"Urban solid waste management system using Geographic Information Systems (GIS): A case study of Kayole – Soweto, Nairobi."

By

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Declaration

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

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This Research report has been submitted for examination with our approval as University Supervisors.

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Acronyms

CBS	Central Bureau of Statistics
EAs	Enumeration Areas
EMCA	Environmental Management and Co-ordination Act
GIS	Geographical Information Systems
GOK	Government Of Kenya
GNP	Gross National Product
IT	Information Technology
KEMA	Kayole Environmental Management Agency
KCPE	Kenya Certificate of Primary Education
KCSE	Kenya Certificate of Secondary Education
LCDs	Least Developed Countries
MSW	Municipal Solid Waste
NCC	Nairobi City Council
NEAP	National Environment Action Plan
NGOs	Non Governmental Organization
UNCED	United Nations Conference on Environment and Development

Definition of terms

Solid waste – All the materials in solid state, arising from human and animal activities that are normally discarded as unwanted.

Savanna/Soweto – The two terms are used interchangeably. Soweto is a small section of the larger Savanna sub-location. The Soweto section borders the Kayole sub-location and the two forms a continuous estate occupied by people who are in the same social-economic class. They are regarded as informal settlement. The other part of the Savanna sub-location include the Donholm estate and is a formal settlement area.

Enumeration Area – Sections of land subdivided by the Central Bureau of statistics for the purpose of conducting the population census. Each EA was regarded as an entity and had its enumerators and their head.

Structures/Plots – A building used for purpose of business or any other activity such as dwelling. Each structure/plot could have several dwelling units each of which could be occupied by members of the same household.

Household – A person or a group of persons who live together in the same homestead/compound/plot who may be related and do things in common.

Abstract

The problem of solid waste is prevalent in Nairobi city in general, and is most acute in the low-income residential estates. It is mainly manifested in form of littering and illegal dumping in areas not designated for dumping, particularly in open, undeveloped plots. This kind of scenario poses an environmental problem as well as hazard to human health.

The objective of the research project was to search for a solution to the problem of urban solid waste management in low–income residential areas. To achieve this, the various types of wastes generated in the study area and their quantities were determined. This was done by actual activity of collecting and weighing waste from sampled households. The factors that interplay and affect management of solid waste and source-separation of waste were also investigated using questionnaires administered to sampled households. Emphasis was laid upon the identification of the appropriate destinations of the different types of wastes, with the aim of directing each type of waste to the right place for recycling, re-use or for composting. All these aided in the planning of an integrated solid waste management system.

The research revealed that organic waste was produced in large proportion (77.2%) and that most of the waste was compositable, recyclable and/or re-usable.

Once the waste types, quantities and destinations of the various wastes were determined, a spatial framework was designed using Geographical Information Systems (GIS). The factors that influence source separation of wastes helped in formulating policies that should be put in place to minimize the magnitude of the problem.

CHAPTER 1

1.0 INTRODUCTION

As far back as 8000 to 9000 BC, people learned to dispose of their waste outside their settlement, to escape or avoid the nuisance of vermin, odour and wild animals (Tchobanoglous, et al, 1993). In antiquity, in many cities in Europe and Asia, waste was collected in clay containers and hauled away. In many other areas, pits were used to collect waste and faeces, which were emptied and cleaned periodically. There are records of regulations (Athens, 320 BC) for the daily sweeping of the streets by residents. Waste haulers were required to move the waste at least 2 km beyond the city wall (Tchobanoglous, et al, 1993). Physicians, like the Greek Scholar Hippocrates (around 400 BC), and the Arab Avicenna (Ibn Sina, 1000 AD), were the first to suspect the link between hygiene, contaminated water, spoiled food and epidemics. The Roman Emperor Domitian (81-96 AD) ordered pest control since his advisors realized that a lack of cleanliness in the city was associated with an increase in the population of rats, lice, bedbugs, *et cetera*.

With increasing population, conglomeration in the urban areas and the increasing industrialization, the quantity of waste has increased immensely. Waste may be generated in the form of solids, sludge, liquids, gases, and any combination thereof. Depending on the source of generation, some of the waste may degrade into harmless products whereas others may be non degradable and hazardous.

Solid waste comprises of all the wastes arising from human and animal activities that are normally discarded as unwanted. The term solid waste is all-inclusive, encompassing the heterogeneous accumulation of domestic, agricultural, industrial and mineral wastes. Disposal of solid waste is a worldwide problem. Inadequately managed waste disposal has the potential to affect the health of the people, damage/degrade the environment and be a barrier to economic development. This necessitates the development of sustainable solid waste management systems.

Cities are centers of production and consumption, and generate vast quantities of solid wastes. Few urban inhabitants, other than those who live in close proximity to waste disposal sites, realize how much waste is generated, or that solid waste collection and disposal are often one of the largest municipal expenditures.

Policies to reduce waste disposal could lead to improved environmental conditions for three main reasons: First, the problem associated with waste disposal sites would be vastly reduced, including their location and the leaching of dangerous pollutants into the ground and water tables. Secondly, an integrated approach to waste management implies the reduction of waste at source, including packaging material and a concerted effort towards re-use and recycling. Thirdly, most waste products are potentially inputs for other industries known as "zero emission production" or "closing the production loop". Such policies have so far been promoted only in a few countries but they constitute a viable alternatives for many cities that struggles with the increasingly politically intractable issue of finding a land fill site in someone else's backyard (Luis and Clarence 1985).

In cities of the south, the waste stream is not only smaller in per capita terms than in the wealthier cities of the North, but made up of a larger proportion of organic waste (Adriana, et al, 2002). Although municipal recycling system are becoming more common in the south, much of the recoverable waste is already being collected by informal recyclers, providing a significant source of employment.

The management of urban solid wastes in Nairobi city is a problematic affair. The city is quite untidy, and particularly the low-income residential estates. There are heaps of wastes all over, signifying lack of proper planning. Open spaces have been turned into dumpsites. There is only one dumpsite located in Dandora and all wastes from all over the city are destined there.

The collection and transportation system of the Nairobi City Council (hereafter, NCC) has almost collapsed, or non-existing in some areas, compounding the problem. Most of the estates are not served with the garbage collection services, leading to the

accumulation of solid wastes in places not designated for dumping. There is therefore need to search for a solution to this problem.

This study was undertaken to develop a waste management system on locational basis, using Geographical Information Systems (hereafter, GIS). Kayole and Soweto sub locations/estates in Embakasi division were considered as the case study.

1.1. Background

The problem of wastes is one among the major global environmental issues that the international community is working to resolve. Environmental degradation proceeded at an alarming rate and had threatened the well being of the human race. This had not been realized until the 1972 Stockholm conference on human environment. This marked a departure from the previous trend where each nation dealt with its own matters including those of environment. In this conference, it was agreed that environmental matters observes no boundary and hence calls for a global approach.

20 years later, another international conference was held in Rio De Janeiro, Brazil in 1992. The conference, titled the "Earth Summit" or United Nations Conference on Environment and Development (UNCED) came up with a policy framework for development in the 21st century. This is the Agenda 21, a far-reaching document in environmental protection.

In Agenda 21, chapter 21 entitled "Environmentally sound management of solid wastes and sewerage-related issues" stipulates what to be done towards the solution of solid wastes and sewage-related problems. Solid wastes, as defined in this chapter, include all domestic refuse and non-hazardous wastes such as commercial and institutional wastes, street sweepings and construction debris.

With regard to solid wastes, the chapter retaliate that environmentally sound waste management must go beyond the mere safe disposal or recovery of wastes that are generated and seek to address the root cause of the problem by attempting to change unsustainable patterns of production and consumption. This implies the application of the

integrated life cycle management concept, to reconcile development and environmental protection. Four major waste - related programme areas have been earmarked for action. These areas are; minimizing wastes, maximizing environmentally sound waste re-use and recycling, promoting environmentally sound waste disposal treatment, and extending waste service coverage.

The four programme areas are interrelated and mutually supportive and must therefore be integrated in order to provide a comprehensive and environmentally responsive framework for managing municipal solid wastes. The mix and emphasis given to each of the four programme areas will vary according to the local socio-economic and physical conditions, rates of waste generation and waste composition.

The Agenda 21 binds the member countries that have ratified and signed it to strive and implement the recommendations. It is upon the member countries to nationalize the Agenda 21. Toward this end, Kenya is on the track, and attempts are being made for the implementation. The National Environment Action Plan (NEAP) gives guidance on matters of environmental protection in general and on dealing with solid waste in particular. In the Environmental management and co-ordination Act of 1999 (EMCA 1999), section 86, 87, 88, 89, and 90 deals with matters of wastes, i.e. standards of wastes, prohibition against dangerous handling and disposal of wastes, application for waste license, licenses for existing wastes disposal sites and plants, and court orders to cease operation. This is a legal document that binds all the players in solid waste management, and those who produce the wastes.

In the National Development Plan of 2002 – 2008, it is acknowledged that most local authorities have been unable to cope with the collection, treatment and disposal of wastes due to inadequate capacity and financial constraints. For instance, Nairobi City produces about 1000 tones per day of solid wastes, of which only 20% of the waste is collected and taken to the approved dumpsite (National Development Plan of 2002 – 2008). This is a clear evidence of the magnitude of the problem of solid waste in Kenya and how urgent measures are required to safeguard the environment and protect the health of the public.

Therefore with regard to solid wastes, and in accordance to fulfilling our national responsibility towards the international commitment to protect the environment and for us as a country to implement the two important environmental strategy documents, i.e. NEAP and EMCA, 1999, it is very important to develop an integrated solid waste management system.

Solid wastes in urban areas are grouped into two broad classification; domestic and commercial-industrial wastes. The research concentrated on the domestic waste, as the study area was mainly residential. Domestic wastes become most offensive and dangerous to human health compared to other types of wastes when not properly disposed of. Domestic wastes consist of refused vegetables, peels from fruits, potatoes, bananas, food leftovers, papers, bones, glass, metal tins, chinaware, iron metal, dilapidated furniture, discarded household goods among others. The composition of domestic wastes varies from one area to another, depending on the resident's social-economic level and living standards; the higher the level, the greater the volume and the variety of solid wastes generated per person per day. This necessitates waste stream analysis and characterization when planning for a management system for an area. Thus, the study undertook to analyze the waste stream, to know the types and amounts of the wastes produced.

With increasing population and rising standards of living, the problem of solid waste disposal is bound to rise. There are increased cases of uncollected refuse and a lot of littering in the study area, ***(see photographs, figures 1.1 and 1.2)***. The problem is exacerbated by the fact that the city council's department responsible for the collection and disposal of solid wastes has failed in its duty. Other factors that have compounded the problem in Nairobi in general, and in the study area in particular include; The Anti – littering by-laws of the City of Nairobi (General Nuisance By- laws 1961) are not sufficiently enforced, the penalties of specific littering are often not specific or clear enough, people are unconcerned with the beautification of the environment, there are too few or no litter baskets in the estates and finally, many commodities are increasingly being bought in disposable packages (Mwaura, 1991).

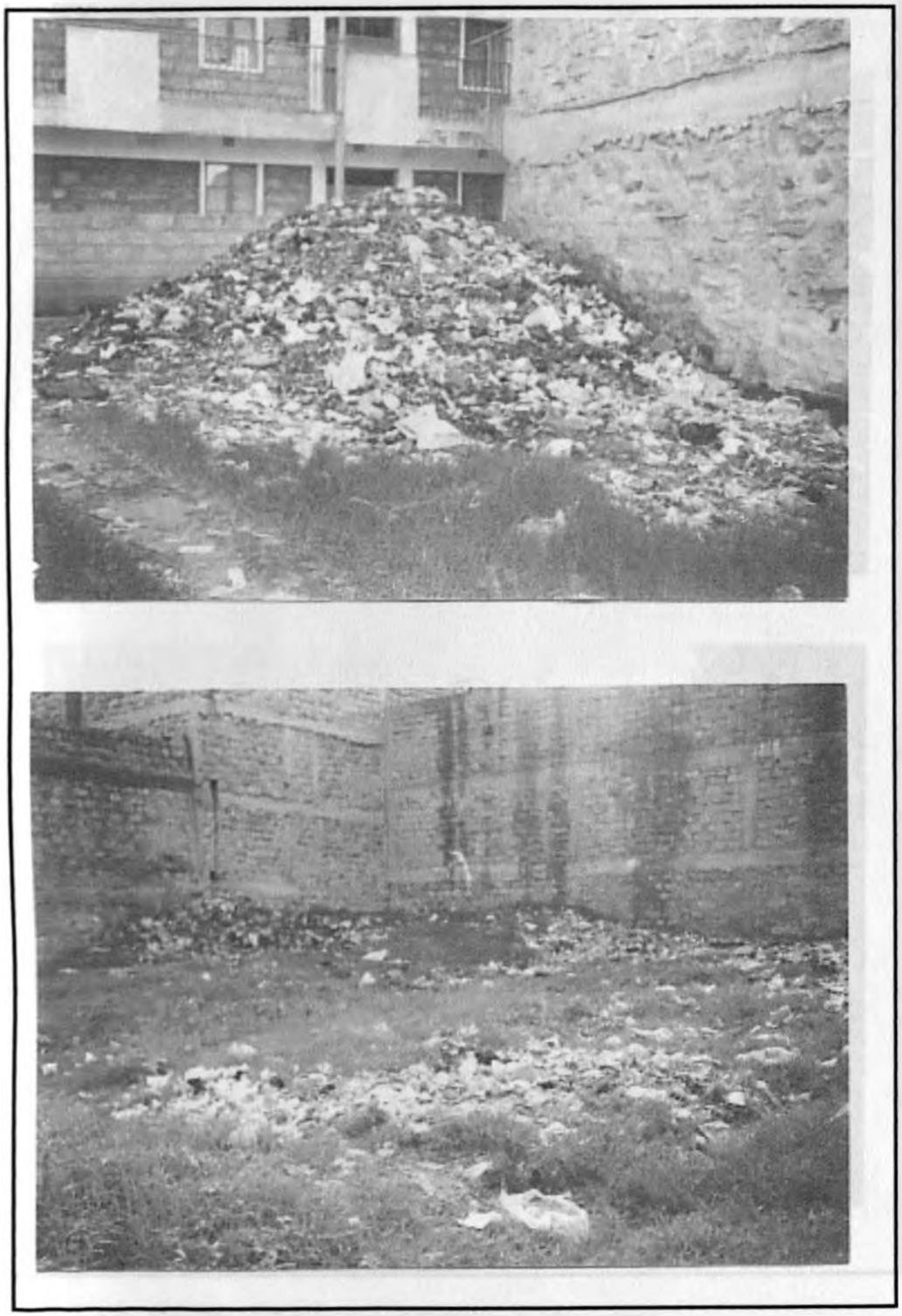


Figure 1.1: Uncollected refuse and littering in the estate.

Source: Field Observation, 2003.

Figure 1.2: Uncollected refuse and littering in the estate.

Source: Field Observation.

Through observation made in the study area, it was noted that there was a lot of littering and dumping in open spaces, mainly on privately owned plots that have not been developed by the owners. This is illustrated on the photographs in ***figure1. 3 and 1. 4.***

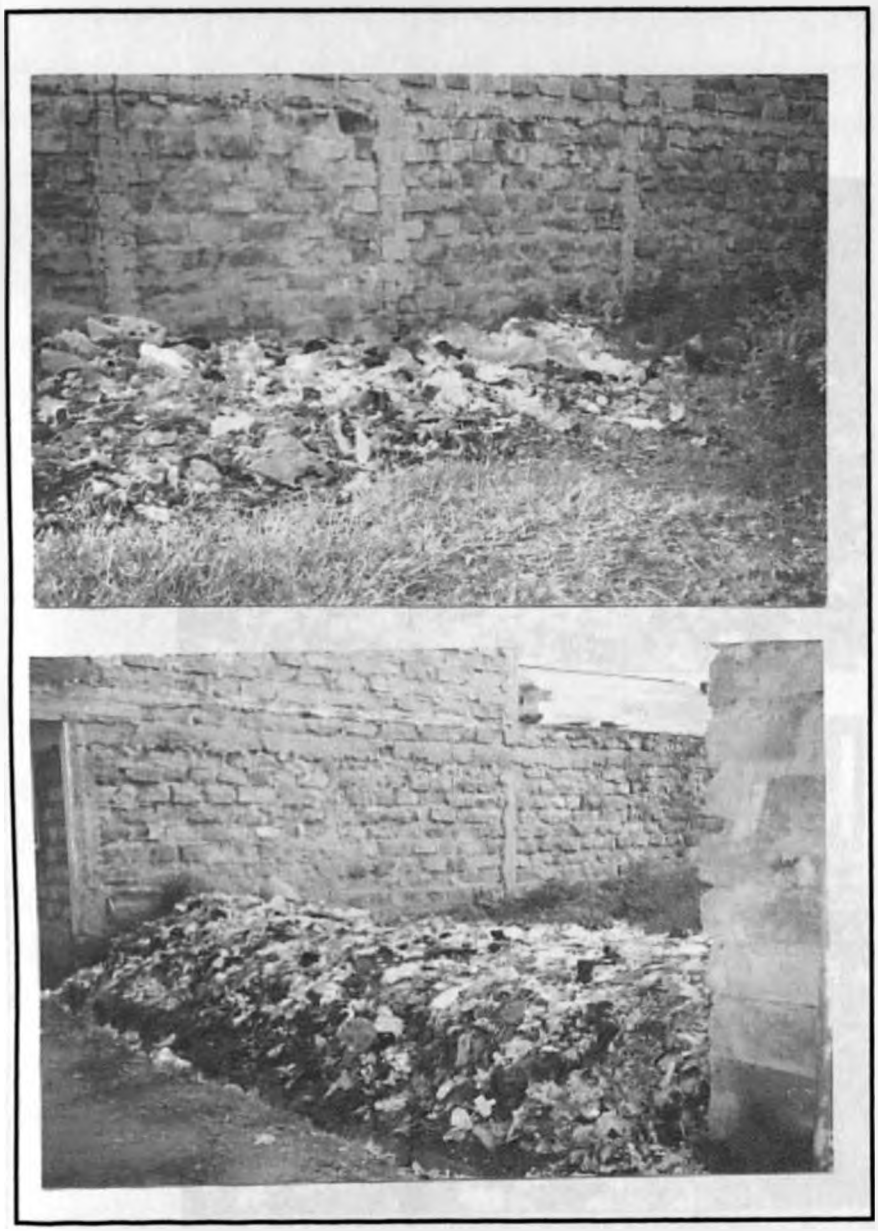


Figure 1.3: Dumping on open spaces and undeveloped plots.

Source: Field Observation, 2003.

Figure 1.4: Dumping on open spaces and undeveloped plots.

Source: Field Observation, 2003.

Most of the wastes are recyclable, e.g. paper, metal cans, bottles, and sheet metals. Others can be composted (especially the organic matter such as food left over, fruits peelings, vegetable wastes and other putrucibles). Compost manure so formed can be used to enrich soil for increased agricultural productivity. The composting is particularly important in the study area due to the existence of a project being undertaken by scientists from the University of Nairobi, at Muungano women group site at Soweto area. The project is utilizing certain species of earthworm to vermin-compost organic waste, turning it into very valuable manure that can be sold to farmers, particularly the organic farmers. Therefore, it is evident that if the waste produced in the study area can be sorted, and each type of sorted material directed to the right place (for recycling or for composting), there could be no problem of solid waste in the area. The process can be adopted in other areas of the city in order to manage the urban solid wastes in a sustainable manner. It is for this reason that the study aimed at developing an integrated solid waste management system that would see the waste was separated at the source and each type of waste directed to the rightful processing point.

1.2. Statement of the problem

The disposal of rejects of once useful products, for instance, waste papers, metal tins, plastics of all kind, fruit peels, food left-overs, vegetable wastes, rags and other forms, occurs practically everywhere; on the streets, open spaces, parks, and open drainage. Getting rid of solid waste has become a serious post – industrial problem, because such wastes pollutes not only the environment but also the ground water resources as well.

There has been a problem in the management of solid waste in the city of Nairobi and particularly in the low-income residential areas. There are heaps of wastes all over, making the places quite untidy. Of particular interest to this study was Kayole and Soweto/Savvanah estates of Embakasi division (the study area), where the problem seem to be of high magnitude due to the fact that these areas are not served with waste collection services by the NCC and that there is no legal dumpsite in the vicinity. Private firms provide the waste collection services for a fee, but not all parts are covered due to lack of proper planning and lack of willingness by some residents to pay for the service.

There is also the question of where the private firms dispose of the wastes, once they collect it from the residents.

In the study area, there are sites that do recycling and composting, whereas others concentrate on material recovery. The effectiveness of these sites is usually hampered by waste handling logistics that need to be solved first.

This research project therefore investigated the logistics involved in dealing with the solid wastes from the source, until the waste reaches the "processing" site. The processing site in this study is considered as the place where waste can be recycled or can be composted.

The research project attempted to answer the following research questions:

- What are the types of wastes produced in the study area and what are the amounts produced?
- What proportion of the waste is recyclable or compostable?
- How can the various waste materials be directed to the appropriate site for recycling or composting?
- Are people willing to separate their waste at the source?
- What are the factors that influence source separation of wastes?
- What distance are people willing to walk to deposit their wastes?

