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THESIS TITLE

MASS BALANCE OF PLASTICS:
CASE STUDY FOR NAIROBI CITY

BY
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DECLARATION

I, Nancy Wanjikú. Múkúi, hereby declare that this thesis is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other Institution of Higher Learning.

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Nancy Wanjikú. Múkúi (F56/7547/2003) DATE

This thesis has been submitted for examination with my approval as University Supervisor.

SIGNATURE: --- ----------------------------------

Prof. Patts M.A. Odira DATE

DEDICATION

Special dedication to my lovely children Isaac, Stephen and Olympia – Any one day, you have within you the power to look full into your circumstances and write how you want your story.

Dedication to my husband Zablon, my parents Beatrice and Stephen - Even the longest night finally succumbs to daybreak!

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ABSTRACT

This thesis focuses on tracking the movement of plastic materials within the City County of Nairobi (CCN) in order to establish the mass quantities of plastics that enter within, where they flow, how they are transferred and where they finally end up. In so doing, identify if there is a problem of pollution by accumulated plastic wastes, and if so, show the point at which it occurs. The objectives were to compile industrial production and waste quantities of various types of plastics, quantify the accumulation and transfer terms useful in writing mass balances and provide data and recommendations that can inform and motivate policy changes so that environmental problems caused by the plastic wastes are reduced

The spatial scope of the study was city-wide for CCN and time, the year 2011. The study established the imports were the entry points for plastic materials, the processes that plastics undergo, namely manufacture, retail, waste disposal and recycle. The study explored the flows and transfers plastics are subjected as retail, plastics waste generation, collection, diversion as well as the exits via exports, resale and disposal. The institutions acting at various processes and transfers in the plastics sector and their roles were established.

Data was collected through administration of questionnaires as follows: - 30 plastic products manufacturers whose age range is 7-44 years, 89 retailers whose age varied from start-ups to 30 years old and 55 recyclers who were 2 years old on average. Data on plastic wastes was obtained from City County of Nairobi (CCN). Key Informant Interviews were conducted with key plastics sector players on relevant standards, policies and operations such as National Environment Management Authority (NEMA), Kenya Association of Manufacturers (KAM), Kenya Bureau of Standards (KEBS) and the Kenya National Cleaner Production Centre (KNCPC). The collected data was analyzed, collated for use in establishing the quantities of common plastic resins imported into the study boundary, to track their flows and transfers through retail, recycle, collection and disposal within a given time period. Mass balances for the movement of the plastics within Nairobi City were developed.

The results of the study established that overall; manufacturers imported 2,437,419 kg of plastics per week. These were manufactured into products comprising the seven common plastic resins namely, 15% Polyethylene Terephthalate (PET, PETE), 21% High Density Polyethylene (HDPE), 16% Polyvinyl Chloride (PVC), 19% Low Density Polyethylene (LDPE), 24% Polypropylene (PP), 1% Polystyrene (PS) and 4% others. Of this production,

manufacturers sold 42% (1,027,525 kg/week) to retail in Nairobi and 58% were sold outside the study boundaries. Plastic products manufactured from the resins were in categories of finished consumer products (62%), plastic packaging (24%), and raw materials for other products (8%), carrier bags (3%) and others (3%).

Retailers obtained 164, 419 kg/week from manufacturers. This is 16% of what the manufacturers sold into Nairobi. The sharp loss (84%) in transfer accountability is attributed to the fact that some of manufactured plastics products such as packaging (24%) and raw materials (8%) are not recognized as plastic materials but rather as commodities in retail. Also, manufacturing occurs in a centralized zone with production data in bulk quantities is recorded in mass while on the other hand, retail is city-wide with much less numbers in sales data recorded as items and rarely in mass quantities.

Plastic wastes generated were 1,352,156 kg/week. This increase in waste generation compared to retailed quantities was attributed to the fact that plastic packaging lost during retail re-enters the waste stream recognized as plastic material. 383,739.04 kg/week (33%) of plastic wastes generated were collected in mixed resins and disposed by CCN. 62,469.15 kg/week (14%) of the generated plastic wastes collected by CCN was diverted to recycling. Overall, 393,462.89 kg/week was recycled by recycling enterprises including their own collections within the study boundary.

It was found that, of the 1,027,525 kg/week plastics that entered the study boundaries, 383,739.04 kg/week (37%) was removed through collection by CCN to final disposal and 393,462.89 kg/week (39%) was removed through informal, private-owned recycling enterprise. 250,323 kg/week (24%) of plastics were not removed. These are the therefore the ones that accumulate and cause pollution problems.

The study reveals the need for good quality plastics material data collection, the need to identify data management institutions and the opportunity provided by privately owned plastic recycling enterprise in removal of plastic wastes. The study recommends that authorities seize this opportunity to offer incentives to these private sector enterprises in order to increase removal of plastics wastes and further reduce pollution.

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LIST OF ABBREVIATIONS

ABS	Acrylonitrile-Butadiene-Styrene
APC	American Plastics Council
BPA	Bisphenol-A
CPET	Crystallisable Grades of PET
DDE	DichloroDiphenylDichloroethylene
DDT	DichloroDiphenylTrichloroethane
ED	Endocrine Disruptor
EMCA	Environmental Management and Coordination Act
EPA	United States Environmental Protection Authority
HDPE	High Density polyethylene
HIPS	High-Impact Polystyrene
IPTF	International Plastics Task Force
ISWM	Integrated Solid Waste Management
ISBM	Injection-Stretch Blow Moulding
JICA	Japan International Co-operation agency
KIPPRA	Kenya Institute of Policy Research and Analysis
LDPE	Low Density Polyethylene
LLDPE	Linear Low Density Polyethylene
CCN	City County/Council of Nairobi
NEMA	National Environment Management Authority
PC	Poly-Carbonated Plastics
PCB	Polychlorinated Bisphenol
PET	Polyethylene Terephthalate
PHB	Polyhydroxybutyrate
PLA	Polylactic Acid
PMMA	Polymethyl Methacrylate(s)
POPS	Persistent Organic Pollutants
PP	Polypropylene
ppm	parts per million
PS	Polystyrene
PVC	Polyvinyl Chloride
SAN	Styrene-Acrylonitrile Copolymer

SPI	Society of Plastics Industry, Inc.
SWM	Solid Waste Management
UNDP	United Nations Development Program
UNEP	United Nations Environment Programme
UNIDO	United Nations
ULDPE	Ultra Low Density Polyethylene
UPVC	Unplasticised Polyvinyl Chloride
US, USA	United States of America

1 INTRODUCTION

1.1 BACKGROUND TO AREA OF STUDY

The problem of inefficient solid waste management is widespread in many developing countries. Kenya is no exception, and particularly the Capital City Nairobi. According to the most recent comprehensive studies for Nairobi, solid waste generation was 1,848 tonnes per day in 2009. Plastics comprise 10% of this and daily collection stands 33% (JICA, 2010). Most of the uncollected solid wastes are disposed of in open dumps and on the ground, contaminating the land and posing serious environmental problems such as littering and ingestion by animals, breeding grounds for mosquitos and blocking stormwater drains. This is attributed to mainly to the plastic component in the solid wastes which is additionally, non-biodegradable and therefore rapidly accumulates and causes visual nuisance.

Authorities have initiated various initiatives over the years to rid the City of these plastic wastes. The City Council of Nairobi, responsible for collection, oversight and enforcement of solid waste collection in Nairobi, formulated a policy document on private sector involvement in solid waste management in 2002. The policy set out guidelines to allow and regulate private operators to engage in solid waste collection and thereby complement the CCN effort to reduce plastic pollution (CCN, 2002). Since then, there is now a network of public and private entities engaged in garbage collection. In February 2005, the United Nations Environment Programme (UNEP) based on a report by Kenya Institute for Public Policy Research and Analysis (KIPPRA) titled "Selection, Design and Implementation of Economic Instruments in the Kenyan Solid Waste Management Sector" proposed a ban on manufacture and sale of flimsy plastic shopping bags as well as a hefty levy to be slapped on thicker ones as part of a new plastic waste reduction strategy (UNEP, 2005). The Kenya Bureau of Standards (KEBS) developed a new standard which was gazetted in October 2005– KS 1794 – raising the minimum polythene bag gauge up from 15 µm which is non-recyclable to 30 µm which is longer lasting and recyclable. The Kenyan Treasury in 2007 moved to implement a 120 per cent levy on plastics to protect the environment from degradation.

Strong environmental legislation such as Environmental Management and Coordination Act (EMCA) 1999, the Environmental Management and Coordination (Waste Management) Regulations of 2006 as well as City Council of Nairobi (CCN) Solid Waste Management By-laws of 2007 have been enacted to rid the city and other parts of the country of problems associated with solid wastes. The East African Legislative Assembly (EALA) introduced the Polythene Materials Control Bill (PMCB) in 2011 seeking to control and regulate manufacturing and use of polythene bags within the East African Community (EAC) member countries by limiting their production and distribution in the region.

Various theses have been written on the status of plastic waste management in Nairobi. A study conducted at the University of Nairobi in 2014 sought to establish the social - economic hazards occasioned by plastic bags litter in peri- urban centres of Kenya (Wachira, 2014). Another study carried out in 2013 explored the niche innovations in production and recycling of plastic waste in urban Kenya (Ombis, 2013). Another study conducted in Masinde Muliro University of Science and Technology (MMUST), assessed the extent to which plastic bag waste management methods used in Nairobi City promote sustainability (Aurah, 2013) Many of the studies have majored on the environmental problems emanating from plastic wastes, the role and need for private sector involvement state of solid waste management service and recommended policy, regulatory and institutional changes to reduce the problems.

Mass balance is a method of Material Flow Analysis (MFA) that was developed about 40 years ago. Its value has been applied in other countries and used in various fields such as environmental management, resource management, waste management, and water quality management as a common method in the engineer's toolboxes for solving resource-oriented problems (Brunner, 2004). Material flow analysis was used to assess the amounts of plastic materials flows and stocks that were annually produced, consumed, imported, exported, collected, recycled, and disposed in the landfills in Serbia in 2010 (Vujic, 2010). Also, substance flow analysis was carried out to establish nitrogen and phosphorus in municipal waste in Finland in order to reduce environmental problems, particularly eutrophication of surface waters (Sokka, 2004).

1.2 PROBLEM STATEMENT AND JUSTIFICATION

With increasing plastic products manufacture, plastic waste generation has been on the increase in the recent past. Most plastics are non-biodegradable. Despite being re-usable and recyclable materials, their continued accumulation has raised a lot of concern for citizens and environmentalists due to the increased visible plastic wastes pollution in the city such as littering. This has prompted various disjointed actions and directives such as introduction of excise tax on some plastics or even a ban on selected production. However, a plastic materials inventory for the city does not exist, that clearly documents how much of what resins is produced, by who, what is recycled, in what quantities, and where it finally ends up.

1.3 STUDY OBJECTIVES

This study aims to provide a positive contribution in compiling data to form an inventory in the plastics sub-sector so that plastic pollution abatement efforts and resources are appropriately channeled. The specific objectives are: -

- To identify and compile industrial production (sources) and waste volumes of the various common types of plastics so as to prepare mass balance models,
- To quantify, to the extent possible, the transfer, source and accumulation terms so that mass balances may be written for the plastics at the city level,
- To provide data and recommendations that can inform and motivate policy changes with respect to plastic products so that environmental problems are reduced.

1.4 JUSTIFICATION FOR THE STUDY

The adage “You cannot manage what you cannot measure” is true in this case. The problem of plastics in waste management will only be effectively addressed if the data gap in sources; transport, consumption and disposal patterns are known and quantified. This study is aimed at filling this data gap.

In spite of previous initiatives and studies, the problem of plastic wastes in Nairobi City is still prevalent; a highly visible eyesore in solid waste management. For this reason, the study in mass balance of plastics; case study for Nairobi has been carried out since a city without data of its plastic wastes lacks the power to make informed changes. It is aimed at generating measurement data applicable for reducing the problem of plastics in line with the old adage “You cannot manage what you cannot measure…and what gets measured gets done”.

1.5 SCOPE OF STUDY

The spatial scope of the study covers the whole area of the City of Nairobi under the jurisdiction of the City County of Nairobi (CCN) (formerly City Council of Nairobi (CCN)) excluding restricted areas and the area designated as the Nairobi National Park.

The study is based on plastics data for the year 2011.

2 LITERATURE REVIEW

2.1 TRENDS OF GROWTH IN USE OF PLASTIC PRODUCTS WORLDWIDE

2.1.1 Historical Growth in development and use of Plastics products

Application of plastic materials has grown in just a few decades. As the plastics industry has matured, the widely accepted approach is to emphasize those applications where plastics are preferable to traditional materials. In the electrical industries, combination of excellent insulation properties with toughness, durability and, where desired, flame retardant characteristics have led to wide acceptance of plastics for plugs, sockets, wire and cable insulation. The ability of polyethylene to act as an excellent insulator at high frequencies was of great significance in the early development of radar. There has been increasing acceptance of plastics for housing electrical and electronic equipment, leading to increased use of the more general purpose plastics. Uses include piping, guttering and conduit, damp course layers, flooring, insulation, wall cladding and window frames (Brydson, 1999).

Plastics have been widely accepted as packaging materials. Plastics bottles have significantly gained application in the bathroom, where breakage of glass containers has led to many serious accidents. The ability of many materials to withstand the most corrosive chemicals has been of benefit to the chemical and related industries whilst the light weight compared with a glass bottle reduces the energy required for transportation. Small containers are also widely made from plastics and for medicines, particularly in tablet form; the use of closures that cannot be prised open by young children is particularly valuable. The wide use of plastics films for wrapping, for bags and sacks is almost too well known for comment (Brydson, 1999).

The automotive industry is now a major user of plastics, with the weight of plastics being used per car increasing year by year. It has recently been stated that in the early 1990s the average car contained some 75 kg of plastics. For many years the main uses were associated with car electrical equipment such as batteries, flex, plugs, switches and distributor caps. Plastics then became established in light fittings, seating upholstery and interior body trim. In recent times there has been increased use in under-the-bonnet (under-the-hood) applications such as radiator fans, drain plugs, petrol tubing and coolant water reservoirs. In many applications the weight of material used is small. For example, it has been stated that in one small European car there were 450 different parts made from polyacetal plastics but which had a total weight of only one kilogram. (Brydson, 1999).

Domestic and commercial utilities, furniture and fittings form another important market. The variety of low cost finishes possible compared to traditional materials and their ease of maintenance is important in raising standards of living around the world. Uses include stacking chairs, tables, cutlery, stools, PVC tiles and carpets, armchair body shells, foam upholstery and desk and cupboard drawers, whilst chipboard and decorative laminates are very widely used. In medicine and pharmaceuticals, uses range from spare-part surgery, such as hip joints and heart valves, through catheters, injection syringes and other sterilisable equipment, to more mundane but nevertheless desirable uses such as quiet-running curtain rails. (Brydson, 1999). In agriculture and horticulture plastics are most widely known in film form but they also find use for water piping containers, automatic watering equipment and greenhouse films. (Brydson, 1999). In clothing, plastics are used for footwear in soles and uppers as well as the increasing use of the all-plastics moulded shoe. In rainwear, plastics continue to be used for waterproof lining and in the manufacture of the packable mackintosh.

2.1.2 Factors Contributing to Growth in development and use of plastics products

In essence the reason for the initial spectacular growth lay in the interaction of following factors:-

- A growing understanding of the characteristics and capabilities of plastics materials.
- An improving capability of plastics due to the appearance of new materials, improved qualities with existing types and better processing equipment.
- A steady reduction in the cost of basic plastics raw materials relative to the cost of such traditional materials as leather, paper, metals and ceramics. (Brydson, 1999)

From the most commonplace tasks to complex and specialized needs, plastics increasingly have provided the performance in products that consumers seek. Though it is difficult to summarize the properties of plastics owing to their diverse behavior, an effort is made to give a few rough generalizations on the characteristics of plastics that have significantly contributed to their continued abundance in application. These are as follows:-

- Low cost of production i.e. most plastics may be fabricated in the melt and at quite low temperatures (e.g. 200°C). Thus, the energy requirements for processing are low.

Plastics generally have low densities. This means costs of transportation and general handling are also relatively low.

- The development of such techniques as injection moulding has made it possible to make highly complex parts in one operation without the need for assembly work or the generation of more than a notional amount of scrap material. The decrease in relative costs for plastics coupled with improvements in the methods of making polymers and their intermediate chemicals may have relevance to future prospects.
- Colouring is not usually restricted to the surface but is throughout the mass so that damage due to scratching and abrasion is less obvious than with coated metals.
- Plastics afford extremely wide range of surface finishes which may not only simulate non-plastics materials but in addition produce novel effects.
- Plastic materials are generally excellent thermal insulators, being particularly useful in expanded form.
- Many plastics are superb electrical insulators including, in many instances, good insulation characteristics at high frequencies
- Plastics are available in a wide range of strengths, flexibilities and degrees of toughness. Many fibre-reinforced grades have strength per unit weight figures as high as those of many metals.
- Plastics are available in a wide range of chemical and solvent resistances. Some materials are available that are water soluble whilst others will withstand such aggressive materials as hydrofluoric acid. (Brydson, 1999)

2.1.3 Growth and Social patterns in use of Plastics Products in Kenya

In Kenya an estimated 24 million plastic bags are given out monthly by supermarkets and other shops. Supermarkets alone give out approximately one million plastic bags every year to shoppers in Nairobi (UNEP, 2005).A study by the Kenya Institute for Public Policy Research and Analysis (KIPPRA) in 2005 called for a plastic bag levy, to be collected from either suppliers or directly from shoppers based on experience from Tanzania to Ireland that suggests that this would reduce the consumption and production of plastic bags considerably. The policy on plastic management also proposes voluntary schemes such as a national code of practice for retailers (UNEP, 2005). Some of the plastic products commonly made by the local industries, Kenpoly Industries Ltd, are shown in Figure 2-1:-

Figure 2-1: Some of the common plastic products made locally (Kenpoly Industries)

According to a UNEP report, there are hardly any alternatives to plastic shopping bags with the exception of some paper bags. Shopping bags made from natural products are available in the market but are hardly used because of the easy and free availability of plastic shopping bags in market outlets and the low price which they are sold in outdoor markets (UNEP, 2005). An estimated 4,000 tonnes of the thin plastic bags are produced each month mainly for shopping purposes but also for products like bread. About half of them are less than 15 microns thick and some are as little as seven microns thick (UNEP, 2005). The industry is growing at between eight and ten per cent a year supplying both the local market and nearby countries in particular Uganda (UNEP, 2005).

The recycling of plastics in Kenya is covered by the relevant regulations produced by the Kenya Bureau of Standards (KEBs) under several standards shown in Table 2-1.

Table 2-1: Relevant KEBs standards applicable to various plastics recycling

No.	KS	Area Addressed	Year developed	Description of Standard
1	KS ISO 15360-2 2001 ICS85.040	Recycled Pulp	2006	Recycled Pulps - Estimation of Stickies and Plastics; Part 2: Image Analysis Method
2	KS ISO 15360-1 2000 ICS 85.040	Recycled Pulp	2006	Recycled Pulps - Estimation of Stickies and Plastics; Part 1: Visual Method

2.1.4 Trends in African Countries

Early in the year 2006, the Tanzania Government made a move to ban the use of various types of plastics. This brought to almost a dozen the countries in Africa that have enacted policies to tackle environmental damage. Tanzania joined countries such as Rwanda and South Africa which have set the best example in plastic waste management in Africa. The black plastic bag has disappeared from Kigali the capital town in Rwanda and other major towns. Manufacturers were given six months to phase out the harmful polythene and switch to recyclable materials or biodegradable alternatives. South Africa successfully banned plastics materials of less than 30 microns thickness in 2003, and backed this initiative with a public awareness campaign. It also introduced a plastics levy some of which goes to a plastic bag recycling company. It has witnessed a decrease in bag litter, a reduction in the manufacture of plastic bags with some layoffs and a growth in alternatives such as canvass bags. In the region, Kenya stands to lose markets for some products packaged in plastic bags that have been banned by its trading partners.

2.1.5 Trends in Developed Countries Worldwide

The trend world-wide is facilitating reduction, re-use and re-cycling of packaging through incentives and disincentives such as tax review and through mandatory or voluntary restraint. Other trends include re-cycling of plastic materials and use of bio-degradable plastics.

2.2 PLASTICS AND THE ENVIRONMENT - THE PROBLEM

The problem with plastics especially the carry bags is that they are victims of their own success: they are cheap to manufacture. At a cost of K.Shs. 1 per bag, retailers often absorb the price of bags into the price of merchandise they sell. This makes the bag appear free to the consumers, who in turn do not value it, and toss the bag away with little reuse. In a vicious circle, the low cost of the bags drives down the amount of material used to manufacture them, creating bags that are flimsy and not easy to reuse. The very qualities that make plastics so useful are precisely what cause them to persist as trash.

2.2.1 Plastics in Municipal Solid Waste Management in Nairobi

The refuse collection and disposal systems in Nairobi City are inadequate. As a result, plastic wastes are commonly dealt with in several ways: terrestrial disposal, disposal into streams, drainage channels and rivers, each having serious consequences. Plastic bags, juice, and water bottles are discarded onto the ground be it streets, fields and unused areas when the consumer has finished with them. These plastics are not biodegradable, and remain at their point of disposal until moved by the wind or by the rain. In the case of the latter, plastics wash downhill and are eventually deposited into the rivers and eventually into the sea. Other plastics commingle with other waste materials in drainage pathways. These form miniature dams and water flow obstructions that disrupts sewage and run-off systems and cause serious urban flooding and mosquito breeding grounds (Krupnik., 2002).

Across Nairobi City, one can see vast clouds of black smoke rising from households, street sides and market places, which clouds come from burning piles of garbage, both organic and inorganic, a serious cause of airborne pollution. While incineration of wastes (in this case community burning or “back yard” burning) appears appealing (the volume of tangible wastes shrinks by up to 80%), it is perhaps the most damaging method of waste disposal from a human health perspective. When plastics are burned they release a mix of chemicals to the atmosphere notably dioxin and furans and other poisonous chemicals. Dioxin particles are carried by the wind until they drop onto land or water. It is now known that dioxin can travel thousands of miles. Grazing animals and fish ingest the toxin, but they cannot break it down, so it travels up the food chain. Ninety percent of human exposure to dioxin occurs through diets of meat, dairy products and fish (Krupnik, 2002).

2.2.2 Plastics in the Environment

It is true that plastics left lying around after use do not disappear from view and such postconsumer waste as foam cups, detergent bottles, and discarded film is a visual annoyance (Roy, 2009). Plastics and other non-biodegradable waste cause health and environmental concerns; they block gutters and drains, creating drainage problems. Consumption of plastic by animals mistakenly as food could lead to their death. The presence of plastic bags in agricultural fields decreases soil productivity. Improper disposal of plastic bags have been linked to spread of malaria because they provide breeding habitats for mosquitoes and pathogens. When burned plastic bags not only release toxic gases such as furan and dioxin, but leave unhealthy residues that include lead and cadmium (NEMA, 2004). Plates 2-1 to 2-3 highlight some of these annoyances associated with plastics in the environment.

Plate 2-1: Plastic carrier bags and other debris in Chiromo River (2-7-2011)

Plate 2-2: Plastic wastes at a dumpsite near Hall 12, University of Nairobi (5-3-2011)

Plate 2-3: Landscape scarred by plastic wastes in Kibera (9-11-2011)

2.2.3 Plastics in the Seas

The United Nations Environment Program (UNEP) estimates that in every square mile of ocean there are over 46,000 pieces of plastic (Weiss, 2005). This puts an enormous strain on the environment. The little pieces of plastic act as a sort of sponge for chemicals. They soak up a million fold greater concentration of such deadly compounds as Polychlorinated Biphenyls (PCBs) and dichlorodiphenyldichloroethylene [DDE] (a breakdown product of dichlorodiphenyltrichloroethane [DDT] insecticide), than the surrounding seawater in which the chemicals do not dissolve (Weiss, 2005). As they absorb toxic chemicals, they become poison pills. Marine life then eats these pieces and dies. It is estimated that over a 100,000 different birds, seals and whales die every year (Weiss, 2005)

Plate 2-4: Remains of adult albatross with gut full of wide variety of plastics (Photo: Cynthia Vanderlip)

The photo in Plate 2-4 was taken at Midway Atoll, an atoll halfway between North America and Japan, with no industrial centers, no fast-food joints, and only a few dozen people. The plastic goes down the gullet quite easily. But since it is not digested, it gets stuck before exiting the stomach blocking the entry and digestion of legitimate food (Weiss, 2005). Wildlife researchers have found plastic pellets, which resemble fish eggs, in the bellies of fish, sea turtles, seabirds and marine mammals (Weiss, 2005). These researches are on-going and are an issue of global concern for action.

About 200,000 of the 500,000 albatross chicks born each year die, mostly from dehydration or starvation. A two-year study funded by the United States Environmental Protection Agency (USEPA) showed that chicks that died from those causes had twice as much plastic in their stomachs as those that died for other reasons. With smaller animals, more damage is done by smaller pieces of plastics (Weiss, 2005). After the animal dies its carcass decomposes and the plastic is free to roam the ocean and kill again. Besides choking to death, wildlife gets entangled in the plastics and is eventually immobilized to death.

2.2.4 Plastics and Human Health

Plastic products contain numerous toxic additives that can be considered a health risk when ingested or inhaled (via burning). Some of the serious problems associated with plastic use are Endocrine Disruption (ED) and Polyvinyl Chloride (PVC) (Krupnik, 2002).

The problem lies in the chemical and structural make up of plastic products mainly the plasticizers, the body of chemicals which are used to soften plastic, mold it into form, and to make it less rigid. An overwhelming number of plasticizers contain phthalates, a toxic chemical material and known endocrine disrupter. Phthalates can be ingested by the body when using plastic products as drinking vessels or for the storage of foods. Carbonated drinks, fatty foods, and products heated in plastic cause leeching of these chemicals from the packaging into the food or drink product itself (Krupnik T.J., 2002). Fatty foods are known to contain higher rates of phthalates as the fats allow a greater potential for migration. When these chemicals migrate into the endocrine system, they mimic the body’s natural hormones. This confuses the endocrine system and is the gateway to serious health disorders (Krupnik, 2002).

Endocrine disrupting compounds can migrate across the placenta in pregnant women, effectively contaminating the fetus. Some of the impacts of ED are a whole range of cancers, Attention Deficit Disorder (ADD), difficulty with coordination, infertility, reproductive problems, physical abnormalities (especially of the sexual organs) and behavioral disorders, all thought to be caused at least in part, by Endocrine Disruption (Krupnik T.J., 2002).The discovery that hormone disrupting chemicals may lurk in unexpected places, including plastics products, earlier considered biologically inert, has challenged traditional notions about human exposure. It suggests that humans may be exposed to far more than previously expected. For these reasons, most plastics would be best avoided, legislated against and solar disinfection of drinking water in plastic bottles not be recommended. While this method may indeed clean water of immediate pollutants, it encourages gradual poisoning due to Endocrine Disruptors (Krupnik, 2002).

PVC, widely used in the country, and by far the most dangerous of plastic resins, has been connected to cancer and other health disorders resulting from dioxin poisoning. Dioxin is the common name for a class of 75 chemicals. It is a toxic waste product formed when waste containing chlorine is burnt or when products containing chlorine are manufactured. It has no commercial use (Krupnik, 2002). The Table 2-2 outlines what compounds migrate into the contents of each type of resin.

Table 2-2: Molecular Migration of Plastic Containers to Contents (Krupnik T.J., 2002)

Plastic resin	Content migrant from plastic container to contents
Polyethylene Terephthalate (PET)	Acetaldehyde
High-Density Polyethylene (HDPE)	Antioxidants, BHT, Chimassorb 81, Irganox PS 800, Irganix 1076, Irganox 1010
Polyvinyl Chloride (PVC)	Plasticizers (Lead, Cadmium, Mercury, Phthalates and the carcinogen, Diethyl Hexyphosphate)
Low-Density Polyethylene (LDPE)	Antioxidants, BHT, Chimassorb 81, Irganox PS 800, Irganix 1076, Irganox 1010
Polypropylene (PP)	BHT, Chimassorb 81, Irganox PS 800, Irganix 1076, Irganox 1010
Polystyrene (PS)	Styrene (traces found in nearly everyone's body fat)
Other	Depends on plastics used. The label does not say.

Polychlorinated Biphenyls (PCB's) and (dichlorodiphenyldichloroethylene) DDE's attach to plastics in the oceans; accumulating in phytoplanktons and zooplanktons, which are then picked up in the food chain in fish, birds, their predators and humans. Another additive, Bi-sphenol A (BPA), widely found in Polycarbonate (PC) used to make lightweight, heat-resistant baby bottles and microwave cookware, has been identified to leach into products, and has been linked to cause health problems in liver, reproductive abnormalities, possibly causes early puberty in children and prostate cancer (Weiss, 2005).

2.2.5 The Ecological Footprint of Plastic materials viz-a-vis the Competition

There has been an increasing awareness of the need for conservation of resources. As a result of this the chemical industries, particularly plastics industries have come under critical scrutiny. Plastics can cause a litter problem. This is like glass, metals and many other materials. However, much of their criticism in litter stems from their longevity. Not to say that sharp metal and glass are not liable to hazards.

Plastics can make a positive contribution though. Every tonne of metal removed from the earth necessitates the removal of hundreds of tons of earth and a severe despoliation of the landscape. Replacement by plastics made from petroleum taken from below the sea-bed helps to preserve the countryside or at least helps to conserve valuable metal resources for the future. There is also little doubt that the use of plastics has helped to raise the quality of life for many people. The telephone, the gramophone record, the tape recorder, the photographic film, the radio, and television, which help us to see and hear things which few of us could see or hear at first hand, depend on the existence of plastics (Brydson, 1999). In addition to these are now the modern day cell phones, smartphones, tablets, and other mobile devices. Many other common applications such as cars, refrigerators and micro-waves, would be afforded by far fewer people were it not for such materials as PVC, expanded and high-impact polystyrene and glass-reinforced polyesters. The mass production possible with plastics has enabled improvements in the standard of living globally, whilst the use of plastics in surgery and medicine is eventually of universal benefit (Brydson, 1999).

2.2.6 Biodegradable Plastics

The environmental impact of persistent plastic wastes is a global concern, and alternative disposal methods are limited. Incineration may generate toxic air pollution, and satisfactory landfill sites are limited. Also, the petroleum resources are finite and are becoming limited. It becomes important to find durable plastic substitutes, especially in short-term packaging and disposable applications. Recently, the continuously growing concern of the public for the problem has stimulated research interest in biodegradable polymers as alternatives to conventional non-degradable polymers such as polyethylene and polystyrene.

Nature itself has an abundance of polymeric material such as proteins, cellulose, starch, lignin and natural rubber which indeed are high polymers. Plastics may be made from such diverse renewable vegetable products as cellulose, natural rubber, seaweed, oat husks, soya bean and molasses (Brydson, 1999). The detailed structures of these materials are complex and highly sophisticated in comparison to the synthetic polymers produced by man which are crude in the quality of their molecular architecture.

It is a renewable degradable carbohydrate biopolymer that can be purified from various sources by environmentally sound processes. By itself, starch has severe limitation due to its water solubility. Articles made from starch will swell and deform upon exposure to moisture. To improve some of the properties, the starch is often blended with hydrophobic petroleum polymers during the past decades to increase biodegradability, and reduce the usage of petroleum polymer (Commission, 2001)

Fully biodegradable synthetic polymers have been commercially available since 1990, such as Polylactic Acid (PLA), polycaprolactone (PCL), and polyhydroxybutyrate~valerate (PHBV). Among these biopolymers, PLA was extensively studied in medical implants, suture, and drug delivery systems since the 1980's due to its biodegradability. PLA has been attractive for disposable and biodegradable plastic substitutes due to its better mechanical properties. However, it is still more expensive than conventional plastics. The degradation rate for these bio-plastics is still slow as compared to the waste accumulation rate (Commission, 2001)

Biopolymers will gradually start to increase as their production is being scaled up from pilot plants to commercial production units. The relatively high cost and limited availability of these materials will restrict their use to specialized applications. Their use will only make environmental sense where composting facilities are available for disposal (Hannay, 2002).

