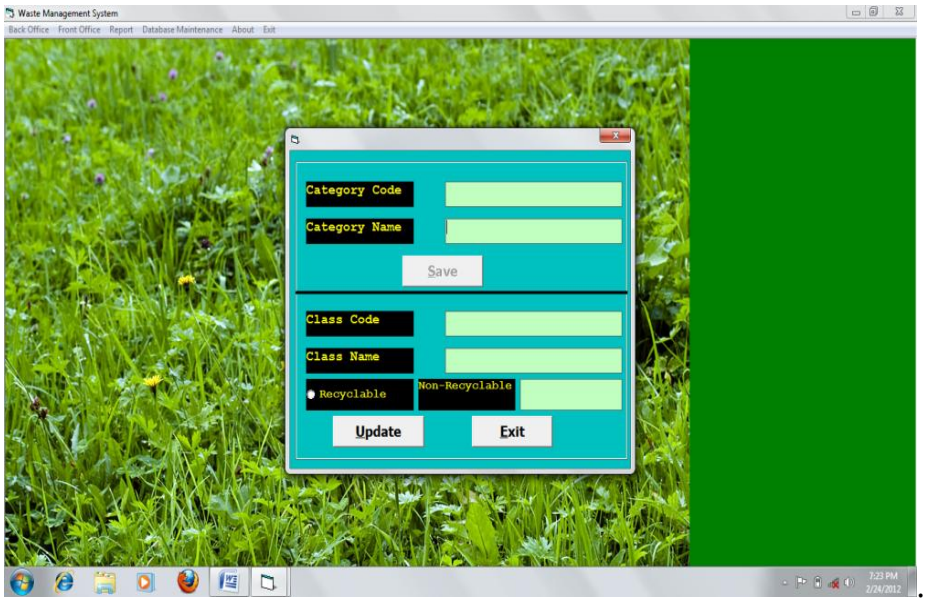


Figure 4.13: Classes

In the system they have been given one name ‘classes’. In this module the user is supposed to select the class and record it as either recyclable or non recyclable.

2. **Front office**

This is where the daily task takes place. It has two subs.

a) ***Plot entries*** – at the juncture the user give the plot name and its code and select the category it falls in.

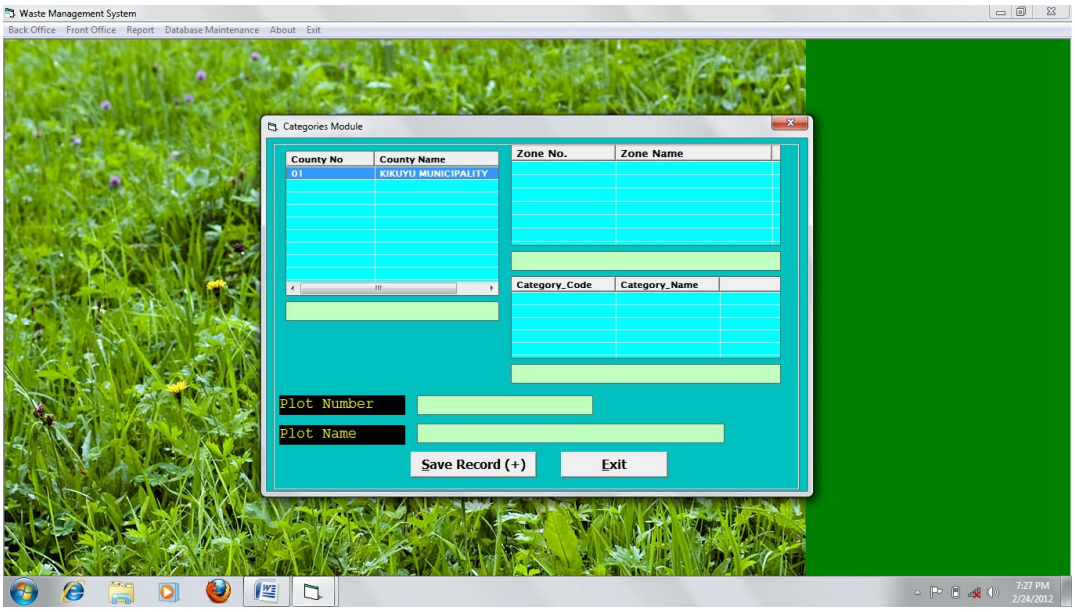


Figure 4.14: Plot entries

b) ***Weight entry*** – weight collected daily is recorded on this module which is under the class module.