Answers to the above questions provided very crucial information for designing an efficient and cost-effective collection and transport system. An efficient collection system is very important due to the fact that, refuse collection is the essential pre-requisite for the effective handling of waste. The tasks connected with the collection and transportation of waste must be solved first; treatment of the waste is the second step; for example, waste treatment plant (be it for recycling or for composting) can only be correctly planned for when the amount and type of waste is known.

1.3. Objectives of the study

The main objective of the research project was to design a sustainable urban solid wastes management system on locational basis, for a cleaner urban environment. To accomplish this, the specific objectives that the study aimed to achieve included the following:

(i) To determine the various types and quantities of wastes emanating from the study area.

(ii) To determine the amount of recyclable and compostable materials.

(iii) To establish the factors that affect source separation of wastes.

(iv) To establish a convenient and cost effective waste collection system, using GIS technology.

1.4. Study area

1.4.1. Size and location

Nairobi, the capital city of Kenya, is at an altitude of 1670 meters above sea level and occupies an area of about 690 Km^2. It lies between $36^0\ 30^l$ East and $37^0\ 00^l$ East lines of longitude, and $1^0\ 00^l$ South $1^0\ 30^l$ South lines of latitude. It is about 80 Km south of the equator, on the Athi plains, (***See figure 1.5***).

The study concentrated on Nairobi's Embakasi Division, specifically Kayole and Savannah (Soweto) sub-locations (***See figure 1.6***). This covers an area of about 6.4 Km^2.

1.4.2. Population

The population numbers are 76,015 persons in Kayole sub-location occupying an area of about 1.9 Km^2, hence a population density of 40,008 persons per Km^2 and 30,300 persons in Savannah sub-location occupying an area of about 4.5 Km^2, hence a population density of 6,733 persons per Km^2.

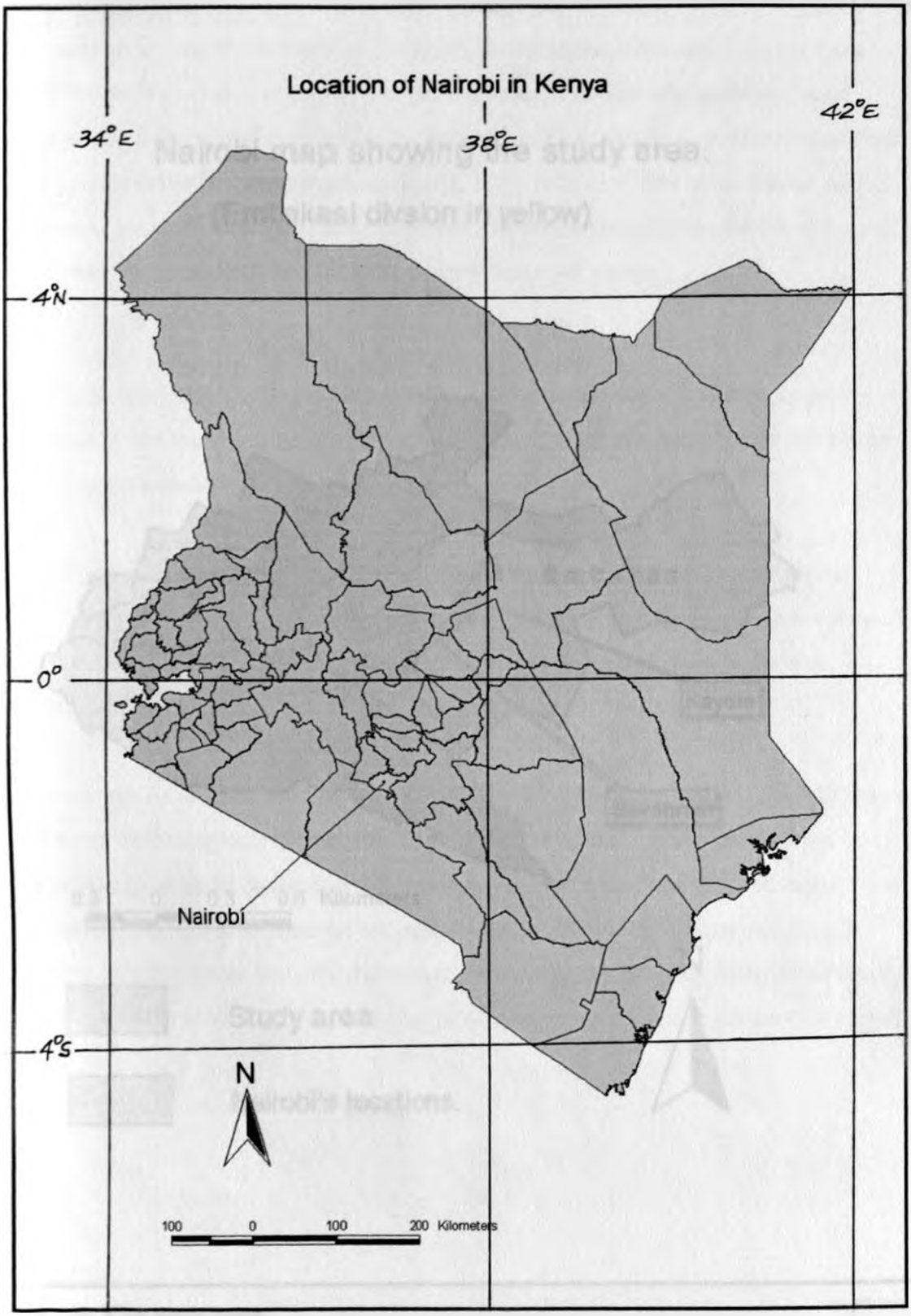


Figure 1.5. Location of Nairobi relative to the other districts in Kenya

Source: Central Bureau of Statistics, 1998.

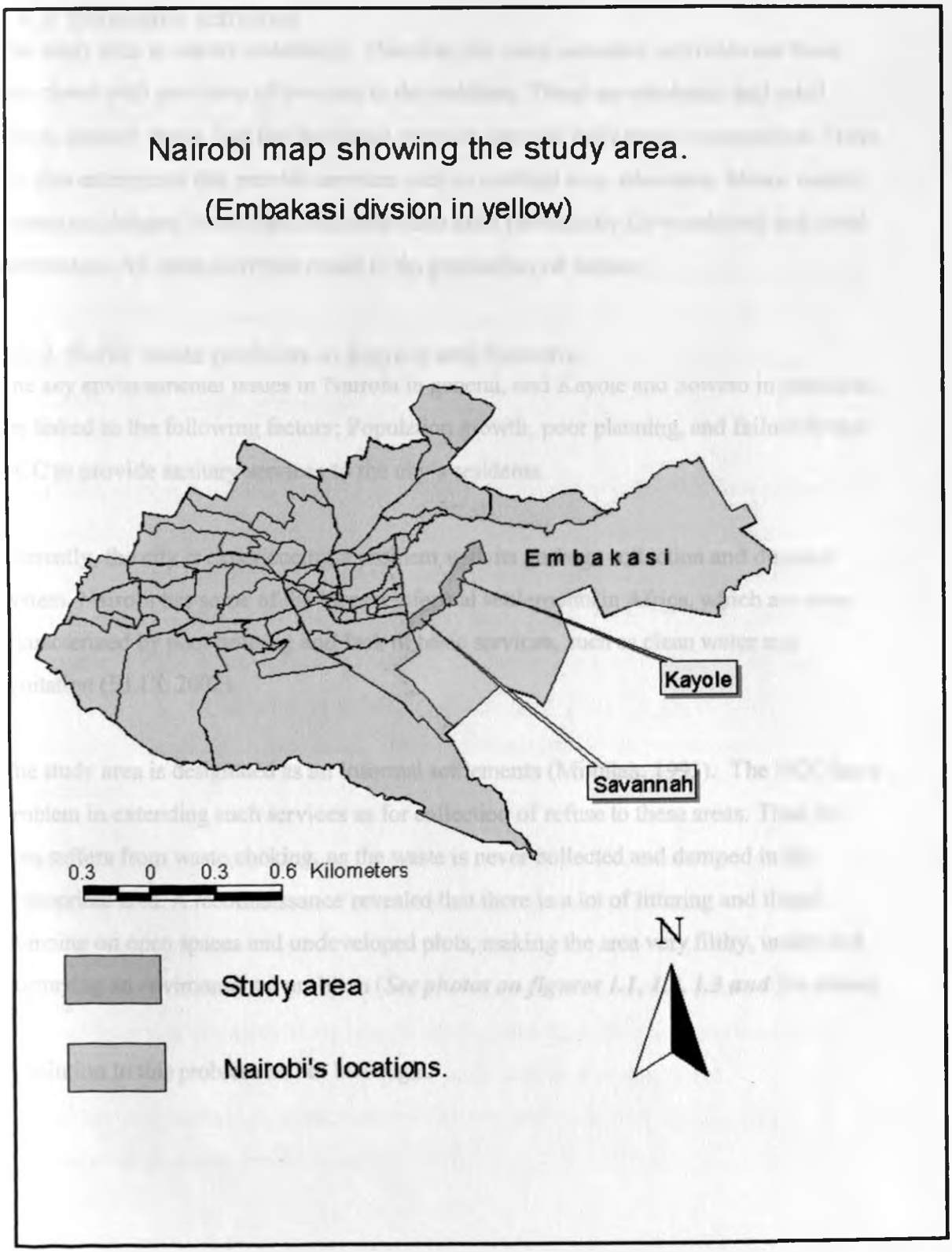


Fig 1.6: The study area.

Source: Central Bureau of Statistics, 1998.

1.4.3. Economic activities

The study area is mainly residential. Therefore the main economic activities are those associated with provision of services to the residents. There are wholesale and retail shops, grocery shops, and butcheries all of which provide daily basic commodities. There are also enterprises that provide services such as medical care, education, Motor vehicle repairs and leisure. Some light industries also exist particularly for woodwork and metal fabrication. All these activities result in the production of wastes.

1.4.4. Solid waste problem in Kayole and Soweto.

The key environmental issues in Nairobi in general, and Kayole and Soweto in particular, are linked to the following factors; Population growth, poor planning, and failure by the NCC to provide sanitary services to the city's residents.

Currently, the city is experiencing a problem with its garbage collection and disposal system. Nairobi has some of the largest informal settlements in Africa, which are areas characterized by poor housing and lack of basic services, such as clean water and sanitation (ELCI, 2002).

The study area is designated as an informal settlements (Mitullah, 1993). The NCC has a problem in extending such services as for collection of refuse to these areas. Thus, the area suffers from waste choking, as the waste is never collected and dumped in the appropriate area. A reconnaissance revealed that there is a lot of littering and illegal dumping on open spaces and undeveloped plots, making the area very filthy, untidy and portraying an environmental problem (***See photos on figures 1.1, 1.2, 1.3 and 1.4 above)***.

A solution to this problem had to be sought.

CHAPTER 2

2. 0 LITERATURE REVIEW

2.1 Introduction

Literature on solid waste management is broad in scope for both developed countries as well as for developing countries. However, few specific studies have been done that attempts to solve the inherent problems related to urban solid waste management, particularly for developing countries.

It has been argued that solid waste is an unofficial measure of prosperity in a nation, but that individual differences within societies must still be considered. For instance, Americans are said to be the highest producers of solid waste on earth, yet America has not produced the dirtiest cities on earth (Rosenbaum, 1974; Sada, 1977). Consequently, the volume of solid waste visible in the cities of developing countries, like Nigeria, cannot be taken as an indicator of prosperity (Akinbami, et al). On the contrary, it reveals the inability of local urban authorities to manage these inevitable products of development.

Increased volume of waste has been attributed to such factors as population growth, urbanization, industrialization, and general economic growth (Akinbami, et al). Consequently, waste has been indiscriminately dumped at open plots of land, particularly along the streets rendering many streets at times impassable in certain cities. This section of literature review attempts to analyze the studies that have been done on the area of waste management. It consists of four parts; waste stream analyses, waste minimization/diversion strategies, waste separation and collection, and finally an analyses of waste management systems.

2.2 The review

2.2.1 Waste stream analysis

Luis and Clarence, (1985) argues that a thorough understanding of the characteristics of the waste is a prior requisite to the making of a rational decision in solid waste management. Hence, a sound quantity and composition survey is important. Reliance should not be placed upon inaccurate method especially upon visual 'estimate' and traffic counts. They contend that a survey of quantity and composition are essential to the determination of the dimensions of key elements in solid waste management.

Several methods can be used for determining the quantity of waste to be disposed. As would be expected, the accuracy of the result depends upon the method followed, and perhaps the only means of arriving at an accurate estimate of the quantity of waste is only that which involves weighing. A full knowledge of the composition of the waste is an essential element in:

- The selection of the type of storage and transport most appropriate to a given situation;
- The determination of the potential for resource recovery;
- The choice of a suitable method of disposal; and
- The determination of the environmental impact exerted by the waste if they are improperly managed.

According to Savas (1976) and Sada (1977), waste is divided into three major classes; gaseous, liquid and solid waste. The sensitivity of different societies to each of these kinds of waste varies, depending on the level of public awareness, technology and social – economic development, developmental ideologies and philosophy.

Akinbami, et al, attest that solid waste can be put into two major categories, depending on its source; Industrial waste and commercial-domestic solid waste. Industrial waste consist of refuse generated in the course of manufacturing and includes, for example, metal scraps, clips, grits from machine shops, saw dust, waste paper, pieces of glass among others. Commercial-domestic solid waste is the byproducts of housekeeping activities

and consumption. It includes food residues, wrapping paper, empty cans and containers. Some of this waste may be toxic, flammable and some non-biodegradable. Other items such as leaves, bones, cotton rags and various food left-over are quite biodegradable and constitute more of a nuisance than a danger to the environment, since they can be decomposed by nature.

In summary therefore, waste characterization/categorization is very important in any waste management system. It involves the determination of the various types of waste and their quantity for proper planning and management of the system.

2.2.2 Waste minimization and diversion strategies

African solid waste experts, researchers and consultants have stressed the need to adopt composting as part of a strategy to improve Municipal Solid Waste (MSW) management in urban areas (Raymond, et al, 1996). This emphasis stems from the fact that the compostable fraction of the waste stream in African cities is very high. The organics consist of food, vegetables, leaves and animal droppings generated by households, food vendors, restaurants and markets. The compostable waste can be diverted from the dump and recycled into compost.

SPREP (1999) noted that, waste minimization strategies include all actions to reduce the quantity of waste requiring disposal. These actions include; Reducing waste at source, re-using materials, recycling waste materials and reducing use of toxic or harmful materials.

Waste minimization has a number of advantages which include reduced volume of waste for disposal, reduced costs of collection and disposal, longer life of disposal sites, reduced environmental and health impacts, and reduced costs through more efficient use of resources.

2.2.3 Waste separation and collection

Feinbaum and Gehr (1995) in their study to test the logistics of source separation of waste found out that in 1990, Alameda county, California waste management plans estimated that about 4.7% of the county's waste stream were food residues from

commercial and industrial sources. If half of that material could be kept out of landfills, the impact of diversion would be as great as from all the county's residential curbside programs. They contend that the first step in assessing the feasibility of diverting commercial and industrial organics was to survey existing composting programs taking food scraps and soiled paper. The focus was on programs that collected materials from a variety of sources. Typically, generators in these programs separated organics at the source. In general, the programs reported positive experiences with separation, collection and processing of food and soiled paper. Generators found out that source separation added little, if any, cost to their operation. Contamination proved to be controlled, and collection logistics were improved. Composting, even with very low technological methods, yielded a product that could be sold in the market place.

Chanyasak and Kubota (1983), in their study 'Source Separation of Garbage for Composting' found that the application of composting to municipal refuse has been very limited. The main reason is the large quantity of biologically non-degradable materials (e.g. plastics, and at times, toxic heavy metals), in municipal refuse, which seriously restricts the use of the compost product. They noted that although mechanical removal of the objectionable materials can be tried in the composting operation, complete separation of the objectionable materials from the product might never be achieved mechanically. On the other hand, separation by hand certainly is not economically feasible. Therefore, source separation, which is a more economical approach, may be the only satisfactory answer for complete separation. However, with source separation, many difficult problems may arise. The most critical point at issue is whether or not housewives would provide the necessary cooperation. Solving this uncertainty will require a courageous decision on the part of the planning authorities.

2.2.4 Waste management systems

Luis and Clarence (1985) in their study, 'Solid Waste Management in Developing Countries' noted that solid waste management is a particularly severe problem in most of the urban areas both in developed countries and less developed countries (LDCs). High population numbers in LDCs increases gravity. In haste to achieve full development,

LDCs often failed to pay attention to the task of properly managing the waste generated by them. But fortunately, a large number of LDCs are becoming aware of the need for carrying out a waste management program.

According to Luis and Clarence, there are essential steps that must precede any solid waste management undertaking if the management is to have a chance for successes. The first step is to determine the composition of the raw waste. Second step is to ascertain not only the amount of raw waste available, but also whether or not the continued access to the waste is assured and at a reasonable cost. A clear idea must be had of the producer's economic and manpower resources so as to be able to determine their adequacy in terms of the need of the undertaking. If manpower is scarce and the economic resources are minimal, one would not select a system that involves sophisticated equipment. If some type of resource recovery is to be practiced, the existence, size and continuity of a market for the reclaimed resources must be determined.

Finally, the management of solid is a difficult problem, which need not be made more difficulty by seeking complex, high technology solutions. The writers have observed the existence of an excessive tendency to transfer technology from one country to another. The danger in such a transfer is the fact that what may be considered to be low technology and readily applicable in one country may be too sophisticated and unacceptable in another. This state of affair applies not only to the method of disposal but also to the collection of wastes and even the devices for storing them.

Surveys of quantity and composition are essential to the determination of the key elements in solid waste management. Among the more important of these elements would be method and type of storage, type and frequency of collection, crew size, method of disposal, and extent of resource recovery. The utility of the survey extends not only to the evaluation of present conditions, but also to the prediction of future trends. Consequently, frequent and continuous surveys are the mainstays of a successful solid waste management program.

SPREP (1999) outlines the steps to go about the planning process for an integrated waste management plan in the small Island developing States in the Pacific region. The steps as outlined are:

1. Knowing what one is dealing with i.e. understanding the source of waste, how it enters the country, the quantity and nature of the material generated. This information is essential for sound waste planning.
2. Consulting widely i.e. seeking the views of people and organizations currently involved in waste management. This is done early in the developing of the waste management plan. The input from these groups will help in identifying concerns and establishing objectives, which everyone supports. Gaining the support of people early on will help in achieving a successful outcome.
3. Setting of objectives of the waste management plan. These objectives should be clear and widely agreed. They make clear what the plan is trying to achieve, provided target against which its success can be measured and will assist in setting priorities for action.
4. Identification of actions needed to overcome the obstacles and achieve each objective.
5. Prioritization of the actions. Ideally, all the actions would be implemented at once – but this is unlikely to be the case. Inevitably, constraints of money and labor will require the implementation of the plan over a number of years. It will be necessary to set priorities. Consider the benefits arising from an objective, the obstacles to achieving it and the resources available. Then sort the actions into the immediately achievable, the medium term and the long term.
6. Getting agreement on the plan. As the plan is taking shape, the solutions proposed will not only be technical, for example requiring new equipment. There will be social and cultural issues also to be addressed. This requires the involvement of many stakeholders. The roles of the stakeholders and budget provision should be made and agreed.
7. Implementation of the waste management plan.
8. Reviewing the progress to ensure it is working. This requires periodic reviewing and updating.

2.2.5 Waste management systems specific to Kenya.

A number of studies have been done with regard to solid waste management in Nairobi. Wachira, (1980) studied refuse storage, collection, transportation and disposal in Nairobi from the architectural point of view. He was particularly interested in four areas of study:

- To provide architects and planners with information that would aid in their designing and planning of refuse storage and collection system in Nairobi;
- To study and understand the problems the Nairobi City Council faces in the field of refuse management;
- To study how far architects have taken refuse storage and collection as a design constant; and
- To study the possibilities of reclaiming refuse into a resource.

His study concentrated much on the designing of a waste management system in a newly developing site/area/locality. He recommended good designing of houses with enough space for keeping storage equipments. He also specified the various types of storage equipment and the factors that should be considered in the designing of the storage equipment. His study did not take into account that later extensions that may arise (as it has happened in many residential areas due to increase in population), can result in pressure being exerted to the refuse handling facilities. The extensions are likely to occur with no proper planning as land resource becomes scarce, leading to congestion and no space for keeping refuse storage equipments. This call for a different design of refuse management that suits the situation of congestion and lack of enough space for keeping refuse equipments in every household or plot of resident. It is for this reason that the current study is undertaken to design such a refuse management system. The study will attempt to solve a problem that has manifested itself in an already developed and congested residential area where development occurred with no proper planning for refuse handling system.

Ikonya, (1991), in his study 'Refuse management in residential areas in Nairobi: a case study of Githurai and Umoja', focused in refuse storage, collection, transportation and disposal methods and their effectiveness. It looked at the existing system and hence hypothesized that, inadequate facilities in refuse storage, collection, transportation and

disposal have contributed significantly to the poor refuse management. His main aim was to provide information on the existing refuse storage, collection, transportation and disposal facilities and their efficiency. He pointed out that the service of solid waste management absorbs a considerable proportion of municipal effort, budget and workforce. Typically, it absorbs up to 1% GNP (Gross National Product) (Fllintoff, 1976) and 20-40 % of municipal revenues in developing countries (Cointreau, 1982). The study recognized the problem but did not offer any solution to the same. It only provided information on the state of the existing refuse management facilities. The current study would aim at providing the solution to the refuse management problem, particularly in the high-density residential areas where the problem is most acute.