2.2.7 The Future for use of Plastics Materials

The widespread use of plastics has been achieved through large-scale investment in research and development by those concerned. Polymer properties have been closely studied and slowly a relationship has been built up between structure and properties of polymers. Studies of polymerization methods have enabled a greater control to be made of the properties and structure of established polymers and have also led to the production of new polymers.

Many polymers would have remained of academic interest had not chemists devised new economic syntheses from raw materials. The polymers produced have been investigated by the technologist and methods of processing and compounding requirements developed. Mathematicians have assisted in interpreting the rheological and heat transfer data important for processing, engineers have developed machines of ever increasing sophistication, whilst suggested new applications have been vigorously pursued by sales organizations, often in conjunction with experts in aesthetics and design. In this way chemist, physicist, mathematician, technologist, engineer, salesman and designer have all played a vital part. In many instances the tasks of these experts overlap but even where there is a clearer delineation it is important that the expert in one field should have knowledge of the work of his counterparts in other fields.

Across history, new technology has altered how things are produced. 3-D Printing is yet another one of these new game-changing technologies, set to alter manufacturing for the next set of decades. This allows plastic components and even entire products to be printed out using devices similar to the inkjets and laser printers currently used to output documents and photos. (Barnatt, 2012)

Plastic recycling for 3D printing has potential to turn plastic waste stream into mainstream manufacturing of various commodities and help clean up the environment. Virgin or recycled plastic pellets can be turned into 3D printer filament, the "ink" for 3D printers. It is continuously heat welded together through a computer controlled process to "print" almost any usable 3-dimensionally shaped object (Bleijerveld, 2014). Using recycled plastic is important for sustainability because post-consumer plastic waste “never goes away” and it is a huge messy issue within the CCN that, even now, a lasting solution has not been found.

2.3 Role of Plastic Industry Players And Their Mandates

2.3.1 Local Government Act (CAP 265)

Solid Waste Management in the country was governed by the Local Government Act until March 2013 when the Devolution Law voided it. The City Council of Nairobi was the statutory body mandated with collection, transportation and final disposal of solid wastes.

a. CCN Department of Environment

The city council by-laws stipulate as follows in regard to Municipal Solid Wastes:-

- It is the City Council's duty to regulate waste and its management within the city.
- The council may revoke/cancel a waste operator's permit in the breach of given conditions.
- Waste operators permit is not transferable without the consent of the council.
- The council must provide a place to dispose waste before it is transferable to a final disposal.
- The council should issue directions for different collections charges at different places.
- Any duly authorized officer may inspect a residential dwelling or trade premises at any time.
- Disturbing a waste disposal site or container approved by the council is wrong.
- Organized groups will be given designs for small scale resource recovery.
- Any person, who produces, carries, keeps, treats, disposes of waste etc. with an exception to domestic household waste must be authorized persons.
- Occupiers/tenants of any building/trade premises must have a sizeable container with a good lid in which the daily domestic waste should be kept.
- Domestic and trade premises occupiers and owners shall separate recyclable waste and place in a different container provided/approved by the council.
- Premises owners/occupiers of the premises should ensure hazardous/clinical waste is managed to the satisfaction of the council.
- Burning and throwing away of a waste in an inappropriate place is an offense (CCN, 2002).

b. *CCN policy on Private Sector Involvement (PSI) in Solid Waste Management*

The policy states that The City Council of Nairobi shall allow private sector involvement in the management of solid wastes within its areas of jurisdiction. It outlines applicable policy guidelines and among others, Guidelines to Private Sector Involvement on Solid Waste Management such as;-

- Solid waste management managers shall possess the following qualifications or discipline: Environment/public health sciences, Environment sciences/minimum diploma certificate or minimum certificate course in solid waste management,
- On vehicles/equipment, besides the manufacturer's standard specifications, the following specifications among others shall also apply: The vehicle/equipment shall be complete with all fittings and fully operational in every aspect with the requirements of the Traffic Act and any other law in order to run on public highways, The

vehicle/equipment shall be complete with a set of standard tools and equipment required for all routine maintenance and operations, The internal coating of the container must withstand corrosion by use of appropriate non-toxic protective paints e.g. bituminous paints. Accessories including the body finish and workmanship are subject to the Department of Environment approval.

- On collection frequency, (i) At least once a week in households, (ii) Once a day in markets and restaurants and (iii) Hospitals and industrial hazardous wastes shall be collected depending on generation while commercial and industrial general waste depends on volumes (CCN, 2002).

On solid waste recycling and composting, the policy guidelines are as follows:-

- Recycling and composting are essential elements towards an integrated solid waste management in the city of Nairobi
- The City Council of Nairobi shall promote, assist, and where possible, conduct recycling and composting of solid waste that is generated within its administrative boundaries.
- Also, the policy notes that recycling and composting of solid waste, however important it may he, cannot be dealt with separately, but should be an integrated part of waste management policy, which in turn has to be implemented within overall environmental policy (CCN, 2002).

2.3.2 The National Environment Management Authority (NEMA)

NEMA is the principal instrument of Government in the implementation of all policies relating to the environment. The Environmental Management and Coordination Act (EMCA) made provision for the establishment of the National Environment Management Authority (NEMA) which has the statutory mandate to supervise and co-ordinate all environmental activities in Kenya. Section 9 (2) of the EMCA of 1999 details the functions that the NEMA is legally bound to carry out. Broadly, these functions are: -

- Coordination of the various environmental management activities being undertaken by the lead agencies and promote the integration of environmental considerations into development policies, plans, programmes, and projects with a view to ensuring the proper management and rational utilization of environmental resources on a sustainable yield basis for the improvement of the quality of human life in the country, preparation and issuance of an annual report on the State of the

Environment in Kenya, Monitor and assess activities, including activities being carried out by relevant lead agencies, in order to ensure that the environment is not degraded by such activities.

- Education/Public Awareness through manuals, codes or guidelines relating to environmental management and prevention or abatement of environmental degradation including rendering of advice and technical support, where possible.
- Compliance and Enforcement
- Advising on Ratification and Domestication of Multi-lateral Environmental Agreements (MEAs) and
- Research, Inventorying and Information among others

a. Environmental Management and Coordination Act 1999 EMCA

The Environmental Management and Coordination Act (EMCA) was enacted in 1999 received Presidential assent on 6th January 2000. It gives provisions for setting of standards, licensing of waste disposal sites and control of hazardous waste. (NEMA). Part V111 Section 87(1) EMCA, 1999 states that no person shall discharge or dispose of any wastes whether generated within or outside Kenya, in such manner as to cause pollution to the environment or ill health to any person (EMCA). Regulations have been developed under EMCA to address specific environmental aspects. EMCA regulations relevant to the study are as follows:-

b. EMCA Waste Management Regulations (2006)

Provisions of Waste Management Regulations (2006) relevant to the study include:

Part 11 section 10(1-5), 11, 12 and 13 of Waste Management Regulations that state as follows:

10(1) any person granted a license under the Act and any other license required by relevant local authority to operate a waste disposal site or plant, shall comply with all conditions imposed by the authority to ensure that such waste disposal site or plant operates in an environmentally sound manner.

10(2) an application for license to operate a waste disposal site or plant shall be in Form V as set out in the first schedule of the regulation and shall be accompanied by the prescribed fees set out in the second schedule

10(3) a license under the Act for the operation of waste disposal site or plant shall be in Form V as set out in the First schedule of these Regulations

10(4) a license to operate a waste disposal site or plant shall be valid for a period of one year from the date of issue and may be renewed for a further period of one year on such terms and conditions as the authority may deem necessary or impose for purposes of ensuing public health and sound environmental management.

10(5) in issuing a waste disposal license, the Authority shall clearly indicate the disposal operation permitted and identified for the particular waste.

11 Any operator of a disposal site or plant shall apply the relevant provisions on waste treatment under the Local Government Act and Regulations to ensure that such waste does not present any imminent and substantial danger to the public health, the environment and natural resources.

12 Every licensed owner or operator shall carry out an annual environmental audit pursuant to the provision of the act

13 Notwithstanding any provision to the contrary in these Regulations, these Regulations shall also apply to plants and sites established for re-use or recycling of wastes.

2.3.3 The Kenya Bureau of Standards (KEBS)

The Kenya Bureau of Standards (KEBS) was established by an Act of Parliament - the Standards Act, Chapter 496 of the Laws of Kenya. It started its operations in July 1974. The aims and objectives of the Bureau include preparation of standards relating to products for quality of life, measurements, materials and processes, and their promotion at national, regional and international levels; certification of industrial products; assistance in the production of quality goods through Quality Assurance and Inspection; improvement of measurement accuracy and circulation of information relating to standards. The institution gives guidelines for importers and exporters of goods.

Its organizational structure comprises a Standards Development and International Trade Division and Quality Assurance Division among others. It is a body member of the International Standards Organization (ISO). A Kenyan Standard is a document established by consensus and approved by the Kenya Bureau of Standards (KEBS) that provides, for common and repeated use, rules, guidelines or characteristics for products and services and related processes or production methods, aimed at the achievement of the optimum degree of order in a given context. It may also include or deal exclusively with terminology, symbols, packaging, marking or labelling requirements as they apply to a product, process or production method.

2.3.4 Kenya National Cleaner Production Centre (KNCPC)

The Kenya National Cleaner Production Center (KNCPC) is registered as a Trust within the Government’s Ministry of Trade and Industry. It was founded by the Government of Kenya through the Kenya Industrial Research and Development Institute (KIRDI) and the United Nations Industrial Development Organization (UNIDO) in July 2000 under the Country Co-operation Framework of (1999-2003) between the Kenyan Government and United Nations Development Program (UNDP). It is one of the over 35 National Cleaner Production Centers (NCPCs) that were solely established to help industrialists and businesses in developing countries and those ones with transition economies to remain competitive and increase their profitability by reducing their water and energy consumption, pollution emissions and waste volumes whilst improving on their product quality and work place safety. In other words, it is to assist industrial and other business enterprises to meet the emerging challenges of the free market economy and globalization by improving on their competitive performance.

The KNCPC is mandated to promote the adoption of contemporary tools of environmental management in Kenyan industrial establishments and the related service sector. The tools currently being promoted by the center include, but are not limited to:

- Cleaner Production covering pollution prevention waste minimization
- Environmental Audits
- Environmental Impact Assessments (EIA) and Energy Audits (EA)
- Environmental Performance Evaluation
- Environmental Cost Accounting
- Life Cycle Assessment (LCA) and Life Cycle Design (LCD)
- Corporate Environmental Reporting

2.3.5 The Kenya Association of Manufacturers (KAM)

The Kenya Association of Manufacturers (KAM) is a Private Sector body established in 1959 as the representative organization for manufacturing industries in Kenya. It is a business association that unites manufacturing industries in the country and provides essential link for co-operation, dialogue and understanding with government by representing the views and concerns of its members to the relevant authorities. KAM's core mandate is policy advocacy. It promotes trade and investments, upholds standards, encourages formulation, enactment and administration of sound policies that facilitate a competitive business environment and reduce the cost of doing business. Among other objectives, KAM aims at providing pro-active, evidence-based and results focused policy advocacy services for its members.

2.3.6 United Nations Environment Programme (UNEP)

The UNEP developed an Integrated Solid Waste Management Plan (ISWMP) for Nairobi city in 2010. The vision of this ISWMP was "A healthy, safe, secure and sustainable solid waste management system fit for a world-class city"

2.3.7 Examples of Private Enterprises Positive Impact on Plastic Waste Management

The private sector includes both formal and informal enterprises, of widely varying sizes and capabilities. New Delhi is an example of a city where primary solid waste collection is done by authorized informal sector collectors/recyclers, who deliver the waste by hand cart to a large private sector operator who provides secondary collection from communal bins (UN-Habitat, 2010).

During the past 10–20 years, high-income countries have been rediscovering the value of recycling as an integral part of their waste (and resource) management systems, and have invested heavily in both physical infrastructure and communication strategies to increase recycling rates. Their motivation is not primarily the commodity value of the recovered materials; rather, the principal driver is that the recycling market offers a competitive 'sink', as an alternative to increasingly expensive landfill, incineration of other treatment options (UN-Habitat, 2010).

Many developing and transitional country cities still have an active informal sector and micro-enterprise recycling, reuse and repair systems, which often achieve recycling and recovery rates comparable to those in the West; the average recovery rate across 20 reference cities was 29 per cent. Moreover, by handling such large quantities of waste, which would otherwise have to be collected and disposed of by the city, the informal recycling sector has been shown to save the city 20 per cent or more of its waste management budget. In effect, the poor are subsidizing the rest of the city (UN-Habitat, 2010).

There is a major opportunity for the cities to build on these existing recycling systems, to increase further the existing recycling rates, to protect and develop people's livelihoods, and to reduce still further the costs to the city of managing the residual wastes. The formal and informal sectors need to work together, for the benefit of both (UN-Habitat, 2010).

2.4 INDUSTRY-DEVELOPED INSTRUMENTS TO ENHANCE PLASTIC WASTES MANAGEMENT

2.4.1 Nairobi City by-laws

CCN identifies two major challenges to achieving a plastic-free environment as; public awareness and enforcement of city by-laws on littering. It is important that a national public awareness campaign is conducted and sustained over a long period of time in order to change the public's attitudes and behavior on plastics disposal, while those who do not comply should be dealt with under city by-laws on littering. (CCN, 2002)

2.4.2 The Nairobi City County Plastic Carry Bags Control Bill, 2014

In June 2014, the Nairobi County Assembly moved a bill, the Nairobi City County Plastic Carry Bags Control Bill (2014) seeking to ban recycled, non-biodegradable plastic bags and containers from virgin plastic of thickness of not less than 30 microns and size not less than 8-by-12 inches made from polyethylene terephthalate, high density polyethylene, Poly Vinyl Chlorine, low density polyethylene, polystyrene and polypropylene. This was aimed at eliminating the prevalent problems caused by plastics such as blocking drainage and sewer systems and at times causing floods and the fact that the plastics are manufactured using fossil fuels and an assortment of chemicals that are not only harmful to animals, but are an environmental nightmare in city. The Bill, if passed, would create a law that prohibits retailers from wrapping or giving shoppers such bags, while the government would be forced to issue new guidelines to manufacturers to produce bags that meet the new regulations. However the bill was not passed and the debate stalled shortly after it was introduced.

2.4.3 NEMA, KAM, UNEP, MoTI, MoE, KNCPC Economic Instruments of 2003

Since May 2003, KAM and NEMA collaborated and developed a strategy on plastic waste management. Some of the key agreements were the phasing out of flimsy plastic bags which are freely blown by the wind, clinging on trees and blocking waterways. This was done through the development of a new Kenya Bureau of Standards (KEBS) standard for plastic bag thickness – KS 1794 – raising the minimum polythene bag gauge up from 15 µm which is non-recyclable to 30 µm which is longer lasting and recyclable. The new standard was gazetted in October 2005 and aimed at promoting re-use, recovery and recycling. However, the onus for enforcement lay with NEMA and the Kenya Bureau of Standards and not KAM (UNEP, 2005).

A taskforce set up of members from NEMA, KIPPRA, and UNEP among others, in February 2005 came up with the following seven-point plan for tackling plastic bags in the country:-

- A ban on plastic shopping bags that are less than 30 microns in thickness.
- Consumer awareness and anti-littering campaign.
- Promotion of voluntary schemes such as a national code of practice for retailers.
- A plastic bag levy collected from either suppliers or directly from shoppers.
- Support for development of environmentally-friendly alternative bags.
- Support for development of an effective plastic bags recycling system.
- Support for development of a managed disposal system to cater for the plastic bags that will enter the waste stream irrespective of the measures taken (UNEP, 2005).

The report proposed that a new body, known as the Plastics Management Fund be established. The fund would be vested in NEMA to manage and implement the new measures to help clean up the plastic waste already in the environment and for the continuous improvement. It recommended that the committee have a wide membership including government ministries, the Kenyan Association of Manufacturers, the City Council of Nairobi, textiles groups, the Kenya Cotton Ginners Association and We Can Do It which is an umbrella of residents associations (UNEP, 2005).

The three parties (NEMA, KAM and KEBS) were in agreement that a plastics levy should be set up. NEMA had indicated that industry had time to adjust from 20 microns to 30 microns by 1st January 2008. Due to the continuous stakeholder engagement, the plastics industry had no objection to the proposal to raise the minimum thickness to 30 microns. What was in contention was one of the recommendations of the KIPPRA report (2005) that required introduction of a 120% excise tax plastic levy which would be used to establish the fund. NEMA was also aware at the time that industry was negotiating with the Ministry of Finance with a view to converting the excise duty into a plastics levy (UNEP, 2005).

On the increased cost of plastic bags, it was agreed that no manufacturer would increase the cost of plastic bags until the new standards took effect. On this basis, anyone increasing the cost of plastic bags did so illegally. However, industry admits that the main reason why bags then started to cost more was that they were now all being made of 20-micron thickness instead of 15 micron and industries had invested in new machines to achieve this in addition to the 120% tax on the bags. Media reports indicated that some industry players had relocated to other East African Countries due to the increased cost. NEMA was of the opinion that industry did not only continue to manufacture or import plastic bags below the acceptable thickness, but were now unfairly “punishing” consumers by hiking the cost of the plastic bags. They said that, had the manufacturers gradually adjusted to the required plastic bags gauge, the cost crisis would never have been and the transition would have been achieved between 2005 and 2008.

2.4.4 NEMA/KRA/KEBS/Ministry of Finance initiatives of 2007

There has been continuous consultation between NEMA, KAM and KEBS on the sustainable management of plastics waste since 2003. The current 30-microns minimum plastic thickness standard gazetted by the Kenya Bureau of Standards in 2005 was developed through consensus. All stakeholders, including industry, agreed on a minimum thickness of thirty (30) microns for both V-type and flat carrier bags, on the understanding that the thickness would be reviewed upwards within one year. The rationale for this increase in thickness is the 3-R principle of plastic waste management: re-use, reduce, and recycle. It was assumed that the consumers would be encouraged to re-use the heavier gauge plastic bags for a second, third and even fourth shopping trip.

The Kenyan Treasury moved to implement a 120 per cent levy on plastics to protect the environment from degradation in 2007. However, protests from traders that the 120 per cent tax would make the plastic bags expensive forced the Parliamentary Departmental Committee on Trade and Finance to propose that a green tax be introduced instead.

2.4.5 Legal and Regulatory Interventions

The Environmental Management and Coordination Act (EMCA) 1999 provide for the establishment of legal and institutional framework for the management of the environment and establish appropriate legal and institutional mechanisms for the management of the environment. EMCA Waste management Regulations of 2006 is tailored to combat indiscriminate generation, handling and disposal of wastes, including plastic wastes.

2.4.6 International Conventions

Kenya is a member of the United Nations Environment Programme UNEP which is the overall coordinating environmental organization of the United Nations. UNEP's mission is to provide leadership and encourage partnerships in caring for the environment by inspiring, informing and enabling nations and people to improve their quality of life without compromising that of future generations. Kenya has also ratified the following conventions:-

- The Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal (SBC)
- The UN Stockholm Convention (UNDP-GEF POPS) on Persistent Organic Pollutants (POPs). The Convention was signed in 2001 after several years of negotiations between representatives of more than 120 countries..

2.4.7 The Polluter Pays Principle (PPP)

One of the core principles of sustainable development is the "Polluter Pays" Principle. This recognizes that the polluter should pay for any environmental damage created, and that the burden of proof in demonstrating that a particular technology, practice or product is safe should lie with the developer, not the general public. When and how much the polluter ought to pay, is often, unfortunately, unclear.

One way to adequately implement the polluter pays principle in the real world makes use of what are known as assurance bonds. Money put up by the "polluter" to insure against a worst case environmental impact, the bond would be recovered only if after sufficient time it had been demonstrated that the technology, process or product in question had been deemed to be safe and reasonably acceptable. Alternatively, if damage occurred, the bond would be used for environmental restoration, and to pay damages to anyone who had been harmed. By allowing the bond to accrue interest, the "polluter" receives an incentive to ensure that best environmental practice is followed, and to demonstrate that the technology, process or product is as safe as is practicably possible, without involving excessive cost. (Lucia, 2013)

The PPP is normally implemented through two different policy approaches: command-and-control and market-based. Command-and-control approaches include performance and technology standards. Market-based instruments include pollution taxes, tradable pollution permits and product labeling (Lucia, 2013). An attempt to employ this principle in the minimization of use of plastic products in Nairobi was made in 2007 when a levy was introduced.

2.5 CHEMICAL NATURE AND PLASTICS MANUFACTURING PROCESSES

2.5.1 The Chemical Nature of Plastics

Plastics are one of the world's most used raw materials. They generally are organic high polymers. They are composed of polymers synthesized from monomeric units mainly produced by the petrochemical industry such as ethylene, propylene; butadiene and styrene (vinylbenzene). A number of commercial polymers are also produced by chemical modification of other polymers, either natural or synthetic. The process of synthetic polymerization can be conducted in three ways under different reaction conditions and using various catalyst systems (Brydson, 1999). These techniques are:-

- Addition polymerisation,
- Condensation polymerisation and
- Re-arrangement polymerisation (poly-addition)

2.5.2 Plastic Resins – Properties, Uses and Common Applications

Before plastics are processed, they are sorted into seven different polymer types. These polymer groups are namely; (1) Polyethylene Terephthalate (PET or PETE), (2) High-Density Polyethylene (HDPE), (3) Vinyl/Polyvinyl Chloride (PVC), (4) Low-Density Polyethylene (LDPE), (5) Polypropylene (PP), (6) Polystyrene (PS) and (7) Others. Polyolefins or polyolefinic plastics generally refer to the polyethylene, polypropylene, and polystyrene group. P-R pipe, known for polypropylene pipes, is a polypropylene random copolymer, made into pipes by extrusion or injection moulding of a tube. It has good impact resistance and long-term creep properties. It is used in most home improvement projects as a water supply pipeline. Among the plastic resins discussed, factors to consider when selecting one of them for a particular packaging application are summarized in Table 2-3.

Table 2-3: Factors considered when selecting one of the plastic resins for a particular application (Hannay, 2002)

	LDPE	HDPE	PP	PVC	PET	PS
Food approval	Yes	Yes	Yes	Yes	Yes	Yes
Approximate hot fill temperature	8 °C	95 °C	12 °C	5 to 65 °C depending on type	6 °C standard , 85 °C partial heat-set, 95+ °C full heat set	6 to 95 °C depending on type
Oxygen barrier	Very poor	poor	poor	Moderate to good	Good	Poor
Moisture barrier	Good	Excellent	Excellent	Moderate	Moderate	Poor
Impact strength	Excellent	Good	Poor to good depending on grade	Poor to good depending on grade	Excellent	Poor to moderate depending on grade
Clarity	Moderate	Poor	Poor to good depending on grade	Good	Excellent	Poor to excellent depending on grade
Main applications	Soft caps	Bottles, caps and closures	Pots and tubs, screw caps, hinged caps, some bottles	Bottles	Carbonated beverage and other bottles	Yoghurt and cheese pots
Moulding processes	Injection moulding, extrusion-blow moulding	Injection moulding, extrusion-blow moulding	Injection moulding, extrusion-blow moulding, thermoforming	Extrusion-blow moulding, thermoforming	Stretch-blow moulding, thermoforming	Injection moulding, thermoforming

2.5.3 The Plastics Resin Identification Code (RIC)

Many plastic items are embossed with a code, usually a number (1 through 7) or a letter abbreviation, which indicates a particular type of plastic. This is the Resin Identification Code (RIC), typically found on the bottom of a container and is often displayed inside a three-arrow chasing symbol. The RIC was introduced in 1988 by The Society of Plastics Industry, Inc. (SPI) at the request of recyclers around the United States of America (USA) to meet recyclers' needs while providing manufacturers a consistent, uniform system that could apply nationwide (SPI Inc., 2000). This type of identification is presented in Table 2-18. This SPI coding system, widely adopted throughout the world, offers a means of identifying the resin content of plastic products commonly found in most waste streams. Back then, it was meant to help facilitate the recovery of post-consumer plastics.

Over time, this RIC was found to be misused by the industry, typically because not all plastic materials identified between 1- 6 is recyclable. Improper use of the RIC can have serious ramifications for individual manufacturers and could jeopardize the integrity of the coding system. In 2008, the code was revised to a new standard that would expand the current RIC system by the SPI in collaboration with American Society for Testing and Materials (ASTM) International, a globally recognized leader in the development and delivery of international voluntary consensus standards. (SPI Inc., 2013)

In 2010, ASTM International issued ASTM D7611 - Standard Practice for Coding Plastic Manufactured Articles to replace the Resin Identification Code, and revised it in 2013. Some of the changes include the graphic marking symbol used to identify resin type used in the product’s packaging under the RIC system. The “chasing arrows” symbol that surrounded numerals from 1 to 7 defining the resin was replaced with a solid equilateral triangle around the number as shown in Table 2-4. This way, the ASTM D7611 stressed the core mission: a focus to resin identification and quality control prior to recycling rather than the “chasing arrows” graphic commonly misunderstood with recycling. (SPI Inc., 2013)

Table 2-4: Resin Identification Codes - Plastic Recycling Codes as developed by The Society of Plastics Industry, Inc. (SPI) in 1988

Codes	Descriptions	Properties	Packaging Applications	Recycled Products
1 PETE	Polyethylene Terephthalate (PET, PETE). PET is clear, tough, and has good gas and moisture barrier properties. Commonly used in soft drink bottles and many injection molded consumer product containers. Other applications include strapping and both food and non-food containers. Cleaned, recycled PET flakes and pellets are in great demand for spinning fiber for carpet yarns, producing fiberfill and geo-textiles.	Clarity, strength, toughness, barrier to gas and moisture, resistance to heat	Plastic soft drink, water, sports drink, beer, mouthwash, catsup and salad dressing bottles. Peanut butter, pickle, jelly and jam jars. Ovenable film and ovenable prepared food trays.	Fiber, tote bags, clothing, film and sheet, food and beverage containers, carpet, strapping, fleece wear, luggage and bottles.
2 HDPE	High Density Polyethylene (HDPE) is used to make bottles for milk, juice, water and laundry products. Un-pigmented bottles are translucent, have good barrier properties and stiffness, and are well suited to packaging products with a short shelf life such as milk. HDPE has good chemical resistance; it is used for packaging many household and industrial chemicals such as detergents and bleach. Pigmented HDPE bottles have better stress crack resistance than un-pigmented HDPE bottles.	Stiffness, strength, toughness, resistance to chemicals and moisture, permeability to gas, ease of processing and forming.	Milk, water, juice, cosmetic, shampoo, dish and laundry detergent bottles; yogurt and margarine tubs; cereal box liners; grocery, trash and retail bags.	Liquid laundry detergent, shampoo and motor oil bottles; pipe, buckets, crates, flower pots, garden edging, film and sheet, recycling bins, benches, dog houses, plastic lumber, floor tiles, picnic tables, fencing.
3 V	Vinyl (Polyvinyl Chloride or PVC): In addition to its stable physical properties, PVC has excellent chemical resistance, good weatherability, flow characteristics and stable electrical properties. The diverse slate of vinyl products can be broadly divided into rigid and flexible materials. Bottles and packaging sheet are major rigid markets, but it is also widely used in the construction market for such applications as pipes and fittings, siding, carpet backing and windows. Flexible vinyl is used in wire and cable insulation, film and sheet, floor coverings synthetic leather products, coatings, blood bags, medical tubing and many other applications.	Versatility, clarity, ease of blending, strength, toughness, resistance to grease, oil and chemicals.	Clear food and non-food packaging, medical tubing, wire and cable insulation, film and sheet, construction products such as pipes, fittings, siding, floor tiles, carpet backing and window frames.	Packaging, loose-leaf binders, decking, panelling, gutters, mud flaps, film and sheet, floor tiles and mats, resilient flooring, cassette trays, electrical boxes, cables, traffic cones, garden hose, mobile home skirting.

Codes	Descriptions	Properties	Packaging Applications	Recycled Products
4 LDPE	Low Density Polyethylene (LDPE).Used predominately in film applications due to its toughness, flexibility and relative transparency, making it popular for use in applications where heat sealing is necessary. LDPE is also used to manufacture some flexible lids and bottles and it is used in wire and cable applications	Ease of processing, strength, toughness, flexibility, ease of sealing, barrier to moisture.	Dry cleaning, bread and frozen food bags, squeezable bottles, e.g. honey, mustard.	Shipping envelopes, garbage can liners, floor tile, furniture, film and sheet, compost bins, panelling, trash cans, landscape timber, lumber
5 PP	Polypropylene (PP). Polypropylene has good chemical resistance, is strong, and has a high melting point making it good for hot-fill liquids. PP is found in flexible and rigid packaging to fibers and large molded parts for automotive and consumer products.	Strength, toughness, resistance to heat, chemicals, grease and oil, versatile, barrier to moisture.	Catsup bottles, yogurt containers and margarine tubs, medicine bottles	Automobile battery cases, signal lights, battery cables, brooms, brushes, oil funnels, rakes, bins, pallets, sheeting, trays.
6 PS	Polystyrene (PS). Polystyrene is a versatile plastic that can be rigid or foamed. General purpose polystyrene is clear, hard and brittle. It has a relatively low melting point. Typical applications include protective packaging, containers, lids, cups, bottles and trays.	Versatility, insulation, clarity, easily formed	Compact disc jackets, food service applications, grocery store meat trays, egg cartons, aspirin bottles, cups, plates, cutlery.	Thermometers, light switch plates, thermal insulation, egg cartons, vents, desk trays, rulers, license plate frames, foam packing, foam plates, cups, utensils
7 OTHER	Other. Use of this code indicates that the package in question is made with a resin other than the six listed above, or is made of more than one resin listed above, and used in a multi-layer combination.	Dependent on resin or combination of resins	Three and five gallon reusable water bottles, some citrus juice and catsup bottles.	Bottles, plastic lumber applications.

Source: (SPI Inc., 2000)

Other modifications to the RIC are being discussed and developed by ASTM's D20.95 subcommittee on recycled plastics. These modifications include proposals for adding sub-codes to the existing 1-6 RICs in order to better identify major variants within each resin and that resins fitting within the category of RIC 7 should be allowed to display their appropriate abbreviated term instead of only the term "OTHER" as shown in Table 2-5 (SPI Inc., 2013).

Table 2-5: Changes to the graphic marking symbol under ASTM D7611 (SPI Inc., 2013)

Resin	Resin Indentification Code-Option A	Resin Indentification Code-Option B
Poly(ethylene terephthalate)	1 PETE	01 PET
High density polyethylene	2 HDPE	02 PE-HE
Poly(vinyl chloride)	3 V	03 PVC
Low density polyethylene	4 LDPE	04 PE-LD
Polypropylene	5 PP	05 PP
Polystyrene	6 PS	06 PS
Other resins	7 OTHER	07 O

2.5.4 The Value of the Resin Identification Codes

Plastic is not any one material. Rather, it is a family of related materials with varying properties that can be engineered to meet the requirements of a broad range of applications. The success of a product often is dependent on matching the right plastic - with the right properties - to the right application. The same is true when the material in question is a recycled plastic. As a result, there is a premium placed on the purity of post-use plastics. The more uniform the post-use plastics going in, the more predictable the properties of the recycled plastic coming out.

Coding enables individuals to perform quality control (i.e., sorting) before recycling, ensuring that the recycled plastic is as homogenous as possible to meet the needs of the end markets. Another potential benefit of coding is that it may facilitate the recovery of plastics not currently collected for recycling. If there is a readily identifiable supply of a given material in the waste stream, it may drive recycling entrepreneurs to explore means of recovering that material in a cost-effective manner.

2.5.5 Biological Behaviour of Plastics

Plastics are generally accepted as a non-toxic and non-carcinogenic material. The plastic homopolymers and copolymers are used in many food contact applications ranging from simple beverage closures to various other food packaging applications. The main requirements for contact with food are that the article must not impart odour or taste to the food and should be suitable for the intended application. The main reason for assessment of plastics for contact with food or potable water comes from the use of additives in material formulation. Additives, monomers, catalyst residues, polymer degradation products etc. can migrate to any food in contact if the concentration of these substances is lower in the food than in the plastic. In the case of PP, the migration of these species is a function of time and temperature. The rate of migration of chemicals or additives is inversely proportional to the molecular weight of the PP. The migration of these species could produce toxicity or the formation of undesirable flavours or odours, commonly known as organoleptic problems (Tripathi, 2002).