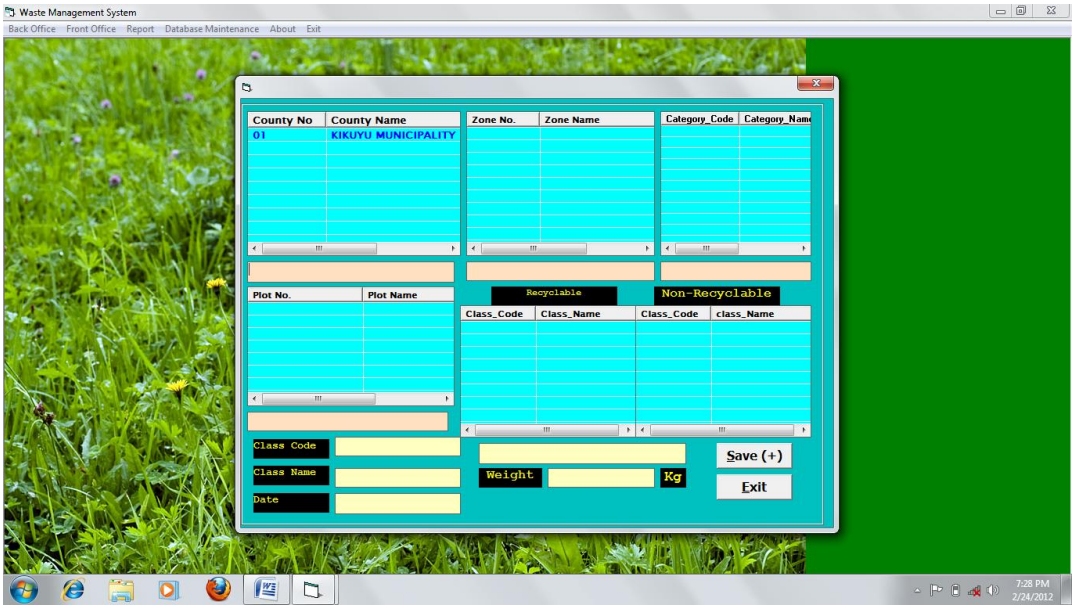


Figure 4.15: Weight entries

3. Database maintenance

This module enables the user to edit information given at the back office and front offices. If the user realizes some errors are appearing, he/she can do the changes on this module. All zone details, categories detail classes' entry and weight can be edited or updated on this particular module.

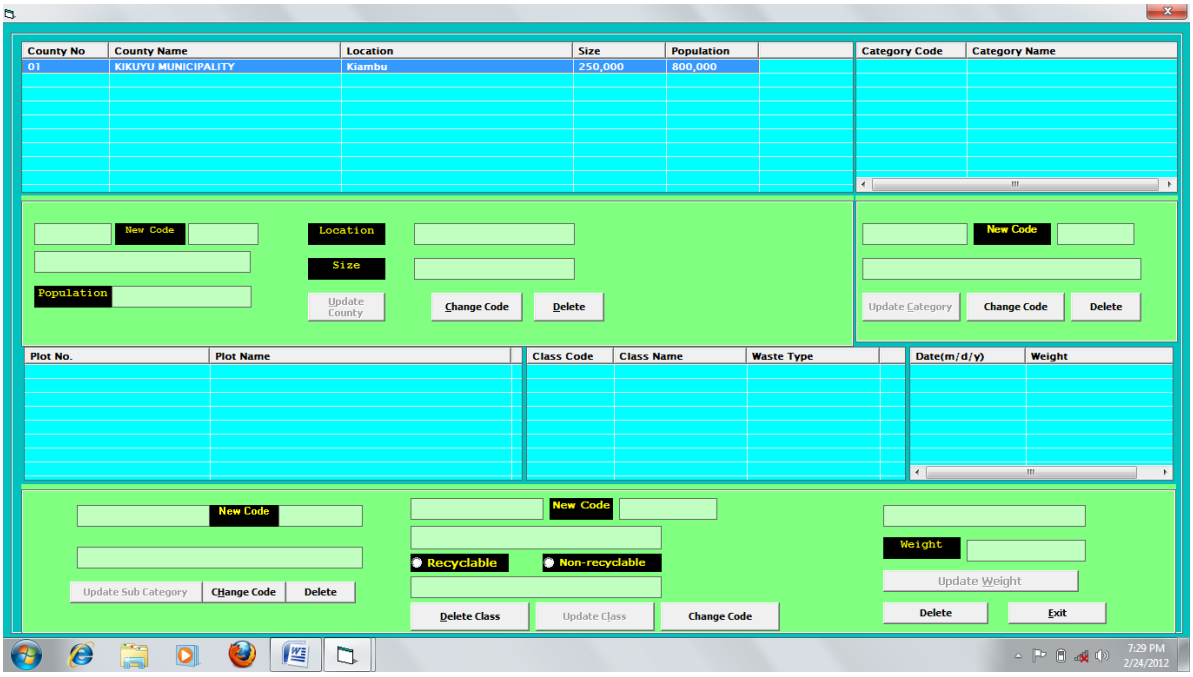


Figure 4.16: Database maintenance

4. Report module

Report module has all the county analysis. If the user is interested on analyzing the whole of county in term of area each zone occupy, the user select the county to analyze and then click the area graph button. The system displays all zone in that county with each the size in hectares it occupy. The comparison is displayed in form of pie chart, bar graph and step graph. The user as the option to choose by right clicking and selecting the display he wants. The user can also compare zones population against county population. To view the graph just click on population graph and it gives you the comparison. In the same module the user select the range to analyze in term of waste composition. He can choose to do it monthly or annually.

5. Hierarchal structure for the county

This module shows the county selected at the previous module with its zones and classes. Its display county with it zone hierarch ally; classes are under the categories, categories are under the zone and zone under the county. The user can analyze data for the Whole County, zone and class separately. Once the data to be analyzed is chosen the user click on data analysis button which shows all data from all areas with its type

Depending with area selected and numbers of days the system gives the user total waste for that period. Recyclable total waste and non recyclable total waste and their percentages, the system also calculates the waste generated per day and both recyclable and non recyclable total per day. This data can be shown in form of graph and be printed.

Figure 4.17: Database maintenance

4.23.2 Calculation for Daily Waste

Since the system has been developed to manage the non recyclable, it automatically puts off the recyclable and picks the figure of non recyclable waste. The system starts to analyze the waste generated by one person per day. It is also able to calculate the number of people needed to generate the same weight in a day in that county, Hence the same annually.