Mwaura, (1991), in his study ' An assessment of the management of garbage collection and disposal in Nairobi' critically examined the nature of garbage management practices in a low-income area (Dandora estate) and a high-income area (Plainsview estate) in Nairobi and the resulting problems. The study also evaluated the alternative methods of garbage management and the accruing benefits. Mwaura noted that, Nairobi, as a rapidly growing city has the problems of urbanization and urban development. For instance, the increasing construction of residential houses in Nairobi due to increase in urban population has seen the loading of the environment by the enormous generation of domestic refuse/garbage. He says that Nairobi was born firmly within a socio-political framework of imperial expansion. Racial segregation was implicit and controlled much of colonial plans, which had separate zones for Africans, Asians and Europeans. Nairobi's land use development was fixed within this racial influence. The Africans residential areas were invariably outside the interest and activity spaces of the colonialists, hence the problem of lack of social infrastructural facilities passed unnoticed.

The situation inherited at independence was that of a city destined for a capitalist expansion with extreme inequalities in the levels of services provided in different residential areas. Towards the 1970s a new population distribution began to emerge with the low-income group being pushed further away from near the central business district areas. This followed the government's policy on facing out squatter settlements sited near the CBD and the introduction of site and service schemes like Dandora and Kayole.

Other sprawling settlements like Kibera and Soweto also began to emerge on the peripheries of the city. This expansion of the city was however not proportionally marched by a similar expansion in solid waste collection and disposal services and hence the beginning of the problem of uncollected garbage, especially in the low-income residential areas.

Mwaura explains that the modern system of refuse collection and disposal by the local authority derives from the Public Health Act of 1875 in London, which made provisions for removal by the sanitary authority on appointed days of accumulation of refuse from premises. In Nairobi, the modern system was started by the introduction of Public Health Ordinance in 1920, whereby each occupier of the premises was obliged to place the refuse in a movable receptacle, to be collected and emptied by the council workers.

According to Mwaura, Nairobi has two broad systems of garbage management; Public and Private systems. The public system is the more conventional and traditional and is undertaken by the Nairobi city council. The private garbage system has been used to complement the effort of the Nairobi city council on a limited scale. Private companies have collected and disposed garbage in some affluence residential estates at a small fee. Besides these are some informal groups of people in Nairobi that are involved in scavenging activities that also assist in collection and disposal of garbage. Mwaura notes that all waste collected by Nairobi city council and by the private sector is all disposed on a site at Dandora.

On alternative methods of garbage management, he looks at the options of scavenging, privatization of garbage collection, composting and sanitary landfills. He examines the benefits that accrue from the use of these alternative methods, particularly the economic aspects, such as the earnings of the scavengers and the life style they lead. Despite of the continued garbage problem, even with the mentioned garbage collection systems and the existence of the alternatives, he does not attempt to provide a lasting solution. He recommends on the development of a master plan and a detailed plan for the handling of garbage. He proposes that the master plan should outline in suitable development phases:

- The expected quantities of garbage within various residential areas;

- Appropriate collection system;
- Transport system and the need of various vehicles;
- The main routing for the transport of garbage;
- The location of transfer stations and central deports;
- Disposal process and sites for disposal plants;
- Economic and financial aspects;
- Organization and management matters; and
- Legal matters.

The current study aims at designing an integrated waste management system that is cyclical as opposed to linear model of resource utilization. It also aims at establishing the expected quantities of the various types of wastes within the study area, design appropriate collection and transport system incorporating the routings and transfer stations. The system would identify the right destination for the various types of wastes for recycling or re-use, with the aim of reducing what is going to the disposal site.

2.2.6 Application of GIS technology in waste management

With advancement in technology, particularly the information technology (IT), it is important that this technology is also applied in any planning, including planning for waste management. Hidehiko (1986) notes that the implication of information system for planning has often been studied and debated, but has less often been explored in a rigorous and coherent manner that integrates both conceptual and empirical aspects including the use and application of information system for urban and regional planning.

Information systems are the operational 'keystone' of the urban and regional planning process. Without effective information system, such a process is impossible. The argument is that information system will improve urban and regional planning performance. Information system may be defined as the organization of data relevant to understand, planning for, and monitoring and evaluation of urban and regional development. They serve various needs, such as increasing planning capability and providing information on which to base the delineation and evaluation of alternatives courses of action. Specifically, information system performs three essential functions:

1. They identify the information required for planning, implementation and monitoring and evaluation;
2. They utilize methods of collecting, processing, analyzing and disseminating data that meet standards of accuracy, timeliness, and cost; and
3. They provide organizational structure, which bring users and suppliers of information in constant dialogue.

In developing countries, very few large cities and sub-national regions have adopted modern information technology. In organizations which have started to use computer technology in information handling, it has so far not produced significant change in the set up of city or regional administration, in the structure of decision making, or in the actual work of the planning and decision making agencies. What have been achieved in most cases, are incomplete inventories of baseline data about social, economic, cultural, political and physical features of the environment, and the automation of routine, record keeping application, primarily in finance and other revenue maximizing services. Experiment or endeavors toward urban or regional planning information system are very recent and still evolving. The concept of 'urban or regional information package' has not yet penetrated governmental policy in developing countries. The concept is yet to be included in governmental mechanisms for coordinating national and local efforts, professional networks and research, and training programs in colleges and universities.

Christopher, et al (1997) in their study, 'Using Geographical Information System (GIS) to evaluate Decentralized Management of Municipal Food Waste' noted that the implementation of decentralized waste management is stymied by an inability to communicate the cost and benefit of these plans in the decision making arena. The use of GIS is vital toward carrying out feasibility test, life-cycle assessment, and in presenting the result thereof. In this study, they pointed out that in the pathology of an environmental problem such as food waste, identification and understanding of the problem could be carried out using traditional sampling and statistical techniques. However, creating new strategies to sound out decentralized management options is impossible without a rigorous and spatial analysis of each option towards comparison with the status quo management system. This is true not only because of the necessity of

itemizing the cost, environmental burden, and environmental impact of each stage of each option, but also because these new schemes must be communicated in a transparently understandable manner to gain consensus among concerned parties to be able to incorporate local objections or improvements in the scheme, and to be able to present the refined management options to a decision maker. More over, GIS – based analysis of new food waste management options become invaluable in the implementation and monitoring of new and decentralized food waste management options, should they win approval.

The study was based at Bang Kapi ward, Bang Kok. Maps of a scale of 1:10,000 were used which were available for security reasons. The selection of Bang Kapi was made for reasons of data availability, time available for digitizing and for the diversity of land use. The GIS software used was ARC/INFO version 6.1.1 (ESRI, 1993). The maps were digitized manually for coverage of almost 8,000 polygons; each polygon was labeled with one of 18 land use classes. Significant buildings were recorded on a separate coverage as points, and centerline road coverage constructed simply by mouse from the polygon coverage.
The concept of life cycle analysis was borrowed from pathology, and borrowed imperfectly. It is common in life cycle assessment (LCA) of waste management to describe the cradle- to- grave sequence in terms of a flow chart, and then quantify environmental burden and impact by analysis of matrices allied to each box of the flow chart (Zeiss, 1994). Linear algebra is then used to aggregate the sum impact of these scalar data.

In contrast, the life cycle in pathology is analyzed for four factors; the variable, the host of the variable, the vector of the variable and the transformation a variable undergoes. For example, the variable food waste undergoes the transformation of composting to become the new variable of compost, which may then be displaced by a truck vector from the old composting site host to the new compost application host of a farmer's field. This traditional analysis is labeled the HVT format, referring to the Host-Vector-Transformation format for life cycle analysis of a particular variable.

The thrust of the study was to suggest how to use GIS to quantify every life cycle host, vector and transformation within a decentralized waste management system. The HVT analysis of waste management life cycle is a primary tool for identifying what manner of GIS analysis will be needed to quantify each stage of the life cycle. In the above example, food waste in a network of decentralized in – vessel composters is georeferenced by a coverage locating the sites of transformation labeled with the amount of the food waste transformed into compost therein. A vector stage, say, transport of source separated food waste to a neighborhood composter by small vehicles such as bicycle carts already used for recyclables recovery in Bang Kok and Manila (Warmer, 1994), is described with network analysis in GIS. Consequently, an HVT analysis is a useful first step in preparing the life cycle of alternative management strategies for GIS – based environmental impact analysis, as well as costing these complex strategies. A viable strategy is one that is decentralized – which involves composting of source separated organic waste.

Christopher, et al (1997), discusses a strategy that involves a network of invessels composters located at institutions preferably with a high generation of food waste, these composters being oversized sufficiently to accommodate source separated food waste collected from the neighborhood. This kind of option is impossible to cost and describe without spatial analysis, and therefore dubious in the eyes of decision makers. Hence, the importance of GIS. In their paper, a control strategy of decentralized, in-vessel composting of source separated organic waste was selected to exemplify the utility of GIS in developing new management strategies, testing their feasibility, and carrying out their life cycle analysis. This strategy has the advantage of low contamination of compost with heavy metals and other undesirables owing to source separation and the short distance between generation source and composting site (Krauss et al, 1987). Calculation of the environmental burden of this LCA is divided into three sections; waste generation, transport and final disposal, not all complete.

Waste generation: Aerial photograph was needed, (maps of scale 1:5,000 or larger scale are essential for true GIS-based analysis of waste generation). However, the study involved a 1:10,000 scale map. A posited infrastructure of in-vessel composters was

tested for feasibility, and through that discussion an explanation of how organic waste generation might be properly addressed is given.

In the first step, two scenarios were posited for decentralized composting; one with composters located at points ('compoints') at schools, markets, police stations, temples, churches, mosques and Hindu mosques. A total of 116 compoints was chosen. The other scenario took compoints at only schools and markets, a total of 92 compoints. The location of the compoints was chosen for among these four reasons; food waste output, spacious grounds, public ownership and connection with social responsibility and education.

Step two was to investigate the service coverage of these compoints. That is to say, how much distance would be necessary to be allocated out from the compoints to cover a decent percentage of the residential land use. Distance of 500 meters, 1 Km and 1.5 Km were tested. An example result is given in appendix 5 (a). Although the detail is small, close inspection will reveal different varieties of line design centered around the various compoints. These are routes. Buffering of these routes to either side with a 50 meter buffer approximating a feasible maximum distance of any household from the road will give an area serviced by this compoint infrastructure for a given distance. This new polygon, the buffer compoint-route polygon, was called a 'service buffer' polygon to indicate that it is an area within which collection service is provided. Overlay of this service buffer polygon onto the land use coverage results in a value for the amount of residential – use land serviced by these compoints.

Close scrutiny of appendix 5 (a) will reveal that many routes overlap where the compoints are more densely placed. Functionally, this is suitable, as more compoints will be needed in highly populated areas. But the service neighborhood of each compoint can easily be divided up by digitizing traditional neighborhood. It would now be easy to estimate organic waste generation for a given compoint neighborhood if maps of a scale 1:5,000 or larger were available. The above 'compoint neighborhood' would include detail on the number and nature of buildings within that neighborhood, as roughly sketched out in appendix 5 (b). The precision of the estimate is limited only by the

precision of census data and Municipal Solid Waste (MSW) generation studies available on per capita organic waste generation. In this fashion, a suitable sized in-vessel composter could be installed at that compoint.

Transport: Transport is often entirely overlooked in waste management life cycle analysis. However, with the construction of the compoints routes as explained above, it is possible to calculate the total length of each compoint route. If 1:5,000 or larger scale maps are available, the waste collection points in each compoint neighborhood can be digitized. In Bang Kapi, both curbside collection and multiuse waste collection points are used, depending on the character of the neighborhood. From these figures, the size and number of collection vehicles needed in each route could easily be calculated. Similarly, transport of finished compost from the compoints to designated local green space or transfer stations could be addressed using GIS in a similar fashion.

2.3. Theoretical framework

In order to design a sustainable waste management system, it is important to first understand the waste stream. The flow of materials and the generation of wastes are shown in a flow diagram in fig 2.1.

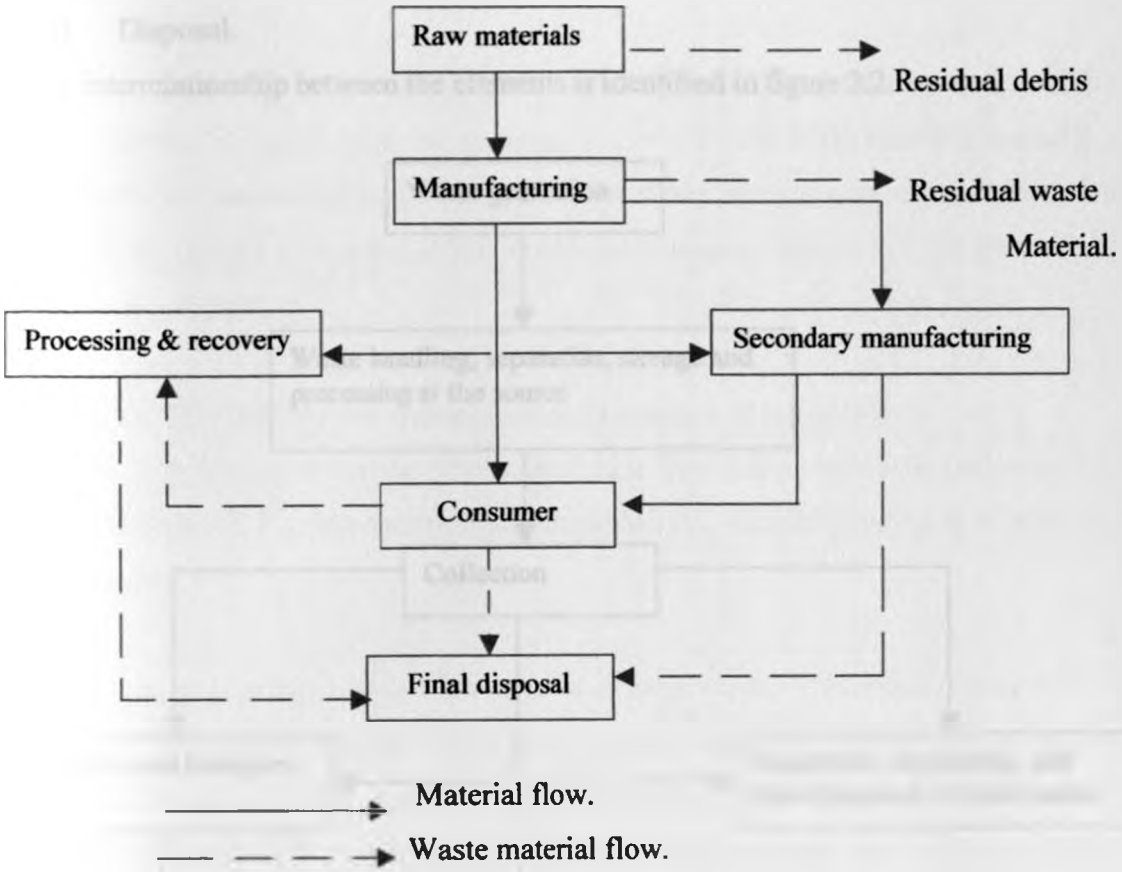


Fig 2.1: Material flow diagram.

Source: Tchobanoglous, Theisen and Vigil, 1993.

Solid wastes (debris) are generated at raw material extraction. Thereafter, solid wastes are generated at every step in the process as raw materials are converted to goods that are then consumed.

In a waste management system, there are six functional elements that need to be considered. (Tchobanoglous, et al ,1993.)

These are:

(i) Waste generation;

(ii) Waste handling and separation, storage and processing at the source;

(iii) Collection;

(iv) Separation and processing, and transformation of solid wastes;

(v) Transfer and transport; and

(vi) Disposal.

The interrelationship between the elements is identified in figure 2.2.

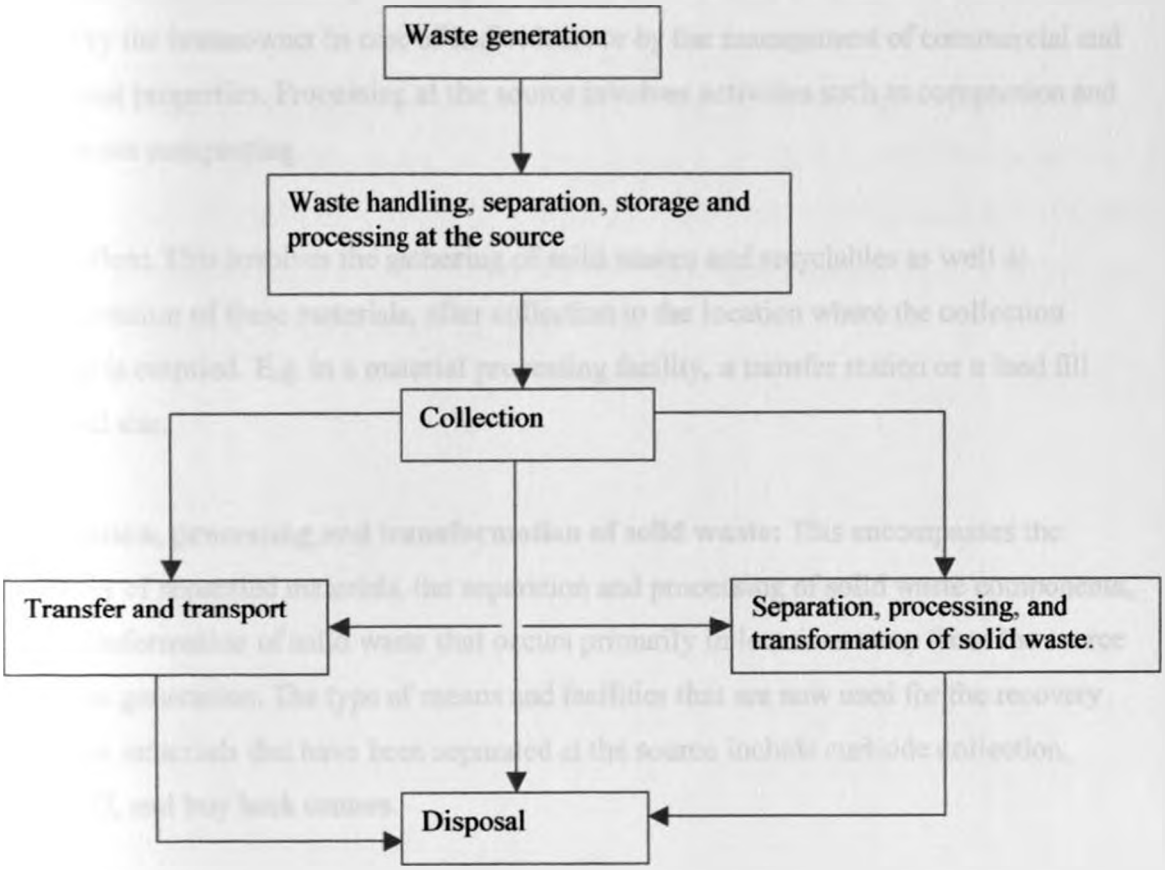


Fig 2.2: Interrelationship between the functional elements in a waste management system.

Source: Tchobanoglous, Theisen and Vigil, 1993

Waste generation: This encompasses activities in which materials are identified as no longer being of value and are either thrown away or gathered together for disposal.

Waste handling and separation, storage and processing at the source: Waste handling and separation involves the activities associated with management of wastes until they are placed in storage containers for collection as well as movement of loaded containers to point of collection. Separation of waste components is an important step as the best place to separate waste materials for reuse and recycling is at the source of generation.

On site storage is of primary importance because of public health concerns and aesthetic considerations. The cost of providing storage for solid wastes at the source is normally borne by the homeowner in case of individuals or by the management of commercial and industrial properties. Processing at the source involves activities such as compaction and yard waste composting.

Collection: This involves the gathering of solid wastes and recyclables as well as transportation of these materials, after collection to the location where the collection vehicle is emptied. E.g. in a material processing facility, a transfer station or a land fill disposal site.

Separation, processing and transformation of solid waste: This encompasses the recovery of separated materials, the separation and processing of solid waste components, and transformation of solid waste that occurs primarily in locations away from the source of waste generation. The type of means and facilities that are now used for the recovery of waste materials that have been separated at the source include curbside collection, drop-off, and buy back centers.

Processing often includes the separation of bulky items, separation of waste components by size using screens, manual separation of waste components, size reduction by shredding, separation of ferrous metals using magnets, volume reduction by compaction and combustion.

Transformation processes are used to reduce the volume and weight of waste requiring disposal and to recover conversion products and energy. The organic waste can be transformed by a variety of chemical and biological processes;

- Chemical transformation – Involves combustion which is used in conjunction with the recovery of energy in the form of heat.
- Biological transformation - Involves aerobic composting.

Transfer and transport: Transfer usually takes place at a transfer station. Cars, pickups, handcarts, and lorries are used to transport waste or recovered materials to appropriate places.

Disposal: This is the final functional element. Land filling or land spreading is the ultimate fate of all solid wastes. A modern sanitary landfill is not a dump; it is an engineered facility used for disposal of solid waste on a land or within the earth's mantle without creating nuisance or hazard to public health or safety, such as the breeding of rats and insects and the contamination of ground water.