The application of various plastics in contact with food, water and pharmaceuticals is covered by the relevant standards/regulations by different authorities in different countries. Health assessment of plastics under food legislation also varies from one country to another. In Kenya, these are covered by the Kenya Bureau of Standards (KEBs) under several standards shown in Table 2-6. KS No 1 and 2 address health assessment while as KS No.3 to 9 in the table address application of various plastics (PP, PS and PVC) in contact with food, water and pharmaceuticals.

Table 2-6: Relevant KEBs standards applicable to various plastics in contact with food, water and pharmaceuticals

No.	KS	Area	Year developed	Description of Standard
1	KS 1667 2001 ICS 83.040.30	Pigments and Colorants	2001	List of Pigments and colorants for use in plastic in contact with foodstuffs, pharmaceuticals and drinking water
2	KS 2319 2011 ICS 67.250; 83.080	Migration of Constituents	2011	Determination of overall migration of constituents of plastic materials and articles intended to come in contact with foodstuffs - Methods and Analysis
3	KS 2323 2011 ICS 67.250; 83.080	PP in food Packaging	2011	Polypropylene (PP) and its copolymers in contact with foodstuffs, pharmaceuticals and drinking water - Specification
4	KS 2321 2011 ICS 67.250; 83.080	PP in food Packaging	2011	Positive list of constituents of Polypropylene (PP) and its copolymers in contact with foodstuffs, pharmaceuticals and drinking water
5	KS 2388 2012 ICS 67.250; 83.140	PP in food Containers	2012	Disposable expanded Polystyrene (PS) food containers - Specification
6	KS 2359 2012 ICS 67.020; 83.080	PS in food Packaging	2012	Polystyrene (PS) (Crystal and High Impact) in contact with foodstuffs, pharmaceuticals and drinking water - Specification
7	KS 2361 2012 ICS 67.020; 83.080	PS in food Packaging	2012	Positive list of constituents of Polystyrene (PS) (Crystal and High Impact) in contact with foodstuffs, pharmaceuticals and drinking water
8	KS 2362 2012 ICS 67.020; 83.080	PVC in food Packaging	2012	Polyvinyl Chloride (PVC) and its copolymers for its safe use in contact with foodstuffs, pharmaceuticals and drinking water - Specification
9	KS 03-1422 1998 ICS 83.080.01	PVC in food Packaging	1998	Positive list of constituents of Polyvinyl Chloride (PVC) and its copolymers in contact with foodstuffs, pharmaceuticals and drinking water

Normally, the migration/extraction of resins and additives is measured for contact with different food simulants, e.g., distilled water, vegetable oil or acetic acid. At all times, approved grades should be used and compliance with relevant regulations checked in using plastics for food, water and pharmaceutical contact applications. However, the finished part must also meet the requirements of the relevant regulations. The degradation of material during processing, use of additives, etc., can make the final product non-compliant to standards (Tripathi, 2002).

2.5.6 Resistance of Plastics to Microorganisms

Plastics are not a nutrient medium for microorganisms and are therefore not attacked by them. Plastic degrades very slowly because its complex chemical bonds make it resistant to natural processes of decomposition. For this reason, since the 1950s, millions of tonnes of plastic have been discarded and the waste may persist for hundreds or even thousands of years. Microorganisms cannot be penetrated plastics with wall or film thickness above 0.1 µm. In thinner walls, small pores may be introduced during manufacture. Low molecular weight additives, such as plasticisers, lubricants, stabilizers and antioxidants, may migrate to the surface of plastic components and encourage the growth of microorganisms. The detrimental effects can be readily seen through the loss of properties, change in aesthetic quality, loss of optical transmission and increase in brittleness. Preservatives, also known as fungicides or biocides, are added to plastic materials to prevent the growth of microorganisms (Tripathi, 2002).

Recently, two fungi, one that can survive exclusively on polyurethane and another that can replace polystyrene foam were discovered by researchers from Yale University. One of the fungi called *pestalotiopsis microspora* can subsist on polyurethane alone in airless environments, like the bottom of a landfill. The other fungi comes from a couple of college friends who discovered that the sticky substance on the bottom of mushrooms called mycelium could be turned into a glue and when that glue is combined with corn husks and other food by-products it takes on a form similar to polystyrene foam (Yahoo, 2012).

Further, these findings were published in the Journal of Applied and Environmental Microbiology. In the journal article, endophytes (micro-organisms that live within the inner tissues of plants without causing any noticeable disease symptoms in their hosts) were isolated from plant stems collected in the Ecuadorian rainforest. A subset of these organisms was screened for their ability to degrade polyurethane. Endophytes reach their greatest diversity in tropical forests. Individual trees can harbor hundreds of endophytic species, some of which are known but many of which are new to science. Several active organisms were identified, including two distinct isolates of *Pestalotiopsis microspora* with the ability to efficiently degrade and utilize PUR as the sole carbon source when grown anaerobically. More intriguing, the fungus thrives in oxygen-free conditions that would prevail at the bottom of a landfill. The study holds out hope that further exploration of properties of endophytes on the more than 300,000 land plant species on earth potentially hosts multiple endophytes species could reveal more miracle metabolisers that could potentially be used to degrade other kinds of plastics. So far, only a small sampling of plants has been examined for their endophytic associations, yet many of these organisms can be readily cultured (Associated Newspapers Ltd, 2012). This process is mycoremediation - using fungi to degrade or sequester contaminants in the environment. This is a beginning that more could be discovered in the future.

2.5.7 Aging and Weathering of Plastics

The aging and weathering behavior of a plastics material will be dependent on many factors such as:-

- Chemical environments, which may include atmospheric oxygen, acidic fumes and water.
- Heat.
- Ultraviolet light.
- High-energy radiation.

In a commercial plastics material there are normally a number of other ingredients present that may also be affected by these factors. Furthermore they may interact with each other and with the polymer so that the effects of the above agencies may be more or less drastic. Different polymers and additives respond in different ways to the influence of chemicals and radiant energy. Therefore, weathering behavior can be very specific (Brydson, 1999) .

2.5.8 Plastics Recycling

With a little bit of care most plastics can be mechanically recycled. Collection of plastics for recycling is increasing rapidly. Plastic recycling faces one huge problem: plastic types must not be mixed for recycling. Yet it is extremely difficult to distinguish one type from another by sight or touch. It is usually very important that plastics are separated prior to recycling due to the fact that plastic recyclers use different processes for different types of plastics, and not all plastics have the same properties, such as melting points. Thus, it is imperative that they can be separated prior to recycling, either by the consumer, the hauler, the processor, or the recycler (Franchetti, 2009).

Plastic recycling can be separated into six steps (Franchetti, 2009) namely:-

- Sorting - The most critical step in the process is a correct identification of the plastics in hand. Mixing different resins leads to a catastrophic loss in quality and to the manufacturing of useless products. Separating plastics is particularly problematic because there is little variation in physical properties (such as density and solubility) to use in sorting, the recycling symbol and number notwithstanding. In addition, the six basic types of plastic resin include multiple grades and colours within each resin type, and often several resin types are used to make a single product (Krupnik, 2002). Once sorted, the plastics are baled before being transported to a plastics reprocessing plant (Franchetti, 2009). Primary plastics reprocessing is therefore strongly limited by the chemical properties of the material. Reprocesses that make plastic products out of other plastic products typically blend virgin resin with the recycled resin to boost the product's performance (Krupnik, 2002).

- Shredding - Once at the reprocessing plant, the plastic is shredded into small pieces which are then washed.
- Cleaning - With plastics, potential contaminants are more plentiful and much more difficult to control. After washing, the plastic pieces are passed under a metal detector to remove any metal, and a de-dusting unit, which removes any lighter particles (Franchetti, 2009).
- Melting - The clean plastic pieces are dried and melted so they can be made into new shapes (Franchetti, 2009).
- Extrusion - The melted plastic is then filtered to remove any remaining contaminants and extruded to form fine spaghetti-like strands (Franchetti, 2009).
- Pelletizing - The plastic strands are then cut into pellets, cooled in water, dried and stored ready to be processed and moulded as new plastic items (Franchetti, 2009).

The most important potential source of plastics waste is to be found in consumer wastes, arising in trade and industry and in private households. Municipal refuse in industrialized countries typically contains about 7% by weight of plastics, mainly packaging materials, consisting of various grades of polyethylene (PE), polypropylene (PP), polyvinylchloride (PVC) and polystyrene. Engineering plastics may occur under the form of kitchen utensils and in various parts and mechanisms. Trade and industrial wastes contain similar types of plastics, but in different proportions.

Consumer wastes form largely untapped sources of recyclable plastics. A major difficulty lies in the logistic problem of collecting suitable amounts of plastics, which are reasonably free from putrescible and contaminants and can be transported economically to the cleaning, grading and reprocessing plant (UNIDO, 1991). Another difficulty occurs with the attempt to separate recyclables with employee involvement. Mostly, material misplacement happens where containers dedicated to certain materials are found to contain other materials as well. This results in higher cost of sorting and cleaning (Franchetti, 2009).

a. Technical barriers to plastics recycling

The largest tonnage of plastics waste available for recycling is post-consumer consisting of mixed and/or contaminated products. Plastics waste is available in a wide variety of types, forms, kinds and levels of contamination depending on previous contents. A substantial range of recycling technologies is required, some are mature, others developmental. To produce a product of acceptable quality, washing and separation of post-consumer plastics waste are essential. Ideally the waste to be recycled should have no color or as a second choice the same color. Variable coloration limits the market for recycled product (UNIDO, 1991). Currently, no mechanical system is proven or available to separate plastics waste into its different constituents and meet the requirements of the recycling industry. Several systems, based on sink/float principles or on hydrocyclone cascades, are being demonstrated and hold the promise of separating at least an olefinic fraction (UNIDO, 1991).

Plastic recyclers also face the issue of contamination from diverse plastic resins. Recycling the number 1 (PET) plastics — the soda bottles — could work economically were it not for the number 3s (PVC) that enter the mix. PVC presents enormous problems because it looks just like PET physically. However, a single bottle of PVC will aesthetically contaminate the entire 10,000-bottle load, causing the new PET bottles made with the material to be yellowed or, with more contamination, to have black streaks (Krupnik T.J., 2002). Both PVC and PET are commonly used in bottling, however, PVC is generally less desirable for recycling because it melts and then decomposes at the lower temperatures experienced during reprocessing. Several recycling ventures are working on X-ray detectors which could then be connected to automated sorting systems to separate PVC from PET (UNIDO, 1991).

b. Economic constraints on plastics recycling

The collection of plastics materials may assume different forms, such as:

- Door to door collection of source separated plastics
- Separate collection by civic associations;
- Collection at schools,
- Manual sorting of household waste at a sorting point
- Source separated waste delivered by an individual to a container park, shop, etc.

- Door to door Scavengers from household dustbins who buy at K.Shs. 2 per kg (self)
- Dumpsite scavengers (though unsanitary and dangerous to public health). This scavenging of recyclable waste materials at the tipping site-dumping site at Dandora, is an essential activity for a number of trades that depend on this supply
- Recyclable materials can be set aside by the rubbish collection crews and marketed on their way to the disposal site. The latter system operates for plastics materials.

It is difficult to assess collection cost, because it may either be on a voluntary basis, with the selling of the material as a reward, or on the basis of cheap labor. Sorting normally is entirely manual. Washing often proceeds by hand with the drying of shredded plastics by solar heat (UNIDO, 1991).

c. Current Status and Challenges of Recycling Industries

Manufacturers are facing such challenges getting a supply of clean used plastic that can be recycled. Current argument is that recycling is not a viable business because of lack of legal and infrastructural support by local authorities who are mandated with the collection of waste in cities and towns. Consumers use plastic bags for disposal of solid waste, and by the time they are picked for recycling they are already too dirty to recycle. For substantial recycling to take place, manufacturers would have to set up secondary recycling plants besides their virgin plastics plants, which is at the moment not considered viable due to lack of economic incentives. Industry is throwing the challenge back to the government to offer tax and energy incentives to plastic recyclers in order to attract new investments in the emerging industry, said to have great potential for job creation

One study reported that it is possible to make containers with recycled contents of up to 50%, if the reclaimed containers used are made of pure virgin resin. At least one blow-moulder was able to produce a 100%-recycled content bottle with the desired properties using a particular blend of post-consumer resins. However, large-scale reprocesses found that using more than 15 - 25% of post-consumer feedstock reduced the strength of containers (Krupnik T.J., 2002).

The plastic recycling process is not entirely safe to human health. Plastic reprocessing plants typically deal with numerous toxic and chemical compounds. If the recycling process is not well designed or regulated, there exists a direct threat to the health of workers and nearby communities. Because of the volatile nature of many of the materials plastic recyclers deal with, explosions and fires are common in reprocessing plants. In the United States for example, recyclers find it difficult to achieve the stringent worker and environmental health standards forced upon the industry by lawmakers. This is one of the reasons that many plastic reprocessing facilities have closed their doors only to be replaced by recycling facilities in developing countries where similar legislation standards are non-existent (Krupnik T.J., 2002)

d. Recycling Technologies

Recycling of plastics materials is now an important field in the plastics industry, not just an activity born under environmental pressure. The plastics industry practiced recycling for many years with attention mainly focused on the recycling of industrial scraps and homogeneous post-consumer plastics, which are easy to collect and reprocess. More recently, the plastics industry accepted the challenge of recycling of heterogeneous plastics waste based on new technologies of separation and reprocessing. Scientific research, scarcely visible only a few years ago, is now a very active, fast-growing discipline, contributing to the development of newer processes (Roy, 2009). According to the type of product obtained from the recycling process and the percentage of the economic value recovered, the following broad classification of recycling technologies can be made:-

- Primary recycling, the reprocessing of plastics waste into the same or similar types of product from which it has been generated (Direct use);
- Secondary recycling, the processing of plastics wastes into plastics products with less demanding properties (Reuse after Modification);
- Tertiary recycling, recovery of chemicals from waste plastics; and
- Quaternary recycling, recovery of energy from waste plastics (incineration - energy recovery by burning) (Roy, 2009).

The processes mainly used to these ends are: direct re-use after separation and/or modification, chemical treatment or pyrolysis for recovery of monomers and/or other products, and burning or incineration (Roy, 2009).

Primary recycling is used when the plastic waste is uniform and uncontaminated and can be processed as such. Only thermoplastic waste can be directly reprocessed; it can be used alone or, more often, added to virgin resin at various ratios. The main problems encountered in primary recycling are degradation of the material resulting in a loss of properties as appearance, mechanical strength, chemical resistance, and processability. Contamination of plastic scrap and handling of low-bulk density scrap such as film or foam are additional problems in primary recycling. Primary recycling is widely performed by plastics processors; it is often considered an avoidance of waste rather than recycling (Roy, 2009).

In the case of Post-consumer Mixed Plastic Wastes (MPW), which are unsuitable for direct use, secondary recycling methods are employed in industry resorts. There are various technical approaches to secondary recycling of MPW. These include reprocessing based on melt homogenization using specialized equipment; use of ground plastics waste as filler; and separation into single homogeneous fractions for further processing, such as partial substitution of virgin resins and blending with other thermoplastics using suitable compatibilizers (Roy, 2009).

In tertiary or chemical recycling of plastic wastes, polymers are chemically unzipped or thermally cracked in order to recover monomers or petrochemicals indistinguishable from virgin materials. Thermal cracking procedures offer viable alternatives by utilizing commingled plastics without decontamination (Roy, 2009).

In quaternary recycling, energy content of plastics waste is recovered. In most cases, plastics are burned, mixed with other waste. Incineration of plastics alone creates a number of problems and requires the use of specially designed incinerators (Roy, 2009).

e. Recycling of Polyethylene Terephthalate (PET)

The largest use of Polyethylene Terephthalate (PET) is in the fiber sector, with PET film and PET bottles representing only about 10% each of the total PET volume produced annually. A large percentage of the total PET output comprising films, plastics, and fibers is recycled by various methods and for several applications, which makes PET one of the largest in volume of recycled polymers in the world (Roy, 2009).

There exists a clear hierarchy in PET-film recycling technologies. Two most important criteria of classification are the degree of purity of PET scrap to be handled and the economics of the process. While for the cleanest PET grade the most economical process is direct reuse in extrusion, for less-clean PET samples it is still possible to reuse them after the modification step at a reasonably low price. More-contaminated PET waste must be degraded into the starting monomers, which can be separated and re-polymerized afterwards, and at a higher cost. Finally, the most heavily contaminated PET wastes have to be incinerated or brought to a landfill (Roy, 2009).

2.5.8.1 Recycling of Polyurethanes (PU)

Polyurethanes are by far the most versatile group of polymers, because the products range from soft thermoplastic elastomers to hard thermoset rigid forms. Polyurethane foams are well known and widely used materials. Polyurethane (PU), is used for car upholstery; front, rear, and side coverings; and also for spoiler.

Various material recycling methods for PU scrap and wastes exist. Among them, thermopressing and kneading processes are especially significant, because these simple processes render the recycling of cross-linked PU products equivalent to that of thermoplastic products (Roy, 2009).

2.5.8.2 Recycling of Polyvinyl Chloride (PVC)

Polyvinyl chloride and some other chlorine-containing polymers belong to the most widely applied thermoplastic materials. There are many applications of rigid and plasticized PVC. In the building sector, for example, very large amounts are used for pipes, profiles for windows, floor coverings, and roofing sheets. By the end of the lifetime of these articles, large amounts of scrap have been produced. It is of economic and environmental interest to recycle this PVC waste as much as possible. Disposal of PVC waste by incineration has its special problems. Due to the high chlorine content of PVC, its incineration yields large amounts of HCL gas in addition to the possibility of formation of toxic dioxins and furans. On the other hand, it is a great advantage that many sources produce large amounts of PVC scrap of the same origin and with similar composition, which simplifies the reuse possibilities from a logistic point of view (Roy, 2009).

Since several chemical reactions occur during processing and use of PVC, which can change the properties of the polymer, it is necessary to characterize PVC scrap before deciding about the reusability. No PVC is processed and used without the addition of stabilizers. Some Post-Consumer PVC (POSTC-PVC) sources are water, food, pharmaceutical, and cosmetic bottles, and film. Another significant source of Post-Consumer PVC is used electric cable, coming principally from plant demolition and, to a lesser degree, from manufacturing scrap and offcuts (Roy, 2009).

PVC bottles, like PET bottles, are very recyclable. Manual sorting of non-pigmented PVC and clear PET bottles is difficult because they look alike. When the two types are received commingled, the re-processor can experience quality deficiencies due to rheological incompatibilities between these two resins. Therefore, all attempts to separate and remove these two resins must be made prior to recycling. Manual sorting techniques are inadequate to meet the market's needed quality standards, so new techniques have been engineered that will detect and separate bottles made from either of these two resins. A simple device senses the presence of chlorine atoms as a means to detect PVC bottles. Once detected, PVC bottles are pneumatically jettisoned from the commingled bottle feed-stream by a microprocessor-based air-blast system (Roy, 2009).

The step after sorting is baling or granulation. Granulation is the preferred method of intermediate processing since the material so processed commands the highest market value. For up-gradation of the resin from the recycled PVC bottles, several steps are explored depending on the results of characterization tests. These include incorporation of virgin resin (10–90%), re-stabilization against Ultra-violet (UV) light and heat, and incorporation of processing aids, impact modifiers, lubricants and plasticizers (Roy, 2009).

The recovery of electric cable is long established because of its valuable copper content. After this conductor material has been extracted, the residue consists of sheathing and insulation that may contain rubber and polyethylene as well as PVC. These other materials can be largely removed from grinding, by flotation, vibration, and filtration, but rubber is especially difficult to remove entirely, so that applications for material recycled from cables containing it are limited to areas such as car mats and carpet underlay (Roy, 2009).

2.5.8.3 Recycling of Mixed Plastics Waste

Commingled plastics currently represent an estimated two-thirds of today's recycled plastics streams. That fraction can be expected to shrink somewhat with the development of more successful identification and segregation technologies in the future. However, commingled plastics streams will continue to make up a significant volume for several reasons: proliferation of grades and types of commodity; profusion of polymer blends and alloys; contamination of recycle plastic parts with metals, coatings, and laminates; and practical cost considerations. Mixed plastics wastes can be divided into two groups depending on their source: mixed plastics from household or municipal solid wastes and plastics from industrial sectors (Roy, 2009).

2.6 CLASSICAL MASS BALANCE CONCEPT AND MATERIAL FLOW ANALYSIS (MFA)

The classical mass balance theory has been adopted as a way of Material Flow Analysis (MFA). Materials Flow Analysis applies the concepts of industrial ecology to study how materials and energy flow into, throughout, and out of a system. Specifically, MFA refers to accounts of physical units such as tonnes or measures of impact from the extraction of, production, transformation, consumption, recycling, and disposal of materials within a system. The target of the analysis can be a selected substance (a chemically defined element or compound such as carbon dioxide), a material (natural or technically transformed matter that is used for commercial or non-commercial purposes such as platinum), a product (such as a fuel cell), or an economy (such as the Kenyan economy). In MFA methodology, the target is one unit of a product within a specific or average process chain.

Creating MFA models that capture the inputs and outputs of a system of processes (such as product manufacturing and materials recycling processes), mines (such as mineral mines), and sinks (such as a landfill or the atmosphere) allows decision-makers to better understand the potentially hidden interactions related to making a decision around a single process, mine, or sink. MFA methods are gaining in popularity as a means to apply “systems view” to many types of decisions: from product development and design, to business management, to public policy, etc. Coordination of Regional and National Material Flow Accounting for environmental sustainability functions as an international platform for MFA discussions.

“Industrial ecology” is the study of the flows of materials and energy in industrial and consumer activities, of the effect of these flows on the environment, and of the influence of economic, political, regulatory and social factors on the flow, use and transformation of resources. The objective of industrial ecology is to understand better how we can integrate environmental concerns into our economic activities. This integration, an on-going process, is necessary if we are to address current and future environmental concerns (White, 1994)

2.6.1 Classical Mass Balance Theory

The mass balance concept is based on the fundamental physical principle that matter can neither be created nor destroyed. Therefore, the mass of inputs to a process, industry or region balances the mass of outputs as products, emissions and wastes, plus any change in stocks. The term 'mass balance' is used to describe this type of analysis (Linstead, 2003). When applied in a systematic manner this simple and straightforward concept of balancing resource use with outputs can provide a robust methodology for analyzing resource flows.

Mass balance accounts for the conservation of mass of a substance within a control volume by equating the rate of accumulation to the difference between its rates of entering and leaving the volume plus the net rate of generation within the volume. The basic mass balance equation can be expressed as:

$$Inflow - Outflow + Generation - Consumption = Accumulation \qquad \text{(i)}$$

Each of these terms will differ, depending on the model. The control volume can be either in terms of a geographic area or an economic sector. The structure in Figure 2-7 provides a conceptual model for the flow of plastics through the study area, with an allowance for import and export of primary materials, products and components. From Figure 2-7, streams that represent movement of material through the economy and are largely associated with distribution, import, export or other transport are symbolized as lines. Nodes are the focus of stream movements and can be related to industrial production or recycling, consumption centers and/or final disposal methods.

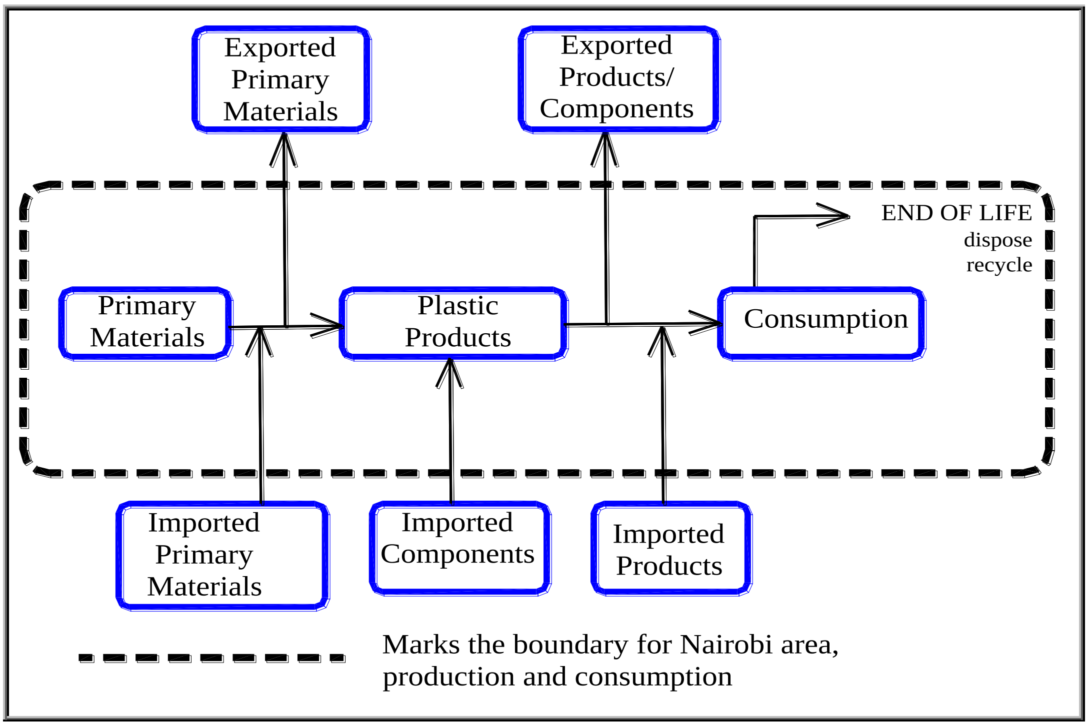

Figure 2-2: Conceptual Mass Balance Structure (Bowman, 2005)

2.6.2 Application of Mass Balance Concepts in Engineering

a. Standard Water Balance in Water Use Audits

The standard water balance is the framework for categorizing and quantifying all water uses in the water use audit. When a water balance is completed, all uses of water in the system equal the amount of water input by the source(s). All water use is accounted for in the standard water balance (eliminating the need for the term "*unaccounted-for water"*). The standard water balance was originally developed by the International Water Association in the 1990's and published in 2000 in *Performance Indicators for Water Supply*.

The standard water balance is a series of simple equations, a four step process outlined in Figure 2-8. Utility managers are able to complete these equations in the simplest manner possible ((IWA, 2003). Starting with the "System Input" category, the vertical height of each category represents a proportional amount of water. Thus, the height of the "System Input" category represents all water delivered into the system in a given time period. This amount of water can be broken down into two additional categories, "Authorized Use" and "Water Losses".

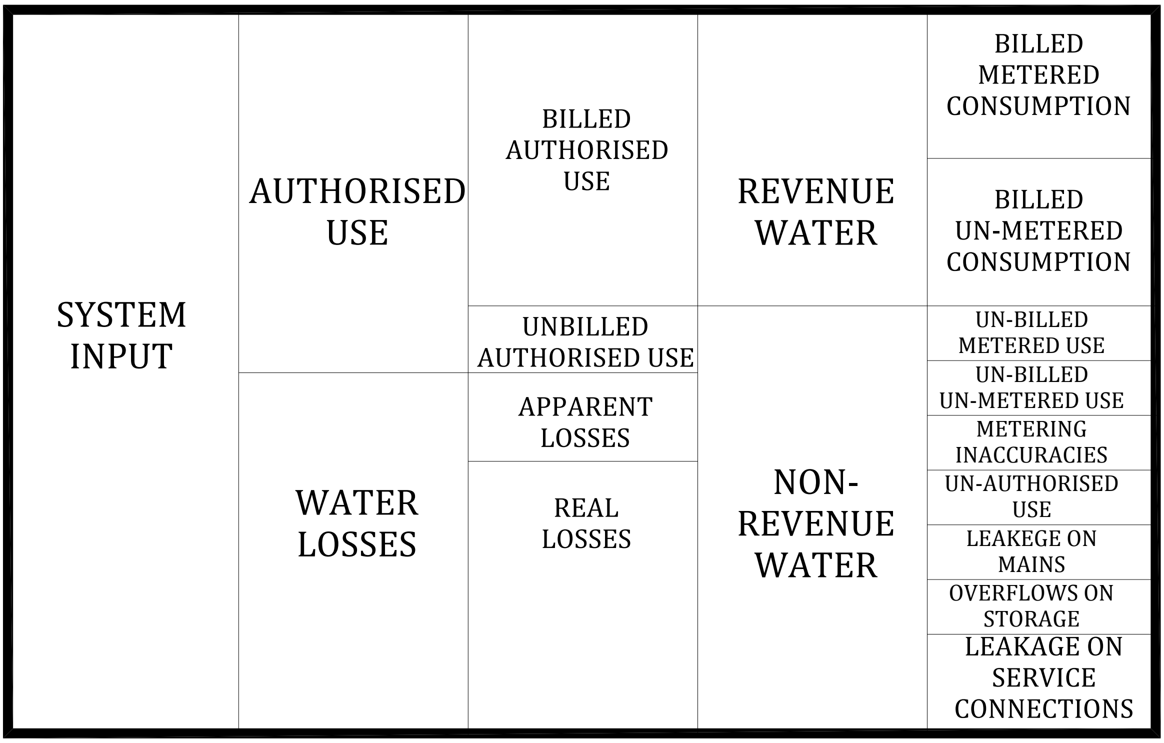

Figure 2-3: Standard Water Balance Model (IWA Task Force, 2003)

Therefore,

$$Authorised\ use + Water\ losses = system\ Input \qquad \text{(ii)}$$

The vertical height of water measurement holds true across the entire standard water balance even for categories that are not right next to each other; equal vertical measurements of categories means an equal quantity of water.

2.6.3 Application of Mass Balance Concepts in Plastics Sector

Though the inputs and outputs of processes are not well defined, nor are the analytical tools sophisticated enough to achieve reliable input−output balances, nevertheless, Material Flow Analysis (MFA) and Substance Flow Analysis (SFA) are valuable tools to support waste management decisions on both strategic and operational levels. The Material Flow Analysis (MFA) method was developed about 40 years ago. Its value has been applied and used in various fields such as environmental management, resource management, waste management, and water quality management as a common method in the engineer's toolboxes for solving resource-oriented problems (Brunner, 2004). SFA serves to identify missing information about a waste management system. This case study exemplifies the potential of MFA to contribute to sustainable materials management in Nairobi City. Emphasis will be placed on the linkage between sources, pathways, and sinks of materials, always observing the law of conservation of matter.

3 METHODOLOGY

3.1 DEFINITION OF STUDY TERMS

In building Mass Balance Models (or Material Flow Analysis Models), various terms utilized should have standardized definition in order to enhance their universal application to material flow analysis. Such terms are described in the following paragraphs:-

The process – Any transport, transformation, or storage of plastic materials. Processes are linked by flows (mass per time) or fluxes (mass per time and cross section) of materials. Flows/fluxes across systems boundaries are called exports. Flows/fluxes of materials entering a process are named inputs, while those exiting are called outputs (Brunner, 2004). Usually, processes are defined as black box processes, meaning that processes within the box are not taken into account. Only the inputs and outputs are of interest. If the internal processes are of interest, the process must be divided into two or more sub-processes that can be described by an extra model (Vienna, 2012). Only those interesting processes located within the system boundary are included in the model. Such processes will be balances using the law of mass conservation. Processes outside of the system boundary are not taken into account. Processes cannot be situated on the system boundary; they have to be either inside or outside of the system boundary.

Stocks - plastic material reservoirs (mass) within the analyzed system, have the physical unit of kilograms. For steady-state conditions (input equals output), the mean residence time of a material in the stock can be calculated by dividing the material mass in the stock by the material flow in or out of the stock. Stocks can stay constant, or they can increase (accumulation of materials) or decrease (depletion of materials) in size (Brunner, 2004). Stock is the total amount of materials stored in a process.

Flows - A flow is defined as a “mass flow rate”, i.e. the ratio of mass per time that flows through a conductor, e.g. a water pipe. The physical unit of flow is given in units of kg/sec or t/yr., (Vienna, 2012). In this case, the flows are the pathways for movement of plastic materials in mass over time. A distinction is made between internal flows (that connect processes within the system) and flows that cross the system boundary. They are called import or export flows respectively. Flows cannot split except at a process stage.

The material – The term material serves as an umbrella term for both substances and goods and it therefore includes raw materials as well as all physically or chemically modified substances. The material under the study is plastics in its raw material form or its any other physically and/or chemically modified variations.