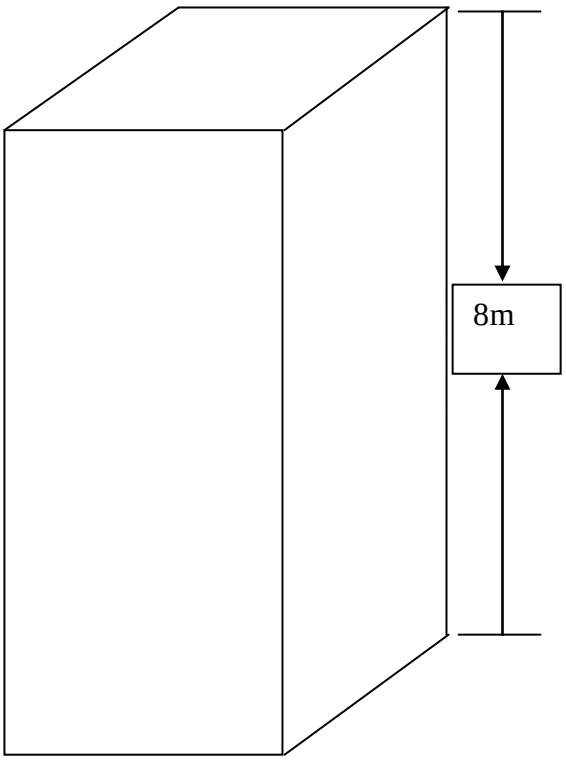
4.23.3 Landfill Calculation Analysis

Assuming we have the total waste of non recyclable of one year and a compaction of a certain percentage is done, the system calculates the waste generated in that year. The system further computes the volume of waste using the average density of the waste in consideration.

The total given is used to calculate the area of the landfill that will be required for the non recyclable waste. The user determines the depth of the landfill.

4.23.4 Example

If we have a total waste of 293,460kgs of non recyclable and



Assuming a Density of 50kg/m^3, 50% compaction and a depth of 8m

Therefore area of the land to be used

$$= \frac{293{,}460 \times 50 \times 50/100}{10{,}000 \times 8}$$

=**0.037 hectares**

NB: 10,000m^2 = I hectare

Figure 4.18: Landfill

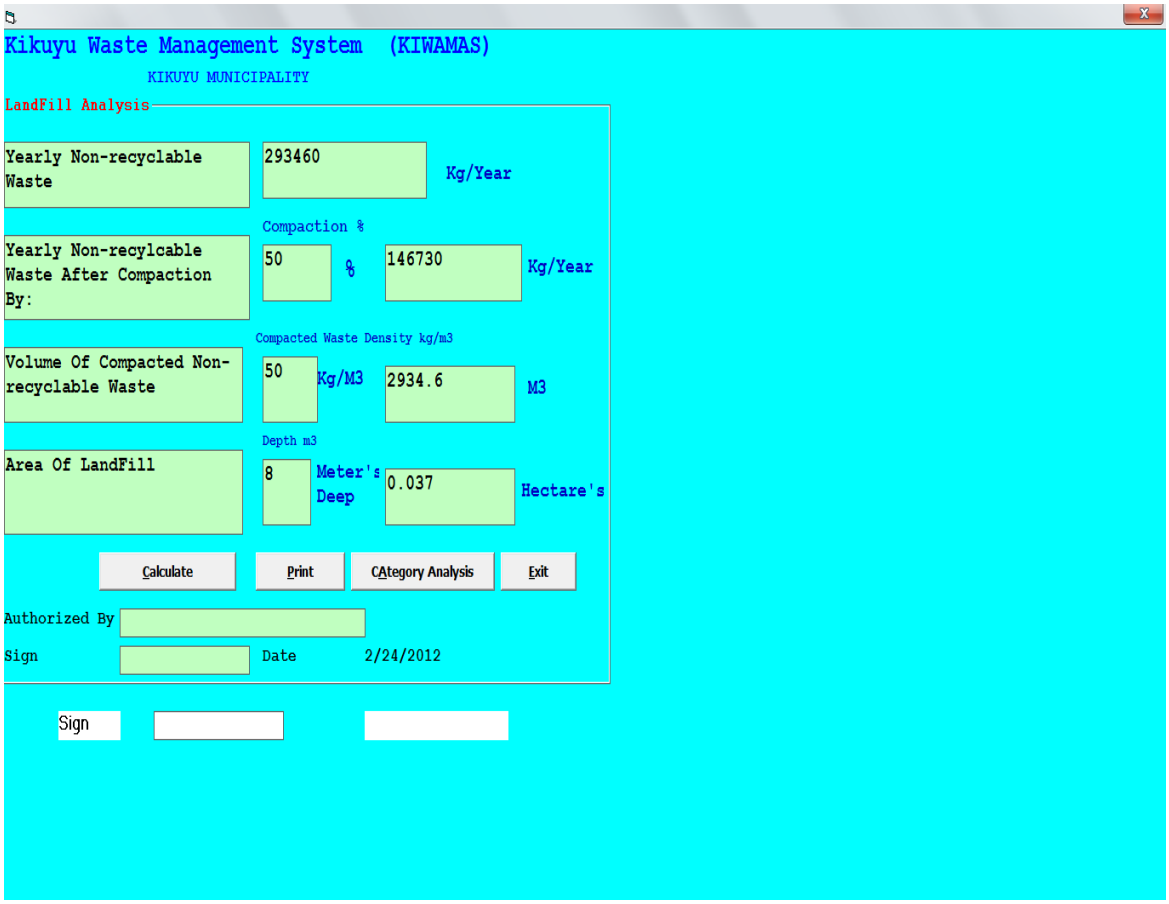


Figure 4.19: P**rint screen from the system showing how the landfill is calculated.**

4.23.5 Category Analysis

Category analysis shows the total waste of each category in particular both recyclable and non recyclable waste. It also shows the total off all recyclable from all the categories and non recyclable. The user can display the report of category recyclable waste per day, category for non recyclable waste per day, classes, recyclable and non recyclable waste in a graph. To do this right click and select.