2.4 Conceptual framework

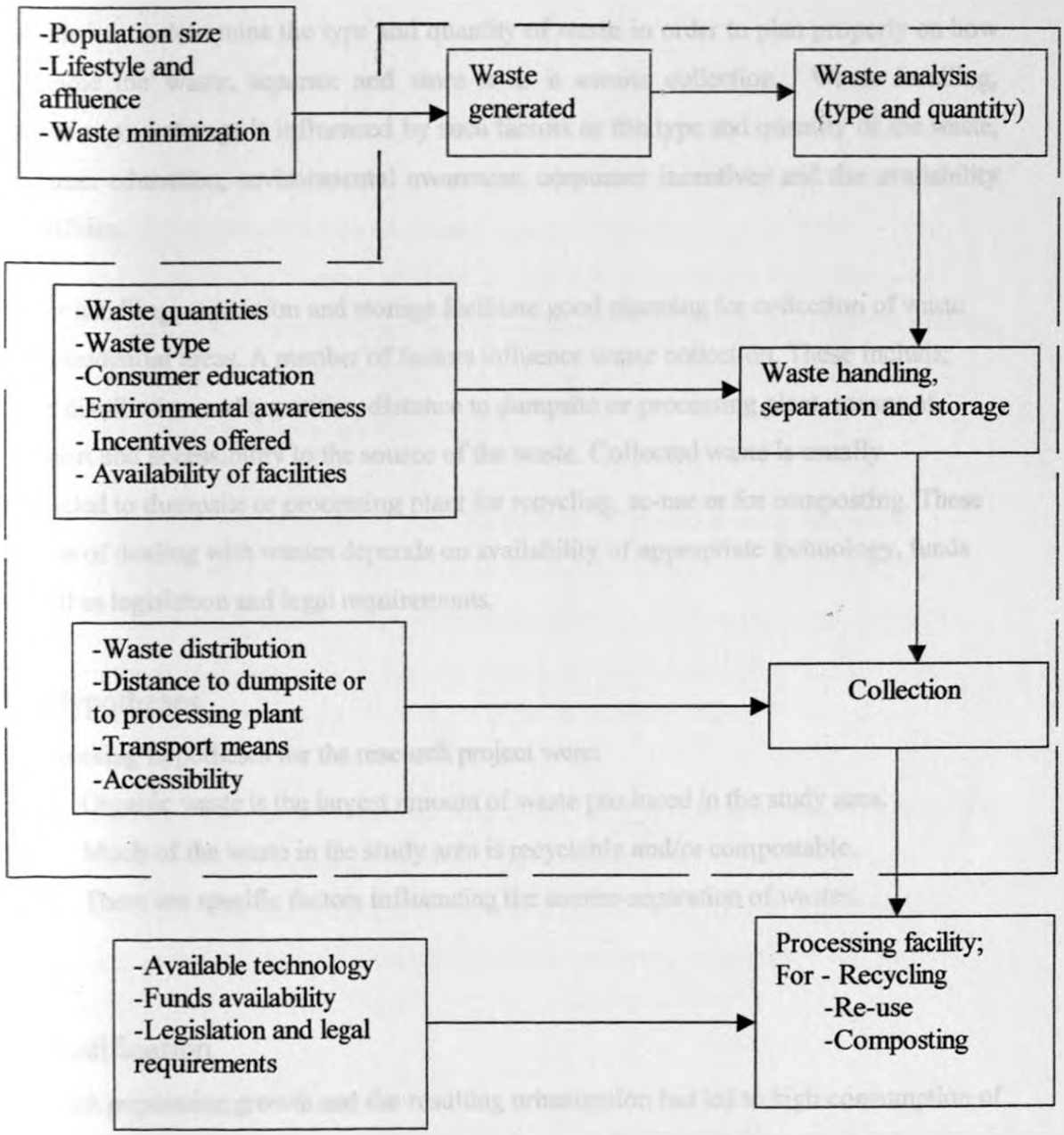


Figure 2.3: Waste material flow and influencing factors.

Source: Modification of Tchobanoglous, Theisen and Vigil, 1993.

Note: Area of interest enclosed in broken lines

Waste generation is influenced by several factors such as the population size, lifestyle and affluence of the residents as well as the waste minimization strategies adopted. All these influence the waste generated in any particular area. It is important to do a waste analysis i.e. to determine the type and quantity of waste in order to plan properly on how to handle the waste, separate and store it as it awaits collection. Waste handling, separation and storage is influenced by such factors as the type and quantity of the waste, consumer education, environmental awareness, consumer incentives and the availability of facilities.

Proper handling, separation and storage facilitate good planning for collection of waste from residential areas. A number of factors influence waste collection. These include; waste distribution and quantities, distance to dumpsite or processing plant, means of transport and accessibility to the source of the waste. Collected waste is usually channeled to dumpsite or processing plant for recycling, re-use or for composting. These options of dealing with wastes depends on availability of appropriate technology, funds as well as legislation and legal requirements.

2.5 Hypotheses

The working hypotheses for the research project were:

1. Organic waste is the largest amount of waste produced in the study area.
2. Much of the waste in the study area is recyclable and/or compostable.
3. There are specific factors influencing the source-separation of wastes.

2.6 Justification

The high population growth and the resulting urbanization has led to high consumption of natural resources and generation of substantial wastes. Most local authorities in general, and NCC in particular, have been unable to cope with the collection, treatment, and disposal of wastes due to inadequate capacity, financial constraints and poor management. Nairobi city produces about 1000 tones per day of solid wastes and only 20% of the waste is collected and taken to the approved dumpsite (GOK, National Development Plan, 2002 – 2008). The rest is left uncollected and is instead dumped on

open spaces in various places making the city untidy, exposing the population to health risk and causing environmental degradation (See photographs above). The scenario is at worst in the low-income residential areas.

Uncontrolled disposal of waste is unsanitary and can degrade freshwater and cause land pollution. Wastes, such as plastics cans do not break down quickly and traps stagnant water where mosquitoes can breed. Open dumping of waste encourages flies and rats; hence diseases can spread as a result. Sharp litter is a common cause of injury. Open burning and uncontrolled burning of waste can result in air pollution and respiratory ailments. Leachate from dumps can contaminate surface and underground waters used for drinking and other uses. These are just but a few examples of how waste and their poor disposal can cause environmental degradation.

With the existence of appropriate technologies (such as for composting, polythene papers' recycling, scrap metals recovery, and waste papers recovery) for turning the waste materials into resources, solid waste disposal needs not be a problem. However, this is not the case. The reason for this lies mainly on the logistics of dealing with the waste materials from its source till they get to the processing site.

In the study area, there exist waste recycling, composting and material recovery sites. The efficiency of the sites has been hampered by the logistics of waste handling. The proprietors of the sites lamented that if they could get the waste in good condition and supply, they would be able to convert it into usable products, and save the environment from pollution.

For the above reasons, it was justifiable to work out the modalities of overcoming the waste materials handling logistics. The study set out to fulfill this on a local scale, covering Kayole and Soweto sub-locations of Embakasi division. It was hoped that this would facilitate the development of a sustainable solid waste management, which could be expanded to cover the whole city of Nairobi.

2.7 The scope and the limitations of the study

The study area comprised mainly of a densely populated residential area. The building structures were such that the households or dwelling units were within blocks/plots. Within the residential area, other commercial activities such as wholesale and retail shops, markets stalls for grocery and cereals, butcheries, bars/pubs, hotels/cafeterias, chemists, salons, barbershops, furniture and general workshops as well as garages existed to serve the residents. In addition, there were also social amenities to provide education and health services i.e. schools and health clinics/hospitals.

The study was mainly interested in determining the wastes generated at the household level. Hence, samples were only drawn from the list of households and did not include commercial establishment and service centers. The study assumed that once the problem of waste collection from households was dealt with, it would be easier to incorporate the commercial establishment and service centers into the system, as they are few.

A number of limitations were encountered in conducting the study but much effort was made to overcome them. Firstly, the population from which to draw the sample was quite large (about 40,000 households). Drawing of a representative sample was therefore difficult. A large sample was required, meaning that the whole process was to be costly and to take a longer time to accomplish. A multistage sampling technique was used to draw the sample using the enumeration areas map of the 1999 Kenya's population census. A digital map showing the enumeration areas was used in a GIS environment to sample out the enumeration areas from which to sample the households. A fair spatial distribution of sampled households was therefore ensured.

Funds were solicited from friends and organizations interested in the findings of the study, such as the Muungano women self-help group. Material resources such as papers for questionnaires were also obtained from the same organizations.

Secondly, accessibility and participation of the household owners was not assured. This was particularly due to suspicion by the household owners about the utility of the

findings, as well as because of fears due to the insecurity prevalent in the area. This problem was tackled by humble approach and good initial introduction by the interviewer, as well as good explanation about the use and importance of the research findings. Confidentiality of the household owner's information was assured. Visits to the sampled households was arranged to either coincide with the weekends during daytime or weekdays in the early evening before late hours. This was to take care of the insecurity problem, which heightened at late hours.

CHAPTER 3

3.0 RESEARCH METHODOLOGY

3.1 Introduction

This chapter deals with research methods that were applied in carrying out the study. It is divided into five sections as follows:

3.2 Data types and Data sources.

The study relied on both primary and secondary data. The secondary data included the baseline map of the study area and the population data. The baseline map was obtained from the Kenya's Central Bureau of Statistics. The map consisted of the enumeration areas/units of the study area, which were demarcated during the 1999 national census of Kenya. The number of persons in each enumeration area was also obtained from the CBS.

The primary data comprised of people's practices on waste handling as well as the type and quantity of waste produced. The information was obtained from the field through the use of questionnaires and practical aspect of collecting, separating and weighing of waste.

3.3 Sampling design.

The study administered two types of questionnaires to two groups of people sampled out. The first group consisted of a sample of 300 households. The second sample consisted of 50 households. These were sampled out from the first sample.

A multistage/cluster sampling procedure was used to draw the samples. According to the Kenya's 1999 population census, there were 167 enumeration areas/units in both Kayole and Soweto estates. These EAs were coded in a systematic manner in the GIS scenario. Using the code numbers, a sample of 50 EAs was randomly selected by use of a random sampling numbers table. The spatial distribution of the sampled EAs is shown on fig 3.1.

Each enumeration area consisted of several structures/blocks/plots, which were owned by individuals. These plots were built up, and rented to several households.

After sampling out 50 EAs, the next stage involved sampling out 6 (six) structures/plots from each and every sampled EA. This was done by using the plot numbers that were indicated at every plot's entry gate, used for the purpose of identification of the plots by the NCC. The plots were arranged in an orderly manner, the numbers following each other in rows. This made it easy even to number those plots whose number was not indicated at their gate. To sample out six plots from each EA, a systematic sampling procedure was used. The number of plots in every sampled EA was determined and the corner of the EA that contained the plot having the plot number with the lowest value. From this corner, counting was done picking the plots after an interval of 10. Those plots, which were picked, constituted the sample.

From the sampled structures/plots, the number of households in the plot was determined. One household was sampled out randomly. This process yielded a total of 300 households.

The second group constituted a sample of 50 households. This was drawn randomly from the above 300 sampled households. A list of the 300 sampled households was prepared and from the list, a sample of 50 households was drawn randomly using the random sampling numbers table.

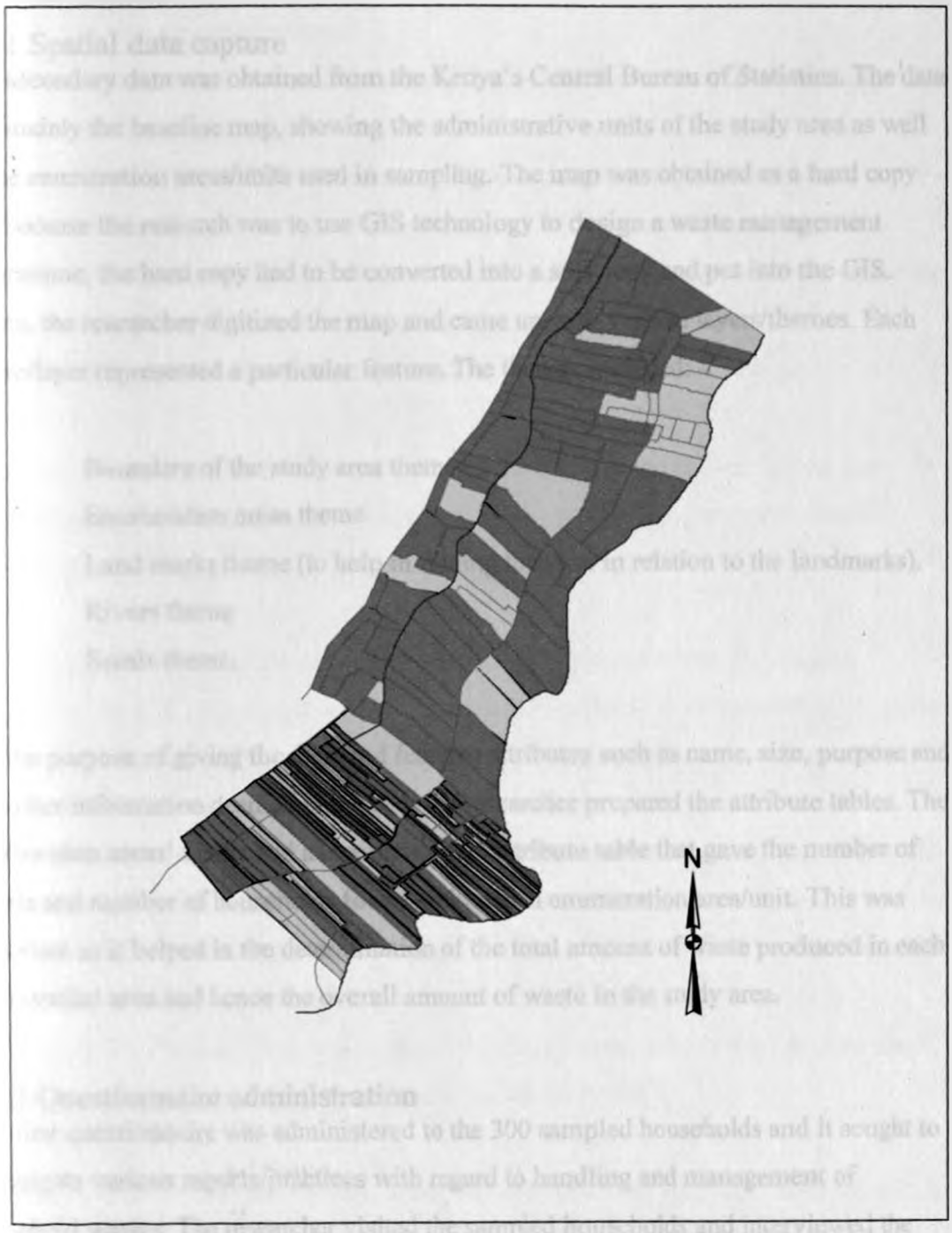


Figure 3.1: Kayole and Soweto: Sampled Enumeration Areas in yellow.

Source: GIS analysis, 2003.

3.4 Data collection

3.4.1 Spatial data capture

The secondary data was obtained from the Kenya's Central Bureau of Statistics. The data was mainly the baseline map, showing the administrative units of the study area as well as the enumeration areas/units used in sampling. The map was obtained as a hard copy and because the research was to use GIS technology to design a waste management programme, the hard copy had to be converted into a soft copy and put into the GIS. Hence, the researcher digitized the map and came up with various layers/themes. Each theme/layer represented a particular feature. The themes included: -

- Boundary of the study area theme
- Enumeration areas theme
- Land marks theme (to help in finding location in relation to the landmarks).
- Rivers theme
- Roads theme.

For the purpose of giving the digitized features attributes such as name, size, purpose and any other information deemed important, the researcher prepared the attribute tables. The enumeration areas' theme had a comprehensive attribute table that gave the number of people and number of households found within each enumeration area/unit. This was important as it helped in the determination of the total amount of waste produced in each enumeration area and hence the overall amount of waste in the study area.

3.4.2 Questionnaire administration

The first questionnaire was administered to the 300 sampled households and it sought to investigate various aspects/practices with regard to handling and management of household wastes. The researcher visited the sampled households and interviewed the person found at that time in the house, using short structured questions (see appendix 1). The questionnaire had several items, which helped the researcher to know;

- How the householder disposed of his/her waste,
- The person who handled the waste in the house,

- If the householder would support organizations that require different materials to recycle or to compost,
- Whether he/she would be willing to separate the waste, and if yes, what he/she would require,
- If poor disposal of waste posed an environmental problem to him/her,
- Which method he/she would prefer to use to dispose of the wastes,
- If he/she would deliver the waste to the collection points, and the distance the he/she was willing to walk to dispose of the waste, and
- The level of education of the householders.

Information on the above provided the basis for the descriptive analysis for the study. It also helped in the formulation of policies, to guide in the management of household wastes in the area.

The second questionnaire was administered to the group constituting 50 sampled households. The 50 households were used to test the workability of the source- separation technique, as well as in the determination of the types and quantity of waste produced in the households. The researcher supplied 2 polythene bags of different colors and requested the householder to deposit organic waste into one bag and the inorganic waste into the other. A brief explanation was given on the organic and inorganic waste, and the importance of the separation. After four days, the researcher went round collecting and weighing the waste. The researcher had to separate by himself, the waste that had not been separated. The procedure was repeated within the same households for three times, to determine the average production of waste by the households.

After the source- separation exercise, the households involved were administered with a questionnaire, which evaluated their attitude towards the exercise. The researcher interviewed the person found in the house during the third collection and weighing period. A short structured questionnaire was used (see appendix 2). The questionnaire had several items, and the researcher sought to know;

- If the householder separated his/her waste,

- If he/she did. into what components and if not, the reason for not separating,
- If he/she had adequate facilities for storage of wastes and enough space for storing the waste facilities,
- The location the waste storage facilities are placed, and
- The main problems the householder experienced during the exercise.

The design for administering the questionnaires was the personal interview. The researcher visited the households sampled and using the short structured questionnaires, asked the questions to the person found at the time of visit (as long as the person seemed to be mature enough to understand).

3.5 Data analysis

The collected data was first subjected to descriptive analysis. The analysis gave the general tendency in the waste distribution in terms of type and the respective quantities. The results were presented in form of graphical representation and tabulation. The resulting information was used in the determination of recycling, composting and/or material recovery options necessary in the area.

To determine the type and quantity of waste produced, waste had been collected, separated and weighed. This exercise had been done three times, to obtain the average waste produced. In each collection, the number of persons in every sampled household had been recorded. It was assumed that these were the persons who contributed to the production of the waste collected. The number of days for which the collected waste was produced had also been recorded. By doing so, the waste produced per person per day was calculated for every collection and for each household.

At the end of the third collection, the average per capita waste production per day was calculated for members of every household. To calculate the per capita waste production per day for the purpose of generalization, the following formula was applied,

$$\text{Per Capita Waste Production Per Day} = \frac{\text{Total Average Waste Production Per Person Per Day}}{N}$$

Where N = Number of households in the sample.

To determine the total waste produced in the study area, the calculated value of per capita waste was multiplied by the total number of persons in the study area. The formula used was;

Total waste produced in the study area = Total number of persons in the study area x Per capita waste production per day.

From the value obtained above, it became possible to determine the quantity of the various types of wastes produced. This was done by considering the percentages of each type of waste.

Separation at the source may be influenced by several factors. The study attempted to determine if there were specific factors that influenced separation at the source. Information on these factors was obtained through the use of a questionnaire. The factors that were investigated included the availability of storage facilities for different waste types and provision of incentives. The data was analyzed using a statistical tool, the Chi-squire, to determine if there was a significance difference between those who expressed willingness to separate their waste at the source, considering the above factors.
The null hypothesis (H_0) was stated that: - availability of storage facilities for different types of wastes and incentives offered do not affect source-separation of wastes.

The frequencies for those who said that they would separate their waste if given different storage facilities for the different wastes as well as incentives, and those who said that they would not separate the waste, were used to calculate the Chi-squire value, using the formula:

$$\chi^2 = \frac{\sum_{i=1}^{k}(O-E)^2}{E}$$

Where,

χ^2 is the chi-squire.
O is the observed frequency
E is the expected value.

The expected values were obtained using the formula,

$E = RC/N$

Where E is the expected value.

R is the total for the row.

C is the total for the column.

N is the total for the columns, which is also equal to the rows total.

If the value calculated at 0.005 (95%) level of confidence and at the right degree of freedom is found to be greater than the critical value in the Chi-squire table, then the hypothesis would be rejected. This would be interpreted to mean that there was a significance difference between those who expressed willingness to separate their waste at the source and therefore, the factors do influence source separation of waste.

The GIS was used as a tool to facilitate the spatial planning for an integrated solid waste management programme for the area. To design a spatial framework for logistical waste handling, the GIS Arc View version 3.2 software was used.

The GIS was used to;

- Categorize/symbolize the study area into several categories, depending on the amount of waste generated in the given enumeration area. This gave rise to EAs with high and low quantity of waste,
- Identify/locate the points where waste processing was taking place,
- Identify "Best" location for setting up the waste transfer stations, based on given criteria.
- Plan the spatial distribution of the transfer stations based on distance people are willing to walk to dispose of their waste and the quantity of waste produced in a given EA, and
- Establish routes network linking the transfer stations and the processing points.