System - comprises a set of material flows, stocks, and processes within a defined boundary (Brunner, 2004). The system might be an enterprise (e.g. waste incineration plant), a region, a nation, or a private household (Vienna, 2012). In this case, the system is the plastic materials flows, stocks and processes within the region described as the City County of Nairobi.

System Boundary - The system boundaries are defined in time and space (temporal and spatial system boundaries). Commonly applied temporal boundaries for anthropogenic systems such as an enterprise, a city, or a nation, periods of 1 year are chosen for reasons of data availability. The spatial system boundary is usually fixed by the geographical area in which the processes are located. Flows into a system are called imports, flows leaving a system are exports (Vienna, 2012). The spatial system boundary for the study is the City County of Nairobi, while the system boundary in time will be 2011.

Material Flow Analysis (MFA) - Material Flow Analysis is a systematic assessment of the flows and stocks of materials within a system defined in space and time. It connects the sources, the pathways and the intermediate and final sinks of a material (Vienna, 2012). The study is a Plastics Material Flow Analysis within the City County of Nairobi in 2011. This time boundary is chosen because this is when the most data was collected and it is also the time when secondary data is fully obtainable.

Transfer Coefficient (TC) - The transfer coefficient $TC_{x,\ j}$ describes the partitioning of a material, x, within a process, and its transfer into a specific output flow j. The sum of the transfer coefficients to all output flows must be 1, considering that transfers into the stocks are also counted as outputs. Depending on the problem, it is possible to count only partial input for the calculation of transfer coefficients, e.g.to calculate the efficiency of oxidation within a waste incineration plant we only count the C in the waste, not the C in the air.

3.2 THE STUDY AREA - NAIROBI CITY

3.2.1 Size and Topography

Nairobi occupies an area of about 700 km^2 at the south-eastern end of Kenya's agricultural heartland. It stands at 1,600 to 1,850 m above sea level. The western part of the city is the highest, with a rugged topography, while the eastern side is lower and generally flat. It is traversed by the Nairobi, Ngong, and Mathare rivers which cross numerous neighborhoods. Minor earthquakes and tremors occasionally shake the city since Nairobi sits next to the Rift Valley, which is still being created as tectonic plates drift apart (UNEP, 2009). Figure 3-1 shows the map of the study area.

Nairobi City is a modern urban area where large amounts of materials are produced and consumed. It is rapidly growing in population and size, thereby comprising a large and growing stock of municipal solid wastes comprising of plastic materials, among others.

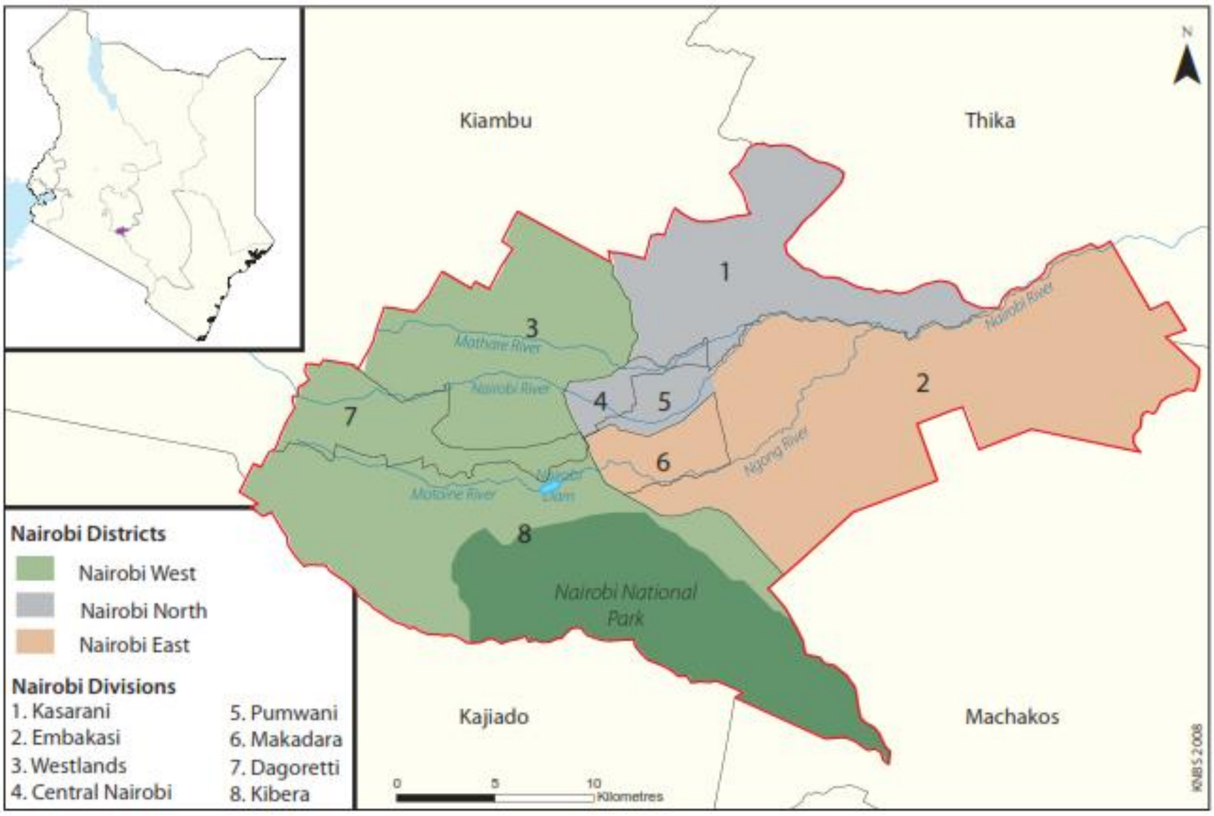

Figure 3-1: Map of the Study Area (UNEP, 2009)

3.2.2 Demography and Population

Population is a major driver of environmental change in Nairobi. It is a determinant of other parameters important to the study such as solid waste generation rate and land-use pattern and settlement. The population of Nairobi grew from 2.1 million in 2000 to 3.2 million in 2010 at an annual growth rate of 4.3%. The city area has expanded from 18.13 km^2 in 1906 to 696 km^2 in 2005, and population density has increased from 635 person/km^2 to 3,954 person/km^2 during the 99 years from 1906 to 2005 (JICA, 2010). Based on the Polynomial

Model for 2008 to 2030, the population projection shows a growth rate of approximately 3% per annum as shown in Table 3-1.

Table 3-1: Population Projection in Nairobi City (in 1,000) (JICA, 2010)

Year	2008	2009	2010	2015	2020	2025	2030
Kenya	35,265	35,884	36,508	39,710	42,569	45,408	48,438
Nairobi	2,930	3,040	3,150	3,760	4,420	5,150	5,940
Share (%)	8.31	8.47	8.63	9.47	10.38	11.34	12.26

3.3 MANAGEMENT OF MUNICIPAL SOLID WASTE IN CITY COUNTY OF NAIROBI (CCN)

3.3.1 Institutional Framework for Solid Waste Management (SWM)

The Department of Environment (DoE) is the arm of the City Council of Nairobi (CCN) that was mandated with management of Municipal Solid wastes within the study boundaries under the Local Government Act until March 4, 2013. Under the City Council of Nairobi, Solid Waste management was guided by the CCN policy.

The DoE is divided into the Administration Section, the Solid Waste Management (SWM) Section, the Parks/Open Spaces Section and the Environmental Management Planning (EMP) Section. It is headed by the Director of Environment, assisted by two Deputy Directors. Figure 3-2 shows the outline of the organizational structure of the DoE and the SWM Section.

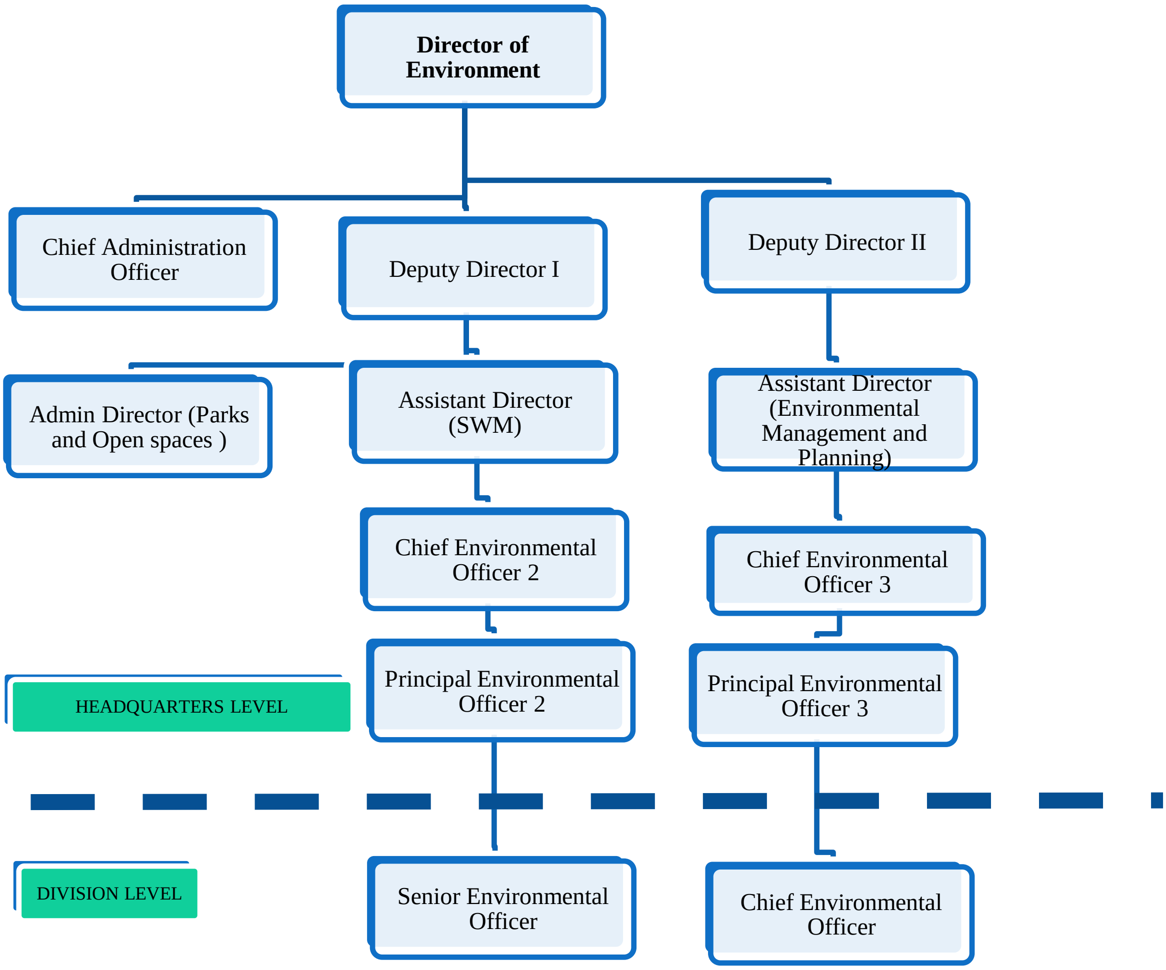

Figure 3-2: Organizational Structure of the Department of Environment (DoE) in CCN

3.3.2 The Transition from City Council of Nairobi to City County of Nairobi

Upon the general elections in 2013, the Constitution of Kenya 2010 took effect, with devolution from City Council of Nairobi to the City County of Nairobi. The Local Government Act with all its mandates, programs, personnel and assets and all other Acts contrary to the new laws stood voided and in their place, the Transition to Devolved Government Act 2012 and the County Government Act 2012 among others, borne out of the Constitution of Kenya 2010, took effect and inherited the mandates, programs, personnel and assets created under the Local Government Act. One such program significant to this study is the "Preparatory Survey for the Integrated Solid Waste Management in Nairobi City in the Republic of Kenya" carried out by the Government of Japan under Japan International Co-operation Agency (JICA) in 2010.

Once in place, prior to rolling out operations, the City County's (CCN) immediate responsibility was to enact laws that govern the various operations in order to align themselves with the provisions of Constitution of Kenya 2010. All programs, assets and personnel previously ran by the City Council of Nairobi were inherited by City County of Nairobi (both CCN). Seeing that the transition is on-going, for the purposes of this study, both entities will be used interchangeably to refer to the same study area, then and now.

The main responsibilities of the Department of Environment (DoE) on solid waste management are summarized as follows:-

- To implement CCN's SWM policies formulated by the Council's Environmental Committee.
- To maintain public cleanliness, protect public health and the environment, and keep public places aesthetically acceptable by providing services for the collection, transportation, treatment and disposal of solid wastes.
- To regulate and monitor the activities of all generators of solid wastes.
- To regulate and monitor private companies engaged in solid waste activities.
- To enforce all laws and regulations relating to SWM.

Currently, the City of Nairobi is divided into nine (9) operation zones based on constitutional boundaries, including the Central Business District (CBD). These zones are CBD, Dagoretti, Embakasi, Kasarani, Kamukunji, Langata, Makadara, Starehe and Westlands.

3.3.3 Sources of Solid Waste within Nairobi

The importance of using a waste classification by source is that; it is the specific composition of each waste category that sometimes dictates a special collection or treatment system for each one. The sources broadly are:-

- Household i.e. Residential Areas
- Commercial Establishments including institutional, industrial, schools and public places
- Markets
- Roads and
- Others

3.3.4 Amounts of solid wastes generated in residential and commercial areas

In solid waste management, waste materials quantification is done either by weight or volume. If by weight, the numbers are given in kilograms or tonnes. When the measures are given by volume, then the numbers are in cubic meters (m^3) (Franchetti, 2009). For the purposes of this study, the weight measure will be adopted for waste quantification. Where recordings were made by volume, then, the approximate weight will be calculated using accordingly. The Apparent Specific Gravity (ASG) in kg/liter of solid waste is an important tool required to assess the mass of waste given the volume. The average ASG of waste in Nairobi City is 0.30 (JICA, 2010).

3.3.4.1 Generation Quantities in Residential Areas in terms of kg/capita/day

The residential generation sources considered included five categories of high income group area, middle income group area, low-middle income group area, low income group area and slum areas. The average waste generation amount per capita per day of each generation source is as shown in Table 3-2.

Table 3-2: Average waste generation rates by source in residential areas (JICA, 2010)

Generation Source	Unit	Weight Generation (kg/day)
High Income	person	0.567
Middle Income	person	0.674
Low-Middle Income	person	0.474
Low Income	person	0.302
Slum	person	0.417

The average waste generation amount per capita per day of the five income groups in residential areas ranges from 0.302 kilograms per capita per day (kg/c/d) to 0.674 kg/c/d, as shown in Figure 3-3.

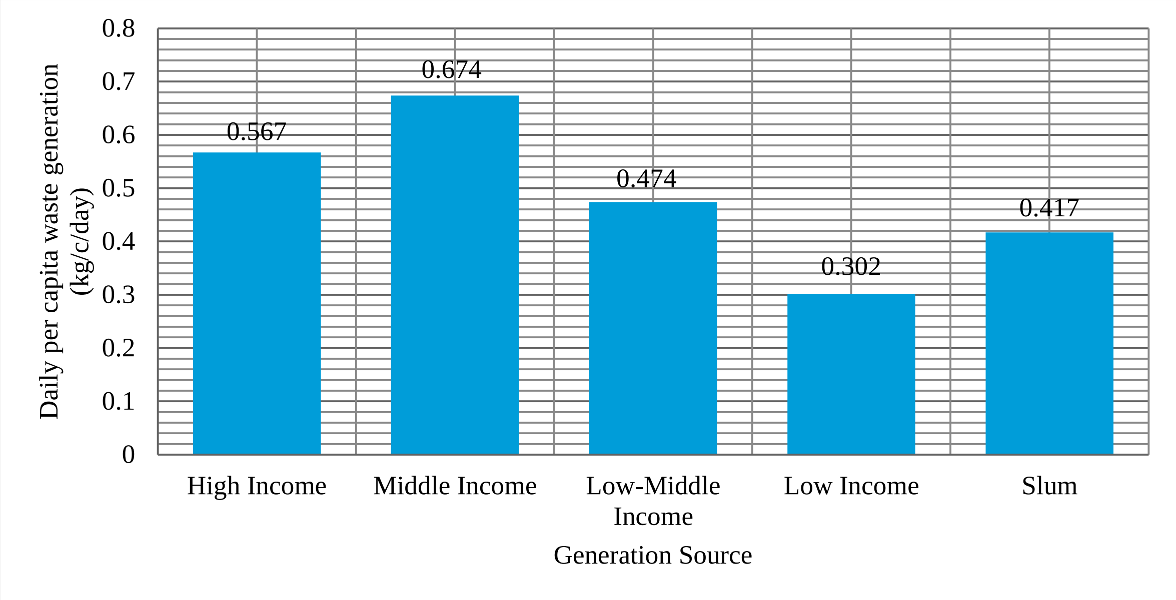

Figure 3-3: Waste Generation per Capita in Residential Area

The per capita waste generation from the high income group is lower than the middle income group because the high income group has a larger family size of about 5.1 compared to the middle income which has only 3.6 as average household members. The waste generation per capita from the low income group is also lower compared to the slum area. This is because most of the types of waste being generated from the slums are dirt or sand, based on the waste composition survey, considering that the slums are located in unpaved areas and most of the houses have earthen floors or not cemented (JICA, 2010).

Overall, this data seems to contradict conventional trends whereby, waste generation from poor areas is generally higher than that from higher income areas. This may be explained by the fact that the domestic waste composition of Nairobi City has a different trend compared to the trend in developed countries (JICA, 2010). The Nairobi trend and that of other developing countries like Dhaka, Bangladesh, were found to be almost the same (JICA, 2010). It may also be due to better management of consumption by residents in low-income communities who have low purchasing power and therefore lower waste generation and disposal than in higher income areas. The higher income groups also have bigger household sizes owing to the inclusion of hired helpers such as home managers, cooks, baby minders and watchmen compared to the low-income areas who have fewer or none.

The average for both the wet and dry season per capita waste generation rates is shown in Table 3-3. (JICA, 2010)

Table 3-3: Wet and Dry Season Per Capita Waste Generation Rates (JICA, 2010)

Income Group	Survey Area	Maximum (kg/day/c)	Mean (kg/day/c)	Minimum (kg/day/c)
High Income	Kitisuru	1.107	0.625	0.329
	Karen	1.226	0.509	0.173
Middle Income	Langata	2.679	0.737	0.248
	South B	1.568	0.611	0.449
Low-Middle Income	Riruta	1.149	0.483	0.24
	Umoja	2.479	0.465	0.16
Low Income	Dandora	1.014	0.28	0.156
	Bahati	1.289	0.325	0.102
Slum	Kibera	1.535	0.464	0.19
	Mukuru	1.012	0.37	0.235

3.3.4.2 Commercial Establishments

Commercial establishments considered include shops, restaurants and hotels, as well as public facilities like schools, private and public offices. While the generation per capita should be the unit rate generation per customer or employee, in the process of gathering the total number required during the survey, insufficient data was obtained and so the computation would be inaccurate. Therefore, the number of establishments was searched through the Computer Department of the City Council of Nairobi so that the unit rate generation of establishments is per structure or establishment and not per person. The average weight of each generation source of establishments is shown in Table 3-4 (JICA, 2010).

Table 3-4: Average Weight of Commercial Establishments Waste Generation

Establishments	Dry Season (kg/day)	Wet Season (kg/day	Average (kg/day)
Shops	0.57	0.43	0.5
Restaurants	30.6	45.52	38
Hotels	346.5	375.06	350
Schools	65.63	87.74	76
Public Offices	109.96	164.08	137

The highest waste generators among the establishments are the hotels, at about 350 kg/day, while the shops are the lowest generators, about 0.5 kg/day.

3.3.4.3 Markets

There are 44 markets in Nairobi City. 30 of these were surveyed and their wastes for seven days collected for the estimation of average waste generation per day. The results show that the average daily waste generation of each market is about 2,045 kg/day. (JICA, 2010)

3.3.4.4 Roads

The estimation was conducted just to show the amount being swept from the roads everyday disregarding residential and commercial dumps onto the roads. The length of roads being swept was 563.3 km. The average waste generation according to the waste amount survey was 50 kg/km/day (JICA, 2010).

3.3.4.5 Total Amount of Waste Generated in Nairobi City

Based on the residential, commercial, market and road wastes, the waste generation for Nairobi City in 2009 was 1,848 ton/day. This is shown in Table 3-5.

Table 3-5: Total Amount of Waste Generated in Nairobi City

Generation Sources	Quantity	Unit	Unit Generation (kg/day)	Total (kg/day)
1. Residential Waste				
a. High Income	397,362	person	0.621	246,635.00
b. Middle Income	1,066,393	person	0.474	505,076.00
c. Low Income	1,576,245	person	0.36	566,670.00
Sub-Total for Residential Waste				1,318,381.00
2. Commercial Waste				
a. Shops	47,941	establishment	0.5	23,970.50
b. Restaurants	1,582	establishment	38	60,116.00
c. Hotels & Guest Houses				
Standard Hotels (D Class)	140	establishment	350	49,000.00
Lodging House (B & C Class)	586	establishment	100	58,600.00
d. Public Facilities/Schools				
Public Facilities	500	establishment	137	68,500.00
School	2,847	establishment	32	91,104.00
e. Industrial Plants	501	establishment	150	75,150.00
f. Other Establishments	27,077	establishment	0.5	13,538.50
Sub-Total for Commercial Waste				439,979.00
3. Market Waste	44	market	2045	90,000.00
4. Road Waste	563.3	km	106	60,000.00
Total				1,848 t/day

Figure 3-4 is generated from Table 2-5. From the table, it will be noted that the total waste by weight, generated by commercial establishments is about 25% of the total waste generated by the residential areas. (JICA, 2010).

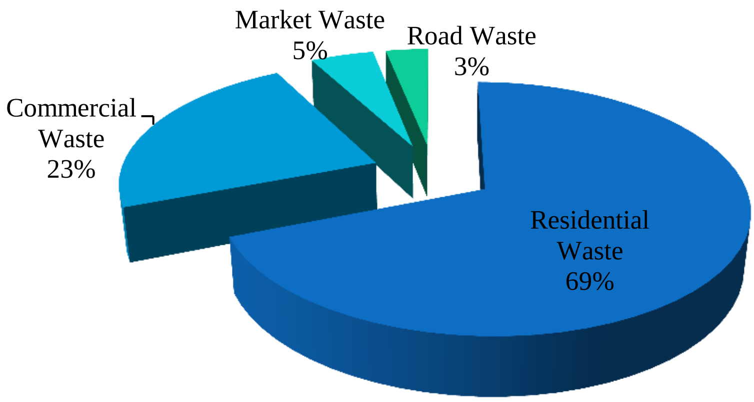

Figure 3-4: Pie Chart of Waste Fractions by Source

3.3.4.6 Waste Composition Results

The Waste Composition at Generation Sources is as shown in Table 3-6 (Units, %).

Table 3-6: Waste Composition of Each Generation Source (Unit %) (JICA, 2010)

Waste Composition		High/ Middle Income	Middle Income	Low Income/ Slum	Shops	Restau-rant	Hotel	Public Facilities	Market	Road
Food Waste		66.38	65.95	58.94	46.15	88.88	85.17	71.48	89.1	16.61
Paper	Recyclable Paper	3.67	3.74	4.55	14.02	0.94	0.65	1.66	0.81	13.14
	Recyclable Cardboard	0.94	0.36	0.11	2.91	0.58	0.5	0.34	3.72	1.97
	Mixed Paper	2.51	0	3.01	1.39	0	0	0.95	0	0.17
	Diapers	4.83	12.89	4.75	0.45	0.15	0	0.07	0	0
	Subtotal - Paper	11.96	16.99	12.41	18.77	1.66	1.15	3.02	4.53	15.28
Plastics	Plastic Sheet	6.38	4.45	9.13	1.84	0.95	0.4	1.63	0	3.04
	Recyclable Plastics	1.66	5.32	2.03	6.72	2.85	2.69	2	1.08	3.51
	PET Bottles	1.1	0.09	0.54	2.87	1.65	1.88	4.89	0.27	4.28
	Other Plastics	0.32	0.48	0	3.72	0.33	0.04	0	0.12	0.09

Waste Composition		High/ Middle Income	Middle Income	Low Income/ Slum	Shops	Restau-rant	Hotel	Public Facilities	Market	Road
	Subtotal - Plastics	9.46	10.34	11.7	15.14	5.77	5.01	8.52	1.48	10.91
Rubber & Leather		0.2	0.58	1.11	0	0	0	0	0.23	0
Textiles		1.27	0.65	2.29	0.81	0	0	0	2.96	0.34
Yard Waste		2.68	0	0	0.67	0.22	1.13	0.2	0	17.2
Lumber & Logs		1.5	0	1.03	0	0	0	0	0	0.3
Other Org. Waste		1.42	0.71	0	2.69	0.7	2.57	4.08	0.67	6.68
Organic Waste - Subtotal		94.86	95.22	87.49	84.23	97.24	95.03	87.3	98.97	67.33
Glass	Returnable Bottles	0.45	0.62	0.06	3.67	0.98	2.76	0	0	0.17
	Other Live Bottles	0.84	0.39	1.4	0.9	0.19	0	0	0.07	0
	Glass bins	0	0	0	0	0	0	0	0	0.3
	Broken Glass	0.19	0.56	0	3.72	0.31	0	5.04	0.43	0.47
	Glass-Subtotal	1.48	1.57	1.46	8.29	1.48	2.76	5.04	0.5	0.94
Metals	Tin Cans (steel cans)	0.32	0.16	0	1.48	0.39	0.48	4.63	0.04	0
	Alumi-nium cans	0.23	0.04	0	1.88	0.82	1.5	1.52	0	0.09
	Copper	0	0	0	0	0	0	0	0	0
	Other Metals	0.75	0.65	0.52	0.09	0	0	0.49	0.14	0.87
	Metal-subtotal	1.3	0.85	0.52	3.45	1.2	1.97	6.64	0.18	0.96
Dirt, Ash, Stone, Sand		2.12	1.77	10.12	2.51	0	0.06	1.02	0.21	29.62
Inorganic Waste - Subtotal		4.9	4.18	12.11	14.25	2.69	4.79	12.7	0.9	31.52
Unclassified Residual Waste		0.1	0.18	0.4	1.43	0.07	0.18	0	0.14	0.9
Domestic Hazardous Waste		0	0	0	0.09	0	0	0	0	0.26
Batteries - Dry Cells		0.05	0.09	0	0.09	0	0	0	0	0.26
Other Domestic Hazardous Wastes		0.1	0.32	0	0	0	0	0	0	0

Waste Composition	High/ Middle Income	Middle Income	Low Income/ Slum	Shops	Restau- rant	Hotel	Public Facilities	Market	Road
Total	100	100	100	100	100	100	100	100	100

Table 3-7 is generated from Table 2-6, and shows the waste composition of each generation source.

Table 3-7: Waste Composition of Each Generation Source by Weight

	Waste Composition	Total (kg)	Total (%)
1	Food Waste	1,191,186.58	65.46
2	Paper	210,433.33	11.56
3	Plastics	175,821.77	9.66
4	Rubber & Leather	9,919.75	0.55
5	Textiles	22,454.16	1.23
6	Yard Waste	18,757.76	1.03
7	Lumber & Logs	9,716.23	0.53
8	Other Organic Waste	22,042.04	1.21
10	Glass	34,757.95	1.91
11	Metals	25,449.88	1.40
12	Dirt, Ash, Stone, Sand	91,770.69	5.04
14	Unclassified Residual Waste	4,666.99	0.26
15	Domestic Hazardous Waste	177.57	0.01
16	Batteries - Dry Cells	755.46	0.04
17	Other Domestic Hazardous Wastes	1,862.88	0.10

From the Table 3-7, food waste, paper and plastics are the topmost compositions of waste. This corresponds to the 1998 JICA Study findings on the types of solid wastes generated in Nairobi, given in Table 3-8 (JICA, 1998).

Table 3-8: Types of Solid Wastes Generated in Nairobi (JICA, 1998)

Waste Type	Abbreviations	Percentage
Food Waste	FW	51.50%
Paper (Recyclable and Other)	PP	7.30%
Textiles	TT	2.70%
Plastic (container and others)	PC	11.80%
Leather	LT	0.90%
Rubber	RB	1.50%

Waste Type	Abbreviations	Percentage
Glass (containers and others)	GL	2.30%
Metal (containers and others)	MT	2.60%
Ceramic and Soil	C&S	2.70%
Grass/Wood	G/W	6.70%

3.3.4.7 Other Characteristics

Other waste characteristics include e.g. density, apparent specific gravity and moisture content. The density of wastes varies depending on its composition. The density of residential area wastes is normally higher where organic matter makes up a large proportion of the waste, and lower in commercial districts where waste contains more paper and cardboard. It also varies with the economic level, being less dense in high income areas where there is a higher percentage of packaging waste. The highest value of moisture content was the waste from the high income groups in residential areas as shown on Table 3-9.

Table 3-9: Moisture Content Analysis of each generation source

Waste Source Generators	Moisture Content
High Income	79.27
Middle Income	73.41
Low-Middle Income	73.37
Low Income	67.80
Slum	59.36

3.3.5 Solid Wastes Collection System

The collection and transportation of municipal solid waste are carried out by four organizations, namely:

- CCN
- Contractors subcontracted by CCN
- Private Service Providers
- CBOs

The Collection and Street Cleansing Section within CCN, headed by the Chief Environmental Officer, is in charge of the management of collection and transportation of municipal solid waste in the city. There are 9 division officers in each Division who head their staff including loaders, road sweepers and drivers.

The functions of the collection and street cleansing section are as follows:

- Waste collection and transportation;
- Street cleansing;
- Roadside and estates drain cleaning (partially);
- Dead animal collection;
- Refuse disposal;
- Grass cutting along roadsides; and
- Destruction of condemned foods and other goods, with the issuance of destruction certificates.

The station type of collection is common and door-to-door collection is very rare. One operation team is composed of 1 supervisor, 3 loading crew and 1 driver. There are 5 collection points currently designated by CCN.

The CCN has not collected waste charges from households since 2002 when the water supply and sewerage works were privatized, but it has been collecting waste charges from business establishments since 2008. The CCN's system is set by unit rate per ton of waste by the category of business establishment, ranging from 100 K.Shs/ton to 5,000 K.Shs/ton. CCN collects waste charges from business establishments based on this unit rate. The collection and transportation subcontractors of CCN are paid on the basis of unit rate per ton of waste (JICA, 2010).

There are 21 contractors engaging in the collection and transportation of waste in the areas designated by CCN under the station collection system. According to the Environmental Management and Coordination Act (EMCA) Waste Management regulations of 2006, no person shall be granted a license to transport garbage without any permission from NEMA. Private companies pay business permit fees to the CCN and permit fees for waste transportation to the National Environment Management Agency (NEMA). They execute contracts with the households and private corporations for the collection and transportation of waste and collect service fees. The average waste charges to households is 1,000 K.Shs/month for business establishments, 200 K.Shs/month for low income areas, 400 K.Shs/month for middle income areas and 600 K.Shs/month for high income areas. Judging from their financial statements, their financial situation is mostly profitable (JICA, 2010).

Most of the collection work is done by the station type of collection. An operation team is composed of 1 CCN supervisor, 5 crew members and 1 driver in most cases. Contractor's vehicles showed the highest efficiency of collected amount of waste compared to the other types of CCN and private collectors, i.e., 120% to 225% of the average collected waste amount per trip. This higher efficiency of contractor's vehicles seems to be caused by several reasons such as 1) their collection area is not time-consuming, or 2) the vehicles used are of large capacity, or 3) their vehicles are equipped with a tipping function.

There were 44 registered and 26 non-registered Private Service Providers (PSPs") as of 2009. The PSPs require a business license from NEMA for the transportation of waste and they have to be registered with CCN as subcontractors of CCN. The operation of the non-registered private collectors is therefore, technically, illegal. However, they can do the business of collection and transportation of wastes due to the lack of enforcement capacity of CCN. The PSPs operate through the door-to-door collection system in areas they have contracted for the collection and transportation of waste generated by customers in middle to high income residential or commercial areas. Their collection points range from 1 to 36. Private collectors showed the most inefficient operation of collection and transportation, especially in unloading work. This seems to be due to the fact that they are still using very old vehicles without a tipping function. There are no remarkable differences on trip number among the three types of collectors. However, CCN vehicles show a comparatively higher trip number compared to the contractors and transporters.