.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

This research provides an assessment of the existing solid waste management system in the Kikuyu municipal area, including a review of the proposed solid waste management system. Analysis based on the key factors, such as waste generation, waste disposal practices, waste collection and transportation, changing nature of waste etc. shows that the current solid waste management system (both existing and proposed) is unsustainable in the long run. The proposed system is an improvement upon the existing system and has much strength, but it does not address the whole issue. The municipal council has initiated a process of solid waste management change that has the ability to develop over time. The municipal council is open to new ideas. General conclusions that relate to the study objectives are detailed below.

Among the many factors influencing solid waste management, five key factors were identified:

1) Decision making process;

2) Public perception of the waste problem;

3) Lack of transparency and information sharing;

4) Relationship between political stability and governance,

5) Self-organized grass roots level organizations.

It was found that basically, decision making is top-down and bureaucratic. There is a gap between decision makers and the people in terms of information transformation. Most of the people are not informed about the decision undertaken by the authorities. People in general are not aware of the decisions made and the municipality does not

involve public for discussion or consultation. It results in the majority of the executed plans failing due to the lack of public support and participation. It was further observed that even though many people regard wastes as a threat, very few people regard waste as a priority problem. In addition, it was found that the plans and processes initiated by one set of people in power are often abandoned mid-way if a new set of people come in power. Finally it was observed that the grassroots level organizations such as Green Loop have the potential to influence the solid waste management in a positive manner by involving and ensuring public participation in solid waste management system and the decision making process.

The sustainability of any solid waste management system depends on numerous factors; however, the most important factor is the will of the people to change the existing system and develop something better. People in the Kikuyu municipal area in general are willing to contribute positively and participate in a solid waste management system. The Kikuyu municipality seems open to ideas and opinions. Given this background, recommendations for development of a sustainable solid waste management system are as follows.

Integrated development plan that should guide present and future developments should be established that improves waste management and minimization.

The Kikuyu municipality needs to set targets and goals in terms of what it wants to achieve in the future. A realistic proposition would be to set a target of diverting at the least 15% of waste each year from going to the dumping site. A goal of ensuring maximum possible diversion may be set to be achieved within five years. In terms of recyclables, targets should be set to improve collection and recovery of recycling

materials, involvement of informal sector in recovery of recyclables should be achieved within first two years.

Littering in all forms should be discouraged, and people who litter should be made liable for legal action. Education, awareness and information sharing regarding solid waste issues, should be made a priority. People should be made a part of the solution. Certain indicators should be developed to monitor the progress. For instance, no plastic bottles being thrown in the garbage could be an indicator of success in terms of recovering recyclables. The Kikuyu municipality should set a target town, i.e. a town it may want to look like in next five or ten years.

Final Thoughts

Following the understanding of the socio-cultural and geo-political setting of the area, along with the understanding of the strengths, weaknesses and problems associated with current waste management system and practices recommendations were made based on the finding of the study. These recommendations have the potential to make the solid waste management system in Kikuyu, more sustainable in the future.

This research endeavors to include a holistic view of the solid waste management situation in Kikuyu. Prior to this study, no research or studies had been carried out in terms of the solid waste management system in the Kikuyu municipality; this study has partially filled that gap. However, a complete study of the problem including geographical, hydrological, environmental and socio-economic factors could help in providing new avenues for knowledge generation. Thus a complete interdisciplinary

study undertaken with the help of GIS and satellite mapping technology will help further understand the problem and solutions.

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APPENDICES

Appendix I: Questionnaire - Household

Thank you for your input. The information that you provide will be used for research purposes only

SECTION A:

1. How often do you generate these wastes? Please enter a symbol in the appropriate space(√ or ×)

WASTE TYPE	**RATE OF GENERATION**		
	Not often	often	Very often
Organic (farm, yard, kitchen, garden)			
Recyclables (plastics, papers, cans)			
Non-recyclables(electronics,)			
Hazardous wastes (batteries, agrocides, used oil, paint, solvents, expired drugs)			

2. How do you dispose of these wastes?

WASTE TYPE	**MODE OF DISPOSAL**			
	Trash bin	Farm yard	Dumpsite	Other (specify)
Organic (farm, kitchen, garden)				
Recyclables (plastics, papers, cans)				
Non-recyclables(electronics,				
Hazardous waste(batteries, agrocides, used oil, paint solvents)				

3. Are the modes of disposal listed in (2) above effective or not in any way, how?

……

……

……

4. What solid waste services, if any, would you like to be made available to you?

……

……

……

What measures, if any, do you take to reduce the volume of solid waste your household produce?

……

……

……

5. Are there any cases of illegal dumping you have noticed in your neighbourhood or at any specific locations within Kikuyu Municipality? If so identify these specific locations?

   ……

   ……

   ……

6. Do you know what recycling is?

   a) Yes

   b) No

7. If yes, do you participate in a recycling programme at home, how?

   ……

   ……

   ……

8. Please share any additional comments**,** concerns or suggestions you may have regarding solid waste in Kikuyu Municipality

   ……

   ……

   ……

Appendix II: Survey Questionnaire for Hospital Waste Management

My name is Engineer Ken Mugo Kamumbu, a student at JKUAT. I am carrying out an evaluation for a solid waste management in fulfillment of MSC degree in ELM in Kikuyu town council and I will be very much appreciate if you participate in this survey by providing answers to some issues on solid waste management. This information is for academic purposes but it is expected to assist in the town council to understand the management of waste and ways the council to adopt to improve the management of waste.