To categorize the study area according to the amount of waste generated, the calculated per capita waste production per day for the study area, (i.e. 0.4 kg – see section on results and discussion) and the absolute number of persons in every EA, were used. From these figures, it was possible to calculate the total amount of waste generated in each and every EA. The GIS facilitated this operation since a digital map of the study area had been inputted into the GIS. The digital map had an attribute table associated with it. It was in the attribute table that the data about the number of EAs in the study area, their code number, and the total number of persons in each EA was available. The total amount of waste in each EA was thus worked out (See appendix 3).

The layer/theme showing the study area demarcated into 167 EAs and the amount of waste in each EA was then used to symbolize the study area according to the amount of waste. Graduated color legend type and five classes were used. The output map obtained is shown on figure 4.4, page 71 on the section of results and discussion. The spatial map showed at a glance the areas with a lot of waste and which could therefore need concentrated transfer stations.

The second step involved identifying the points where waste processing (recycling, composting and material recovery) was taking place in the study area. During digitization process (i.e. conversion from analogue to a digital map) of the map of the study area, an effort was made to earmark some landmarks. The landmarks chosen included; Schools (nursery, primary, and secondary schools), churches, restaurants/pubs, market places, open playing grounds, special purpose areas (areas where some special undertakings were taking place. These undertakings included youth group offices, self help group offices, government offices, material recovery points as well as points for small scale recycling of materials).

The marking of the special purpose areas proofed very useful as it led to the identification of the waste processing points. It was found that in the study area, there were several centers that handled waste. Some concentrated on recycling, others on composting while others were involved in material recovery. Materials recovered were sold outside the

study area, to other places that probably recycled the material. Figure 4.5 on page 73 shows the spatial distribution of the centers.

Having established the amount of waste and the areas with the most quantities, as well as areas that utilize the waste for economic benefits, it became proper to plan a spatial programme for ensuring that each waste type is channeled to the appropriate place. This was deemed necessary as the people involved in material recycling, composting and recovery, lamented that their work was hampered by improper handling of waste.

To facilitate proper handling, transfer stations were thought a good idea. It is at the transfer stations where people/residents of the estate should deliver their separated waste. The transfer stations should have compartments for the various waste types. At given interval of time, the waste at the transfer stations should be transferred to the waste processing points.

The GIS was used to determine the 'best location' for transfer stations, based on given criteria. The criteria included the availability of 'free land' (i.e. land not already developed), ease of accessibility and distance from water resources. The undeveloped plots, **(see figures 3.2 and 3.3 below)** were considered as the starting point for defining best locations for the transfer stations in the GIS scenario. Thus, based on the above;

- The transfer station should be in an open, underdeveloped space or in a publicly owned land such as a school, playground, or an area earmarked for a market. (NB the transfer station need not occupy a large area. It can be curved off the edge of a public land or the authorities involved can buy back from private owners. The transfer station will be a public property).
- A transfer station should be within 20 meters of a road to facilitate easy transportation of the waste. Thus, the roads were given a 20-meter buffer on either side, and the transfer stations were to be within the buffer.
- A transfer station should be 50 meters away from a river or stream, to avoid the leachate from contaminating the water. Thus the rivers/streams in the study area

were buffered 50 meters on both sides. The transfer stations were to be outside the buffer.

Figure 4.6 on page 75 shows the candidate areas for locating the transfer stations after considering the above points.

The number of transfer stations in the study area was determined by the quantity of waste in the particular EA and the distance people expressed willingness to walk to dispose of their waste.

All the above factors were put into consideration when planning the spatial distribution of the transfer stations. The information was inputted into the GIS and synthesized. The output obtained is shown on figure 4.7, page 77.

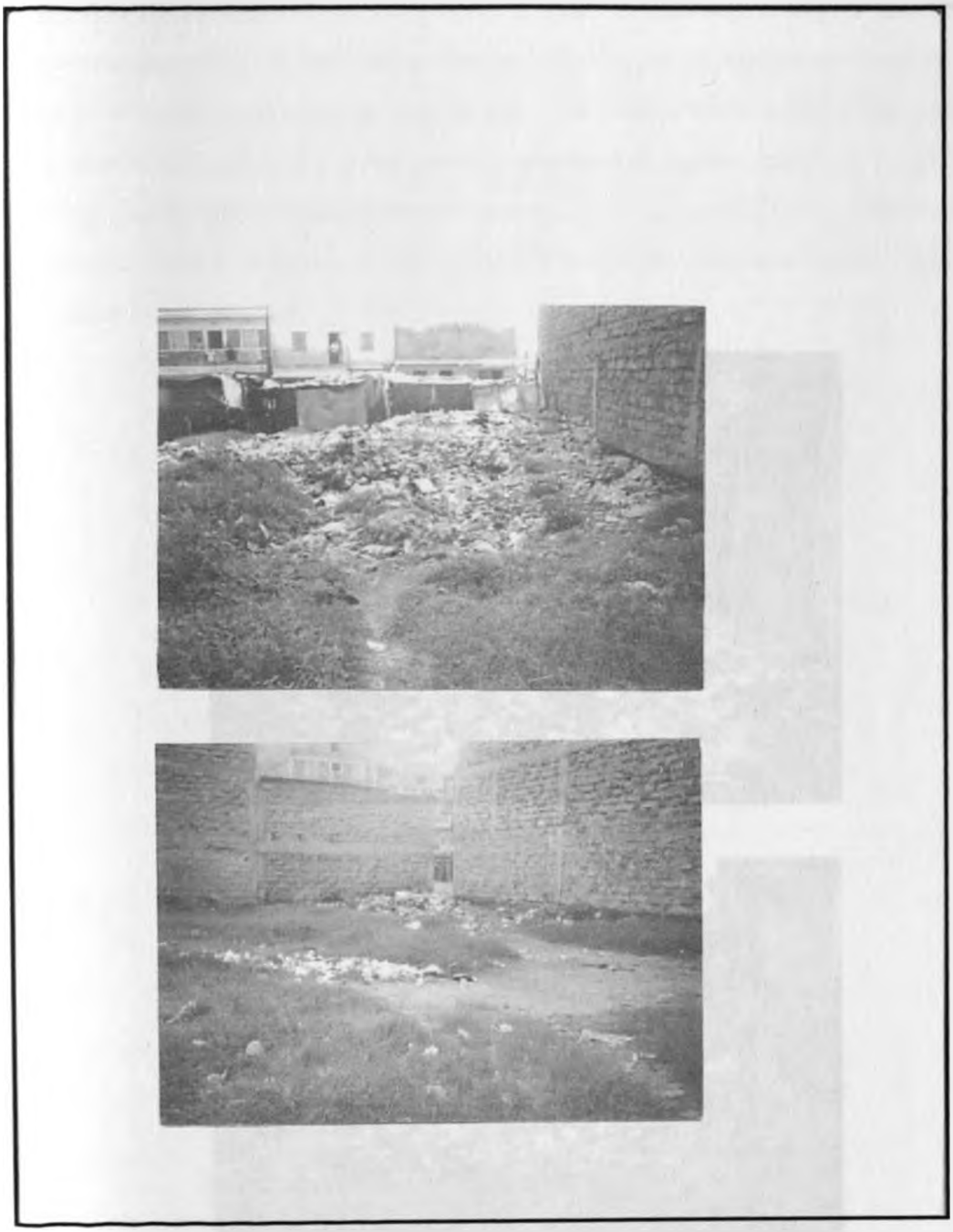


Figure 3.2. Freeland / free space for transfer stations.

Source: Field observation, 2003.

Figure 3.3: Freeland / free space for transfer stations.

Source: Field observation, 2003.

The last step involved establishing a network that linked the transfer stations and the waste processing sites. All the transfer stations had all types of wastes and therefore needed to be linked to all waste processing sites. The links were to facilitate the planning of a routine for collection of a given type of waste i.e. a collection vehicle of a particular waste type should link several transfer stations and pick that type of waste. This would minimize the number of trips a collection vehicle would have to make. Figure 4.8 on page 79 shows the linkages.

CHAPTER 4

4.0 RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results as obtained from the field. The chapter is organized under two sections. The first entails an analysis of the questionnaire return rate. The second section presents the research findings and discussions.

4.2 Questionnaire return rate.

During the administration of the questionnaires, there was high level of cooperation as the researcher approached the residents with meekness and simplicity and explained to them the importance of the study. However, in few instances, there were some households that did not co-operate. In such cases, the researcher proceeded to the neighboring household to seek the information. This way, a high return rate was ensured as shown in the table 4.1 below.

Target	Sample size	No. Responded to	Percentage
Estate households	300	297	99
H/h in source-separation	50	46	92

Table 4.1 characteristics of the sample.

Source: Field Research 2004.

The rate was considered adequate since a questionnaire return rate of 50% and above is considered a good response (Peil, 1995).

4.3 Research findings and analysis

This section presents the research findings and analysis as per each objectives of the study. It is divided into four sub–titles as follows: -

4.3.1 Types and amount of waste produced.

The research was based on a residential area in an urban setting. It therefore focused on the domestic wastes produced by the residents. The study revealed that both organic and inorganic wastes were produced. The organic waste identified included; food leftover, fruit peelings, vegetable wastes and other putrucibles.

The inorganic waste included; plastics in general (broken buckets, plates, mugs, plastic bottles and tins, washing troughs among others), glassware and chinaware (broken bottles, glass plates, glass cups, melamine plates and mugs), and others (bones, fabrics, leather, wood and Metallic materials).

Based on the 50 households that were sampled out to be involved in the source – separation exercise, an analysis of the waste types and quantity was done. The exercise involved the collection and separation of wastes produced in the households. This exercise was repeated three times, and the totals of the waste collected during the 3 collection exercises were represented in table 4.2 below.

Waste Type	**1st Collection**	**2nd Collection**	**3rd Collection**	**Average**	**Percentage of the tota:**
Organic	243.9	268.4	245.7	252.7	77.2
Inorganic	90.2	51.1	83.2	74.8	22.8
Total	**334.1**	**319.5**	**328.9**	**327.5**	**100.0**

Table 4.2: Totals (in kg) of waste collected during the 3 collection exercises, by type.

Source: Field study, 2004.

The table below shows the various types and amounts of the inorganic waste. The percentage is of the total waste (Including the organic waste).

Waste Type	1st Collection	2nd Collection	3rd Collection	Average Weight (kg)	Percentage of the total waste
Plastic	21.3	11.6	14.5	15.8	4.8
Glassware	7.2	4.4	7.3	6.3	1.9
Others	61.7	35.1	61.4	52.7	16.1

Table 4.3: Average weight (in kg) of inorganic waste collected during the 3 collection exercises, by type.

Source: Field study, 2004.

Figure 4.1 shows the percentages of the various waste types produced by the sampled 50 households.

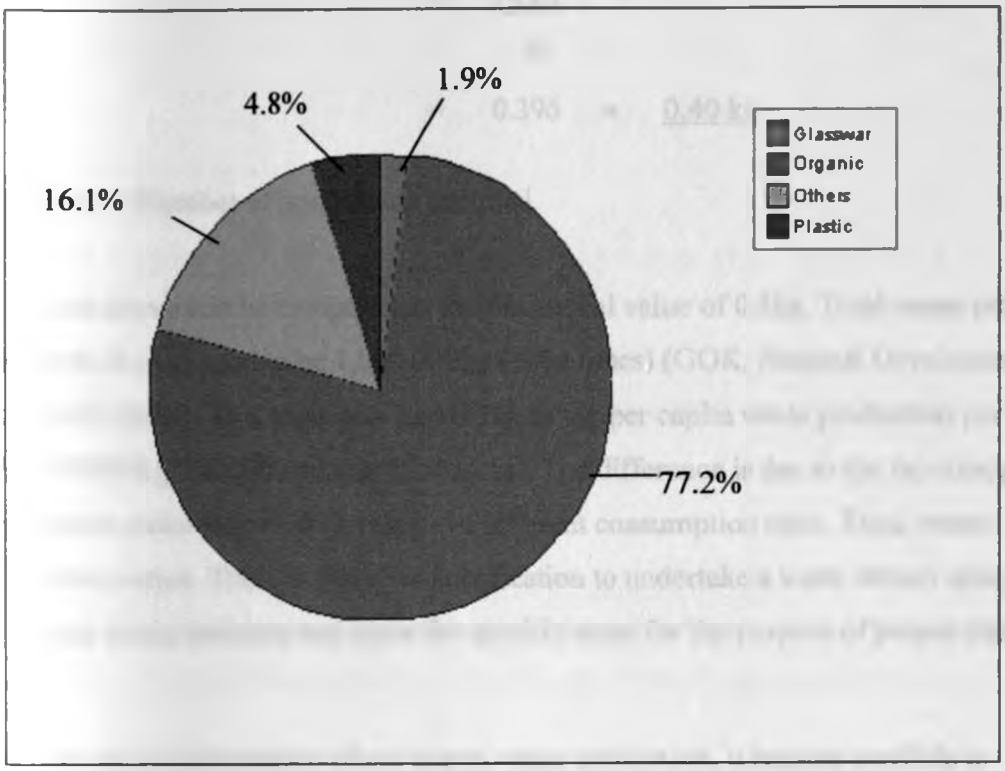


Figure 4.1: Percentage average waste production by type.

Source: Field Research, 2004

To calculate the per capita waste production per day for the purpose of generalization, the average per capita waste production per day was calculated for members of every household. The values for this column (average per capita waste production per day) were summed up, and totaled to 19.80 (See appendix 4).

Thus.

$$\text{Per Capita Waste Production Per Day} = \frac{\text{Total Average Waste Production Per Person Per Day}}{N}$$

$$= \frac{19.80}{50}$$

$$= 0.396 \approx \underline{0.40 \text{ kg}}$$

Where N = Number of households sampled.

The value above can be compared to the theoretical value of 0.5kg. Total waste produced in Nairobi is estimated to be 1,000,000kg (1000 tones) (GOK, National Development Plan, 2002-2008). This translates into 0.5kg as the per capita waste production per day (i.e. 1000000kg/2000000 people in Nairobi). The difference is due to the fact that people in different social-economic levels have different consumption rates. Thus, waste production varies. There is therefore justification to undertake a waste stream analysis to determine waste amounts and types for specific areas for the purpose of proper planning.

From the above information of per capita waste production, it became possible to determine the total amount of waste produced in the study area. Information on the absolute numbers of population was used to arrive to this.

The population of the study area as at 2003 stood at 121,529 persons. Thus,

Total waste produced in the study area = Total number of persons in the study area x 0.40 kg

$$= 121{,}529 \times 0.40 = \underline{48{,}612 \text{ kg}}$$

Hence, on average, 48,612 kg of waste is produced in the study area per day. This translates into 17,743,380 kg (17,743.380 tones) of waste per year.

The quantity of the various types of wastes produced is given in the table below.

WASTE TYPE	AMOUNT (KG)	PERCENTAGE
Organic	37,528	77.2
Inorganic		
- Plastics	2.333	4.8
- Glassware	924	1.9
- Others	7,827	16.1
Total	**48,612**	**100**

Table 4.4 Total amount of waste produced in the study area by type per day.
Source: Field Research, 2004.

From the discussion, it became evident that the organic waste was the waste produced in large amount.

4.3.2 Amount of compostable and recyclable materials

From the above information on the quantity of wastes produced in the area, it can be seen that much of it can be composited and the rest, can either be recycled or re–used.

The organic waste, which amounted to 37,528 kg (77.2 %) is all compositible. This waste can be directed to the Muungano women Group site, where there is the practice of compositing. The plastics, constituting 4.8 % could be directed to Kayole Environmental Management Agency (KEMA), where the plastics are melted and remolded into other products such as fencing poles, roofing tiles and building plastics bricks. The glassware and chinaware, constituting a small fraction of the total waste 924 kg (1.9 %) may be collected and sorted out. The Glass may be sold to the Central Glass Industry, where it may be melted and remolded into some other glass products such as bottles or even household glass cups and plates. The chinaware may be disposed of safely in the landfill, as they do not contain heavy metals.

From the above results, it can be seen that much of the waste, (above 90 %) produced in the study area can be composited, re-used and/or recycled within the area. This confirms

the second hypothesis that "Much of the waste in the study area is recyclable and/or compostable". All that is required is a well-planned programme that would ensure that the waste is sorted at the source and each type of material directed to the rightful place. The programme should be based on the 3Rs i.e. Reduce, Re–use, and Recycle and it should not contribute to environmental pollution.

4.3.3 Pertinent issues with regard to solid waste management and handling.

Two questionnaires were administered to seek information from the residents. The first questionnaire was administered to 300 randomly sampled households and it sought a wide range of information with regard to the handling of the solid waste, produced at the household level.

The research revealed that there were several means by which the residents got rid of their wastes from their houses. The table below gives the information on this.

Means of disposal	**No. of Households**	Percentag.
Through private waste collectors	111	37.6
Throw at the open spaces in the estate	163	55.3
Surrender to voluntary groups to compost	21	7.1
Nairobi City Council collectors	0	0
Total	**295**	**100.0**

Table 4.5 Means of disposal of waste by the residents.

Source: Field Research 2004.

From the table, it can be seen that 37.6 % disposed of their waste through private waste collection organizations for a fee. Of those who dispose through private waste collection organizations, 106 (95.5 %) use polythene bags, 3 (2.7 %) use metallic bins and 2 (1.8 %) use plastic bins, as the waste storage facility. (See fig 4.2 below).

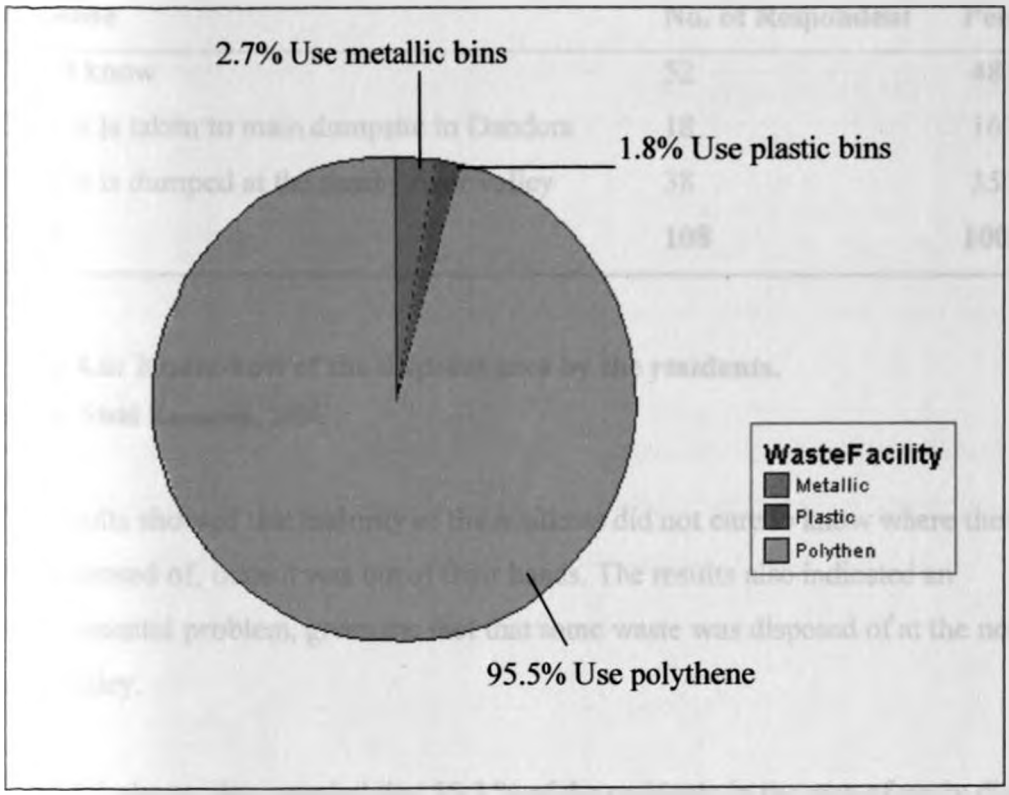


Figure 4.2: Percentage of people who use different waste storage facilities

Source: Field Research, 2004.

The use of the polythene bags for waste storage means that it is more preferred to other receptors. However, it is itself disposable and it adds to the waste. A policy need to be put in place to discourage its use in preference for more durable and non-disposable waste receptors. This would reduce the share the receptor adds to the total waste as well as reduce the running cost for an organization that may be involved in the waste management.

The research sought to know if the people who disposed of their waste through the private waste collectors knew where the waste was dumped. Table 4.6 gives the results.

Response	No. of Respondent	Percentage
Do not know	52	48.1
Knew it is taken to main dumpsite in Dandora	18	16.7
Knew it is dumped at the nearby river valley	38	35.2
Total	**108**	**100.0**

Table 4.6: Know-how of the disposal area by the residents.

Source: Field Research, 2004.

The results showed that majority of the residents did not care to know where the waste was disposed of, once it was out of their hands. The results also indicated an environmental problem, given the fact that some waste was disposed of at the nearby river valley.

Table 4.5 above also revealed that 55.3 % of the residents in the area of study disposed of their wastes at the open spaces in the estates. The photographs on the figures 1.1 through 1.4 evidenced this. There is therefore a real environmental and health hazard problem in the area and something need to be done.

Incidentally, despite the fact that there were several locations for material recovery, recycling and compositing in the study area, only 7.1 % households disposed of their waste through surrendering to voluntary groups, which were interested in recycling and/or composting. The 7.1 % represented 21 households of the 295 households sampled out that responded to this item.