The CBOs collect wastes and transport them to the designated stations. They also collect waste charges from the waste generators based on their contract. CBOs conduct their collection activities with license to collect from CCN, mainly in slum and low income areas. There are 140 CBOs in Nairobi City including the local youth groups. They conduct their collection activities occasionally with the support of NGOs, including the solicitation of funds for the purpose. The CBOs sell plastic bags to the residents of low income and slum areas (8 bags/household/month: 200 K.Shs/household/month), then collect the plastic bags containing garbage and bring them to the collection points using handcarts. The wastes at the collection points are then transported by the vehicles of CCN or the subcontractors to the Dandora Dumpsite. The residents who can afford to buy plastic bags are below 20% of the total number of residents, which is presumed to be one of the causes of illegal dumping of waste everywhere in those areas. Several unlicensed CBOs also operate in those areas and the collection frequency of CCN or its subcontractors is very low (usually, once a month). These facts are also presumed to have caused the illegal dumping activities. The CBOs financial condition is also assumed to be profitable. A survey conducted on the CBOs showed as follows:

- About 46% are registered with CCN, while 44% are not registered.
- 68% are operating in collection activity, while 28% are doing recycling and composting activities.
- 80% make contracts with households.
- The most significant problem is that collection vehicles do not go to the collection points of the CBO's activities.

The high and middle income areas are well serviced with waste collection. The lowest rate of collection is in the slum areas. Here, solid wastes are disposed by the residents along the roads, river banks and in open spaces. More than 70% of residents have not received any guidance or instruction on methods of proper waste disposal and have not participated in any public education programme on SWM. There is therefore a necessity of implementing educational programs to residents to raise awareness on proper waste management.

The daily waste collection amount in Nairobi City as of 2009 was about 609 t/day and the collection service area was about 38% of the entire city. The waste collection ratio to waste generation is roughly estimated at only 33% as of 2009, and the remaining waste is presumed to be illegally dumped or self-treated at the generation source (JICA, 2010).

3.3.6 Final Disposal at the Dandora Dumpsite

Dandora landfill, located at approximately 7.5 km northeast from the centre of Nairobi, is the only officially designated and authorized site for the final disposal and treatment of municipal solid wastes, within the study area. The site is adjoined by residential houses on the east and west and a school to the south. The Nairobi River flows past the north side. It was established as an engineered landfill site in 1981 (JICA, 2010). From the JICA study, there is no official registry on the number of waste pickers who dump at the Dandora Dumpsite although this number is estimated from 1,200 to 1,500. However, some CCN officials had estimated that the number of waste pickers is 600 and that half of them would like to continue scavenging at the site and would protest if the site is closed (JICA, 2010).

Engineered operations have fluctuated over the years. It currently operates as a dumpsite, not fenced and with several entrances controlled by scavenger gangs who collect the tipping charges. Gun fights among the gangs over control of tipping routes are commonplace. Fresh garbage is dumped at the entrances from which scavengers sort out items with re-sale value such as glass, plastics and scrap metals. Wastes are dumped in unsorted comingled state that makes the site appear as a dump mountain shown on Plates 3-1 and 3-2.

Plate 3-1: Dump Mountain at the Dandora dumpsite (Source: This Study)

Plate 3-2: Status of one of the Dandora dumpsite (Source: This Study)

The amount of waste carried into this site is weighed by the truck scales installed at the site entrance in 2006. Privately owned heavy equipment is hired to operate at the dumpsite. Earth covering is not carried out and there is hardly any appropriate landfill management being undertaken. The amount of waste so far disposed at the site is estimated to be approximately 3,500,000 tons while the landfill volume is estimated to be around 1.8 million m^3.

Dandora is an open dumping site without any landfill management conducted. Therefore, negative environmental impacts such as health risks imparted due to the littering of waste and the generation of odor and landfill gas abound among the local residents.

3.3.7 Disposal Quantities at the Dandora Dumpsite

According to the JICA study of Solid Waste Management (SWM) for Nairobi, developed in 2009; Nairobi generates 1,848 tonnes of wastes daily. Of this, only 33% is collected and of this, not all reaches the final disposal at Dandora dumpsite (JICA, 2010). According to the 1998 JICA Study, only about 27 per cent of the estimated 1,500 tonnes of solid waste then daily generated was collected (JICA, 1998). The remaining 1,095 tonnes was unaccounted for. The solid wastes collection rate has, therefore, only slightly improved over time.

Some of the waste is diverted at the source and recyclable materials are recovered at various points such as junkshops; through composting of biodegradables by residents, Community Based Organizations (CBOs) and pilot plants; recovered by the collection crew at the Material Recovery Facilities (MRF) or recovered at the final Dandora disposal site. Assumptions included to arrive at the diverted wastes were as follows (JICA, 2010):-

- Target Waste Reduction at Source is 0%.
- Target Recovery Ratio for Recyclable Materials (Paper and Plastics) by Junk Shops - 30% from the 5% Ratio in Comingled Waste.
- Target Recovery Ratio for Recyclable Materials (Glass and Metals) by Junk Shops - 50% from the 1% Ratio in Comingled Waste.
- Target Recovery Ratio for Recovery through Composting - 1% from the 64% Ratio in Comingled Waste.
- Assumed Waste Recovery Ratio by Collection Crew and at MRF(s) - 1%.
- Assumed Waste Recovery Ratio at Disposal Sites - 1%.

Using the assumptions, this translates to quantities of diverted wastes shown on Table 3-10.

Table 3-10: Diverted Wastes not reaching Final Disposal (ton/day) (JICA, 2010)

Item	Amount (t/day)
Waste Reduction Amount at Sources	0
Recovery Amount of Recyclable Materials by Junk Shops	63
Recovery through Composting of Biodegradables by Residents, CBOs and Pilot Plant	10
Recovery Amount by Collection Crew and at MRF(s)	6
Recovery Amount at Waste Disposal Site(s)	6
Total Diversion Amount	86

a. Illegal Dumpsites

There are many other illegal dump areas in Nairobi City. For the purposes of this study, it will be assumed that these receive the 67% of wastes that are not collected by the CCN.

3.3.7.1 CCN Future Plans

The 2010 Integrated Solid Waste Management Plan (ISWMP) recommended, among other things, that recycling and composting would be realistic to complements a landfill. Much waste could be disposed of this way since 65% of Nairobi's waste is bio-waste while the next largest group is plastics (Kamunyori, 2013). It further recommended decommissioning of the Dandora dumpsite and creating a sanitary landfill at Ruai in addition to two transfer stations for Nairobi. There are plans by the Nairobi County Government to partner with foreign firms in order to generate energy from the solid wastes at the Dandora dumpsite. The JICA Study proposed establishment of seven new landfill sites at Dagoretti Forest, Ruiru, Juja, Ruai, Athi River, Mavoko and Ongata Rongai as shown on Figure 3-5.

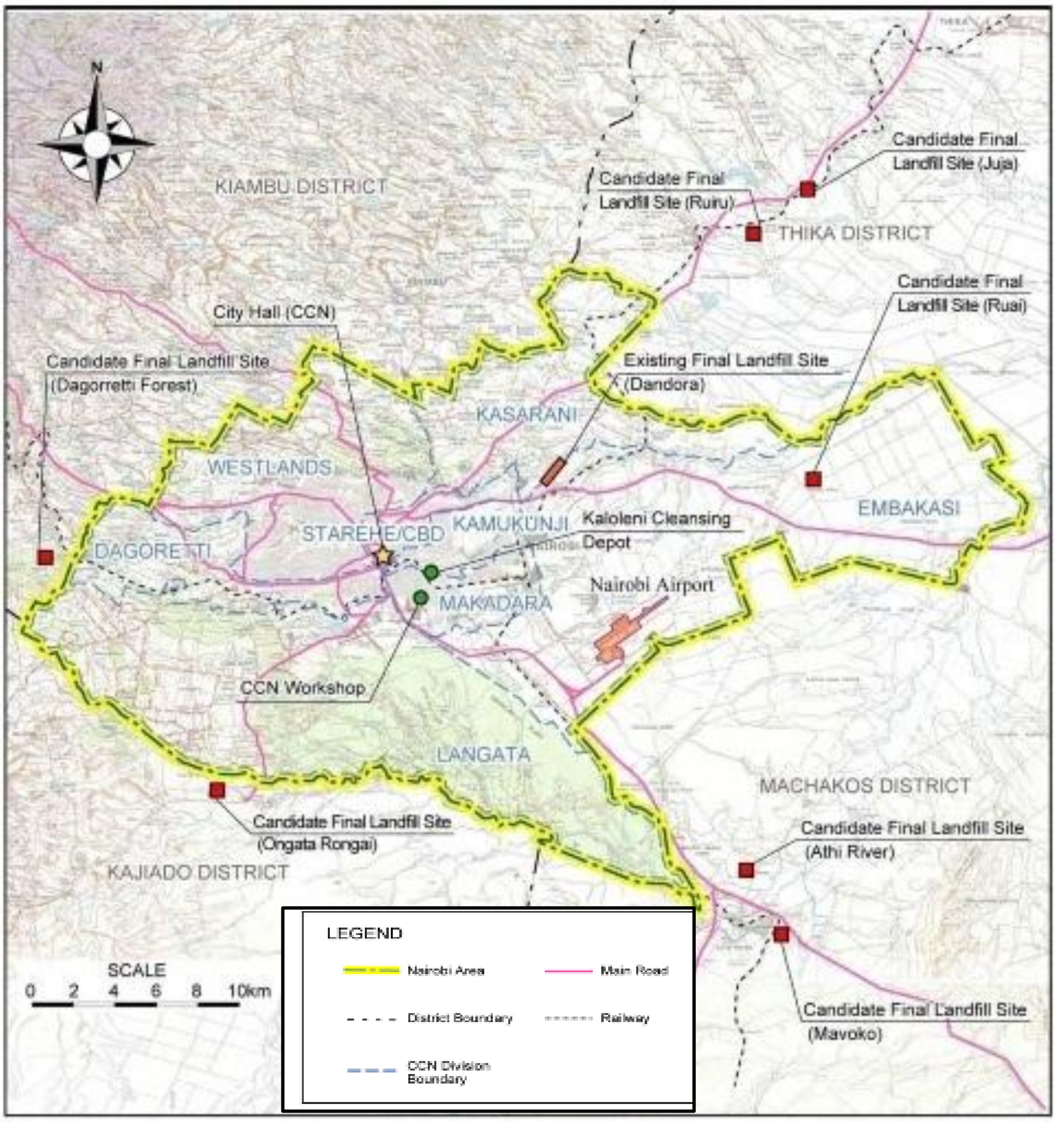

Figure 3-5: Proposed new landfill sites to replace the one at Dandora (JICA, 2010)

3.3.7.2 Private Sector Initiatives

Nairobi already has a vibrant recycling economy, albeit at a small-scale level. EcoPost is a Kenyan firm that uses recycled plastic to manufacture durable and environmentally friendly fencing posts using injection moulding. It purchases tonnes of plastic wastes from the streets and dumpsites around Nairobi which is processed and transformed into fencing posts. These posts provide an alternative to timber and thus should be useful in preventing the cutting down of trees. They are good for use in areas with high termite attack on timber and for road signage. They were used on Thika Road to defeat scrap metal vandals. Each month, EcoPost uses 40 tonnes of waste plastics. This enterprise, in addition to reducing plastic wastes, employs hundreds of workers. The firm hopes to expand production to support beams and roofing trusses for the construction industry in addition to furniture (UNIDO, 2013).

A relatively new private sector waste management service provider, Taka Kenya, is tackling the challenge of low plastics recycling. The company found that the most evident constraint to changes in human behavior towards recycling was accessibility to recycling collection points. It has now partnered with Nakumatt, Kenya’s largest supermarket chain, and will install recycling containers in 21 of Nakumatt branches in Nairobi and a few more outside Nairobi. In this case, it is expected that merging recycling with shopping trips will alter waste management habits (Kamunyori, 2013).

3.3.8 Projection of Future Waste Generation Amount

The population projection since 2009 when the JICA study was first conducted shows the growth rate of approximately 3% per annum from 2008 to 2030, and the future solid waste generation by the year 2030 estimated based on the field survey results and following considerations of population growth, area, income group and gross domestic product, the total amount of waste generated in Nairobi City is forecasted at 3,990 tons/day for year 2030, as shown in Table 3-11 (JICA, 2010).

Table 3-11: Projection of waste amount generated in Nairobi in 2030 (ton/day)

Zone	2009	2015	2020	2025	2030
Residential	1,318	1,747	2,025	2,419	2,860
Commercial	439	538	675	806	953
Road	(60)	60	60	60	60
Market	90	111	131	152	176
Total	1,848	2,352	2,831	3,378	3,990

By extrapolation, the projected Total Waste Amount Generated in Nairobi City (ton/day) in intermediate years is shown in Table 3-12.

Table 3-12: Projected waste generated in intermediate years (ton/day) (JICA, 2010)

Zone	2009	2010	2011	2013	2014	2015
Residential	1,318	1,390	1,462	1,534	1,606	1,677
Commercial	439	463	487	511	535	559
Road	(60)	60	60	60	60	60
Market	90	95	100	105	110	115
Total	1,848	1,949	2,050	2,150	2,251	2,352

Using 2009 as the base year and assuming the waste composition is unchanged, the total plastic waste composition is 9.42%. Therefore Total Plastics Waste Amount Generated in Nairobi City (ton/day) in intermediate years is shown in Table 3-13.

Table 3-13: Projected Plastics Waste Amount Generated in Nairobi City (ton/day)

Zone	2009	2010	2011	2013	2014	2015
Residential (includes roads)	124	131	138	144	151	158
Commercial (includes roads)	41	44	46	48	50	53
Market	8	9	9	10	10	11
Total	174	183	193	202	212	221

Breaking this data down to respective plastics wastes groups, plastic wastes generation in Nairobi City (ton/day) are shown in Table 3-14:-

Table 3-14: Projected Plastic Wastes Generation in Nairobi City (ton/day)

	2009	2010	2011	2013	2014	2015
Plastic Sheet	65	69	73	76	80	83
Recyclable Plastics	61	65	68	71	75	78
PET Bottles	34	36	38	40	42	44
Other Plastics	13	14	14	15	16	16
Total	174	183	193	202	212	221

3.3.9 Difficulties Experienced in Solid Waste Management within CCN

The Department of Environment is experiencing difficulties in the efficient provision of SWM services. This is owing to constraints of organizational, institutional or human resources development nature such as; over-staffing. Under the current vertical structure exists overlapping and duplication of staff responsibilities; poor intra-departmental and inter-departmental coordination and communication; individual mandates and job descriptions are unclear; managers are unaccountable with slow decision-making processes and insufficient monitoring of individual work performance together with lack of standardized and planned working procedures. The mandate to waste generators, collectors and transporters is clearly stipulated in the law or by-law, including the mandate to administrators concerning inspection or monitoring of practices on waste generation and discharge of waste generators. However, the inspection and monitoring capacity seems to be weak.

Waste transportation within Department of Environment is a challenge. The collection and transportation practices of the CCN and its contracted actors are plagued with inefficiency of their collection vehicles. In addition, waste pickers disturb the unloading operation of transporters at the Dandora open dump site since these vehicles lack the tipping function. Illegal dumping sites are scattered in many areas all around the city. Various reasons are presumed, such as the absence of garbage skips, low collection frequency, or the residents' inability to pay collection fees to the Community-Based Organizations (CBOs). (JICA, 2010)

3.4 SYSTEM BOUNDARIES FOR THE STUDY

The problem of solid waste management in the City has been highlighted in Section **Error! Reference source not found.**. Specific challenges posed by plastic wastes within the municipal wastes are discussed in Section 2.2. In addition, notable initiatives undertaken to bring down the levels of the plastics menace have been chronicled in Section2.4 in which case, among these initiatives so far undertaken, MFA has not been attempted. It is for this reason that Nairobi City was chosen for the case study. It is desirable to investigate and know the city's urban metabolism as a whole if sustainable solutions for future development are to be found. However, time and resources allow investigating and finding only the plastics metabolism.

3.4.1 The Zoning

The Map of Nairobi delineating the study areas was zoned into five regions bounded by the major roads traversing the city as shown in Figure 3-1. These zones are as follows:-

- Zone A :- All the area within the Nairobi City bounded by Waiyaki Way and Thika Road intersecting at Museum Hill Interchange. This is predominantly an up-market area, mainly characterised by residential and service sectors.

- Zone B: - All the area within the Nairobi City to the West and South of Waiyaki Way and Mombasa Road. This too is largely an up-market area characterised mainly by residential and commercial sectors.
- Zone C: - All the area within the Nairobi City bounded by Mombasa Road and Jogoo Road intersecting at the Bunyala Road Roundabout via Factory Lane. This is predominantly the industrial manufacturing zone of the study area.
- Zone D: - All the area within the Nairobi City bounded by Thika Road and Jogoo Road as connected by Limuru Road, Ring Road Ngara through Pumwani and Landhies Road. This is as well rapidly emerging as an industrial manufacturing zone. It also has residential and commercial sectors.
- Zone E: - All the area within the Nairobi City bounded by the circle starting at Museum Hill Interchange, then along Thika Road connecting to Limuru Road, Ring Road Ngara through Pumwani to where Landhies Road joins Factory street, Bunyala Road and back through Mombasa Road to Museum Hill Interchange. This is the area covering the Nairobi Central Business District (CBD)

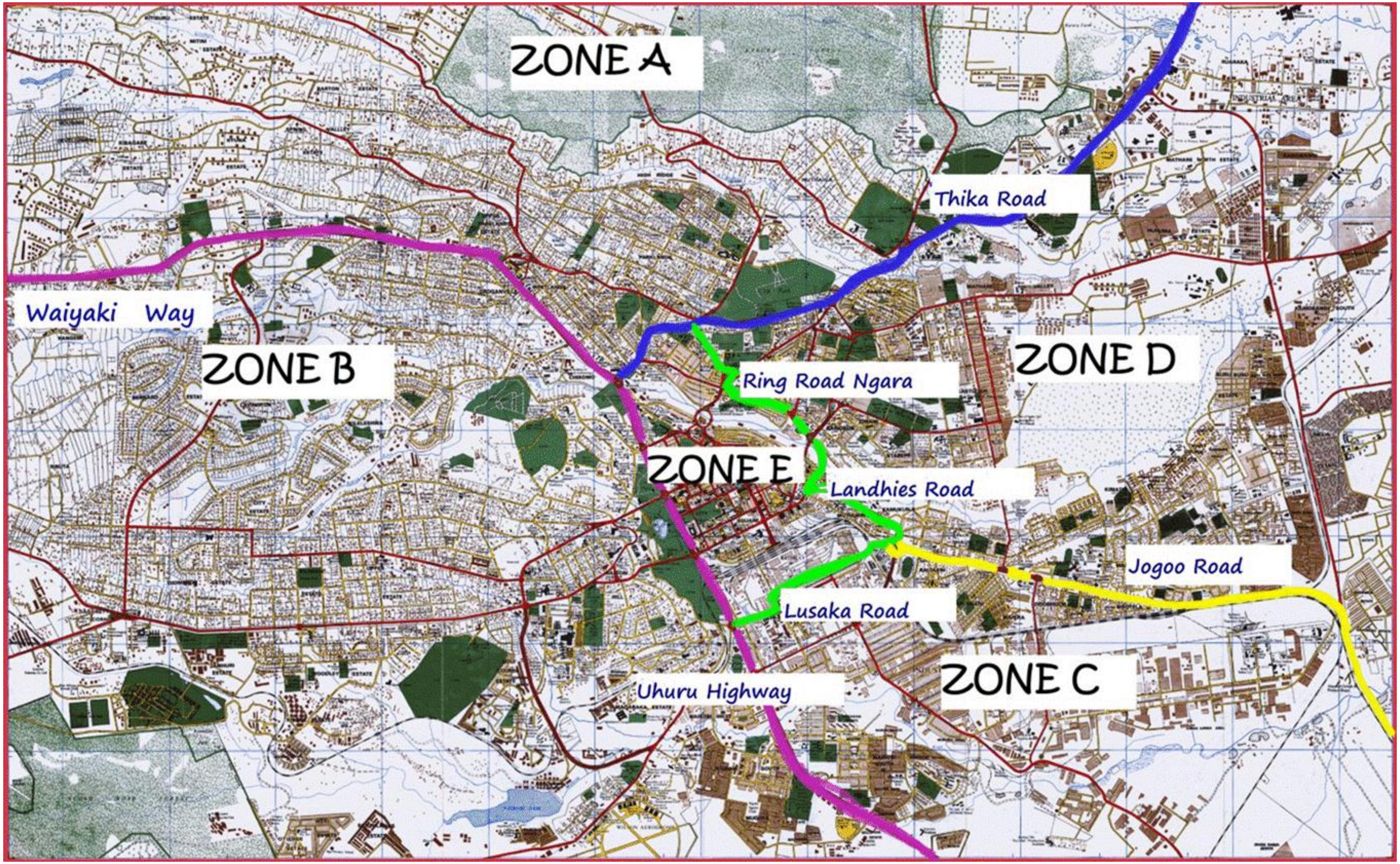

Figure 3-6: Map showing the Delineation of Zones within the Study Boundary (Geodev (K) Ltd., 2006)

3.5 DATA COLLECTION

3.5.1 Administration of Questionnaires

Four groups handling plastic products were identified. These were:-

- Manufacturers,
- Retailers,
- Recyclers and
- Plastic waste handlers (collection and disposal).

Four different questionnaires were developed targeting each group. The manufacturers, retailers and recyclers questionnaires were administered in the five zones of the study area. The plastic waste handler's questionnaire was administered to the City County of Nairobi's Department of Environment, who are the only waste handler, since all other waste pickers in the study area are contracted and licensed to report and submit their data to them.

The study design targeted a sample size of 25 questionnaires to be administered to the manufactures per zone (125 manufacturers), fifty (50) to the retailers per zone (250 retailers), and twenty (20) questionnaires to be administered to the recyclers per zone (100 recyclers). However, these numbers were redistributed according to the actors encountered in each zone. For example, there were no manufacturers encountered in Zone A and no retailers were encountered in Zone E. Since the data collection was by random sampling, the administration of questionnaires was adjusted accordingly whereby more of the retailers encountered in Zone A were interviewed.

a. Plastics Manufacturers' Questionnaire

The questionnaire for plastics manufacturers aimed at collecting data on sources of plastic materials in Nairobi either through direct importation or manufacture. It comprised of four (4) sections as follows:

- Section A: - information on organization's data such as name, location, age, contacts, names and designations of respondents.
- Section B: - containing quantity data on plastic production details such as weekly sales, resin types used and products made.
- Section C: - Containing quantitative data on plastic products destination details.

- Section D: - Containing qualitative data on manufacturer's opinion concerning plastic production industry challenges and suggestions for recommendations on policy directions as well as the prospects for future growth of their plastic manufacturing.

The survey tool used is in Appendix 1. In all, the response rate was 91 questionnaires out of a possible 125 manufacturers in accordance to the 7 resin categories. Upon compilation of the data by manufacturer's names, there were thirty (30) identified. The reason for this was that there were many instances in which one manufacturer produced several if not the whole wide spectrum of the seven (7) plastic resin products discussed in Section 2.5.2. The list of manufacturing industries sampled is given in Appendix 2.

b. Plastics Retailers' Questionnaire

This aimed at collecting data on pathways of plastic materials in Nairobi, this pathway being the next most likely destination after manufacture. It comprised four (4) sections namely:

- Section A: - containing organization's data such as name, location, contacts, names and designations of respondents.
- Section B: - containing quantity data on plastic products procurement details.
- Section C: - Containing quantitative data on plastic products destination details.
- Section D: - Containing qualitative data on plastic products retailer's opinion concerning challenges to the industry, recommendations on policy directions and prospects for future growth.

322 retailers were sampled against an initial target of 250 retailers. Upon data compilation by retailer names, there were eighty nine (89) retailers in total, interviewed using the survey tool in Appendix 3. The number of manufacturers is nearly a third of the retailers. Like with the manufacturers, the study established that in all instances, an individual retailer handles a few if not the whole spectrum of seven plastic resins in common use. The list of surveyed retailers is in Appendix 4.

c. Plastics Recyclers' Questionnaire

This aimed at collecting data on intermediate sinks of plastic materials in the study boundaries. It comprised four (4) sections. These are:

- Section A: - containing organization's data such as name, location, contacts, names and designations of respondents.

- Section B: - containing quantitative data on plastic products recycling details.
- Section C: - Containing quantitative data on recycled plastic products destination details.
- Section D: - Containing qualitative data on plastic products recycler's opinion concerning challenges to the industry, recommendations on policy directions and prospects for future growth.

In total, the response rate for recyclers was 90 interviews against a target of 100. Upon compilation of data by recycler names, there were found to be fifty five (55) recyclers interviewed using the survey tool in Appendix 5. This is nearly two-thirds of the retailers. Just like with the manufacturers and retailers, there were numerous instances in which an individual recycler handles several of the seven plastic resins in common application discussed in Section 2.5.2. The list of recyclers who were surveyed is in Appendix 6.

d. Plastic Waste Handler's Questionnaire

This aimed at collecting data on final sinks of plastic materials in Nairobi. This was a single questionnaire due to the fact that only the City Council of Nairobi is charged with waste collection. All other actors operate under CCN's licensing. It comprised four (4) sections namely:

- Section A: - containing organization's data such as name, location, contacts, names and designations of respondents.
- Section B: - containing quantitative data on plastic waste production details.
- Section C: - Containing quantitative data on waste plastic products destination details.
- Section D: - Containing qualitative data on plastic products recycler's opinion concerning challenges to the industry, recommendations on policy directions and prospects for future growth.

The sample questionnaire prepared to collect data from the waste handlers i.e. the City County of Nairobi was used for discussion purposes with the Department of Environment officers. From these discussions, it became clear that the data records with most comprehensive and recent data was contained from the results of a study carried out by Japan International Cooperation Agency (JICA) in 2010 titled, "Preparatory Survey for Integrated Solid Waste Management in Nairobi City in the Republic of Kenya"

3.5.2 Key Informant Interviews (KII)

Other questionnaires developed were targeted at key informants in relevant institutions. These are the institutions that were identified as mandated with policy and/or standards development, inspection and enforcement of compliance and in regard to production, recycling, transport or disposal of plastic products and who are also stakeholders in environmental protection. These are the National Environmental Management Authority (NEMA), the Kenya Bureau of Standards (KEBS), The Kenya National Cleaner Productions Centre (KNCPC) and the Kenya Association of Manufacturers (KAM).

3.6 DATA ANALYSIS

Data analysis was conducted through:-

- Quantitative methods for processes and flows data. This covered production, consumption, and accumulation and disposal data. Software was employed to do this as described in Section 3.6.1.
- Qualitative methods were employed for data deemed valuable at informing and motivating policy directions. This is described in Section 3.6.2.

3.6.1 Quantitative Data Analysis

a. Calculation Methods

The following steps were adopted in calculating the weights of plastic materials:-

- Establish a model linking sources, pathways, and sinks for plastic materials
- Present complete and consistent set of information about all flows and stocks of plastic materials within City County of Nairobi
- Carry out simple material balance comparing all inputs, stocks, and outputs of plastic waste streams
- Balance inputs and outputs, the flows of wastes and environmental loadings, and identify their sources

3.6.1.1 Microsoft excel

A large volume of data was collected from the questionnaires. To ease the sheer complexity of handling, the data was entered in MS-Excel spreadsheets and computations carried out for basic operations and collation of the primary data. Some data from the Key Informant Interviews was also computed in this way.

3.6.1.2 STAN (subSTance flow Analysis) Software

Having lumped data sets in MS-Excel, it was then easier to further process the data, where applicable, in specialized software, STAN (short for subSTance flow ANalysis). This is a free software that helps to perform Material Flow Analysis according to the Austrian standard ÖNorm S 2096 (Material flow analysis - Application in waste management) where MFA has been widely researched and found broad application (Vienna T. U., 2012). The software was freely downloaded from the internet. Data was imported or exported into STAN using MS-Excel as an interface. The graphical pictures of the STAN models were similarly exported to Microsoft applications.

Basic assumptions were made in order to localize the STAN model to available data. The following are the localized descriptions and assumptions used in the STAN Models developed for this case study:

3.6.1.2.1 Analysis Assumptions

These include the following:-

- All plastics products manufactured within or directly imported into the study boundaries do not re-enter back; neither for retail nor as a waste stream. It can only re-enter through recycling in which case, sources considered comprise of a sum of manufactured and recycled plastics products.
- Some of the plastic products which end up in the waste stream may not be manufactured, recycled or retailed in Nairobi. It may be directly imported by users from outside the study boundaries. *This may explain why the waste streams are higher than retailed products.*
- Some plastic products consumed within the study boundaries may leave before disposal through other export avenues and may not be accounted for in the final balance.

3.6.1.2.2 Input - Sources

The input was considered as the sources of the plastic materials. Manufacturers and retailers are the sources and represent the rate of accumulation. This accumulation is quantified.

3.6.1.2.3 Reactor - pathways

The reactor was considered as the pathways that the plastic materials take once they entered the study boundaries. The first reactor is the retailers who represent the accumulation, the transformation, the processes and pathways for the plastics products. The recyclers who source plastic wastes and release plastic products into the study boundaries are also considered as reactors.

3.6.1.2.4 Output - sinks

The outputs were considered as the sinks through which plastic products exit the study boundary. The sinks encountered include retailers, recyclers and collectors who represent the rate of removal of plastic products out of the study boundaries.

3.6.1.2.5 Material Flows

Plastic products material flows were assumed to be linear within and across the study boundary.

After building the graphical model with STAN pre-defined components (processes, flows, system boundary, text fields) known data (mass flows and stocks, volume flows and stocks, concentrations, transfer coefficients) was entered or imported for different layers (various plastic resins) as well as the periods for calculating the unknown quantities. All flows were displayed in Sankey style, i.e. the width of a flow is proportional to its value (Vienna T. U., 2012). In the MFA diagram, every flow and stock should have a value.

The STAN analyzed data presentation is shown in Figure 4-27 along with the Material Flow Analysis Models developed and presented in Chapter 4.

3.6.2 Qualitative Data Analysis

Qualitative data was obtained from the last section of the questionnaires administered on manufacturers, retailers and recyclers as well as all the data obtained from Key Informant Interviews. This data was collated with field data as well as relevant data obtained in literature for meaning. The analysis and inferences are detailed in Chapter 4.

4 RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

The following processes and actors, shown in Figure 4-1 were examined:-

- Plastics manufacturers/Importers
- Plastics retailers
- Plastic Waste Generators/ Consumers of retailed plastics
- Plastics recyclers/re-users
- Plastics waste management organizations
- Other key players in the plastic sector namely; NEMA, KEBS, KNCPC and KAM

Figure 4-1: Groups Evaluated in the Mass Balance Study

Field data was obtained from the following groups:

- Plastics manufacturers
- Plastics retailers
- Plastics recyclers
- Other players i.e. NEMA

Desk data was obtained from the following groups:-

- Plastic waste generators

- Plastics Waste disposal handlers
- Other players i.e. KEBS, KNCPC and KAM

The results from both field and desk data is as presented in the following sections. The findings of field data collection obtained from manufacturers, retailers and recyclers is shown in Figure 4 2.