The information you provide will be treated in strict confidence it deserves. Participation in this survey is voluntary and you can choose not to answer any individual questions or all the questions. However, I hope that you will participate in this survey since your views are important. At this time, if you have any question regarding the survey, feel free to ask me.

Name ……. Signature……..

Reg no……

1. Hospital (name, location)

……

……

……

2. Type of hospital (tick one): Specialist

General/Referal	
University (training/provincial)	
Regional	
District	
Sub-district	

3. No. of inpatients: _____/day No. of outpatients: _____/day

4. No. of beds (total): _____/day

5. **Waste category**

Type of solid waste produced and estimated quantity (Consult classification and mark X where waste is produced)

sources	**General**	**Pathological**	**Radioactive**	**Chemical**	**Infectious**	**Pharmaceutical**	**Sharps**	**Pressurized containers**	**Est. quantity, Kg/day**
Patient services									
Medical									

Surgical									
Operating theatre									
Recovery /intensive									
care									
Isolation ward									
Dialysis unit									
Oncology unit									
Emergency									
Outpatient clinic									
Autopsy room									
Radiology									
Laboratories									
Biochemistry									

Microbiology									
Hematology									
Research									
Pathology									
Nuclear medicine									
Support services									
Blood bank									
Pharmacy									
Central sterile supply									
Laundry									
Kitchen									
Engineering									
Administration									
Public									

areas									
Long-term health care									
Patient services									

6. Waste segregation, collection, storage, and handling

Describe briefly what happens between segregation (if any) and final disposal of:

Sharps _____

Pathological waste _____

Infectious waste _____

Radioactive waste _____

Chemical waste _____

Pharmaceutical waste _____

Pressurized containers _____

7. Waste segregation, collection, storage, and handling

Handling of segregated waste Sharps Pathological	**waste**	**Infectious**	**Waste**	**Radioactive**	**waste**	**Chemical waste Pharmaceutical**	**waste**
Indicate by X the type of waste (in any) that is segregated from general waste stream							
Where is the segregation taking place (i.e. operating room, laboratory, etc.)?							
What type of containers/bags (primary containment							

vessels) are used to segregate waste (bags, cardboard boxes, plastic containers, metal containers, etc.)? Describe accurately.							
What type of labeling, colour-coding (if any) is used for marking segregated waste? Describe.							
1Who handles (removes) the segregated waste							

(Designation of the hospital staff member)? 2. Is the waste handler using any protective clothing (gloves, etc.) during waste handling? Yes/No.							
What type of containers (plastic bins, bags, cardboard boxes, trolleys, wheelbarrows, etc.) is used for collection and internal transport of the waste?							

Describe							
Where is the segregated waste stored while awaiting removal from the hospital or disposal? Describe							
Describe briefly the final disposal of segregated waste (Taken to municipal landfill, buried on hospital grounds, incinerated, open burned, etc.).							

8. Personnel involved in the management of hospital solid waste

(a) Designation of person (s) responsible for organization and management of waste collection, handling, storage, and disposal at the hospital administration level

_____

_____

(b) General qualification and level of education of designated person.

_____

_____

(c) Has he/she received any training on hospital waste management?

Yes ☐ No ☐

9. Indicate the number of persons involved in the collection, handling and storage of hospital waste, their designation, their training in solid waste handling and management, and the number of years of experience of this type of work.

Number	Designation	Training	Experience

10. Does the waste management staff have job descriptions detailing their tasks?

11. Are instructions/training given to newly hired waste management staff?

Yes
No

12. Hospital waste management policy

13. Are you aware of any legislation application to hospital waste management?

Yes
No

If yes, please list the legislative acts:

_____

_____

14. Are you aware of a document outlining the hospital waste management policy?

Yes
No

If yes, give title of document (and attach a copy if possible):

_____

_____

15. Is there a manual or guideline document on management of hospital wastes available?

(a) In the Ministry of Health?

Yes
No

If yes, give a title of document:

_____

_____

(b) In your hospital?

Yes
No

If yes, give a title of document:

_____

_____

16. Does your hospital have a Waste Management Plan?

Yes
No

If yes, please attach a copy.

17. Does your hospital have a Waste Management Team (or Teams)?

Yes
No

If yes, please list the members by designation:

Designation No:_____

Team leader: _____

Team members: _____

Waste handling staff: _____

18. Are there clearly defined procedures for collection and handling of wastes from specified units in the hospital?

Yes
No

19. Are there waste management responsibilities included in the job descriptions of hospital supervisory staff (Head of Hospital, Department Heads, Matron/Senior Nursing Officer, Hospital Engineer, Infection Control Officer, Pharmacist, Laboratory Supervisor, etc.)?

Yes
No

If yes, provide sample copies.

20. How are the present waste collection, handling, and disposal responsibilities defined in the job descriptions of the staff involved? (Cite appropriate statement or provide copies).

_____

_____

_____

Appendix III: *Questionnaire for Commercial Enterprises*

(Shops, Markets, recreational facilities)

My name is Engineer Ken Mugo Kamumbu a student at JKUAT. I am carrying out an evaluation for a solid waste management in fulfillment of MSC degree in ELM in Kikuyu town council and I will very much appreciate if you participate in this survey by providing answers to some issues on solid waste management. This information is for academic purposes but it is expected to assist in the town council to understand the management of waste and ways the council to adopt to improve the management of waste.

The information you provide will be treated in strict confidence it deserves. Participation in this survey is voluntary and you can choose not to answer any individual questions or all the questions. However, I hope that you will participate in this survey since your views are important.