Out of the 21 households, 19 (90.5 %) admitted to have been requested by the waste collectors to separate their wastes. 20 out of 21 (95.2) admitted to have been provided with different collection facilities for different waste types. Of those provided with collection facilities for different wastes types, only 3 out of 20 (15 %) separated their wastes. The rest, 17 (85 %) did not. Those who did not separate their wastes gave different reasons as indicated in table 4.7 below.

Reason	No. of people out of 17	Percentage
No time	4	23.5
Dirty work	4	23.5
Don't know the reason for separating	1	5.9
No co-operation of others	11	64.7

Table 4.7 Reasons for not separating wastes.

Source: Field Research 2004.

The researcher was interested in knowing the particular person who handled the waste in the household. It emerged from the field that the housewife and the house girl (if any) were the ones who mainly handled the waste. (See fig 4.3 below).

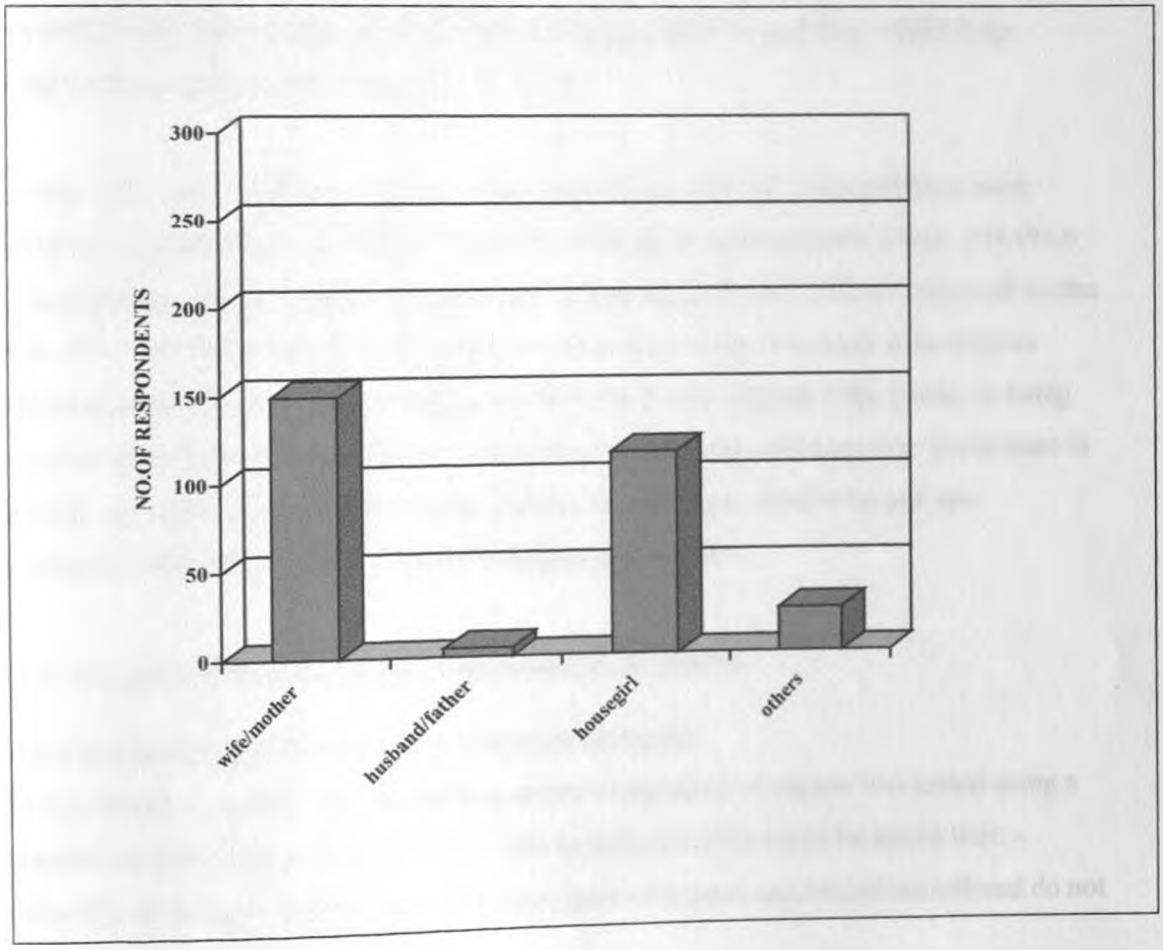


Figure 4.3. Person who handles the waste in the household.

Source: Field Research 2004.

The information above was deemed necessary as it could give guidance as to who to target when it comes to educating people on the area of handling and separating waste at the source, to improve the management of urban solid wastes. Thus, the housewives and the house girls are the main targets.

The researcher also sought to know if the residents of the area were willing to help self-help organizations that required different materials for recycling or composting. 92.6 % (274 people out of 296 respondents) said that they were willing, whereas 7.4 % (22 / 296) said they were not. Those willing to help the self-help organizations were asked in which way they would help. Given choices, 181 out of 270 respondents (67 %) said that they were willing to pay the organizations if they collected the waste from them. 33 % said they would offer advice and encouragement whereas 28.9 % said they would help through doing manual jobs when they were free.

For those 181 who would pay for the waste collection, 149 (82.3 %) said they were willing to separate their waste. Out of the 149 willing to separate their waste, 144 (96.6 %) said that they would require different collection facilities for different types of wastes while 110 (73.8 %) said they would require some incentives. The kind of incentives requested varied from reduced waste collection fee if one separated the waste, to being invited to contest for prizes in green events as well as being called upon to participate in seminars and workshops on environmental issues. All these need to be put into consideration while designing a waste management system.

4.3.4. Factors affecting source-separation of waste.

4.3.4.1 Requirements for source-separation of waste.

The hypothesis on the factors that affect source-separation of wastes was tested using a statistical tool, the Chi-square (x^2). The null hypothesis (H_0) could be stated that: - availability of storage facilities for different types of wastes and incentives offered do not influence source-separation of wastes.

To enable the application of the Chi-square, a questionnaire had been used to collect information from the residents with regard to what they require to undertake source separation. The table below gives the specific requirements, and the respective frequencies.

Factor	Number of people that		
	Would separate	Would not separate	Total
If waste storage facility is available for different waste types.	144	5	149
If incentives were provided.	110	39	149
TOTAL	**254**	**44**	**298**

The expected values were,

$E_{11} = 127$

$E_{12} = 22$

$E_{21} = 127$

$E_{22} = 22.$

Observed (O)	Expected (E)	$(O-E)^2$	$(O-E)^2 / E$
144	127	289	2.276
110	127	289	2.276
5	22	289	13.136
39	22	289	13.136

Thus,

$$\chi^2 = \frac{\sum_{i=1}^{k}(O-E)^2}{E}$$

$$= 30.824$$

d.f = (r-1)(c-1) = 1

At d.f 1 and level of significance 0.005, the critical value is 7.879

The calculated chi-squire value (30.824) was greater than the critical value. Hence, the hypothesis was rejected. Thus, availability of storage facilities for different types of wastes as well as incentives offered do influence source-separation of wastes.

4.3.4.2 Education and environmental awareness of the populace.

On the education factor, it was assumed that anybody who had attained a Kenya Certificate of Secondary Education (KCSE) and above was well educated to make sound judgment on issues in life, including those of cleanliness. From the research, it was found that about 67.9 % (201 persons) had attained K.C.S.E and above (see table 4.8).

Certificate attained	No. of people	Percentage
None at all	3	1
K.C.P.E	95	31.1
K.C.S.E	125	42.2
A - Level	31	10.5
Diploma	29	9.5
Degree and Above	16	5.4
Total	**296**	**99.7**

Table 4.8 Education level of the residents

Source: Field Research 2004

The above information tallies closely with that obtained by the Kenya Government during the 1999 population census conducted by the Central Bureau of Statistics. For

Nairobi, 28 % of the population had attained K.C.P.E Certificate and 38 % had attained K.C.S.E Certificate (GOK, 2001).

On the environmental awareness factor, the questionnaire had included a test to the respondents on environmental issues. The test was administered to the people without them knowing and therefore the researcher was able to gauge the level of environmental awareness on the part of the respondent, depending on the marks obtained on the test. The test formed part of the questions on the questionnaire and it was awarded marks on a scale of 1 to 15. The table below gives the scores.

Scores	No. of people
15	0
14	1
13	21
12	24
11	16
10	30
9	37
8	46
7	38
6	54
5	22
4	12
Total	**300**

Table 4.9: Scores obtained on the test to measure the environmental awareness of residents.

Source: Field Research 2004.

It was taken that a 60 % (9/15) and above mark was appropriate. Those who had attained a pass mark of 60 were taken to have environmental awareness. They were 139 out of 300 (46%). Proper handling of waste, including proper disposal and source-separation is directly related to environmental awareness of a populace (UNEP, IETC, 1996).

The results on the education level and environmental awareness of the population of the study area indicate that something need to be done. Most people were well educated past the basic education, but they lacked environmental awareness. There is therefore need to

inculcate environmental education in the school curriculum, right from the lower levels. It is also important that a thorough environmental awareness campaign must be undertaken if the country need to achieve its objectives on environmental matters.

4.3.5 Problems likely to face the source–separation of waste technique.

The questionnaire administered during the last collection and weighing session was to evaluate the attitude of the people in the source-separation of waste. It also aimed at investigating the problems likely to be encountered if a waste management programme incorporating source separation was introduced. Understanding of the problems was deemed important as solutions to the problems could be worked out when designing an integrated solid waste management programme, which was the paramount aim for the study.

Through the analysis of the questionnaire, it was found out that out of 50 households, 16 households (32 %) separated their wastes while 34 (68 %) did not. All the households had been supplied with waste collection facilities for different wastes, hence the issue of lack of facilities should not have arisen. The researcher therefore sought to know the reason for the non-separation of the waste. The table below gives the reasons and the number of respondents to each reason.

Reason	No. of respondents/34	Percentage
The exercise was tedious	15	44.1
The exercise was dirty	13	38.2
The exercise had no benefit to me	19	55.9
Had no time	7	20.6

Table 4.11: Reasons for not separating wastes.

Source: Field Research, 2004.

The study also revealed that majority, 44/50 (88 %) of the households admitted that they lacked adequate space for keeping the waste storage facilities. This could be attributed to the design of the houses (majority of which were rental, hence small with no adequate

space). 29 household (representing 58 %) stored their waste storage facilities inside their houses, while 19 households (38 %) stored outside.

Asked of the problems likely to be faced in the source-separation of wastes, the respondents gave the following.

- Lack of facilities
- Lack of enough space for storing waste collection facilities
- Lack of interest
- Lack of information on the importance of the whole exercise.

This means that these factors need to be put into consideration while designing a waste management programme.

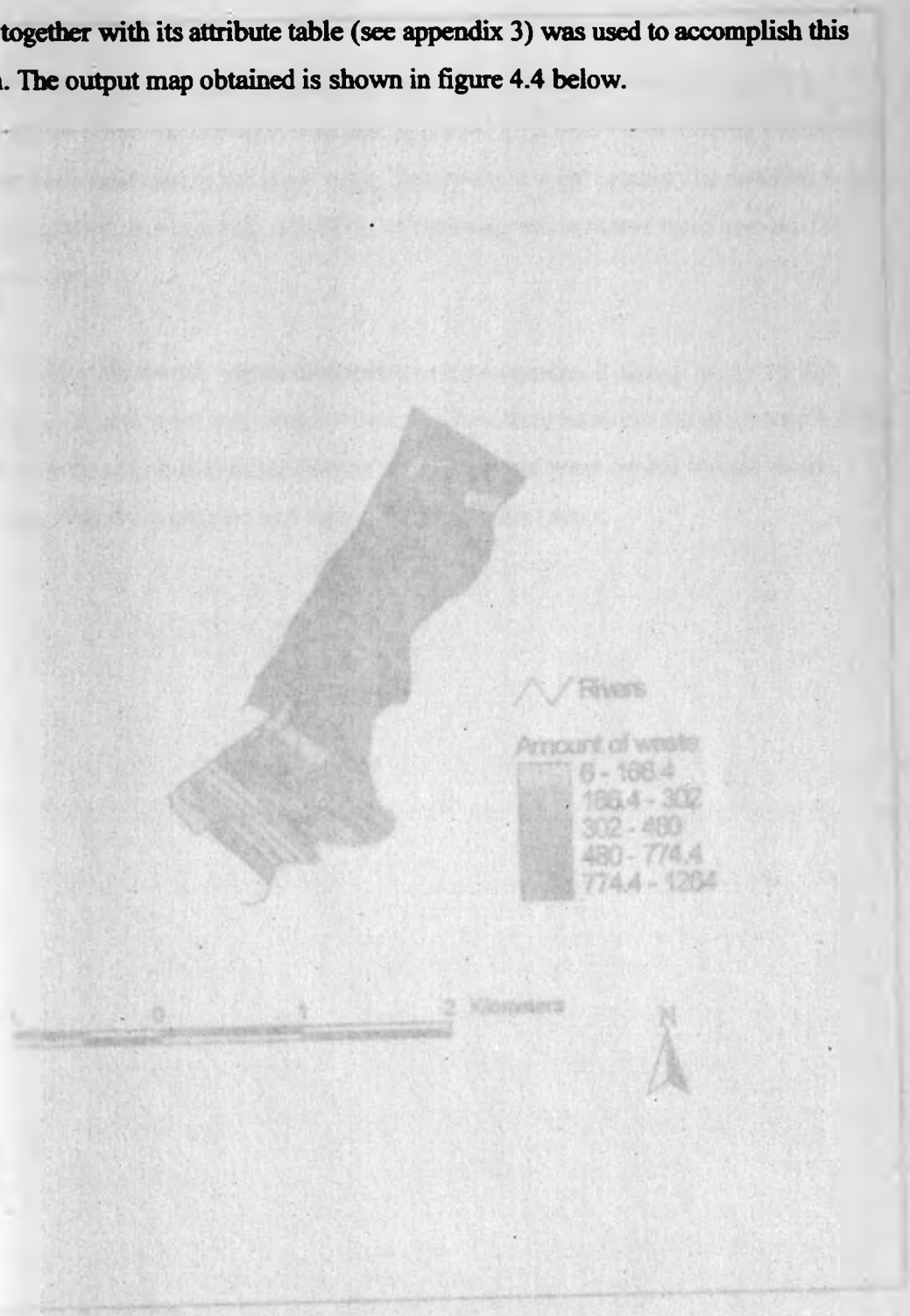
4.3.6: Towards a spatial framework for an integrated solid waste management system.

A system involves two or more entities working together as a whole. An integrated solid waste management system encompasses many activities/elements, and an understanding of the relationships among the various elements is a key element in achieving integrated waste management, a single, over all approach to managing waste in a city, town or a region (UNEP, IETC, 1996).

The current study aimed at collecting data that would help in designing an integrated solid waste management system on locational-basis. Some of the data obtained led to the formulation of policies as shall be discussed later. The other data was used to design a spatial framework for waste handling. This was accomplished by use of the GIS technology.

In the GIS analysis, the first step involved categorizing the study area according to the amount of waste generated in each EA. The digital map of the study area demarcated into

167 EAs together with its attribute table (see appendix 3) was used to accomplish this operation. The output map obtained is shown in figure 4.4 below.



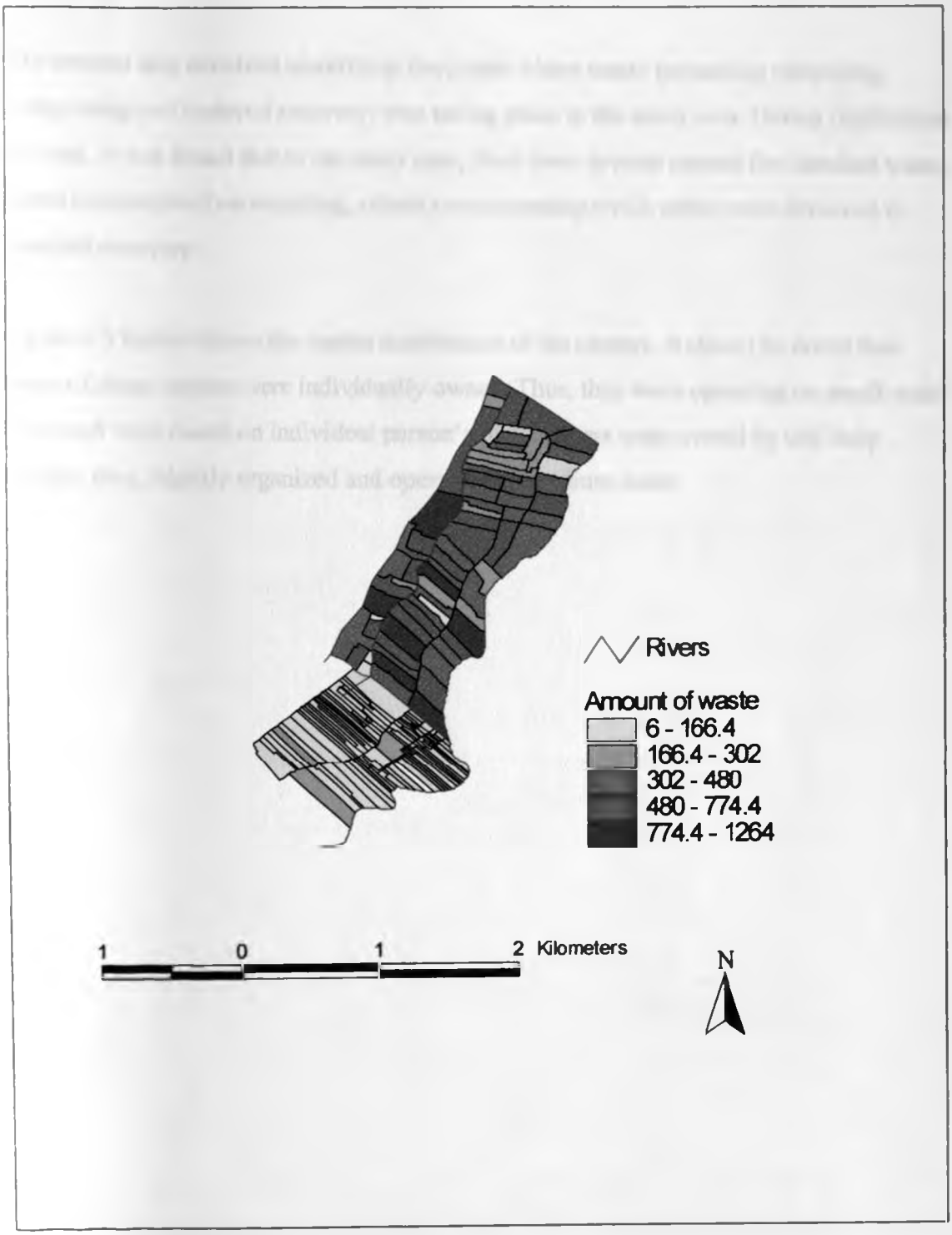


Figure 4.4: Enumeration Areas symbolized according to amount of waste produced.

Source: GIS analysis, 2004.

The spatial map showed at a glance the areas with a lot of waste. The waste was in kilograms. These areas could therefore need concentrated transfer stations.

The second step involved identifying the points where waste processing (recycling, composting and material recovery) was taking place in the study area. During digitization process, it was found that in the study area, there were several centers that handled waste. Some concentrated on recycling, others on composting while others were involved in material recovery.

Figure 4.5 below shows the spatial distribution of the centers. It should be noted that some of these centers were individually owned. Thus, they were operating on small-scale basis and were based on individual person's plots. Others were owned by self–help groups, thus, slightly organized and operating on medium scale.