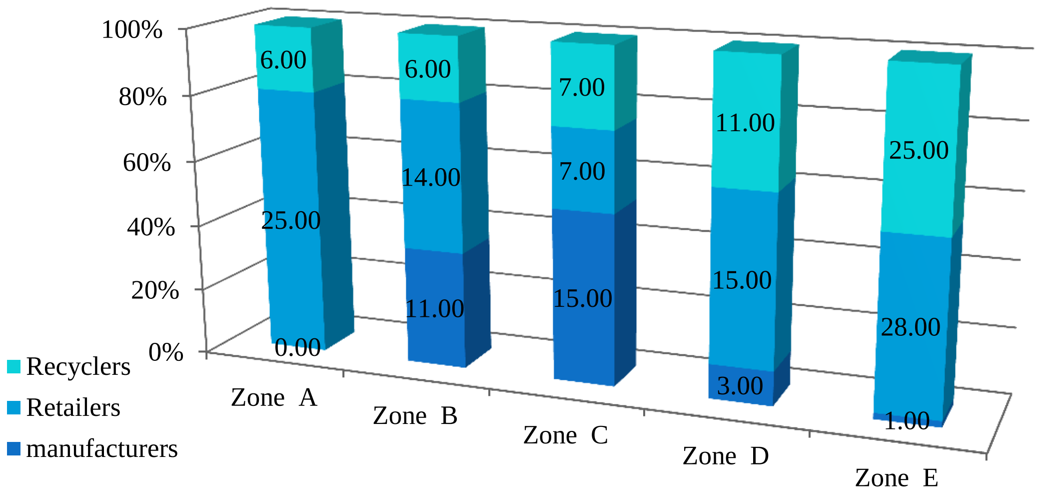

Figure 4-2: Findings of field data collection – manufacturers, retailers and recyclers

4.2 FINDINGS ON MANUFACTURERS OF PLASTIC PRODUCTS

4.2.1 Plastic Products Manufacturing Organizations'

A total of 30 plastic manufacturers were sampled in the city. Of those sampled, Zone A which is predominantly an up-market area bounded by Waiyaki Way and Thika Road intersecting at Museum Hill Interchange had none. Zone B, predominantly characterized by residential and commercial sectors to the West and South of Waiyaki Way and Mombasa Road had 11, Zone C had 15, and this is predominantly the industrial manufacturing area bounded by Mombasa Road and Jogoo Road intersecting at the Bunyala Road Roundabout via Factory Lane. Zone D, all the area within the Nairobi City bounded by Thika Road and Jogoo Road as connected by Limuru Road, Ring Road Ngara through Pumwani and Landhies Road had only 3 manufacturers. Zone E, the Central Business District (CBD) had 1 manufacturer as shown in Table 4-1 and Figure 4-3.

Table 4-1: Distribution of Manufacturers by Zones

Zone A	Zone B	Zone C	Zone D	Zone E	Total
0	11	15	3	1	30

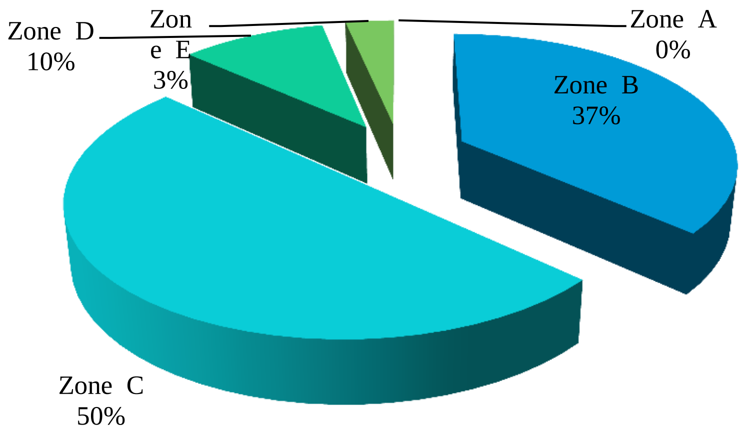

Figure 4-3: Distribution of Plastic Products Manufacturers by zones

Zone C, which is typically the industrial zone had highest number of manufacturers. The age range for the plastic manufacturing/ importing organizations varies from 7 to 44 years with the average and mode age being 21 and 11 years respectively. This implies that the industries are relatively well established, employing an appreciable workforce.

4.2.2 Plastic Products commonly produced through Manufacture

Of the 30 plastic manufacturers sampled, the highest number produced Polypropylene followed by HDPE and LDPE plastic resin types in that order as shown in Table 4-2 and Figure 4-4. There is no plastic resin that is produced by all 30 manufacturers.

Table 4-2: Distribution of Plastic Resins Manufacturers/Importers

HDPE	PET	LDPE	PP	PS	PVC	Others
20	9	18	21	5	10	11

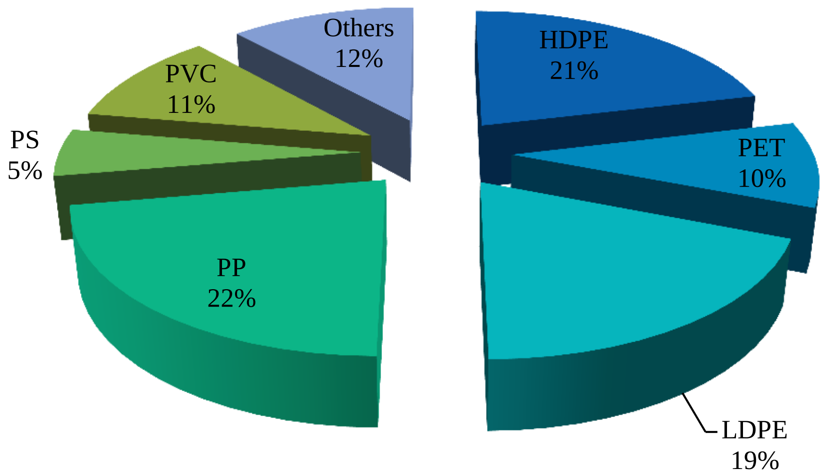

Figure 4-4: Distribution of Plastic Manufacturers by Resin Types

This data does not add up to 30 since some of the manufacturers produce more than one resin. The category of others comprises of ABS, PMMA, SAN, PE, PPR and Polyurethane. The sources of raw materials for manufacture of the plastics by mass are as shown in Table 4-3 and Figure 4-5:

Table 4-3: Sources of Raw Material for Manufacture by Mass (kg)

Outside Kenya	Nairobi	Mombasa, Nakuru, Kisumu, Thika or Eldoret	Other towns in Kenya	Total
2,026,285.97	299,276.79	14,376.51	97,479.73	2,437,419

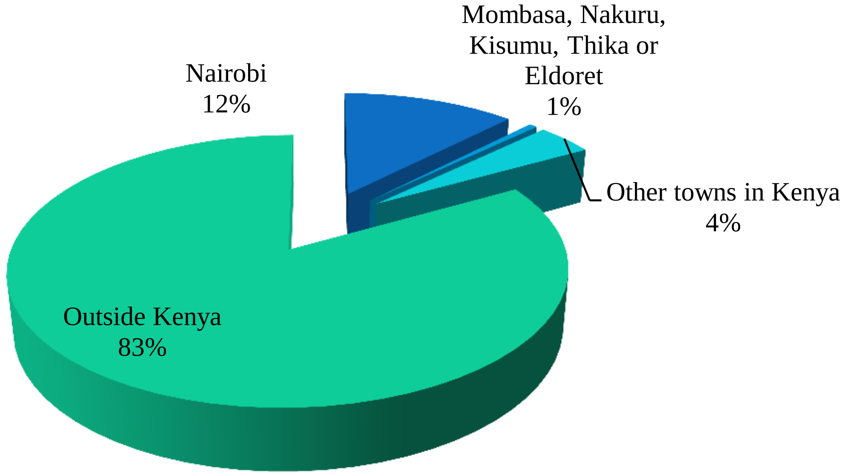

Figure 4-5: Sources of Raw Material for Manufacture by mass (kg)

Clearly, 83% of the raw materials were imported from outside the country. The balance of the 17% will appear to be redistribution within Nairobi or from outside Nairobi but within the boundaries of Kenya. The Average weekly production by resin type is as shown in Table 4-4 and Figure 4-6:-

Table 4-4: Average weekly production/importation by resin type (kg)

HDPE	PET	LDPE	PP	PS	PVC	Others	Total
500,300	366,000	455,750	585,500	32,000	392,625	104,000	2,436,175

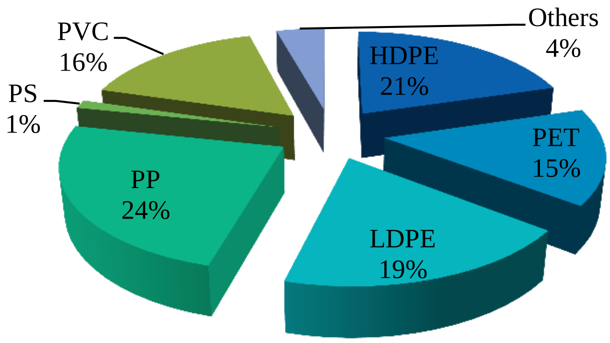

Figure 4-6: Average weekly production/importation by resin type

Polypropylene is the most abundantly produced resin at 24% (585,500.00 kg/week) followed by HDPE and LDPE. There is 1,244.00 kg/week loss of plastic resin from importation through manufacturing. A comparison of Figure 4-3 and 4-5, shows a pattern in which the PP manufacturing industries lead both in number and in production quantities by mass followed by HDPE and LDPE. The various plastic resins put to application are generally categorized as follows:-

- Packaging material,
- Carrier bags,
- Other finished consumer products,
- Raw materials for other products and
- Other uses

The category of other finished consumer products includes items such as combs, plates, cups, chairs, stools and tables, jerry cans, jugs, plastic furniture and cutlery in general, folders, pens, tanks and toys among others. These quantities produced by resin type and application category are as shown in Table 4-5 and Figure 4-7.

Table 4-5: Uses to which the plastic resins are put by Product and Resin Type (kg)

	HDPE	PET	LDPE	PP	PS	PVC	Others	Total
Packaging Material	229,920	125,500	76,450	96,800	0	0	50,000	578,670
Carrier Bags	30,000	0	28,500	20,000	0	0	0	78,500
Finished Consumer Products	209,540	190,500	260,800	438,200	32,000	337,000	54,000	1,522,040
Raw Materials	30,840	50,000	40,000	30,500	0	40,000	0	191,340
Others	0	0	50,000	0	0	15,625	0	65,625
Total	500,300	366,000	455,750	585,500	32,000	392,625	104,000	2,436,175

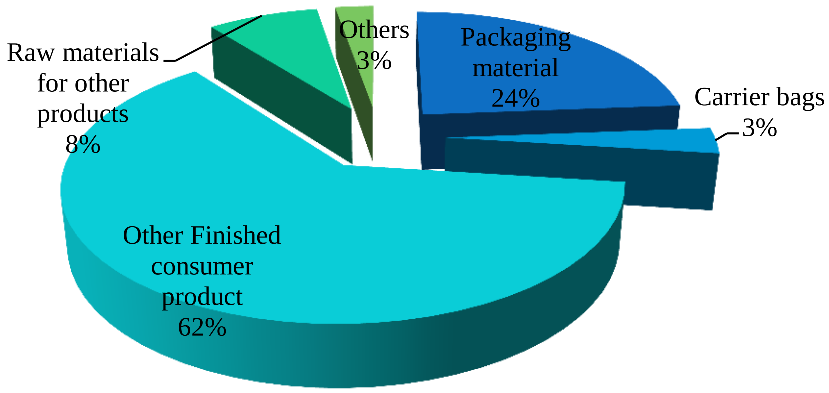

Figure 4-7: Uses to which the plastic resins are put by product type (kg)

In total, 2,436, 175.00 kilograms of plastic products are produced per week. The category of "other finished consumer products" had the highest production at 62%. 92 % of the plastic resins is used for manufacture of finished goods. Only 8% of the plastic resins is used as raw materials for other industries. Contrary to popularly held notion, the carrier bags manufacture is only 3% of overall plastic production.

4.2.3 Destinations for Manufactured Plastic Products

The average duration taken for procured raw materials to exit the manufacturing process (residence time) as products is 4 weeks. This hold up time for manufactured products is generally short. This implies a high uptake of the manufactured commodities in the market. The target destination markets for manufactured plastic products were identified in four categories namely; (i) Nairobi, (ii) Other major towns such as Mombasa, Nakuru and Kisumu, (iii) other towns in Kenya and (iv) exports outside the country. These are shown in Table 4-6 and Figure 4-8.

Table 4-6: Target Destination Markets for Manufactured Plastic Products (kg)

Nairobi	Mombasa, Nakuru, Kisumu, Thika or Eldoret	Other towns in Kenya	Outside Kenya	Totals
1,027,525	543,040	536,890	316,565	2,424,020

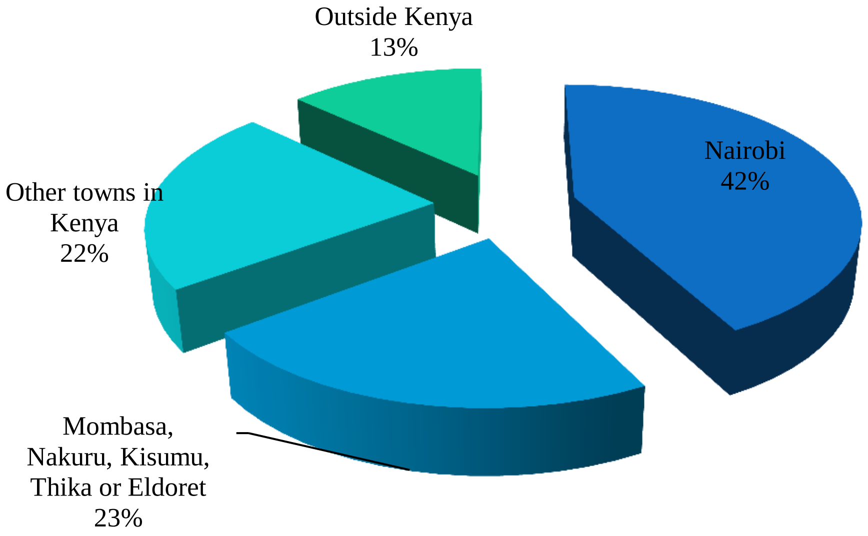

Figure 4-8: Target Destination Markets for Manufactured Plastic Products

Nairobi is the largest consumer of the plastic products from the data consuming 42% of the total (1,027,525 kg/week). The rest of the country consumes 45% of manufactured plastic products while 13 % is exported outside the country. The total weekly production is 2,436,175 kg/week. The products that reach the market is 2,424,020 kg/week. The difference of 12,155 kg/week may be explained as manufactured losses through breakage, rejection by the standards supervisors, storage or misplacement. It is assumed that these losses are maintained within Nairobi.

As shown in Figure 4-9, 53% of the manufacturers indicated that they recycle some of their products. The rest do not engage in recycling. These manufacturers recycled content comprises mainly of the product rejects. The recycling extent varies from industry to industry and with resin type in question, but generally ranged between 2-20% of the manufactured quantities.

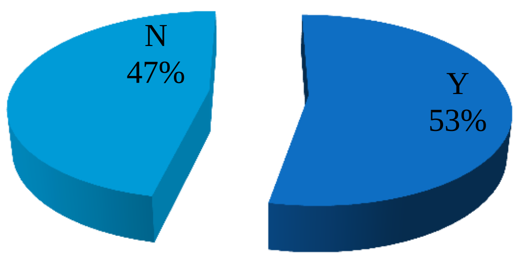

Figure 4-9: Number of Manufacturers who recycle own products

4.2.4 Challenges and Opinions of Plastic Manufacturers that can inform policy directions

The following are the main challenges faced by plastic products manufacturers in relation to the wastes generated by their industries:-

- Power – The manufacturers cited power related challenges as high cost of power for manufacturing, high cost of power for re-grinding in order to recycle that is even higher than manufacturing from raw resins and rampant power outages which disrupt the processing at odd points.
- Wastes and recycling – The main challenges are that the plastic wastes are bulky and expensive to transport or store which makes the high percentage of manufacturing rejects and wastes expensive to manage. The recycling effort is also hampered by failure of local authorities to collect solid wastes and sort into respective plastics streams which would enable easy recycling; the recycling plants are few in number and unreliable in capacity to carry out recycling. In addition, the target industries for manufactured plastic materials especially the food processing do not use recycled products,
- Labour – The costs for manufacturing and recycling labour are high coupled with shortage of appropriate skills among the labour force.
- High Cost of raw materials - - The raw materials for manufacturing are imported and are therefore expensive due to duty fees and high transport cost. There are also challenges of scarcity of the raw materials, fluctuating market rates depending on the currency used such as the USD which affects sourcing and escalation in cost of importation.
- Equipment – manufacturing and recycling equipment is expensive. There is a shortage of equipment maintenance expertise.

The following are the policy developments recommended by manufacturers of plastic products in relation to production and management of the types of plastics:-

- Electric power – the government should consider to offer subsidy on power tariff for both production and recycling,
- Wastes and recycling –The manufacturers recommended the need for a government policy that enables linkages that allow manufacturers to form partnerships with recycling companies who could recycle their products. They also recommended the

need for a policy that supports more recycling initiatives and eliminates the rampant harassment and interference by regular police and CCN law enforcers of recycling facilities.

- Labour – manufacturers identified the training gap in the labour market and recommended for policy directions that would address this
- High cost of raw materials – The manufactures recommended that the dollar be stabilised and that the plastics be zero rated on VAT.
- Existing policies – They also recommended that passing the policies would not be enough without their implementation and that many good existing policies are not implemented. Also that the government policy makers need to carry out public consultations with manufacturers prior to policy changes and implementations.

On the future prospects of plastics manufacturing, twenty seven (27) manufacturers out of thirty (87%), projected growth in the sector as shown on Figure 4-9.

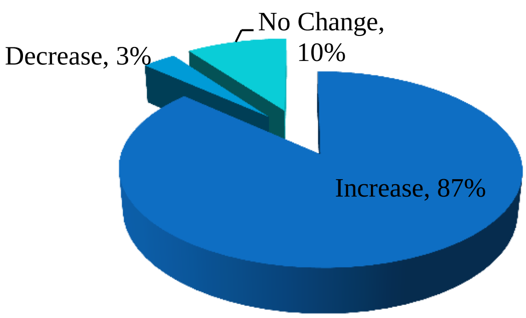

Figure 4-10: Prospects of future growth in Plastics Manufacturing

This implies that the challenges currently experienced in management of plastics, if not addressed, will be present even in the future.

4.3 Findings on Retailers of Plastic Products

4.3.1 Plastic Products Retail Organizations'

A total of 89 retailers were sampled in the city. This is three times higher the number of manufactures. Most of the retail outlets sampled were supermarkets, hardware shops and general merchants. HDPE is the product most retailed, with every one of the retailers stocking it as shown on Figure 4-11. All retailers use carrier bags and hence they stocking it. The other HDPE products are low weight and have unspecialized use to the general public such as water tanks, plastic water pipes, mats files and folders and general packaging materials and hence their widespread retail. In contrast, despite PP being the most highly manufactured resin, it is not as widely retailed as PP products. A possible explanation for this is that PP products are widely used as containers for other processed products and therefore are more widely used in other processing industries such as cooking oil and cosmetics.

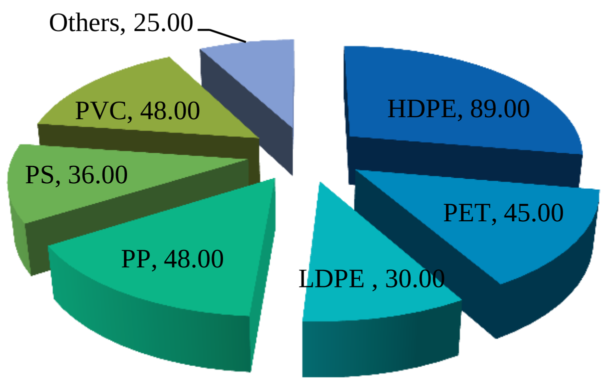

Figure 4-11: Distribution of Retailers by Resin Type

The category of "others" comprised retail of the following plastic resins; PC, PPR and PPR Pipes, TP1 and UPVC. The average age of plastic retailing organizations varies across board with outlets as old as 30 years and others in the start-up years. This implies that the trend of the plastics sector is one of continuous growth and expansion since 30 years ago.

4.3.2 Commonly Retailed Plastic Products

Sources for retailed products are as shown in Table 4-7 and Figure 4-12. To enable material accounting, the sources of retailed plastic products were assessed for; (i) Nairobi, (ii) other major towns such as Mombasa, Nakuru and Kisumu, (iii) other towns in Kenya and (iv) exports outside the country

Table 4-7: Sources for Retailed Plastic Products by mass (kg/week)

Nairobi	Mombasa, Nakuru, Kisumu, Thika or Eldoret	Other towns in Kenya	Outside Kenya	Total
162,744	525	407.	742	164,418.5

Figure 4-11 is generated from data in Table 4-7 and shows the sources of retailed plastics

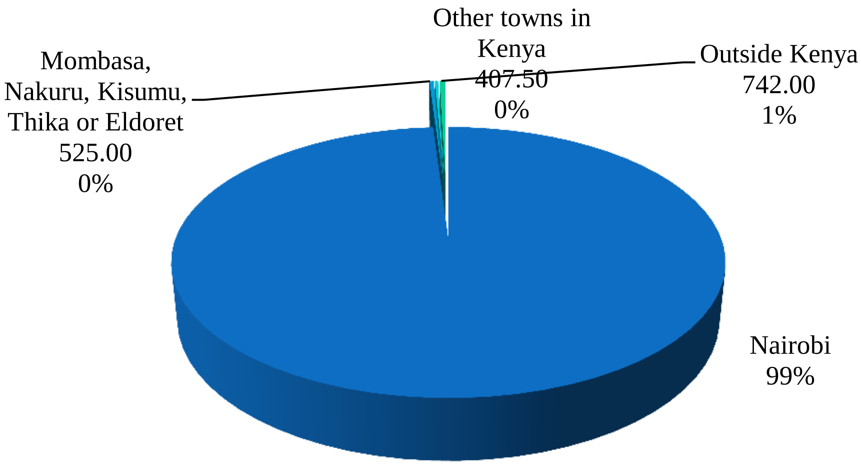

Figure 4-12: Sources of Retailed Plastics

It is clear from Figure 4-12 that almost all (99%) of the plastics retailed within Nairobi is also sourced from within. There is a wide gap between what is manufactured and sold into Nairobi (1,027,525.00 kg/week) and that which is sold by retailers in Nairobi (164,418.50 kg/week). This shows that only 16% of weekly manufactured release reaches the retail outlets. This implies that not all manufactured products sold into Nairobi from the manufacturers are released for retail in Nairobi.

Some possible reasons for this lack of accountability for 84 % data are that:-

- The plastic products accumulate held in stock probably by mid-level enterprises that buy from manufacturers and sell to the retailers. A reason why this possibly happens is the limited storage space that retailers have to hold bulky plastic products.
- The retail outlets do not sell their products by mass in kilograms but rather in batches without recognising the weight whereas the manufacturers keep production records by mass even when they may sell in batches.
- The retailers recognise plastic products as the direct plastic product that they sell such as jugs, chairs, combs, cutlery and buckets. They do not recognise the product holding container as a plastic product such as cooking oil, paints, drinking water, sodas and soap containers as well as composites such as mops and general packaging for almost all anything. They sell these products in other categories other than plastic. This constitutes a large unaccounted for category.
- There is another category of retailed plastic materials that are not widely explained as plastics by retailers are such as mattresses.

This explains the wide gap and also the point at which accountability for transfer, storage and accumulation is lost.

The average weekly sale of retailed plastics was as shown in Table 4-8 and Figure 4-13.

Table 4-8: Average weekly sale of Retailed Plastic Products (kg)

HDPE	PET	LDPE	PP	PS	PVC	Others	Totals
59,032	10,111	8,344	13,192	61,697	9,540	2,502.5	164,418.5

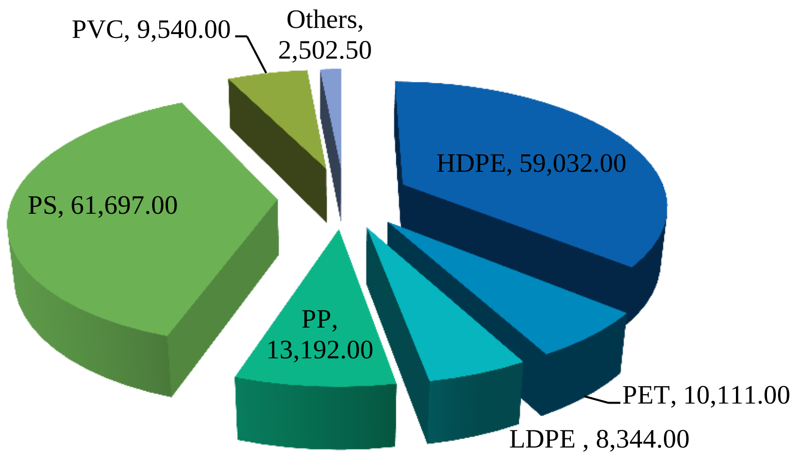

Figure 4-13: Average Weekly Distribution of Retailed Plastics

From these results, PS, HDPE and PP are the most common products retailed. This is captured because of these products that are easily visible. The commonly retailed PS products are throwaway utensils, meat packing and protective packing, the HDPE products are toys and plastic carrier bags, crates, containers for household goods such as milk, detergent and oil bottles, bottles for healthcare products, pails and buckets while PP products are buckets, bowls, crates, toys, bottle caps and bottles.

4.3.3 Destinations for Retailed Plastic Products

The duration taken for procured plastic products to exit the retail chain is on average, one week. However, this time varies between one and five weeks with a mode of one week. The manufacturers gave a retention period of 4 weeks. The difference in this retention time can be explained in that for the retailer, a longer holding up time reflects tied down capital and higher space requirements for storing the bulky products. For the manufacturer, the time reflects the processing time required to effect the transformation of resin to product and the time for accumulation in order to transfer the products. The destination targets for the retailed products are shown in Table 4-9 and Figure 4-14.

Table 4-9: Target Destination for Retailed Plastic Products (kg)

Nairobi	Mombasa, Nakuru, Kisumu, Thika and Eldoret	Other towns in Kenya	Outside Kenya	Total
127,170.6	14,831.95	21,065.95	1,350	164,418.5

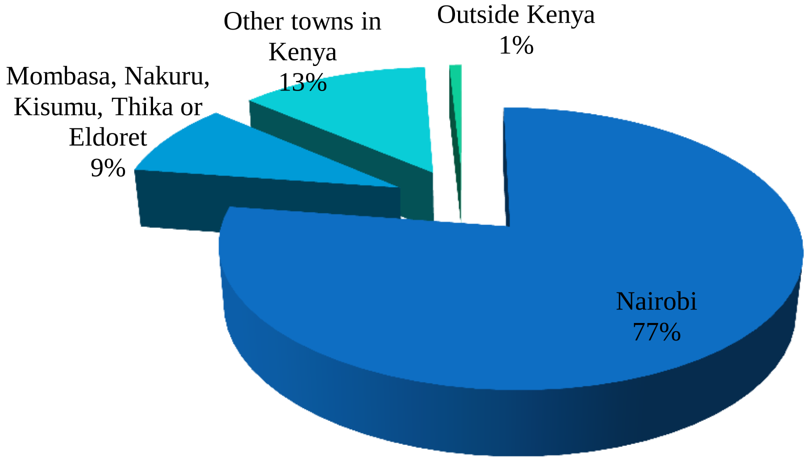

Figure 4-14: Target Destination for Retailed Plastic Products (%)

Nairobi receives the most retailed plastic products at 77%. The balance of 23% shows that some products that are retailed in Nairobi end up outside Nairobi. Some of the retailers indicated that they are involved in one or the other forms of the 3R's (Reduce, Recycle Re-use). The products subjected to the 3R's are as shown on Table 4-10 and Figure 4-15.

Table 4-10: Retailed Plastic Products subjected to the 3R (kg)

Non-3R Products (kg)	3R products (kG0
159,273.75	5,144.75

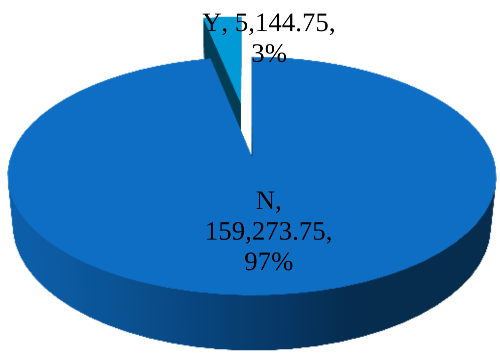

Figure 4-15: Retailed Plastic Products subjected to the 3R (%)

Figure 4-15 shows that only 3% of the plastic materials retailed are subjected to the 3R's.

4.3.4 Challenges and Opinions of Plastic Products retailers that can inform policy directions

The following are the main challenges faced by retailers of plastic products in managing the plastic products and the associated wastes:-

- Quality - The retailer's experience poor quality of plastic products by manufacturers that leads to breakages of fragile plastics and subsequent wastage. They also experience dust accumulation on products that affects quality and therefore likely rejection. They also experience irregular standardization of mattress gauges.
- Bulkiness – Retailers experience problems due to bulkiness. This lends itself to high cost of transportation; besides bulky commodities take up lots of space leading to insufficient space for storage before collection for disposal.
- Environmental pollution – The retail outlets especially the supermarkets indicated that few customers are willing to use the re-usable bags provided, preferring to use the plastic carrier bags instead. They indicated improper dumping by consumers, challenges in handling packaging waste materials, no cooperation with the public users
- Recycling – the retailers indicated willingness to get involved in recycling but that they lacked the capacity to carry out recycling and there is lack of recycling facilities
- Market changes –The instability borne of ever-changing price variations and high price of plastic products is challenging. PVC is constantly facing poor sales since introduction of PPR.

Retailers offered the following recommendations on challenges encountered:-

- Quality - KEBs should enforce standardisation of products and enforce uniform gauges during production as well as continuously promote maintenance of quality. This would reduce rejects and wastage. In the same breadth, regular inspections of industrial production would ensure quality such as checking the weight of HDPE gauges used in packaging.
- Bulkiness – While aware that this challenge is not unique only to retail outlets, retailers proposed that the government should work to reduce cost of petrol/diesel

to enable for easy transportation to recyclers and give incentives towards availability of more storage space.

- Environmental pollution – Relevant authorities should encourage manufacture of eco-friendly packaging and other products. More effort is required to increase customer awareness on the re-use capability of plastic products especially carrier bags. There is need to promote customer use of re-usable bags provided by the supermarket chains, promote use of plastics with less environmental impact and need for Government to sensitize public on proper waste disposal in general.
- Recycling – the government should give incentives to the currently young and informal recycling sector initiatives such as make arrangements with manufacturers to buy back some of the packaging paper, encourage recycling habits among consumers, establish pick-up points for collection of used plastic products for recycling and introduce tax waivers for recyclers such as on import of recycling plant.
- Market changes – The government should institute mechanisms to tame inflation and rapid price variations.

Figure 4-16 shows the future growth prospects in plastics retail. It shows that 77% of the retailers expect growth in the sector. Just like the projection by the manufacturers, this implies that the issues currently experienced in management of plastics, if not addressed, will still be present even in the future.

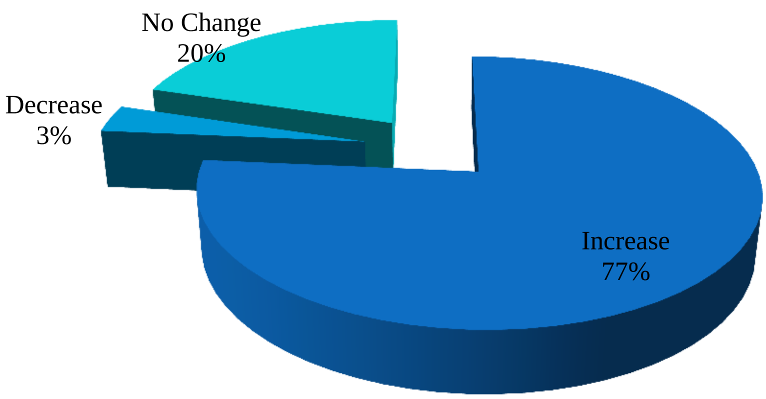

Figure 4-16: Retailers projected prospects of growth in the retail of plastic products

4.4 PLASTIC WASTES GENERATED BY CONSUMERS OF RETAILED PRODUCTS

The purpose of the consumer plastic wastes generation data is to help fill the data gap necessary for comparison of retail data viz-a-viz the combined plastic recycling and final disposal data in order for the mass balance to be developed. The data trend observed is that whereas the manufacturer data is good and largely reliable, the reliability diminishes significantly due to data collection gaps and losses through the retail, consumption, recycling and waste collection to disposal cycle.

The applicable data for consumer generated plastic wastes was based on the CCN JICA Study of 2010 that were able to gather statistically representative data on the city-wide waste generation trend. This data is as presented in the Section 0 with inferences, interpretation and projections as necessary.