At this time, if you have any question regarding the survey, feel free to ask me.

Name ……. Signature……..

Reg no……

1. Which are the main types of solid waste generated by this enterprise?

   ……

   ……

   ……

2. Make a general estimation of the volume of solid waste generated in a working day?

   ……..

3. How do you manage/dispose off these wastes?

Mode of disposal	**(√ or ×)**
Trash bin	
Dumpsite	
Farm	
Burning	
Other (specify)	

4. According to you, is this the most appropriate way of managing these wastes, why? …….
5. Are there any particular problems you encounter while managing the wastes?

   ……

   ……

6. What solid waste services, if any, would you like to be made available to you?

   ……

   ……

7. To what extend has your enterprise employed the five Rs; recycle, reuse, reduce, refuse (to use products that create non-biodegradable solid waste) and

rethink (alternative processes or inputs that will reduce solid waste production)?

……

……

8. Is there any economic instrument, policy measures or regulation in place on solid waste management?

……

……

……

9. Does the solid waste generated by this industry contribute to the nuisance caused by poorly managed wastes in Kikuyu municipality?

……

……

10. Please share any additional comments, concerns or suggestions you may have regarding solid waste in Kikuyu Municipality

……

……

……

Appendix IV: *Questionnaire: Institutional wastes*

(Material originating from schools, hospitals, prisons, research institutions, and other public buildings).

My name is Engineer Ken Mugo Kamumbu a student at JKUAT. I am carrying out an evaluation for a solid waste management in fulfillment of MSC degree in ELM in Kikuyu town council and I will very much appreciate if you participate in this survey by providing answers to some issues on solid waste management. This information is for academic purposes but it is expected to assist in the town council to understand the management of waste and ways the council to adopt to improve the management of waste.

The information you provide will be treated in strict confidence it deserves. Participation in this survey is voluntary and you can choose not to answer any individual questions or all the questions. However, I hope that you will participate in this survey since your views are important.

At this time, if you have any question regarding the survey, feel free to ask me.

Name ……. Signature……..

Reg no……

1. How often does your institution generate these wastes?

   (√ or ×)

WASTE TYPE	**RATE OF GENERATION**		
	Not often	often	Very often
Organic (farm, yard, kitchen, garden)			
Recyclables (plastics, papers, cans)			
Non-recyclables(electronics,)			
Hazardous wastes (batteries, agrocides, used oil, paint, solvents, expired drugs)			

2. How do you dispose of these wastes?

WASTE TYPE	**MODE OF DISPOSAL**				
	Trash bin	**Dumpsite**	**Farm yard**	**Incinerating**	**Other (specify)**
Organic (farm, yard, kitchen, garden)					
Recyclables (plastics, papers, cans)					
Non-recyclables(electronics)					
Hazardous wastes (batteries, agrocides, used oil, paint, solvents, expired drugs)					

3. Are these modes of solid waste disposal effective for your institution or not, how?

……

……

……

4. Make a general estimation of the volume of net solid waste generated from the institution in a day?

……

…..……..……

……

5. Are there any particular problems the institution faces while managing the wastes?

…….....

.....

.....

6. What solid waste services, if any, would you like to be made available to you?

…….....

.....

To what extent has your Waste management programme emphasized on job creation, poverty alleviation and community participation?

.....…….....

.....

.....

7. Does this institution have any policies meant to promote efficiency in the use of resources, emphasizing on waste prevention and the productive use of wastes?

   .....

   .....

   .....

8. Is there any notable rural-urban alliance in as much as solid waste management of this institution is concerned?

   .....

   .....

   .....

9. To what extent has the attitude and habits of individuals of the institution supported or frustrated proper solid waste management?

   .....

   .....

10. Describe any waste management concern your institution has noted in the larger Kikuyu municipality.

    .....

    .....

    .....

Appendix V: Questionnaire for industries:

My name is Engineer Ken Mugo Kamumbu a student at JKUAT. I am carrying out an evaluation for a solid waste management in fulfillment of MSC degree in ELM in Kikuyu town council and I will very much appreciate if you participate in this survey by providing answers to some issues on solid waste management. This information is for academic purposes but it is expected to assist in the town council to understand the management of waste and ways the council to adopt to improve the management of waste.

The information you provide will be treated in strict confidence it deserves. Participation in this survey is voluntary and you can choose not to answer any individual questions or all the questions. However, I hope that you will participate in this survey since your views are important.

At this time, if you have any question regarding the survey, feel free to ask me.

Name ……. Signature……..

Reg no……

1. Which are the main categories of solid waste generated by this industry?

   ……

   …..……...……

   ……

2. Make a general estimation of the volume of solid waste generated by the industry in a day?

   ……

   ….……

3. How is the solid waste managed?

   ……

   ……..……..……

   ……..…..

4. Are there any particular problems the industry faces while managing the wastes?

   ……

   …..……..

5. How effective is the industry's mode of solid waste management in terms of costs and its efficiency in totally dealing with the generated waste?

   ……..……

   ……..……

6. Are there any technological solutions you have employed to deal with the solid waste generated?

   ……..…….

   ……

7. Are there any processes or technologies incorporated in the production process to reduce solid waste generation?

   ……

   ……

   ……

8. What solid waste management issues does your industry regard with most importance? (Reducing wastes, recycling, incorporating technologies?)

   ……

   …..……..……

   ……..…..

9. Any economic instruments, policies measures or regulation explicit or implicit, local or national, governing waste management in the industry?

   ……

   …..……..……

   ……...…..