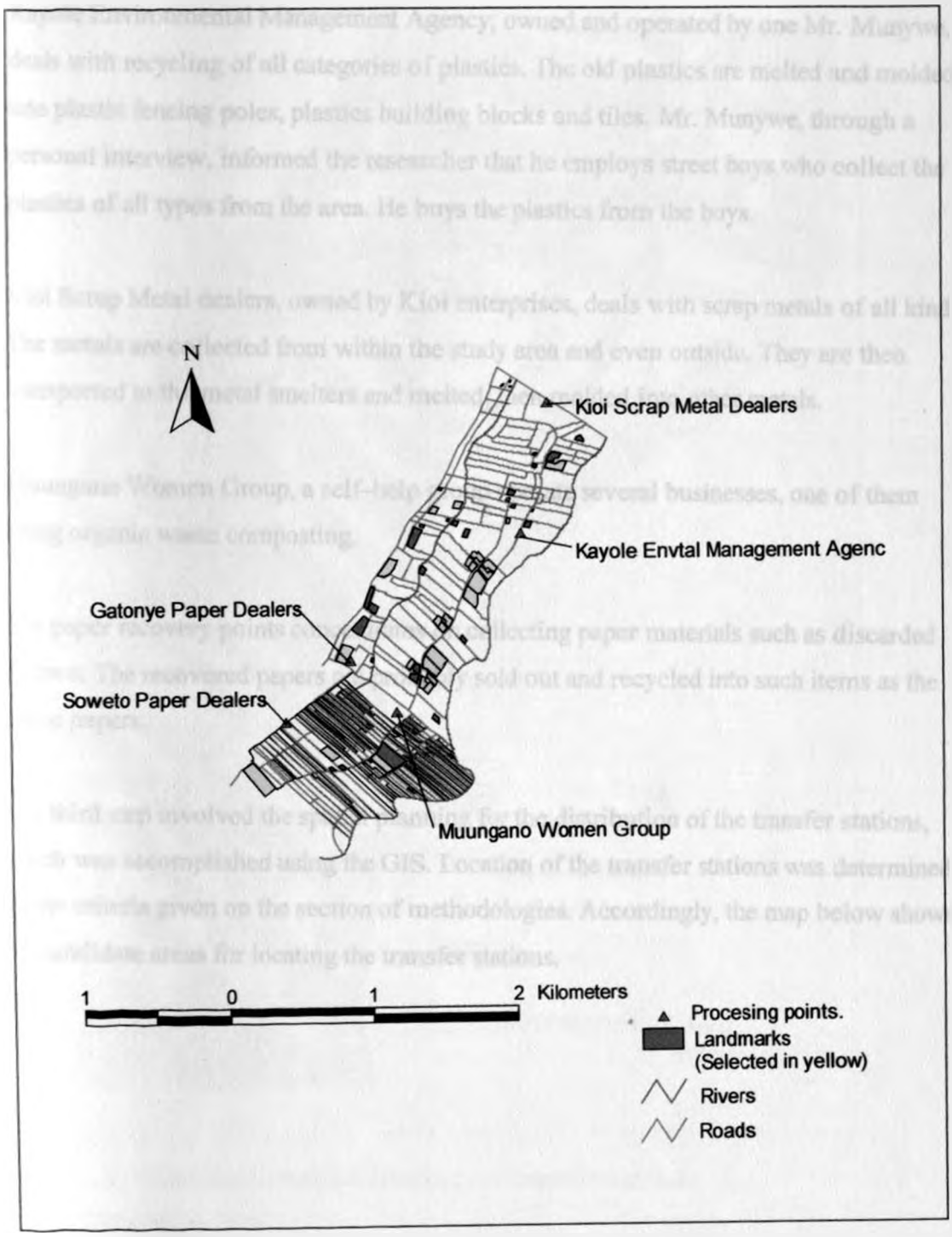


Figure 4.5: Spatial distribution of recycling/composting and/or waste material recovery centres.

Source: GIS analysis, 2004.

Kayole Environmental Management Agency, owned and operated by one Mr. Munywe, deals with recycling of all categories of plastics. The old plastics are melted and molded into plastic fencing poles, plastics building blocks and tiles. Mr. Munywe, through a personal interview, informed the researcher that he employs street boys who collect the plastics of all types from the area. He buys the plastics from the boys.

Kioi Scrap Metal dealers, owned by Kioi enterprises, deals with scrap metals of all kind. The metals are collected from within the study area and even outside. They are then transported to the metal smelters and melted, then molded into other metals.

Muungano Women Group, a self–help group operate several businesses, one of them being organic waste composting.

The paper recovery points concentrates on collecting paper materials such as discarded cartons. The recovered papers are probably sold out and recycled into such items as the tissue papers.

The third step involved the spatial planning for the distribution of the transfer stations, which was accomplished using the GIS. Location of the transfer stations was determined by the criteria given on the section of methodologies. Accordingly, the map below shows the candidate areas for locating the transfer stations.

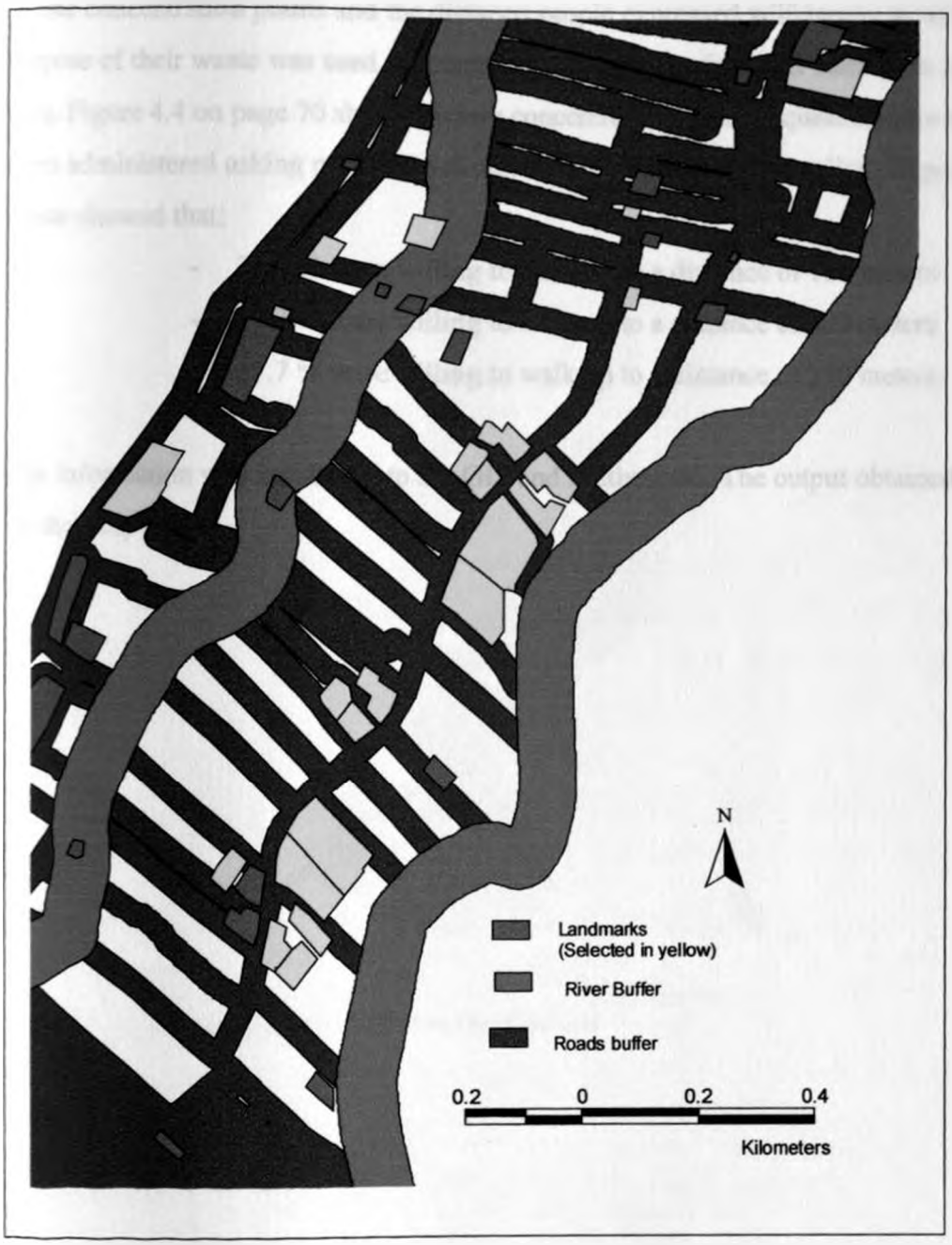


Figure 4.6: Candidate areas for locating the transfer stations.

Source: GIS analysis, 2004.

The transfer station should be outside the pink river buffer, within the blue roads buffer and within the yellow marked landmarks (which are open, underdeveloped space or publicly owned land such as a school, playground, or an area earmarked for a market).

Waste concentration points and the distance people expressed willingness to walk to dispose of their waste was used to determine the number of transfer stations in the study area. Figure 4.4 on page 70 showed waste concentration areas. A questionnaire that had been administered asking people the distance they were willing to walk to dispose of their waste showed that;

- 35.1 % were willing to walk up to a distance of 100 meters
- 47.2 % were willing to walk up to a distance of 200 meters
- 17.7 % were willing to walk up to a distance of 300 meters.

The information was inputted into the GIS and synthesized. The output obtained is shown on the Map below.

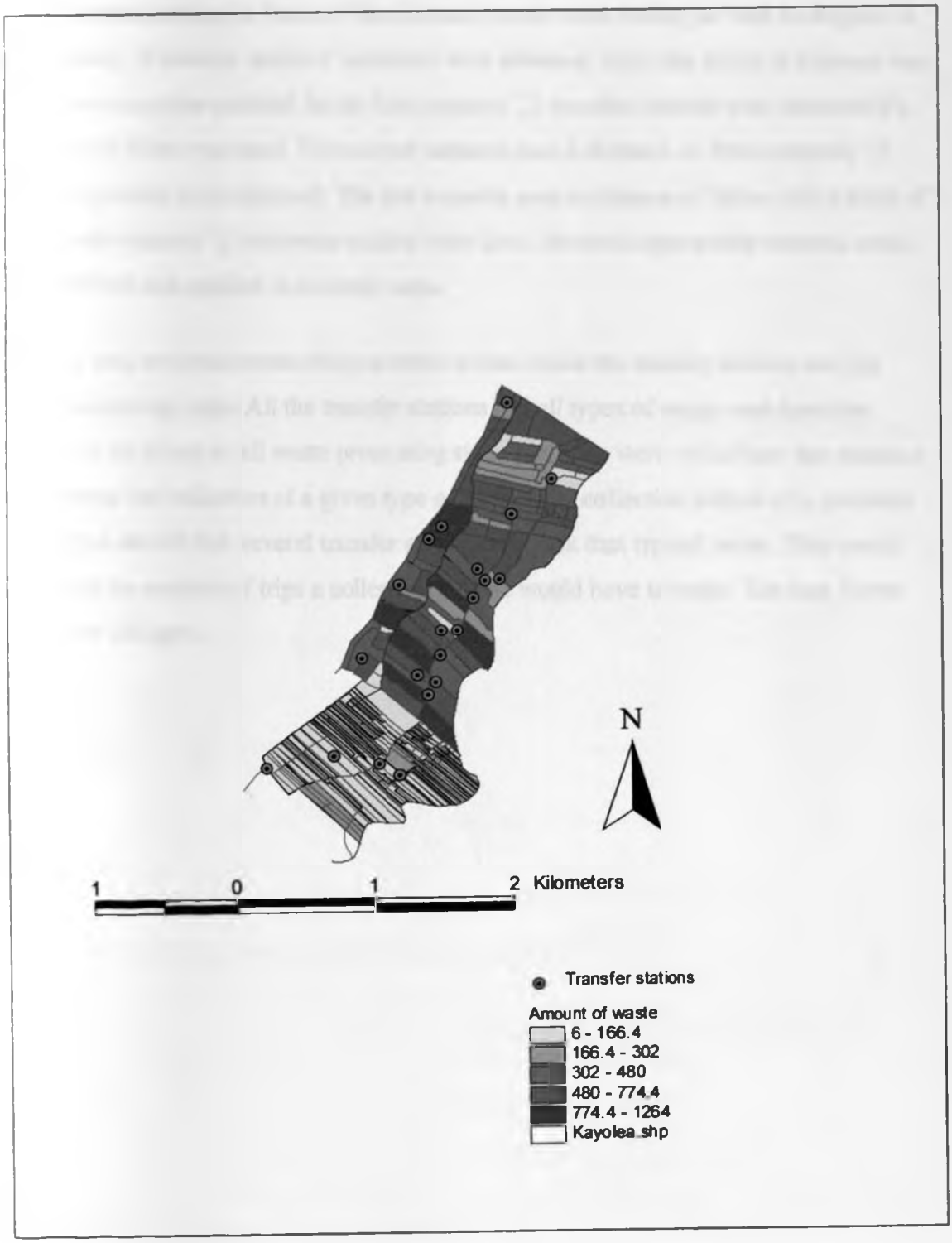


Figure 4.7: Spatial distribution of the transfer stations (Scenario 1, 100m).

Source: GIS analysis, 2004.

Without considering the factor of the distance people were willing to walk to dispose of their waste, 26 transfer stations' locations were obtained. Once the factor of distance was put, three scenarios resulted. In the first scenario, 21 transfer stations were obtained if a distance of 100m was used. The second scenario used a distance of 200m whereby 18 transfer stations were obtained. The last scenario used a distance of 300m with a result of 12 transfer stations. If economic studies were done, the most appropriate scenario could be identified and applied in the study area.

The last step involved establishing a network that linked the transfer stations and the waste processing sites. All the transfer stations had all types of wastes and therefore needed to be linked to all waste processing sites. The links were to facilitate the planning of a routine for collection of a given type of waste i.e. a collection vehicle of a particular waste type should link several transfer stations and pick that type of waste. This would minimize the number of trips a collection vehicle would have to make. The map below shows the linkages.

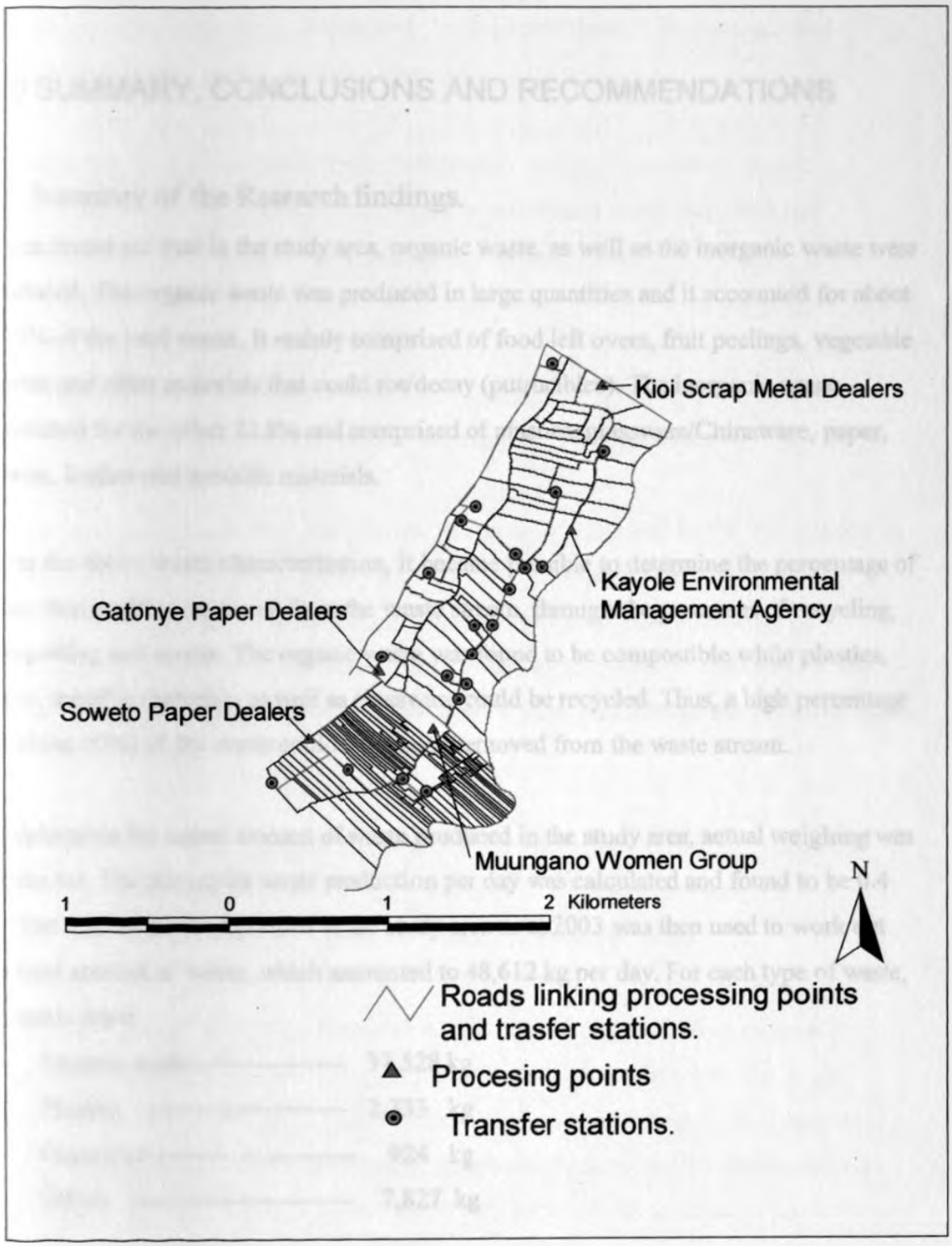


Figure 4.8: Map showing the linkages of the transfer stations and the waste processing sites.

Source: GIS analysis, 2004.

CHAPTER 5

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of the Research findings.

It was found out that in the study area, organic waste, as well as the inorganic waste were produced. The organic waste was produced in large quantities and it accounted for about 77.2% of the total waste. It mainly comprised of food left overs, fruit peelings, vegetable wastes and other materials that could rot/decay (putrucibles). The inorganic waste accounted for the other 22.8% and comprised of plastics, glassware/Chinaware, paper, fabrics, leather and metallic materials.

From the above waste characterization, it became possible to determine the percentage of waste that could be removed from the waste stream, through the processes of recycling, composting and re-use. The organic waste was found to be compostible while plastics, paper, metallic materials as well as glassware could be recycled. Thus, a high percentage (of about 90%) of the waste could have been removed from the waste stream.

To determine the actual amount of waste produced in the study area, actual weighing was conducted. The per capita waste production per day was calculated and found to be 0.4 kg. The total number of persons in the study area as at 2003 was then used to work out the total amount of waste, which amounted to 48,612 kg per day. For each type of waste, the totals were;

- Organic waste---------- 37,528 kg
- Plastics ---------- 2,333 kg
- Glassware ---------- 924 kg
- Others ---------- 7,827 kg

Several issues/facts with regard to solid waste management and handling were established. It was found out that about 37.6% of the residents disposed of their waste through private waste collection organizations. 55.3% disposed of their waste at the open

spaces while only 7.1% surrendered their waste to voluntary groups interested in recycling and/or composting. Majority of the residents (about 95%) used polythene bags as the waste storage facility, awaiting disposal.

For those who surrendered their waste to voluntary groups for recycling and/or composting, a high percentage (85%) did not separate their waste, despite being requested to do so. They gave various reasons, which included;

- Lack of time
- The work being dirty
- Lack of co-operation from others
- Lack of information with regard to the importance of separating.

It was established that in most households, the waste was handled by the wife/mother in the house or by the house girl where there was one. It was also found out that many households, about (92.6%) were willing to support self-help groups that may be interested in recycling and/or composting. The support was mainly to be in the form of payment for waste collection, source-separation of waste and willingness to deliver waste to designated points.

It was on the basis of the research findings that the researcher designed an integrated solid waste management system, for the study area. The system was designed in such a manner that it incorporated all aspects as established through the study.

The quantity of waste in the study area as well as the willingness of the residents to support the self help groups interested in recycling and composting were the major factors considered in planning a spatial framework for waste management. The spatial framework resulted in the establishment of transfer stations, where the residents are to deliver their separated waste. A spatial framework could not be achieved without the use of Geographical Information Systems (GIS). Thus, GIS was used as a tool to facilitate the spatial planning.

5.2 Conclusion.

The various types and quantities of wastes have been established for the study area. Similarly, the relevant centers that do compost, recycle or recover the various waste types have been identified. A spatial framework have also been worked out that would facilitate the collection and transportation of the waste, diverting each type of waste to its appropriate point for composting, recycling or recovery. It is therefore imperative to implement the programme. This is so because it was found out that the area's wastes could be dealt with within the area. The availability of the waste processing/handling centers is an important factor that would see the area exporting no waste to other areas. This would reduce the need to transport the waste to the only one landfill in Nairobi at Dandora.

The other issues emerging from the study were used to formulate policies with regard to solid waste management and handling. These policies are outlined in the recommendation section.

5.3 Recommendations

To implement the programme, there is need to work out policies with regard to waste handling, right from the source to the recycling/composting/recovery centers. Many issues with regard to waste handling emerged from the study that needs to be put into consideration while working out the policies. Thus, the researcher recommends that;

(i) Though plastic waste was found to be produced in small quantity by mass, by volume it could be very high. The plastics, particularly the polythene were all over and one could easily/mistakenly judge that it was the waste produced in large quantity. This could probably be attributed to the fact that there is increase in use of polythene for material packaging. Most of the consumer commodities are packed in polythene, ranging from commodities from supermarkets/shops to groceries. This has led to the increase in the polythene and the problem is coupled by the fact that the society is also uncaring about its environment. There is therefore need to adopt the 3R's, reduce, re-use and recycle. The society should reduce the use of the

polythene as much as possible. The polythene should also be used several times before being discarded and when discarding, it should be disposed of in a cleaner manner so that the recyclers will find their work easy. The government should also come in and enact a legislative that would reduce use of polythene for packaging of commodities and encourage the practice of recycling. A high tax could be imposed on the polythene and plastic materials to make them expensive thus discourage their lucrative usage.

(ii) It was found out that people were not utilizing the composting / recycling/recovery points to dispose of their wastes. Instead, majority dispose of their waste at the open spaces, dirtifying the area. There is therefore need to undertake a vigorous campaign on environmental awareness. The relevant authorities, particularly the NCC, NGO'S, Self-help Groups etc should use the media, posters, workshops, seminars, demonstrations among other means to sensitize people on the need to keep the environment clean. People should be encouraged to utilize the locally existing waste material processing plants to dispose of their waste, where it could be processed into another commodity thus avoiding dumping into the environment.

(iii) It should be noted that during the study, it was established that the women (mothers/wife) and the house girls were the ones who handled the waste in the household. Thus the environmental campaigns should aim at this group, but should include others as well.

(iv) During the environmental campaigns, people should be informed of the importance of separating their waste at the source. This would facilitate the composting, recycling and recovery of waste materials.