4.4.1 Plastic Wastes Generation Quantities in Residential Areas

The waste from residential areas is considered in terms of kg/capita/day. Household makeup and categories considered were the high income group, middle income group, low-middle income group, low income group and Slum area. The average waste generation rates per capita showed that the slum and middle income areas generated the largest amounts of waste. The high income areas, having a higher number of people per household than the low income areas generated less per capita waste. The average per capita waste generation rates is shown in Table 4-11. (JICA, 2010)

Table 4-11: Average per Capita Waste Generation Rates (JICA, 2010)

Income Group	Household makeup (persons)	Survey Area	Mean (kg/day/c)
High Income	5.1	Kitisuru	0.625
		Karen	0.509
Middle Income	(3.6	Langata	0.737
		South B	0.611
Low-Middle Income	3.8	Riruta	0.483
		Umoja	0.465
Low Income	2.7	Dandora	0.28
		Bahati	0.325
Slum	3.7	Kibera	0.464
		Mukuru	0.37

4.4.2 Plastic Wastes Generation Quantities in Commercial Establishments

Commercial establishments considered were shops, restaurants and hotels, public facilities like schools and offices (public and private). The average weight of each generation source of establishments is shown in Table 4-12 (JICA, 2010).

Table 4-12: Average Weight of Commercial Establishments Generated Waste

Establishments	Average (kg/day)
Shops	0.5
Restaurants	38
Hotels	350
Schools	76
Public Offices	137

4.4.3 Plastic Wastes Generation Quantities in Markets

Out of the 44 markets in Nairobi City, 30 markets were surveyed; the average daily waste generation of each market is about 2,045 kg/day. (JICA, 2010)

4.4.4 Plastic Wastes Generation Quantities in Roads

The average waste generation was 50 kg/km/day (JICA, 2010).

4.4.5 Total Amount of Waste Generation by Source

Based on the residential, commercial, market and road wastes, the waste generation for Nairobi City is shown in Table 4-13. However, the amount of waste generation from roads was not added to the estimation of total waste generation considering that the waste generators are also from the residential and commercial areas. Therefore, from the Table 4-13 the waste generation for Nairobi was 1,848 ton/day. The waste generation fractions by source are shown in the pie chart in Figure 4 17.

Table 4-13: Total Amount of Waste Generated in Nairobi City

Generation Sources	Total (kg/day)
1. Residential Waste	1,318,381
2.Commercial Waste	439,979
3.Market Waste	90,000
4.Road Waste	(60,000)
Total	1,8048,360

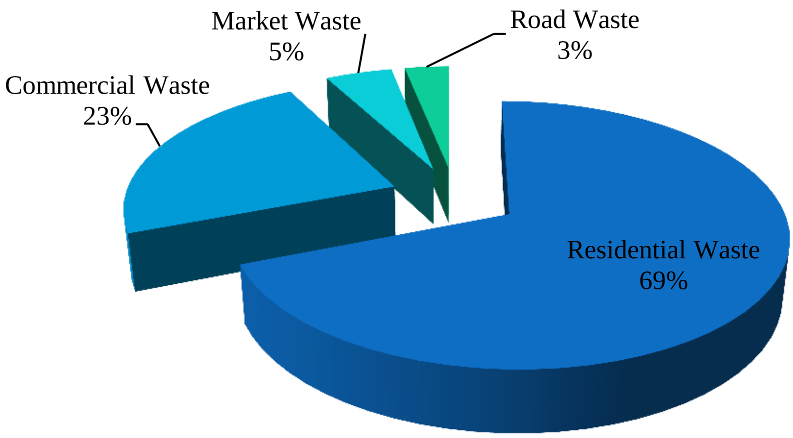

Figure 4-17: Waste Generation Fractions by Source

From Figure 4-17, the waste generation from residential areas comprises 69% of the total. The waste generated by commercial establishments is one third of the total waste generated by the residential areas by weight. The residential areas therefore yield the highest generation of solid wastes by weight in the city. However, the weight of residential wastes is normally higher where organic matter makes up a large proportion of the waste, and lower in commercial districts where waste contains more paper and cardboard. It does not therefore necessarily imply that the residential areas are the highest producers of plastic wastes.

4.4.6 Plastic Wastes Generation by Resin Category Type

The composition of the wastes under the JICA study was carried out in reference to the physical properties of the solid wastes important in the selection and operation of equipment and facilities, disposal strategy and disposal process. In this case, the category of plastic wastes was further classified into four groups, namely:-

- Plastic sheet
- Recyclable plastics
- PET bottles and
- Other plastics

In contrast, the composition of plastic wastes under this mass balance study is by the seven commonly used plastic resin types. There is therefore a wide disparity between these two categories of the plastic wastes under the JICA Study and this mass balance study. The categories of Plastic Sheet, Recyclable Plastics, PET Bottles, and Other Plastics cannot be compared with that of the plastic resin types. Accountability in transfer and accumulation data from retail, to consumption and consequently waste generation is therefore lost as it is impossible to deduce the quantities of each of the plastic resins would be apportioned to plastic sheet, recyclable plastic, PET bottles or even other plastics. For this reason, the PET bottles as referred to do not imply the PET resin which is number 1 as per the Resin Identification Code (RIC). Similarly, "other plastics" does not refer to the "Others", the seventh resin category under the Resin Identification Code.

The plastic waste categories identified under the JICA Study can comprise of a number of the plastic resins type in the RIC as shown on Table 4-14:-

Table 4-14: Categories of Waste Plastics in CCN Data

Plastic Sheet	Recyclable Plastic	PET bottles	Other plastics
HDPE and LDPE	HDPE, PET, LDPE & PP	PET, HDPE, LDPE & PP	PVC, PS, and Others

The estimation of composition of the plastic wastes by the categories under the JICA Study is shown in Table 4-15.

Table 4-15: Estimation of Daily Plastic Waste Generation Amount for 2011 (kg/day)

Generation Sources	Total (kg/day)	Plastic Sheet (%)	Recyclable Plastics (%)	PET Bottles (%)	Other Plastics (%)	Subtotal-Plastics (%)	Plastic Sheet (kg/day)	Recyclable (kg/day) Plastics	PET Bottles (kg/day)	Other Plastics (kg/day)	Subtotal-Plastics (kg/day)
1. Residential Waste											
a. High Income	246,635.00	6.38	1.66	1.1	0.32	9.46	15,735	4,094	2,713	789	23,332
b. Middle Income	505,076.00	4.45	5.32	0.09	0.48	10.34	22,476	26,870	455	2,424	52,225
c. Low Income	566,670.00	9.13	2.03	0.54	0	11.7	51,737	11,503	3,060	0	66,300
2. Commercial Waste											
a. Shops	23,970.50	1.84	6.72	2.87	3.72	15.14	441	1,611	688	892	3,632
b. Restaurants	60,116.00	0.95	2.85	1.65	0.33	5.77	571	1,713	992	198	3,475
c. Hotels & Guest Houses	107600	0.4	2.69	1.88	0.04	5.01	430	2,894	2,023	43	5,391
d. Public Facilities/Schools/*Commercial*	439,979.00	1.63	2	4.89	0	8.52	7,172	8,800	21,515	0	37,486
3. Market Waste	90,000.00	0	1.08	0.27	0.12	1.48	0	972	243	108	1,323
4. Street Waste	(60,000.00)	3.04	3.51	4.28	0.09	10.91					
Total	1,848,360						98,562	58,458	31,688	4,455	193,163

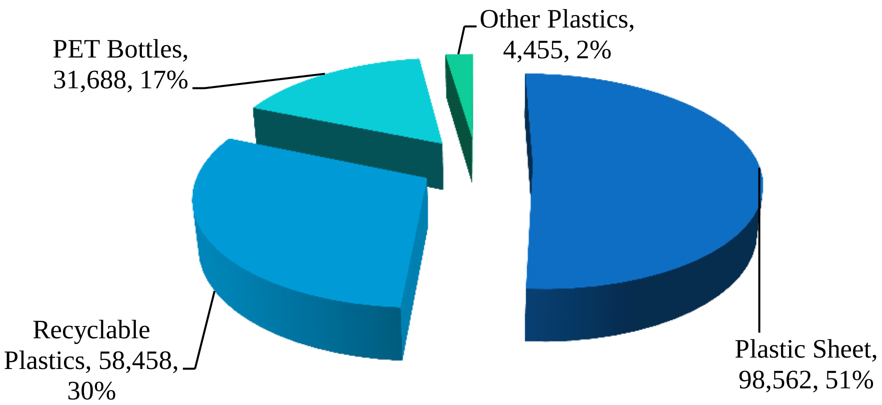

Figure 4-18: Generation of various plastic wastes

From Figure 4-18, the daily generation of plastic sheet is 51% compared to recyclable plastics at 30% and PET at 17%. This daily plastic waste generation of 193,163 kg/day is not comparable to that which is generated in retail and sold within Nairobi at an average weekly sales rate of 127, 170.60 kg/week from Table 4-9 (18,167.23 kg/day). Compared to daily waste generation of 1,848 tonnes/day within Nairobi, the daily plastic wastes generation constitutes 10.5 % of the total amount of wastes generated. The daily plastic waste generation is 10 times more than that released in the same area through retail. This confirms the explanations given earlier in Section 4.3 (4.3.1) about loss of accumulation and transfer data at the retail level.

It implies that there are more plastics available to the consumers who generate retailed plastics into wastes than is accounted for from the retail data. Some of these unaccounted for plastics are containers of products directly imported into the retail chain and disposed of as wastes. Others are packaging plastics which are encased inside other outer packaging and enter into the waste streams unaccounted for.

4.5 FINDINGS ON PLASTIC WASTE DATA FROM CCN

4.5.1 CCN on Plastic Waste Management

Only one waste management institution was considered in the city, the CCN in terms of collection, transport and final disposal of plastic wastes. All other waste collection and disposal operators are licensed, regulated and supervised by the CCN. The most recent and reliable data on waste collection obtained from the NCC is the JICA Study of 2010. This is what is used to complement and compile the collection and disposal data necessary to develop the mass balance.

The CCN is charged with collection of solid wastes from households and business establishments. All collected wastes are disposed of at the Dandora dumpsite. CCN executes its mandate using its own equipment and through engagement of licensed subcontractors. The operations of the subcontractors are guided by the CCN Private Sector Involvement in Solid Waste Policy and supplemented by NEMA regulations. The subcontractors operate within defined zones. The annual recycling permit fees for waste transporters are K.Shs. 12,000.00. The CCN is responsible for issuing licenses to plastic wastes recyclers. The annual recycling permit fees are K.Shs. 30,000.00.

4.5.2 CCN Data on Plastic Waste Collection

According to the JICA study, of the 1, 848 tonnes of wastes generated in Nairobi daily, only 33% is collected (approximately 610 tonnes) (JICA, 2010). The uncollected waste (1, 238 tonnes) was unaccounted for.

4.5.3 CCN Data on Plastic Wastes Disposal at Destination

Of the wastes collected daily, not all reaches the final disposal at Dandora dumpsite. Some of it is diverted at the source and recyclable materials are recovered at various points such as junkshops; through composting of biodegradables by residents, Community Based Organizations (CBOs) and pilot plants; recovered by the collection crew at the Material Recovery Facilities (MRF) and recovered at the final Dandora disposal site.

Using various assumptions, JICA computed the quantities of diverted wastes shown on Table 2-9. From this data, the total waste diversion was 86 tonnes/day, equivalent to 14% of the total daily collections by weight. The overall daily waste collection rate is 33 % of all generated wastes. Assuming this percentage applies linearly, and then 33% of the total plastic wastes daily generated are collected. Therefore 63.7 tonnes (63,744.03 kg) is collected against the 193,163.00 kg generated. 14% of the collected plastic wastes is diverted (recycled), and therefore 54 tonnes (54,819.86 kg) is what reaches the final disposal daily. It can therefore be explained that 129 tonnes (129,419.69 kg) of plastics daily generated is unaccounted for.

The balance represents the recycle/re-use rate of 8,924.16 kg daily. Compared to the average uptake of plastic content for recycling from Nairobi of 240,893.00 kg/ week, it can be explained that the recycling materials comprise of 62,469.15 kg/week of diverted plastic materials from comingled waste streams. In addition, other recycled plastics for recycling (178,423.85 kg/week) are variously sourced including from the uncollected sources. It is not possible to correlate the proportion of each of the individual seven plastic resins with the total waste collected and disposed under this JICA study. In addition, the JICA study classified the plastic materials into four categories namely; plastic sheet, recyclable plastics, PET bottles and other plastics, none of them corresponding to the seven commonly established and utilized resins.

Comparing the data for final disposal of plastic wastes with the production data, 1,027,525.00 kg of the manufactured plastic products is sold into Nairobi every week as shown in Table 4-6. From the retailers, 127,170.60 kg of the retailed plastics is sold into Nairobi every week whereas 193,163.00 kg of plastic wastes is generated every day. Therefore 1,352,146.02 kg of plastic wastes is generated every week. This exceeds the weekly manufacture rate.

The average duration taken for collected plastic products to reach the final disposal at Dandora was not established. The duration of this period is dependent on such factors as the use to which the plastic product is put, the longevity of use and to a limited extent, the proximity of the final point of use to the collection and final disposal site.

4.5.4 Challenges and Opinions faced by CCN on Plastic Waste Handling that can inform policy directions

The following are the main challenges faced by CCN in plastic wastes management:-

- Plastic wastes – there is lack of ready markets for much of the plastic wastes. Plastic wastes are always in comingled state and not separated at source. While CCN is desirous of implementing waste sorting at source, this is not supported by existing policy.
- Plastic recyclers – The challenge is that most plastic recycling enterprises do not seek authority to operate from CCN by way of applying for licenses. Therefore the alleged common harassment by CCN law enforcement crews. However, CCN acknowledge the role they play and are desirous to allow them the space to operate.
- The waste mountains at the Dandora dumpsite which have accumulated over a long time are challenging to manage. Modern thinking is that it would be useful for power generation. Some of the international enterprises which have explored this proposal gave the verdict that the wastes have stayed long and are obsolete for economically viable enterprise.

The following are the policy developments recommended by the CCN:-

- The application of the Polluter-Pays Principle will enhance plastic waste management as it would put the responsibility for clean-up of generated wastes on the plastic manufacturers.
- Implementation of recommendations carried out by the JICA studies of 1998 and 2010 would improve waste management in terms of collection, transportation and transfer of wastes as well as final disposal.
- Recycling should be encouraged as a noble plastic and other wastes minimization strategy
- There is need to have a CCN policy on waste sorting instituted at the waste sources and at transfer stations. CCN has been in consultation with stakeholders such as leading supermarket chains geared towards coming up with a waste sorting system. These efforts have produced the pilot work on colour coded waste bins introduced in some city areas.

4.6 FINDINGS ON RECYCLERS OF PLASTIC PRODUCTS

4.6.1 Plastic Wastes Recycling Organizations

A total of 55 recyclers were sampled in the city. These are nearly twice the number of manufacturers. Of those sampled, Zone A and B had six recyclers each, Zone C had 7, Zone D had 11 and Zone E had 25 recyclers as shown in Table 4-16 and Figure 4-19.

Table 4-16: Distribution of Plastics Recyclers by zones

Zone A	Zone B	Zone C	Zone D	Zone E	Total
6	6	7	11	25	55

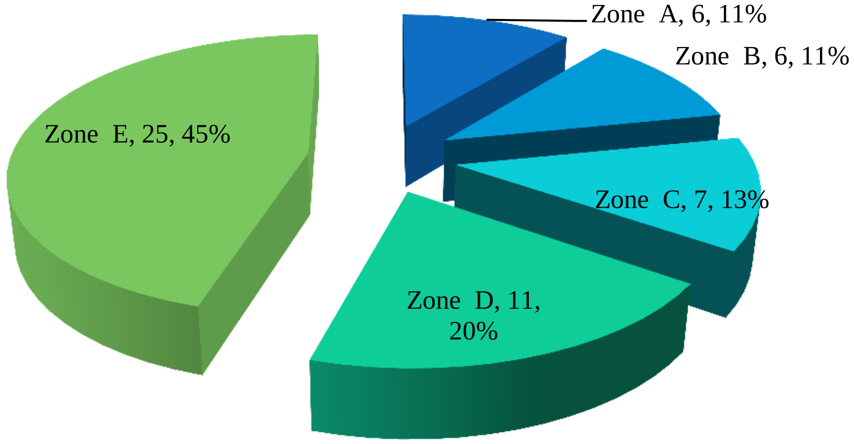

Figure 4-19: Distribution of Plastics Recyclers by zones within the Study Boundaries

Contrary to the distribution of the manufacturers, Zone E, which is typically the CBD had the highest number of recyclers at 25 out of 55 (45%). Zone D is also a rapidly growing recycling zone. This may be explained as being a result of the high generation and accumulation rate of plastic wastes within the CBD as well as the low cost of transfer of small batches of the plastic wastes. In addition, these recyclers largely depend on delivery of the plastic wastes by the waste scavengers who walk to collect the wastes from dust bins and other trash piles and also deliver to the recyclers for a pay.

The average age of plastic recycling organizations is 2 years. This implies that most organizations are start-ups and relatively young compared to retail and manufacturing. It also implies that there is a recent upsurge in demand to recycle/re-use/reduce plastic wastes. It represents new-found opportunities for enterprise.

4.6.2 Recycling/Re-use of Plastic Products

Of the 55 plastic recyclers/re-users sampled, the HDPE recycling was leading at 45 followed by PET, then LDPE and PP plastic resin types in that order as shown in Table 4-17 and Figure 4-20. Some of the recyclers handle more than one resin type.

Table 4-17: Distribution of Plastic Resins Recyclers/Re-users

HDPE	PET	LDPE	PP	PS	PVC	Others
45	33	19	19	2	4	0

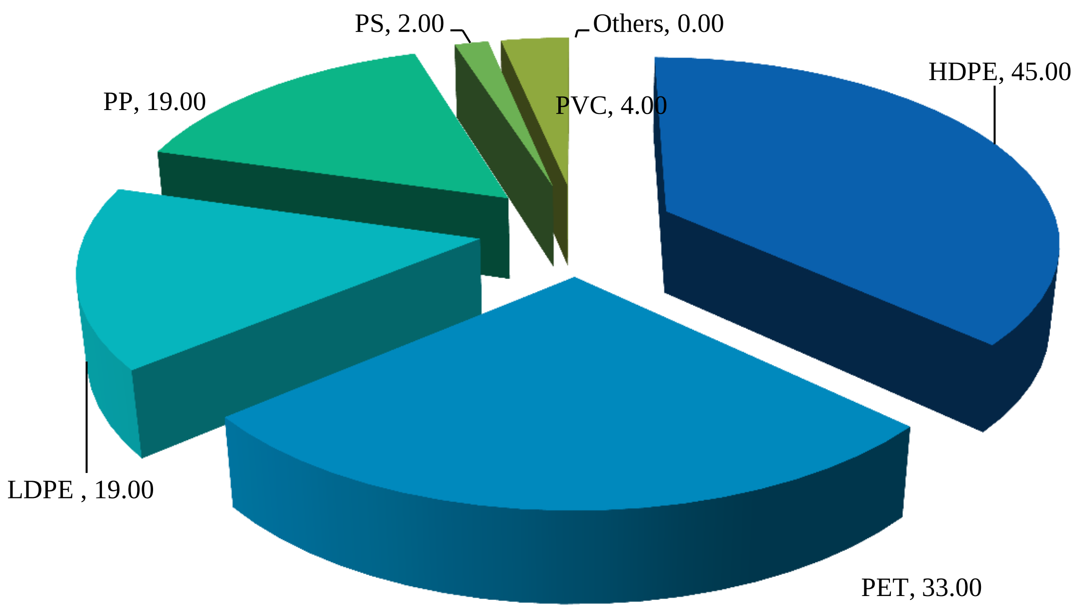

Figure 4-20: Distribution of Plastic Recyclers by Resin Types

The resin category of "others" is not locally recycled / reused. The sources of plastic waste materials for recycling were as shown in Table 4-18 and Figure 4-21 by mass.

Table 4-18: Sources of Plastic Products for Recycling by mass (kg/week)

Nairobi	Mombasa, Nakuru, Kisumu, Thika or Eldoret	Other towns in Kenya	Outside Kenya	Total
240,893	1,197	70,360	0	312,450

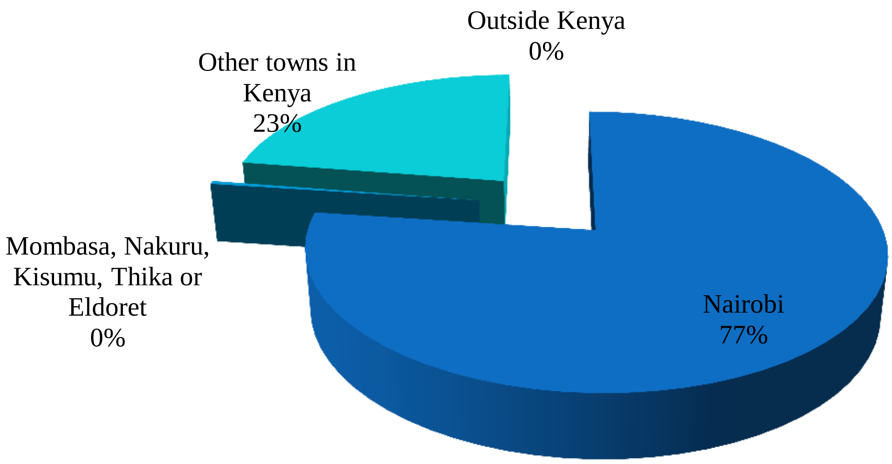

Figure 4-21: Sources of plastics for the recycling industry by mass (kg)

From the Figure 4-21, 77% of the plastic materials recycled were sourced from Nairobi while the balance of 23% came from other towns Kenya. None of the recycled plastic materials is sourced from outside the country. In comparison to retailing for Nairobi, the recycling industry takes back more per week at 240,893 kg than the retailing gives out at 164,418.5 kg per week. This may be explained in various ways, singly or in combination. First, that some of the plastic content sourced from Nairobi for recycling has travelled back from retail and manufacture in other areas outside Nairobi. Secondly, that with time, more of the plastic materials that have been transferred to users and accumulated over time gets released and travels back for recycling. Thirdly, there is significant data loss on the retail quantities and therefore the quantities obtained lack accuracy as explained in Section 4.2.2 (a). The Average weekly uptake of plastic content for recycling by resin type is as shown on Table 4-19 and Figure 4-22.

Table 4-19: Average Weekly uptake of Recycling Plastics by Resin Type (kg)

HDPE	PET	LDPE	PP	PS	PVC	Others	Total
177,740	37,940	26,650	30,650	300	770	0	274,050

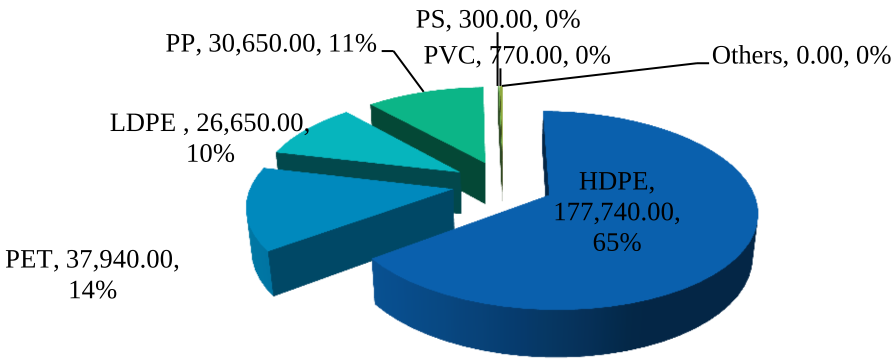

Figure 4-22: Average weekly production/importation by resin type

HDPE is the most abundantly recycled resin at 65% followed by PET at 14% and PP at 11%. There is gap in the total plastics sourced for recycle by weight (312,450.00 kg) and the total plastic content for recycle by resin type (274,050.00 kg). This could be explained by the fact that some of the plastics sourced are not of a category of a recyclable resin. In addition, some of the plastics sourced are rejected on the basis of color or lack of other clearly identifiable symbol. Still, other plastic materials contain products that must be discarded in order for them to be recycled. The recovered plastic resins are put to the following applications; remolded into construction poles/pipes, shredded to pellets for export, compacted into bales for re-sale, resold in similar form and put to other unspecified uses. These are shown in Table 4-20 and Figure 4-23.

Table 4-20: Uses to which the Recycled Plastic Resins are put (kg)

Remoulded into Construction poles/pipes	Shredded to Pellets for export	Compacted into bales for re-sale	Resold in similar form	Others	Total
2,000	175,464	50	348,412	44,814	570,740

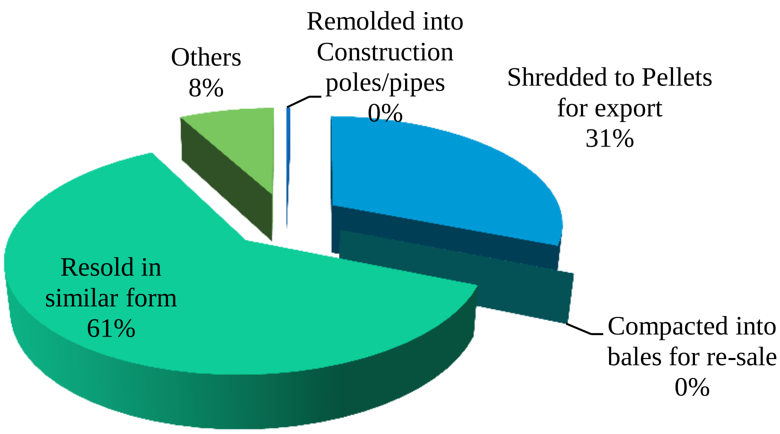

Figure 4-23: Uses to which the recycled plastic products are put (%)

From Table 4-20, the quantities for the uses to which recycled plastic resins are put is 570,740.00 kg/week. This far outstrips the weekly sourced plastic products for recycling at 312,450.00 kg/week. There is a gap of 258,290.00 kg/week. Possible explanations are that:-

- Recyclers procure additional materials for recycling from unaccounted for sources such as rejects from manufacturing and imported resins as well as retail rejects and 3R.
- Recyclers import recycling ingredients to boost the quality of recycled products that also bulk up the mass of recycled plastic products
- Recycled feedstock bulks and weighs more than virgin feedstock

From Figure 4-23, resale in similar form is the most common form of recycling at 61%. This can be explained by the fact that some of the recycling enterprises are middlemen who re-sell to other recyclers or second hand users. The actual recycle rate therefore stands at 31%. Compaction of the waste plastic materials into bales for resale (volume reduction) is not commonly practised. Remodelling of the waste plastic materials into construction poles is not captured under this recycling data.

4.6.3 Destination for Recycled Plastic Products

The duration in weeks before recycled materials exits the plant is on average 1.3 weeks with a mode of 1 week. This can be explained as necessitated by the limited storage space coupled with harassment from law enforcement agents. It also represents the ready market for re-use and uptake of recycled plastic content. The destinations for recycled plastic products are shown on Table 4-21 and Figure 4-24.

Table 4-21: Destination Markets for Recycled Plastics (kg)

Nairobi	Mombasa, Nakuru, Kisumu, Thika or Eldoret	Other towns in Kenya	Outside Kenya	Total
118,507	73,811	39,532	43,200	275,050

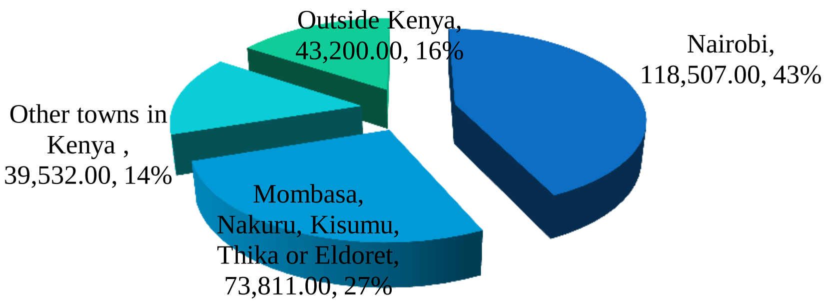

Figure 4-24: Destination markets for recycled plastic products

Nairobi consumes 43% of the recycled plastic materials. Of the 55 plastic recyclers' sampled, 19 indicated that they made use of their own recycled content at a re-use rate that varied between 0.01 to 0.3 %. This is a total of 1,587.4kg of plastics per week.

4.6.4 Challenges and Opinions of Plastic Products recyclers that can inform policy directions

The following are the main challenges encountered in the management of recycling/re-use activities for the various plastic products:-

- Health & Safety threats – there are many health and safety threats to the plastic product re-users, recyclers and collectors in general. These range from exposure to likely hazardous left-over contents in plastic containers, exposure to occupation hazards from emissions during recycling and lack of proper protective equipment. Most plastic materials are recovered from solid wastes in comingled state.
- Harassment – The plastic waste pickers and resale/recycle outlets experience harassment and extortion from regular police, NEMA officers and CCN law enforcers. The law enforcers charge them on issues ranging from unlicensed dumping of wastes to hoarding of stolen property which in most cases is not true. Most of the plastic wastes are delivered to the recyclers at night or early morning to avoid traffic.
- Storage – Recyclers in general complained of inadequate storage space prior to recycling which fills up rapidly and attracts complaints from adjacent residents on grounds of pollution, dirt and unsightly neighbourhood. Seasons of adverse weather both rainfall & scorching sunshine are also challenging.
- Transport – It is expensive to transport the bulky plastic wastes as well as the recycled content and sometimes it is difficult to fill a truck. Sometimes these plastic wastes have to be transported from far flung collection areas and to far flung disposal areas. Lack of designated drop-off and pick-up points for recyclers to easily access the materials give opportunity to brokers and middlemen, which lengthens the chain and increases cost. Some of the travel journeys for waste plastics would be unnecessary if better collection systems were in place such as sorting at source.
- Collection of plastic wastes for recycling – The collection of waste plastic materials for recycle/reuse is irregular and therefore the supply is irregular. This has created groups competing for areas to collect plastics from. The competition has even reached a level where there is foul play between the collectors to the extent of even deadly

fights occurring in the waste dump areas. This affects and controls the cost of sourcing to sometimes high and unstable cost making it to be unacceptable to the recycling plants.

- Sorting - Generally, consumers dispose mixed wastes together rather than sell the plastic wastes. Some plastics carry unused/ partially used contents making the sorting slow. Sorting of the plastics for re-use/recycle from mixed unsorted wastes therefore takes a long time and effort. In addition, different types of plastic resins must be sorted out into their respective groups. People on site do not know the different plastic resins.
- Business – The recyclers complained that there are too many agencies that want to licence them for doing business. An example is NCC, NEMA and KEBs, all who have different criteria for their licensing without contributing an enabling environment for the recycler. The total charges from these agencies exceed the money to be made from the recycling business; low profits accrue to brokers.
- Cost of power – The power input into manufacture of a plastic product from recycled feedstock is higher than that of manufacture of the same product from virgin feedstock. This means that the recycler has to absorb the cost of power while charging low for the recycled feedstock. This does not make money for the collector and effectively does not encourage recycling enterprise.
- Markets - rejection of recycled products in the markets is common.

The following are the policy developments recommended by recyclers of plastic products:-

- Policies should be developed to guide acceptable products from recycled plastic content.
- Policies that give incentives on availability of space, possibly recycling zones similar to the manufacturing zones. These would allow trade movements for recyclers and sheltered storage from adverse weather such as rains and sunshine, and keep away harassment.
- Education on various issues - a policy that makes it easy for consumers to recycle rather than dump should be enacted. This will make consumers to sort wastes at source, making the transport of the wastes to the various destinations easier.
- Enact a policy that demands for direct delivery to recycler, cutting out middle men, demands for manufacturers to recycle the plastic wastes they generate,

- Policies that give incentives for entrepreneurs to investment in plastics recycling such as tax waivers on machinery and reduced cost of electric power since recycling cleans the environment.

On the future prospects in plastics recycling, 90% of recyclers were optimistic that the industry is poised for growth in the near future as shown in Figure 4-25.