10. To what extend does the industry practice the five Rs; recycle, reuse, reduce, refuse (to use products that create non-biodegradable solid waste) and rethink (alternative processes or inputs that will reduce solid waste production)?

……

……

……

11. Does the solid waste generated by this industry contribute to the nuisance caused by poorly managed wastes in Kikuyu municipality?

12. Please share any additional comments**,** concerns or suggestions you may have regarding solid waste in Kikuyu Municipality

……

……

……

Appendix VI: Area report codes

```
Option Explicit
Dim mydb As Database
Dim rstpass As Recordset
Dim rstcust As Recordset

Private Sub Command1_Click()
If txtwhat.Text = "area" Then
Else
rstkenya.MoveFirst
txtvalue.Text = rstkenya.Fields("size")
& "  " & "hectares"
"
bln = False
start
Exit Sub
Else
rstkenya.MoveFirst
txtvalue.Text =
rstkenya.Fields("population") & "  " &
"Millions"
lblkenya.Caption = "Total Population"
End If
Loop
End If
```

CATEGORIES CODES

```
Option Explicit
Dim mydb As Database
Dim rstcust As Recordset
Dim rstfinal As Recordset
Dim rst As Recordset
Dim num, cat As ListItem
Dim no, l As Long
Private Sub cmdcancel_Click()
Unload Me
End Sub
rstfinal.MoveFirst
Do While Not rstfinal.EOF
If rstfinal.Fields("code") = txtcat.Text
Then
MsgBox "Check your licence number"
assigncat
Exit Sub
Else
```

```
num.SubItems(1) =
rstcust.Fields("code")
num.SubItems(2) =
rstcust.Fields("name")
rstcust.MoveNext
no = no + 1
If rstcust.EOF Then
ListView1.Enabled = True
fillcategory
cleartextboxes
txtcategory.Text = txtcode.Text & "/"
&
ListView2.SelectedItem.ListSubItems(
1)
txtcat.SetFocus
End If
cancel:
End Sub
Private Sub cleartextboxes()
txtcat.Text = ""
txtcatname.Text = ""
txtpopulation.Text = ""
End Sub
Private Sub txtpopulation_Change()
If Not IsNumeric(txtpopulation.Text)
Then
txtpopulation.Text = ""
txtpopulation.SetFocus
Exit Sub
End If
End Sub
```