(v) As people expressed willingness to deliver their waste to transfer stations, the transfer stations should have compartments for the various waste types. The person delivering the waste should deposit each type of waste to its rightful compartment. The person manning the transfer station should ensure that this is followed. The factor of incentive could be applied here, whereby the household that separates its

waste is charged less. Each household should have a waste delivery sheet, which should be carried while delivering waste. The frequency of delivery should be entered as well as noting the households that are separating their waste. A household with very low frequency of delivery should be suspected as disposing waste at the open spaces and hence the environmental groups with the help of other stakeholders could launch an investigation.

(vi) To ensure that people refrain from disposing waste on the open spaces, the owners of the undeveloped plots should be asked to develop their plots or fence their plots properly. The environmental groups in the study area should be strengthened to oversee that the environment is not polluted. They could be given the mandate to prosecute those found polluting the environment through careless disposal of wastes. The Government, through the office of the provincial administration e.g. the district officer, chief and sub-chief's offices could as well help and lend hand the environmental groups. The polluter pays principle should be put into application whereby those found polluting the environment should pay for the cost of cleaning it.

(vii) To facilitate collection of fee for waste collection from the households, a system incorporating paying stations at the transfer stations as well as field clerks could be introduced. The area could be divided into small sections and each section to have persons responsible for fee collection and receipting. An action could be taken for defaulters. However, the fee should be minimal to encourage people to pay. The organizations should make use of available technologies to convert the waste materials into other economically important products to generate money to run the programme. The separated materials could also be sold out to those who can recycle them.

5.3.1 Recommendations for further research

The current study concentrated on finding out the types and quantities of waste emanating from the study area as well as investigating the various issues/facts with

regard to waste handling and management. Using this information, a spatial framework was worked out. The framework adopted the notion of transfer stations that are linked through a network of roads to recycling/composting/recovery centers. The study only looked at the environmental aspects.

For the programme to be sustainable, and self-propagating, the economic aspects also need to be studied. Particularly, it is important to work out the design and capacity of the transfer stations. Knowing the capacity, it would be possible to work out the frequency of the removal of the waste from the stations and a route could be worked out to combine two or more stations depending on their capacities. This would lead into the determination of the cost of collection of waste from the transfer stations–in terms of number of vehicles needed and their capacities, crew size, fuel costs as distance is known and any levy that might be imposed.

Therefore, the researcher proposes that a study be done to;

- Determine the capacities of the various transfer stations depending on the waste quantity in the area served by the transfer stations.
- Determine the waste removal frequency from the transfer station
- Determine the cost of running the programme.

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Appendix 1: Questionnaire to Residents.

Dear resident,
This questionnaire is part of a research inquiring on issues related to handling and management of solid waste in Kayole and Soweto estates. Please respond to all items in this questionnaire expressing your opinion accurately. All your responses will be treated in confidence and will be used only for this research inquiry.

Part 1
Name of collaborator: _____. Position in the house _____.
Reference number: _____
House type: [ ] Single storey. [ ] Flat. [ ] Single rental
Number of people living in the house: _____
Part 2
(a) How do you dispose of your waste?
[ ] Through private waste collection organizations for a fee.
[ ] Throw the waste at the dumpsites at the open spaces in the estate.
[ ] Deposit the waste at strategic points for the city councils personnel to pick and dump in the approved dumpsite.
[ ] Surrender the waste to voluntary waste collectors who are interested in recycling.
[ ] Other means, specify. _____
(b) (i)If through private waste collection organizations, what types of collection facilities are provided?
[ ] None [ ] Metallic dustbins [ ] Polythene bags [ ] Cartons
[ ] Plastic bins [ ] Others, specify _____
(ii) Where do the organizations dispose the waste they collect from you?
[ ] I don't know [ ] At the main dumpsite in Dandora.
[ ] At the nearby river valley.
(c) (i) If to voluntary waste recyclers, do they require the waste separated?
[ ] Yes [ ] No
(ii) If yes, do they provide facilities for different types of wastes?
[ ] Yes [ ] No
(iii) If yes, do you separate the wastes? [ ] Yes [ ] No
(iv) If you do not separate, why? [ ] Have no time [ ] It's dirty [ ] I don't know why I should do it.
[ ] Other people whom we share the facility do not separate their waste.
(d) Who deals with the household waste in the house? [ ] Wife/Mother [ ] Husband/Father [ ] House girl [ ]Other
(a) Would you support /help organizations that require different materials (otherwise regarded as waste) for recycling or composting? [ ] Yes [ ] No
(b) If yes, how would you support such organizations?
[ ] By paying them to collect my waste to recycle or compost.
[ ] By giving them advice and encouraging them to continue with their work.

[ ] By helping them do manual jobs when I am free.

(a) If you were to support the organizations by surrendering your waste for them to recycle or to compost, would you separate the waste before you give it out, if requested?

[ ] Yes [ ] No

(b) If yes, what would you require?

[ ] Different collection facilities for the different types of wastes.

[ ] Some incentives for me to separate the waste.

(c) If you need some incentives, of what kind?

[ ] Reduced waste collection fee if I deliver separated materials

[ ] Being invited to contest for prizes in green events

[ ] Being called upon to participate in seminars and/or workshops on environmental issues. [ ] Any other. Specify _____

(a) Waste disposal contributes to environmental degradation in this area. What is your view?

[ ] Agree strongly with this statement. [ ] Agree moderately with this statement.

[ ] Undecided. [ ] Disagree moderately. [ ] Disagree strongly.

According to you, in which way(s) do waste disposal pose a problem?

_____

_____

_____

(c) (i) Given a number of options for waste disposal, which one would you prefer?

[ ] Dumping in an approved dumpsite if near it.

[ ] Dumping in any open space near my home.

[ ] Taking the waste for recycling or for composting.

(d) Would you avail yourself to seminars and/or workshops covering topics on environmental issues? [ ] Yes [ ] No

(a) Due to great number of households in the locality, collection of separated waste is not possible from each and every household. Would you be willing to deliver your waste to a nearby designated collection point?

[ ] Yes [ ] No

(b) If yes, what distance are you willing to walk, to dispose of your waste?

[ ] Less than 100 meters. [ ] Up to 200 meters. [ ] Up to 300 meters.

Of the following, tick the highest education certificate obtained.

[ ] KCPE [ ] KCSE [ ] A-LEVE [ ] DIPLOMA

[ ] DEGREE [ ]NONE [ ] OTHER,

SPECIFY_____

Appendix 2: **Questionnaire to evaluate householder's attitude on the source separation technique.**

Dear correspondent,

This questionnaire is part of a research inquiring on issues related to handling and management of solid waste in Kayole and Soweto estates. Please respond to all items in this questionnaire expressing your opinion accurately. All your responses will be treated in confidence and will be used only for this research inquiry.

Name of collaborator

Reference number

House type [i] Single storey [ii] Flat.

Number of people living in the house

(a) Did you separate your household waste? [i] Yes [ii] No

(b) If yes, into what components? [i] Organic [ii] Glass [iii] metal [iv] Plastic

[v] Other, specify _____.

(c) If no, why? [i] It is tedious [ii] It is dirty [iii] Has no benefit to me

[iv] Other reason(s) – explain _____.

Did you have adequate facilities for storage of the various types of wastes? [i] Yes [ii] No

(a) Do you have enough space for your waste storage facilities at your homestead?

[i] Yes [ii] No

(b) Where are the storage facilities placed? [i] Inside the house [ii] outside the house.

8. What is/are the main problem(s) did you experience in the source separation of waste? [i] Lack of facilities

[ii] Lack of space for storing waste collection facilities.

[iii] Lack of interest.

[iv] Lack of information on the importance of the whole exercise.

Appendix 3: Table showing EA number, number of households, population of 2003 and total waste in each enumeration area.

Kayole ID	EA. NO	S/name	H/holds	Pop2003	TotWst2003
302002	302- 0022	Savanna	51	174	69.6
302003	302 - 0032	Savanna	112	364	145.6
302004	42	Savanna	104	369	147.6
302005	52	Savanna	86	280	112
302006	62	Savanna	76	237	94.8
302007	72	Savanna	104	306	122.4
302008	82	Savanna	105	298	119.2
302009	92	Savanna	105	306	122.4
302010	102	Savanna	98	268	104.2
302011	112	Savanna	110	328	131.2
302012	122	Savanna	67	214	85.6
302013	132	Savanna	97	270	108
302014	142	Savanna	28	71	28.4
302015	152	Savanna	102	319	127.6
302016	162	Savanna	69	241	96.4
302017	172	Savanna	114	321	128.4
302018	182	Savanna	105	311	124.4
302019	192	Savanna	135	358	143.2
302020	202	Savanna	79	246	98.4
302021	212	Savanna	79	215	86
302022	222	Savanna	98	280	112
302023	232	Savanna	60	163	65.2
302024	242	Savanna	94	288	115.2
302025	252	Savanna	211	594	237.6
302026	262	Savanna	82	286	114.4
302027	272	Savanna	97	299	119.6
302028	282	Savanna	56	151	60.4
302029	292	Savanna	89	275	110
302030	302	Savanna	86	240	96
302031	312	Savanna	90	271	108.4
302032	322	Savanna	94	285	114
302033	332	Savanna	105	302	120.8
302034	342	Savanna	72	211	84.4
302035	352	Savanna	73	182	72.8
302036	362	Savanna	69	187	74.8
302037	372	Savanna	71	191	76.4
302038	382	Savanna	103	334	133.6
302039	392	Savanna	49	157	62.8
302040	402	Savanna	107	322	128.8
302041	412	Savanna	108	307	122.8
302042	422	Savanna	105	380	152
302043	432	Savanna	103	297	118.8

302044	442	Savanna	119	328	131.2
302045	452	Savanna	214	593	237.2
302046	462	Savanna	81	244	97.6
302047	472	Savanna	76	200	80
302048	482	Savanna	87	243	97.2
302049	492	Savanna	55	197	78.8
302065	652	Savanna	181	475	190
302066	662	Savanna	140	399	159.6
302067	672	Savanna	43	110	44
302068	682	Savanna	27	85	34
302069	692	Savanna	107	338	135.2
302070	702	Savanna	86	279	111.6
302071	712	Savanna	68	202	80.8
302072	722	Savanna	300	885	354
302073	732	Savanna	101	319	127.6
302074	742	Savanna	136	381	152.4
302075	752	Savanna	99	255	102
302076	762	Savanna	86	256	102.4
302077	772	Savanna	83	215	86
302078	782	Savanna	69	190	76
302079	792	Savanna	92	314	125.6
302080	802	Savanna	67	191	76.4
302081	812	Savanna	71	205	82
302082	822	Savanna	94	249	99.6
302083	832	Savanna	150	399	159.6
302084	842	Savanna	64	177	70.8
302085	852	Savanna	176	488	195.2
302086	862	Savanna	67	191	76.4
302087	872	Savanna	32	86	34.4
302088	882	Savanna	36	91	36.4
302089	892	Savanna	100	301	120.4
302090	902	Savanna	92	261	104.4
302091	912	Savanna	82	226	90.4
302092	922	Savanna	222	620	248
302093	932	Savanna	72	229	91.6
302095	952	Savanna	70	175	70
302096	962	Savanna	102	320	128
302097	972	Savanna	48	137	54.8
302098	982	Savanna	38	120	48
302099	992	Savanna	106	350	140
302100	1002	Savanna	75	213	85.2
302101	1012	Savanna	94	326	130.4
302102	1022	Savanna	88	297	118.8
302103	1032	Savanna	104	299	119.6
302104	1042	Savanna	78	240	96
302105	1052	Savanna	100	290	116
302106	1062	Savanna	88	282	112.8
302107	1072	Savanna	5	15	6

302108	1082	Savanna	69	226	90.4
302109	1092	Savanna	93	310	124
302110	1102	Savanna	88	318	127.2
302111	1112	Savanna	82	250	100
302112	1122	Savanna	109	303	121.2
302113	1132	Savanna	100	398	159.2
302114	1142	Savanna	64	168	67.2
401001	401-12	Kayole	438	1376	550.4
401002	22	Kayole	462	1509	603.6
401003	32	Kayole	477	1602	640.8
401004	42	Kayole	237	834	333.6
401005	52	Kayole	84	272	108.8
401006	62	Kayole	316	1117	446.8
401007	72	Kayole	391	1398	559.2
401008	82	Kayole	275	839	335.6
401009	92	Kayole	247	845	338
401010	102	Kayole	428	1449	579.6
401011	112	Kayole	357	1041	416.4
401012	122	Kayole	124	403	161.2
401013	132	Kayole	242	895	358
401014	142	Kayole	231	818	327.2
401015	152	Kayole	131	466	186.4
401016	162	Kayole	96	364	145.6
401017	172	Kayole	162	551	220.4
401018	182	Kayole	175	698	279.2
401019	192	Kayole	189	614	255.6
401020	202	Kayole	229	755	302
401021	212	Kayole	264	906	362.4
401022	222	Kayole	387	1196	478.4
401023	232	Kayole	409	1441	576.4
401024	242	Kayole	278	994	397.6
401025	252	Kayole	325	1175	470
401026	262	Kayole	292	1100	440
401027	272	Kayole	157	495	198
401028	282	Kayole	352	1310	524
401029	292	Kayole	422	1512	604.8
401030	302	Kayole	286	975	390
401031	312	Kayole	525	1796	718.4
401032	322	Kayole	290	864	345.6
401033	332	Kayole	700	2380	952
401034	342	Kayole	209	673	269.2
401035	352	Kayole	387	1161	464.4
401036	362	Kayole	98	389	155.6
401037	372	Kayole	267	894	357.6
401038	382	Kayole	552	1814	725.6
401039	392	Kayole	533	1756	702.4
401040	402	Kayole	945	3160	1264
401041	412	Kayole	347	1282	512.8

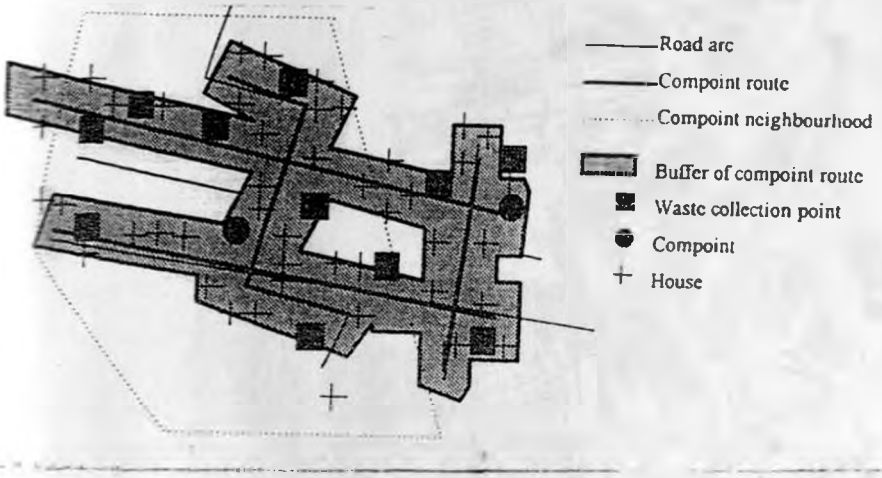
401042	422	Kayole	296	1057	422.8
401043	432	Kayole	678	2152	860.8
401044	442	Kayole	502	1708	683.2
401045	452	Kayole	231	732	292.8
401046	462	Kayole	289	1017	406.8
401047	472	Kayole	179	578	231.2
401048	482	Kayole	716	2536	1014.4
401049	492	Kayole	389	1357	542.8
401050	502	Kayole	296	959	383.6
401051	512	Kayole	352	1200	480
401052	522	Kayole	517	1936	774.4
401053	532	Kayole	678	2408	963.2
401055	552	Kayole	514	1753	701.2
401056	562	Kayole	69	259	103.6
401057	572	Kayole	267	898	359.2
401058	582	Kayole	439	1486	594.4
401059	592	Kayole	89	354	141.6
401060	602	Kayole	675	2269	907.6
401061	612	Kayole	409	1519	607.6
401062	622	Kayole	179	613	245.2
401063	632	Kayole	250	910	364
401064	642	Kayole	449	1529	611.6
401065	652	Kayole	263	844	337.6
401066	662	Kayole	490	1787	714.8
401067	672	Kayole	882	3111	1244.4
401068	682	Kayole	481	1684	673.6
401069	692	Kayole	192	745	298
401070	702	Kayole	403	1408	563.2

Appendix 4:Table showing waste production by the households during the three collection periods.

		1st collection		2nd collection		3rd collection		
Household Reference number	Number of persons	Weight of waste collected	Weight of waste/ person/ day	Weight of waste collected	Weight of waste/ person/ day	Weight of waste collected	Weight of waste/ person/day	Average Weight of waste/ person/day
0142-3	4	7.0	0.44	6.5	0.41	7.2	0.45	0.43
0052-5	5	8.0	0.40	7.0	0.35	7.9	0.40	0.38
0062-3	6	12.0	0.50	11	0.46	11.3	0.47	0.47
0062-4	3	4.0	0.33	3.8	0.32	3.6	0.30	0.32
0222-2	5	7.0	0.35	7.3	0.37	7.6	0.38	0.37
0072-1	5	6.5	0.32	6.9	0.34	7.0	0.35	0.34
0072-6	3	4.0	0.33	4.0	0.33	3.8	0.32	0.33
0082-4	3	5.0	0.41	5.2	0.43	4.8	0.40	0.41
0292-3	5	9.0	0.45	8.5	0.43	7.9	0.40	0.43
0292-4	6	11.0	0.46	10.0	0.42	11.3	0.47	0.45
0662-1	6	10.0	0.41	10.0	0.42	11.0	0.46	0.43
0322-1	4	5.0	0.31	5.2	0.33	4.9	0.30	0.31
0322-3	4	7.0	0.44	7.5	0.47	8.1	0.51	0.47
0322-6	5	8.0	0.40	7.5	0.38	9.1	0.46	0.41
0342-5	6	10.5	0.44	10.0	0.42	9.6	0.40	0.42
0612-6	4	6.0	0.38	6.5	0.41	7.0	0.44	0.41
0352-1	4	5.0	0.31	5.5	0.34	5.1	0.32	0.32
0362-1	3	4.0	0.33	3.5	0.29	4.5	0.38	0.33
0502-3	3	4.0	0.33	4.2	0.35	3.9	0.33	0.34
0502-5	3	3.0	0.25	3.0	0.25	3.6	0.30	0.27
0502-6	6	10.0	0.42	9.0	0.38	11.1	0.46	0.42
0512-6	5	8.0	0.40	8.5	0.43	9.0	0.45	0.43
0272-5	4	6.0	0.38	6.0	0.38	6.5	0.41	0.39
0302-3	4	4.0	0.25	4.2	0.26	3.8	0.24	0.25
0382-5	5	7.0	0.35	7.3	0.37	6.5	0.33	0.35
0432-3	4	5.0	0.31	4.8	0.30	5.3	0.33	0.31
0242-1	2	3.0	0.38	3.5	0.43	4.0	0.50	0.44
0242-6	3	6.0	0.50	5.6	0.47	5.4	0.45	0.47
0442-1	3	4.0	0.33	3.0	0.25	3.9	0.33	0.30
0292-1	5	10.0	0.50	9.0	0.45	8.2	0.41	0.45
0292-6	4	6.0	0.38	5.5	0.34	6.3	0.39	0.37
0822-1	4	6.0	0.38	6.2	0.39	7.0	0.44	0.40
0822-3	3	4.7	0.39	5.0	0.41	5.5	0.45	0.41
0822-5	3	4.5	0.38	4.0	0.33	3.5	0.25	0.33
0862-6	3	5.0	0.42	4.0	0.33	3.2	0.27	0.35
0892-3	3	4.0	0.33	3.8	0.32	4.3	0.36	0.34

0892-6	3	4.0	0.33	4.0	0.33	5.0	0.41	036
0982-1	5	8.0	0.40	7.2	0.36	8.0	0.40	0.39
0082-1	6	7.0	0.29	6.3	0.26	5.3	0.22	0.26
0082-5	3	5.0	0.42	4.0	0.33	4.5	0.38	0.38
0112-2	4	7.0	0.44	7.5	0.47	6.0	0.38	0.43
1062-6	3	5.2	0.43	4.8	0.40	6.0	0.50	0.44
1052-3	4	7.0	0.44	7.5	0.47	7.0	0.44	0.45
1052-6	5	9.0	0.45	8.0	0.40	7.0	0.35	0.40
1032-1	6	11.5	0.48	10.0	0.42	11.0	0.45	0.45
0932-1	2	2.5	0.31	2.7	0.34	3.4	0.42	0.36
0892-5	5	8.0	0.40	7.0	0.35	6.5	0.33	0.36
0932-1	6	8.5	0.35	8.0	0.33	6.5	0.27	0.32
0692-3	6	11.5	0.47	10.0	0.42	11.0	0.46	0.45
0512-4	6	11.0	0.46	10.0	0.42	9.0	0.38	0.42
Total								**19.80**

Appendix 5(b): A sketch of the procedure for determining the food waste generation potential around a given compoint.



The compoint route is the allocation out of a given distance, say 1.5 km, from the compoint, and the buffer of the collection neighborhood, but because this will overlap into the collection neighborhood of the adjacent compoints this collection neighborhood is further cut by the tessellation boundary. Waste generation can be estimated by counting up the number of houses.

Appendix 5 (a): Potential 1.5 km service area for Bank Kapi compoints. (Map originally based on 1:60,000 scale). Inset is enlarged to show detail.