COUNTIES ANALYSIS

```
Option Explicit
Dim mydb As Database
Dim rst As Recordset
Dim rstcust As Recordset
Dim rstpass As Recordset
Dim num, cat, pass As ListItem
.txtpath.Text = txtpath.Text
.txtwhat.Text = "area"
.lblme.Caption = "County's
Area(Hectares) Comparison Report"
.MSChart1.Title.Text = "Graph of
County's Area Against Country Area"
.MSChart1.Title.VtFont.size = 16
.MSChart1.Title.VtFont.VtColor.Blue
= True
frmareareport.Show
```

```
End With
Exit Sub
End If
End Sub

With frmdisplaycategory
.txtpath.Text = txtpath.Text
.txtfrom.Text = txtfrom.Text
.txtto.Text = txtto.Text
frmdisplaycategory.Show
End With
End If
End Sub

Private Sub cmdpass_Click()
If rstpass.BOF = True And
rstpass.EOF = True Then
rstpass.AddNew
rstpass.Fields("code") = txtcode.Text
rstpass.Fields("name") = txtname.Text
rstpass.Update
fillpass
Exit Sub
Else
rstpass.MoveFirst
Private Sub fillpass()
ListView3.ListItems.Clear
If rstpass.BOF = True And
rstpass.EOF = True Then
ListView3.Enabled = False
Exit Sub
Else
rstpass.MoveFirst
passno = 1
Do While Not rstpass.EOF
Set pass = ListView3.ListItems.Add(, ,
passno)
pass.SubItems(1) =
rstpass.Fields("code")
pass.SubItems(2) =
rstpass.Fields("name")
passno = passno + 1
rstpass.MoveNext
If rstpass.EOF Then
ListView3.Enabled = True
Exit Sub
End If
Loop
```

```
Private Sub cmdreset_Click()
txtfrom.Text = ""
Text1.Text = ""
txtto.Text = ""
Text2.Text = ""
End Sub

Private Sub Form_Activate()
Set mydb =
OpenDatabase(txtpath.Text)
Set rst =
mydb.OpenRecordset("county")
Set rstcust =
mydb.OpenRecordset("class details")
Set rstpass =
mydb.OpenRecordset("passone")
Option1.Value = True
cmdnext.Enabled = True
deletepassone
txtfrom.Text = ""
txtto.Text = ""
ListView1.ListItems.Clear
ListView3.ListItems.Clear
fillcounty
filldate
rstpass.MoveNext
If rstpass.EOF Then
cmdnext.Enabled = False
Exit Sub
Else
l = 1
rst.MoveFirst
Do While Not rst.EOF
Set num = ListView1.ListItems.Add(,
, l)
num.SubItems(1) = rst.Fields("code")
num.SubItems(2) = rst.Fields("name")
l = l + 1
rst.MoveNext
If rst.EOF Then
ListView1.Enabled = True
Exit Sub
End If
Loop
End If
End Sub
Private Sub ListView1_Click()
On Error GoTo cancel
```

```
Option1.Value = True
txtcode.Text =
ListView1.SelectedItem.ListSubItems(
1)
txtname.Text =
ListView1.SelectedItem.ListSubItems(
2)
txtwhat.Text = ""
cancel:
End Sub
Private Sub ListView2_Click()
On Error GoTo cancel
If rstpass.BOF = True And
rstpass.EOF = True Then
cmdall.Value = True
If txtfrom.Text = "" Then
txtfrom.Text =
ListView2.SelectedItem.ListSubItems(
1)
Text1.Text =
ListView2.SelectedItem.Index
Text2.Text = ""
txtto.Text = ""
cmdnext.Enabled = True
Else
Text2.Text =
ListView2.SelectedItem.Index
If Text1.Text > Text2.Text Then
MsgBox "Invalid selection"
txtfrom.Text = ""
Text1.Text = ""
Text2.Text = ""
txtto.Text = ""
Exit Sub
Else
txtto.Text =
ListView2.SelectedItem.ListSubItems(
1)
cmdnext.Enabled = True
End If
End If
Else
If txtfrom.Text = "" Then
txtfrom.Text =
ListView2.SelectedItem.ListSubItems(
1)
Text1.Text =
ListView2.SelectedItem.Index
```

```
Text2.Text = ""
txtto.Text = ""
cmdnext.Enabled = True
Else
Text2.Text =
ListView2.SelectedItem.Index
If Text1.Text > Text2.Text Then
cancel:
End Sub

Private Sub ListView3_Click()
On Error GoTo cancel
txtwhat.Text = ""
If rstpass.BOF = True And
rstpass.EOF = True Then
ListView3.Enabled = False
cmdnext.Enabled = False
Exit Sub
Else
txtno.Text =
ListView3.SelectedItem.ListSubItems(
1)
rstpass.MoveFirst
Do While Not rstpass.EOF
If rstpass.Fields("code") = txtno.Text
Then
rstpass.Delete
fillpass
Exit Sub
Else
rstpass.MoveNext
If rstpass.EOF Then
Exit Sub
End If
End If
Loop
End If
cancel:
End Sub
DISPLAY CATEGORIES CODES
Option Explicit
Dim mydb As Database
Private Sub cmdpopulation_Click()
If txtpopulation.Text = "" Then
MsgBox "You have not selected
county ,or population for that count
couldn't be found"
Exit Sub
```

```
Else
.txtto.Text = txtto.Text
.lblname.Caption = txtname.Text
frmpopulationgraph.Show
End With
End If
End Sub


Private Sub Form_Activate()
Set mydb =
OpenDatabase(txtpath.Text)
Set rstpass =
mydb.OpenRecordset("passone")
Set rst =
mydb.OpenRecordset("category")
Set rstcust =
mydb.OpenRecordset("category
details")
txtpopulation.Visible = False
txtpopulation.Text = ""
End Sub
Private Sub createfirstnode()
If rstpass.BOF = True And
rstpass.EOF = True Then
Exit Sub
Else
rstpass.MoveFirst
l = 1
Do While Not rstpass.EOF
Set tree = TreeView1.Nodes.Add(, , ,
l)
tree.Key = codeone
nameone = codeone
l = l + 1
setsubnodeone
rstpass.MoveNext
If rstpass.EOF Then

Exit Sub
End If
Loop
End If
End Sub
Private Sub setsubnodeone()
If rst.BOF = True And rst.EOF = True
Then
```

```
Exit Sub
Else
rst.MoveFirst
n = 1
Do While Not rst.EOF
Set one =
TreeView1.Nodes.Add(nameone,
tvwChild, , n)
one.Text = rst.Fields("name")
setsubnodetwo
rst.MoveNext
n = n + 1
If rst.EOF Then
Exit Sub
End If
Loop
End If
End Sub
Private Sub setsubnodetwo()
checkforentry
rstcust.MoveNext
If rstcust.EOF Then
Exit Sub
End If
Loop
End If
End Sub
Private Sub checkforentry()
If Left(rstcust.Fields("code"), size) =
codetwo Then
Set two =
TreeView1.Nodes.Add(nametwo,
tvwChild, , k)
two.Text = rstcust.Fields("name")
codethree = rstcust.Fields("code")
codethree = codethree & "/"
two.Key = codethree
k = k + 1
Exit Sub
End If
End Sub

If txtname.Left < Me.ScaleWidth
Then
change = change * -1
End If
End Sub
```

```
Private Sub TreeView1_Click()
On Error GoTo cancel
Text1.Text =
TreeView1.SelectedItem.Key
rstcust.MoveFirst
Do While Not rstcust.EOF
If rstcust.Fields("code") =
Left(Text1.Text, sizetwo - 1) Then
checkclass
Exit Sub
Else
rstcust.MoveNext
If rstcust.EOF Then
Exit Sub
End If
End If
Loop
End If
End Sub
Private Sub checkclass()
EOF
If Left(rstclass.Fields("code"),
sizetwo) = Text1.Text Then
With frmeach
.txtpath.Text = txtpath.Text
.txtcode.Text = Text1.Text
.txtfrom.Text = txtfrom.Text
.txtto.Text = txtto.Text
.lblname.Caption = txtname.Text
frmeach.Show
End With
Exit Sub
Else
rstclass.MoveNext
If rstclass.EOF Then
MsgBox "No Waste produced from"
& "  " & rstcust.Fields("name")
Exit Sub
End If
Exit Sub
Else
rstcounty.MoveFirst
Do While Not rstcounty.EOF
If Left(rstcounty.Fields("code"),
sizetwo - 1) = Left(Text1.Text,
sizetwo - 1) Then
lblpopulation.Visible = True
txtpopulation.Visible = True
```

```
txtpopulation.Text =
rstcounty.Fields("population")
Exit Sub
Else
rstcounty.MoveNext
If rstcounty.EOF Then
lblpopulation.Visible = False
txtpopulation.Visible = False
txtpopulation.Text = ""
```