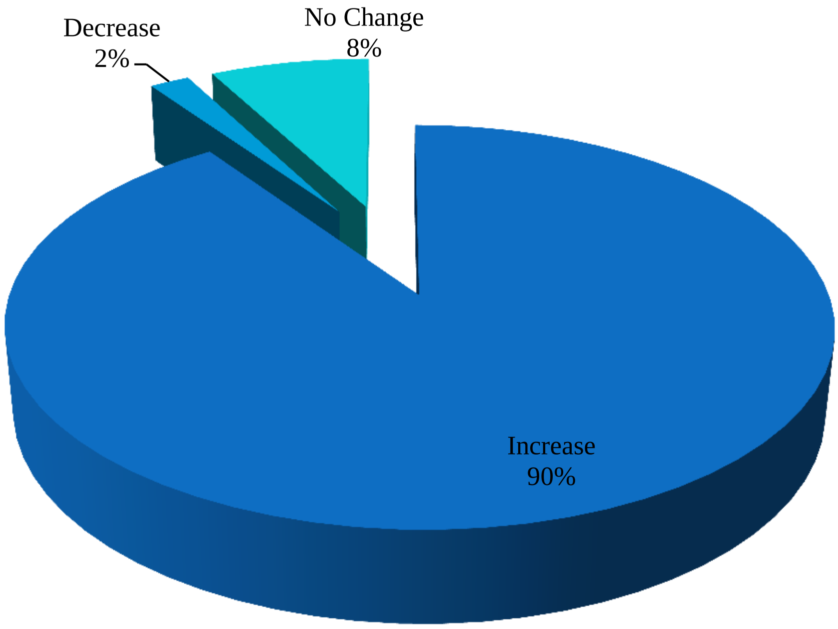

Figure 4-25: Prospects on Projected Growth of Recycling Plastic Industry

4.7 FIELD AND DESK DATA FROM NATIONAL ENVIRONMENTAL MANAGEMENT AUTHORITY

Pursuant to the provisions of the EMCA Waste Management Regulations (2006), NEMA carries out Initial and Annual registration and issuance of licenses to operate to three categories of waste handlers namely:-

- Transporters are charged K.Shs. 3, 000.00 to apply and K.Shs. 5, 000.00 for the annual licence
- Plastic and paper recyclers are charged K.Shs. 3, 000.00 to apply and K.Shs. 40, 000.00 for the annual licence while
- Waste Transfer Stations are charged K.Shs. 3, 000.00 to apply and K.Shs. 40, 000.00 for the annual licence

The processing of the license proceeds upon submission of necessary documents, within a maximum of 30 working days. Such necessary documents include a site plan of the area of operation, provision by the applicant of proposals for an environmental management system, enterprise organizational structure, and proof of sufficient resources allocated to achieve compliance with the requirements and conditions of the license, commitment to keep records such as Environmental Audit report and emission monitoring reports among others.

The licensing criterion for both plastic and paper handlers is similar as follows:-

(a) the applicant purchases standard application forms and fills them

(b) NEMA reviews and rejects application or grants approval with conditions

(c) If approval is granted, the applicant gives consent in writing and pays up an annual operating license.

The license must be renewed annually upon expiration (every 12 months) without the application charge except in circumstances where the twelve months have lapsed. NEMA field officers periodically carry out field inspections to verify if license conditions are adhered to. If the conditions are violated, the licenses can be revoked.

4.7.1 Waste Collection and Transportation

Data obtained from NEMA concerning the licensing of the various actors was in unsorted state. It was mixed in time over recent years, mixed in type (paper and plastics) as well as mixed in location, countrywide in Kenya. Of the fifty five (55) plastics and paper waste transporters licensed by NEMA to operate countrywide within the 2011-2014 periods, thirty three (33) were within Nairobi. Of the thirty three (33), twenty four (24) were licensed to transport plastic wastes, eighteen (18) handling plastics only while six handled both paper and plastic waste streams.

4.7.2 Waste Transfer Stations

NEMA licensed twelve (12) waste transfer stations to operate countrywide within the 2011-2014 periods. Of these, nine (9) are licensed to operate within Nairobi and only two (2) are licensed to handle plastic wastes.

4.7.3 Waste Recycling Stations

NEMA licensed ten (10) plastic recycling enterprises to operate countrywide within the 2011-2014 periods. Five (5) of these were licensed to operate within Nairobi, with four (4) of them licensed to handle plastic recycling. One (1) is licensed to recycle paper wastes.

4.7.4 Plastic Waste Quantities

By the time of the data collection, NEMA had no data records for the amounts transported, recycled or transferred. It is therefore not possible to track how much plastic material was collected, transported, transferred or recycled within Nairobi in any given year within the period of the records from the NEMA data.

4.7.5 Overlap between NEMA and CCN Licensing Mandates

There has been conflict over the double licensing of solid waste transporters and recyclers by the CCN and NEMA. This has contributed to the complaints, protests and licensing dodging manifested by the collection, transport and recycling operators.

Following consultations with stakeholders among them NEMA, CCN and the operators, it was amicably agreed that NEMA's mandate as espoused in EMCA 1999 is industry regulation through development of standards and inspection for compliance to the set standards. Other actors are implementers (such as CCN), recognized under EMCA as "Lead Agencies". Therefore, since January 2014, NEMA ceased to issue licenses to operators.

4.8 FIELD AND DESK DATA FROM THE KENYA BUREAU OF STANDARDS (KEBS)

4.8.1 Standards Development

Standards are developed by the Standards Technical Committee which comprises of KEBS Officers and relevant industry players to render requisite expertise in accordance to ISO guidelines. The relevant industry players in regard to development of standards in the plastics industry include manufacturers, consumers and lead agencies. All manufacturers are required to register and pay for the Standards Levy to KEBS in accordance to the Standards Levy Order which was gazetted by the Minister for Industry vide Legal Notice No. 267 of 2nd June 1990 which came into operation on 1st July 1990. These standards help to make sure that the plastic products and services are fit for their purpose and that the products manufactured by different enterprises are comparable and compatible. KEBS had no data on the number of plastic manufacturers or on plastic production by the plastics manufacturers.

4.8.2 KEBS Stamps and Quality Marks

KEBS accredited products are stamped with various quality marks with diverse meanings. These are shown in Table 4-22. These quality marks apply to the plastic products locally manufactured or imported.

Table 4-22: KEBS Quality Marks and their meanings

Quality Marks	Name	Application
	Standardization mark	This is a mandatory mark for all locally manufactured products. Products with the Diamond Mark of Quality automatically qualify for the Standardization mark.
	Diamond mark	It is a voluntary (optional) mark of quality based on excellent performance of the products and is superior to all the other quality marks.
	ISM Mark	This is a mark of quality for imported products with impact on Health and Safety (Foodstuffs, Electricals, Infant wears and Toys).
	Fortified Logo	This is a logo for foods that have been added one or more vitamins and/or minerals to correct or prevent a demonstrated micronutrient deficiency.

4.8.3 Kenyan Standards Applicable to Manufacture of Plastic Resins

The processing of plastics in the country is covered by the relevant standards/regulations developed by the Kenya Bureau of Standards (KEBs). Several standards applicable to various plastics are shown in Table 4-23.

Table 4-23: Relevant KEBs standards applicable to plastics processing in the country

No.	KS	Area Addressed	Year developed	Description of Standard
1	KS 511-3 2001 ICS 55.100	Plastic Bottles	2001	Specification for Plastic Containers Part 3: Plastic Bottles
2	KS 511-2 1994 ICS 55.120	Basins	1994	Specification for Plastic Containers Part 2: Basins
3	KS 511-1 1991 ICS 55.120	Buckets	2011	Specification for Plastic Containers Part 1: Buckets
4	KS 1794 2007 ICS 55.080	PET & PP	2007	Polyethylene (PET) and Polypropylene (PP) bags for general purposes - Specification
5	KS ISO 15874-2 2003 ICS 85.040	PPR Pipes	2003, 2012	PPR Pipes

4.9 Field and Desk Data - Kenya National Cleaner Productions Centre

The Kenya National Cleaner Productions Centre (KNCPC) has been eager to work in promoting cleaner production in the plastic manufacturing sector. Their approach is tailored to be voluntary whereby individual companies analyze the benefits that can come out of adoption of cleaner production with respect of both economic gains and environmental accountability. KNCPC recommend for plastic manufacturing industries to have a standardized manufacturing policy on product life cycle and recyclability. In their experience, the spread of cleaner production to the plastics manufacturing sector has been adversely affected by lack of political will for top management to commit to adoption of cleaner production technologies and challenges such as non-compliance to KEBS specifications. KNCPC have no data on plastics manufacturing, collection, transfer or disposal.

4.10 Field and Desk Data from Kenya Association of Manufacturers (KAM)

The Kenya Association of Manufacturers actively offers input into current issues affecting the plastics manufacturing sector.

4.10.1 KAM Overview on Plastics Manufacturing Industries

KAM is an umbrella body for manufacturing industries. It publishes an annual directory of Kenyan Manufacturers and Importers. KAM annually publishes Manufacturers and Exporters Directory. In the plastic and rubber manufacturers' category of the 2011 directory, they had a total of 64 manufacturers. Other plastic manufacturers were found in other categories such as foam and pharmaceutical, and medical equipment manufacturers. 79% of industries under KAM membership are located in Nairobi. An overview of the plastics manufacturing sector in 2011 by KAM is as follows (Kithinji, 2013):-

- Membership to KAM by manufacturing enterprise is voluntary. KAM had 67 members in the plastics manufacturing sector. 42 of these dealt with polythene while the remaining dealt with PVC, PP, PS and others.
- Plastics manufacturing is a K.Shs. 43 billion worth industry providing direct employment to 9,000 persons and indirect employment to 80,000 persons, at an estimated annual wage bill of K.Shs. 3 billion.
- The industry provides needed packaging materials, rigid plastic items and sheeting services to other industries

- The country produces an estimated 6,000 tonnes/month of plastics countrywide, 70% of it used in packaging by other industries. In comparison, Tanzania and Uganda combined produce 600 tonnes/month.
- There are no manufacturing industries dealing in biodegradable plastics

However, the data is only on the number of plastic manufacturers who are KAM members but not plastic production data by the whole plastic manufacturing industry.

4.10.2 KAM on Policy, Regulatory and Legislative Development

In 2011, the Polythene Materials Control Bill (PMCB) 2011 was introduced before the East African Legislative Assembly (EALA). The bill sought to control and regulate manufacturing and use of polythene bags within the East African Community (EAC) member countries by limiting their production and distribution in the region. This was a private members bill with the objective of providing a legal framework for the preservation of a clean and healthy environment through the prohibition of manufacturing, sale, importation and use of polythene materials. Some provisions of the bill included proposals on introduction of a levy whose proceeds would be used to help with management of waste.

During an East African Business Community (EABC) Stake Holders Consultative Forum on the proposed bill held on 2nd March 2012 in Nairobi, KAM presented a paper detailing reasons why they were opposed to this bill as follows (Kithinji, 2013):-

- Such a move would kill the industry which contributes a tax remittance of an estimated K. Shs.1.5 Billion per year. Businesses in Kenya would stand to lose K.Shs. 43 Billion worth of investments if a Bill seeking to ban use of polythene material in the East African Community is passed
- The proposed bill did not provide viable alternatives to the use of polythene packaging
- Kenyan manufacturers export to countries outside of EAC. Besides, a variety of imported goods come pre-packed in polythene. Hence, it would be unrealistic to expect the "whole world" to adjust their packing specifications to suit EAC requirements.
- They argued that polyethene in the environment is a waste disposal issue of which polyethene is just one component. They were of the opinion that the bill should target waste management including sorting at source, handling, transportation disposal and recycling and not manufacture. The bill blamed the industry for environmental

pollution yet industry is not wholly responsible for waste management & disposal of plastics.

- KAM proposed that rather than the total ban and prohibition in trade of polythene materials in East Africa, the Bill should focus on waste management and regulation of polythene imports from external markets through introduction of taxes under the polluter-pays model.
- Industrialists feared that the said levy would increase the cost of doing business and render goods from the EAC common market less competitive.
- KAM pointed out that polyethylene is one of the easiest plastics to recycle into a diverse range of recycled products and cited examples of classic cases of roads built with recycled plastics, bridges made entirely of recycled plastics and polymer reinforced concrete. Lastly, among others,
- KAM advanced that, worldwide, there's no classical case that has successfully banned the manufacture of polythene.

As a result, some amendments were proposed to the bill. Some that sailed through during the debates included a change in title with the replacement of the word polythene with plastic to read "The East African Community Plastic Control Bill". The introduction of a levy on producers and consumers of polythene materials was included in the final text of the bill. It was proposed that technical teams from the bloc would sit and set the new levy prior to implementation (Kithinji, 2013). This bill was passed in the EALA on 2nd February 2012 waiting to be accented by the five (5) respective heads of states into an Act. The Act mandates that the Partner States shall, upon the coming into force of this Act, take such measures as may be necessary to eliminate polythene materials prohibited under this Act in their territories (Kithinji, 2013).

4.10.3 KAM on Plastic Waste Management

KAM is involved in plastic waste management initiatives such as the Clean Kenya media campaign which started in 2012. The aim of the campaign is to rid the country of the damaging effects of plastics litter. This initiative targets plastic products industry players, mainly manufacturers, retailers such as supermarket chains, end-consumers and recyclers.. In a paper titled "The Role of the Manufacturing Sector in Municipal Solid Waste Management" presented to a Consultative Forum on the Clean Kenya Campaign on 28th August, 2012 in Nairobi, KAM highlights were the solid waste status, reasons why the manufacturing industry ought to take part in waste management, the challenges faced by the manufacturing industry in waste management and a proposed way forward as follows (Kithinji, 2013):-

- An estimated 2,000 tonnes of solid waste is generated daily in Nairobi. Of this only about 25 per cent is collected. Total municipal waste quantities are large and continue to grow.
- Currently, a lot of manufacturers are doing waste management as a Corporate Social Responsibility (CSR) activity. This is extra over their core business mandate, and yet, waste management and collection is solely mandated to the County governments, previously the Local Authorities.
- The plastic manufacturing sector is “allegedly” the biggest producers of non-biodegradable wastes. KAM protested this as untrue given that this sector produces useful, economically viable products that are fully recyclable and therefore they do not manufacture a waste product.
- The plastics manufacturing sector has taken a lead role in sensitizing and educating the public on waste management, proper disposal and the rewards of recycling and re-using.
- The reasons for the manufacturing industry’s involvement in waste management are due to the fact that the waste products from the manufacturing are hazardous to the environment, human and animal life. Yet, these are wastes that can be turned into treasures through recycling/re-use and allow income diversification. Some locally made plastics using waste plastic carrier bags were demonstrated as shown in Figure 4-25.

Figure 4-26: Baskets Weaved from Waste Polythene Carrier Bags (Kithinji, 2013)

- Current solid waste management challenges include; a marked inequality characterizing the geographical distribution of collection service – the high-income and some middle-income residential areas and commercial areas are served while low-income areas, where a higher population live are neglected. There are widespread illegal dumpsites and waste pickers littering the city coupled with low consumer education on waste management.

- KAM proposed partnerships between the CCN, manufacturers, consumers and NEMA in waste management, development of an Integrated Solid Waste Management Strategy which includes source reduction and separation, recycling and re-use as well as materials recovery and development of a vibrant, sustainable consumer education and sensitization on responsible waste disposal. This media campaign did not pick up as envisaged

4.10.4 KAM on Plastic Recycling Enterprise

KAM is further working with a Supermarkets Chain – Nakumatt, on the Nakumatt Environment Campaign. This is a campaign that was officially launched in June 2013 and targets primary and secondary schools in Nairobi. 44 schools are netted into the campaign. Nakumatt organizes for collection of plastic carrier bags and PET bottles by the students from the city streets and drop-off to the supermarket stores. KAM on their part contribute funds to pay the students for the collection and deliver the wastes to recyclers.

This collection has encountered resistance from the scavengers who have apportioned and “own” various streets among themselves. The scavengers collect and sell especially PET bottles from these streets to the recyclers. As such, other operators will not safely penetrate the trade. KAM was involved in such similar clean-up initiatives earlier on. They would collect waste plastics and donate to recyclers. This did not yield much since residents continued indiscriminate disposal of plastic wastes into illegal dumpsites which would again, quickly accumulate. KAM has no data on quantities of how much plastic is manufactured, how much plastic waste is generated, collected, transferred or recycled.

4.10.5 KAM’s Prospects on Future of Plastic Manufacturing Industry

KAM’s prospect for future growth is to see more industries develop, especially the plastic recovery industries through recycling. KAM proposes to encourage plastics recycling in the following ways:-

- To lobby for zero-rating of plastic recycling machines by the government

- Scavengers own the streets and it is difficult to recover especially PET bottles from the streets. This scenario can be overturned if bodies mandated with solid waste collection did their work.
- The PET recycling industry is already developed in the country. Products of recycled content include roof tiles and storm water drainage invert block drains. The polyethene and other plastic resins recycling are not as well developed and KAM is keen to work with the Government on initiatives geared towards increasing the recycling of more plastic resins (Kithinji, 2013).

4.11 CHALLENGES ENCOUNTERED IN DATA COLLECTION AND ANALYSIS

4.11.1 Limitations in Data Acquisition

Effort was employed to ensure the data obtained was representative, objective, evidence-based, trusted and predictable. Limitations experienced in preparing the mass balance models were as follows:-

- The absence of current waste collection and disposal data disaggregated into respective plastic resins at the county level.
- Data definitions and norms were not standardized, and data collection and reporting mechanisms are not synchronized to be homogenous across the various actors.
- Statistically, in random sampling as was the case in this study, for a 99% confidence level with 5% margin of error, a sample size of 87 is representative of a population of 100 whereas a sample size of 285 is representative of a population size of 500.
- While it was desirable to work within a statistically representative sample that gives 5% margin of error and 95% confidence level and 20% response rate, the plastic sector does not have established data on the population size of manufacturers, the retailers and the recyclers.
- The confidence level for the study was based on available data from KAM, whereby the total number of manufacturers was 67. A sample size of 30 was was high enough to be representative of the manufacturer population without sacrificing certainty in the results. This was taken to apply to the sample sizes for recyclers and retailers within time and cost.
- Therefore, the number of actors sampled out of the population in order to achieve the required sample size was based on the response rate.

4.11.2 Challenges in Data Uncertainty

The data collection was idealized to represent only producers, retailers, recyclers and waste collectors deemed to represent significant pathways. The data therefore does not capture all the manufacturers/importers, recyclers and re-users and retail outlets in their entirety. Possible omissions include:

- Outlets that retail and dispose of plastics such as food preparation joints, salons, computer shops, flower vendors and general merchandise businesses which handle lots of packaging in general
- Plastics importers who are not necessarily manufacturers
- Other plastic waste collectors/handlers/scavengers not formally licensed by NEMA and CCN and whose input is not captured in CCN data.
- Retailed plastics in composite products such as sponges.
- Data management of plastic products is spread across various institutions and industry players, some formal and others informal, within the city. Accessing, collating and corroborating it is challenging
- Most enterprises polled expressed reservations regarding confidential business information. Data available from them is therefore largely estimates that would be verified by institutions that they would trust such as KAM.

4.11.3 Propagation of Uncertainties

Gaps in data collection and validation exist. These are highlighted as follows:-

- While the production cycle of a commodity in the manufacturing plant may require an overall duration of 2 weeks only, it is not established how long it takes before all produced commodities exit the plant and new raw materials are received
- Similarly, it was not established how much of and how long it takes before the various plastic resins streams sold out in retail outlets enter the waste cycle either for re-use, recycling or final disposal
- It was not established how many times various plastic resin streams are re-used/recycled before final disposal.
- There were disparities between total plastics manufactured, and the total sold. This may be attributed to various reasons singly or in combination. The disparities arose from inaccuracies in manufacturer’s records, fewer retailers polled in comparison to the manufacturers; the manufacturers were easier to locate as these are larger entities

producing bulk quantities and who are mainly established within designated industrial zones while the retailers and recyclers are much smaller numerous entities, spread all over within the study boundaries and handling small quantities. In addition, the manufacturers keep better mass records of their production than the retailers who keep numbers rather than mass records of the plastics and the recyclers whose mass measurement of the materials they handle is spread to countless handlers. For this reason, the estimates for respective plastic material disposal were based relative to the manufacture quantities as it would be more reliable.

4.12 DISCUSSIONS ON MASS BALANCE MODELS- PLASTIC MANUFACTURING

A complete and clear picture of plastic material flows at the city wide level has not been developed before. The geographic spread of plastic materials generation, pathways and disposal for Nairobi City has therefore not been earlier assessed. Best efforts were made to establish and fill the data gaps and inaccuracies through interpolation of available data.

Based on data analyzed in Section 4-1, the following mass balance models was developed for the study area and idealized into;

INFLOW ⟶ PROCESS ⟶ OUTFLOW

In order to develop the Mass Balance Models, the plastic mass quantities computations were assessed through idealizing five stages namely:

1. The Plastic Manufacture-Retail Transfer
2. The Plastic Retail-Consumer Transfer
3. The Plastic Consumption-Waste Generation Transfer cycle and the
4. The Plastic Waste Generation- Collection/disposal Transfer
5. The Plastic Waste Recycle-Re-use Transfer

The mass balance models were concluded so that the information therein would contribute to the first application of mass balance in plastic materials resource management. The models will also contribute to evidence-based decisions, policy and public debate for plastic materials use in Nairobi.

4.13 MANUFACTURE-RETAIL TRANSFER MASS BALANCE MODEL

4.13.1 Mass balance of Import to Manufacture

The Mass Balance Model 1 presents the mass quantities of plastics globally imported into and manufactured, converted into products and released for retail within the study boundaries. It also presents the mass that is imported but not converted into products.

Mass Balance Model 1: Plastics imported and converted into products

Imported resins (kg/week)	Process by Resin Type (kg/week)		Manufactured Resins (kg/week)	Resins loss (kg/week)
2,437,419.00	HDPE	500,300.00	2,436,175.00	1,244.00
	PET	366,000.00		
	LDPE	455,750.00		
	PP	585,500.00		
	PS	32,000.00		
	PVC	392,625.00		
	Others	104,000.00		
	Process by Product Type (kg/week)			
	Packaging materials	578,670.00		
	Carrier bags	78,500.00		
	Finished consumer products	1,522,040.00		
	Raw materials	191,340.00		
	Others	65,625.00		

In this model, there is a resin loss of 1,244 kg/week during the manufacturing process. Overall, 99.95% of imported plastic resins are converted into products. This loss is assumed to be taken up in recycling.

4.13.2 Plastics Sold from Manufacturing Industries in Nairobi

The Mass Balance Model 2 presents the mass of all plastics quantities manufactured and released for retail within Nairobi.

Mass Balance Model 2: Plastics Sold from Manufacturing Industries in Nairobi

Manufactured resins (kg/week)	Industrial Manufacturing Process	Sold resins (kg/week)	Resin loss (kg/week)
2,436,175.00		2,424,020.00	12,155.00

In this model, there is 12,155.00 kg/week resin loss during the transfer from manufacture into the retail process. Overall, 99.5% of manufactured plastic resins are sold out.

4.13.3 Plastics Retailed within Nairobi

The Mass Balance Model 3 presents the mass of plastic quantities that are manufactured and sold which end up in retail outlets within the study boundaries.

Mass Balance Model 3: Plastics Retailed within Nairobi

Resins manufactured & sold in Nairobi (kg/week)		Resins retailed and sold Nairobi (kg/week)	Total Resins loss (kg/week)
2,424,020.00	89 Retail Outlets	1,027,525.00	1,396,495.00

Weekly sales yielded 1,027,525.00 kg of plastic products sold to retail in Nairobi while the balance is sold outside the study boundaries. Therefore, overall, Nairobi retains 42.16 % of plastic materials in retail outlets and 42.7% (1,040,924.00 kg) of the total imported plastics.

4.14 RETAIL-CONSUMER TRANSFER MASS BALANCE MODEL

4.14.1 Plastics sold to Consumers from Retail Outlets within Nairobi

The Mass Balance Model 4 presents the mass of plastic resin quantities that are weekly sold to consumers in Nairobi from retail outlets.

Mass Balance Model 4: Retailed Plastics procured by retail outlets within Nairobi

Resins in released by industries to retail (kg/week)		Resins procured by retailers (kg/week)	Resins held in stock (kg/week)
1,027,525.00	Plastic Sales from Retail outlets in Nairobi	164,418.50	863,106.50

In Mass Balance Model 4, out of the 1,027,525.00 kg of plastic products reported by industries released to retail outlets into Nairobi, the study established only 164,418.50 kg as the mass procured by retailers per week. This is equivalent to 16 % of the retailed plastic materials are released for consumption. The balance of 84% is a huge data gap. Rather than un-accounted for, this quantity is assumed to be held up in stock, sold in composite form and sold in containers/packaging for other retailed products. In addition, the mass data record is critical and mandatory within the Manufacture-Retail Transfer while on the other hand, , the number of pieces and price among others as opposed to the mass data, is the crucial data in the Retail-Consumer Transfer cycle. Similarly, the Manufacture-Retail Transfer occurs in a controlled environment by few industries concentrated in one region and producing large masses per industry compared to the widespread environment within which the Retail-Consumer Transfer occurs with many retail outlets spread far apart selling only a few units per station. This gap is therefore attributed to the fact that some of the manufactured plastics products such as those used in packaging (24 %) and as raw materials for other products (8%) are not recognized in retail as plastic materials but rather as the commodities that they contain e.g. cooking oil, cosmetics. Manufacturers keep up-to-date records of mass quantities whereas retailers record numbers of units sold and rarely, the mass. Besides, manufacturing occurs in a centralized area producing bulk quantities whereby one manufacturer can supply to a wide area with high number of retailers city-wide holding small retail quantities. This is notwithstanding the fact that retailers sampled (89) were approximately three times as many as the manufacturers (30).

4.14.2 Retailed Plastics consumed within Nairobi

In this stage, the Mass Balance Model 5 is developed. It presents the mass transfer of plastic quantities sold from retailed to consumers within the study boundary.

Mass Balance Model 5: Retailed Plastics Sold to Consumers within Nairobi

Resins retailed in Nairobi (kg/week)	Retail Outlets Sales of Plastic in Nairobi	Resins sold from retail into Nairobi (kg/week)	Total Resins loss (kg/week)
164,418.50		127,170.60	37,247.90

In Mass Balance Model 5, of the 164,418.50 kg of plastic products sold to consumers in Nairobi weekly, 127,170.60 kg is retained within Nairobi while the balance is transferred out. Therefore, 77.35 % of retailed plastic materials are retained within Nairobi weekly.

4.15 PLASTIC CONSUMPTION - WASTE GENERATION - COLLECTION TRANSFER MODEL

4.15.1 Plastics Consumption to Waste Generation within Nairobi

The Mass Balance Model 6 presents the mass of plastics quantities sold to consumers and plastic wastes generation from the consumers in Nairobi.

Mass Balance Model 6: Waste Generation of Plastics Consumed within Nairobi

Total Resins sold from retail into Nairobi (kg/week)	CCN Plastic Waste Generation	Total plastic wastes generated in Nairobi (kg/week)	Total Resins Addition (kg/week)
127,170.60		1,352,141.00	(1,224,970.40)

In this Mass Balance Model 6, weekly, 127,170.60 kg of plastic products is sold to consumers in Nairobi. However, 1,352,141.00 kg/week of plastic wastes are generated within Nairobi. Given this data, the gap in tracking the consumer-waste generation transfer of the plastic products is attributed to the fact that waste data obtained from CCN was city-wide compared to data from sample retailers. It is assumed that the 863,106 kg/week that is captured lost at the retail is re-captured here by the CCN data. The plastic packaging sold out in retail (578,670 kg/week) and that used as a raw material for other production re-enters the waste stream as plastic materials. Essentially, the amount of plastics stocked in households in various uses remains for a longer time and becomes waste which additionally contributes to the plastic wastes generated. There is also the likelihood that plastic products obtained elsewhere e.g. direct imports by consumers within the study boundaries are disposed within.

4.15.2 Plastic Waste Generation and CCN Collection in Nairobi

The Mass Balance Model 7 presents the mass of generated plastic waste quantities that is collected within Nairobi. In Mass Balance Model 7, of the 1,352,141.00 kg of plastic wastes generated in Nairobi per week, 446,206.53 kg/week is collected by the CCN. This is equivalent to 33% collection within Nairobi weekly.

Mass Balance Model 7: Generated Plastic Wastes Quantities Collected within Nairobi.

Consumer - generated plastic wastes in Nairobi (kg/week)	CCN Plastic Waste Collection	CCN plastic wastes collection in Nairobi (kg/week)	Total uncollected Resins (kg/week)
1,352,141.00		446,206.53	905,934.47

4.16 PLASTIC WASTE COLLECTION- DISPOSAL TRANSFER MASS BALANCE MODEL

4.16.1 CCN Waste Collection, Diversion and Final Disposal in Nairobi

The Mass Balance Model 8 presents the mass of plastic wastes quantities collected, diverted and disposed in Nairobi.

Mass Balance Model 8: Plastic Wastes Diverted after Collection within Nairobi.

CCN plastic wastes collection in Nairobi (kg/week)	CCN Plastic Waste Diversion	CCN plastic wastes diversion in Nairobi (kg/week)	Total Disposed Resins (kg/week)
446,206.53		62,468.91	383,737.62

In Mass Balance Model 8, of the 446,206.53 kg plastic wastes weekly collected, 62,468.91 kg/week is diverted and does not reach final disposal. It is assumed that the diverted wastes are taken up in recycling and re-use. This is equivalent to 33% collection within Nairobi weekly. Therefore, only 28.38% of the plastic wastes generated weekly reach final disposal.

4.17 PLASTIC WASTE RECYCLE/RE-USE TRANSFER

4.17.1 Plastics Wastes Recycled within Nairobi

This presents the mass balance of recycled plastic wastes quantities in Nairobi.

Mass Balance Model 9: Plastic Wastes Quantities Recycled Within Nairobi.

	Plastic recycling sources (kg/week)	Recycling plastic materials sourced in Nairobi (kg/week)	Recycled plastic products sold in Nairobi (kg/week)	Swell for recycled resins (kg/week)
Import Rejects	1,244.00	393,462.66	570,740.00	-177,277.34
Manufacturing loss	12,155.00			
3R in Retail	5,144.75			
Recyclers from other towns	71,557.00			
Recyclers from Nairobi	240,893.00			
Diverted from CCN	62,468.91			

Quantities that constitute recycled content are as follows; the imported plastic resins lost at manufacturing stage, plastic manufacturing rejects, plastics subjected to 3R by retailers, recycling materials directly obtained from Nairobi and other towns and collected plastic wastes that are diverted from CCN prior to final disposal. This constitutes 393,462.66 kg/week taken in for recycling and it is equivalent to a 38.29 % of manufactured plastics retailed in Nairobi. This recycling rate compares well with findings for other developing countries such as Delhi which had a 27% recycling rate (UN-Habitat, 2010). In a 2010 report, the UN-Habitat found that many developing and transitional country cities have active informal sector recycling, reuse and repair systems, which are achieving recycling rates comparable to those in the developed countries (UN-Habitat, 2010).

However, recycled plastic products constituted 570,740.00 kg/week. There is therefore a data gap in transfer of material taken in for recycling and materials made from recycled plastic content. This data gap can be explained as the arising from the additional use of recycling ingredients to boost the quality of recycled products whereby recycled feedstock bulks and weighs more than virgin feedstock.

4.17.2 Plastics Manufactured, Collected and Recycled within Nairobi

This presents the mass balance of manufactured, collected and recycled plastic wastes quantities in Nairobi.

Mass Balance Model 10: Quantities of Manufactured, Disposal and Recycled Plastic within Nairobi.

<table>
<tr><td>Resins Manufactured and sold into retail (kg/week)</td><td rowspan="4">Recycled and Disposed</td><td>plastic materials sourced for recycle in Nairobi (kg/week)</td><td>Plastic materials recovered (recycle/disposed) in (kg/week)</td></tr>
<tr><td rowspan="3">1,027,525.00</td><td>393,462.66</td><td rowspan="3">777,200.28</td></tr>
<tr><td>Total collected and disposed Resins (kg/week)</td></tr>
<tr><td>383,737.62</td></tr>
</table>

In this Mass Balance Model 10, the quantity of plastics that enters in Nairobi is 1,027,525.00 kg/week. The combined quantities of disposed and recycled plastics are 777,200.28 kg/week. This is equivalent to 75.64% removal rate. The mass balance case study identifies that 24.36% of plastic products is not accounted for through the plastic material flow system.

4.18 The Benefits of the Mass Balance Models

The plastic materials flow for Nairobi.is graphically presented in Figure 4-26 and Figure 4-27

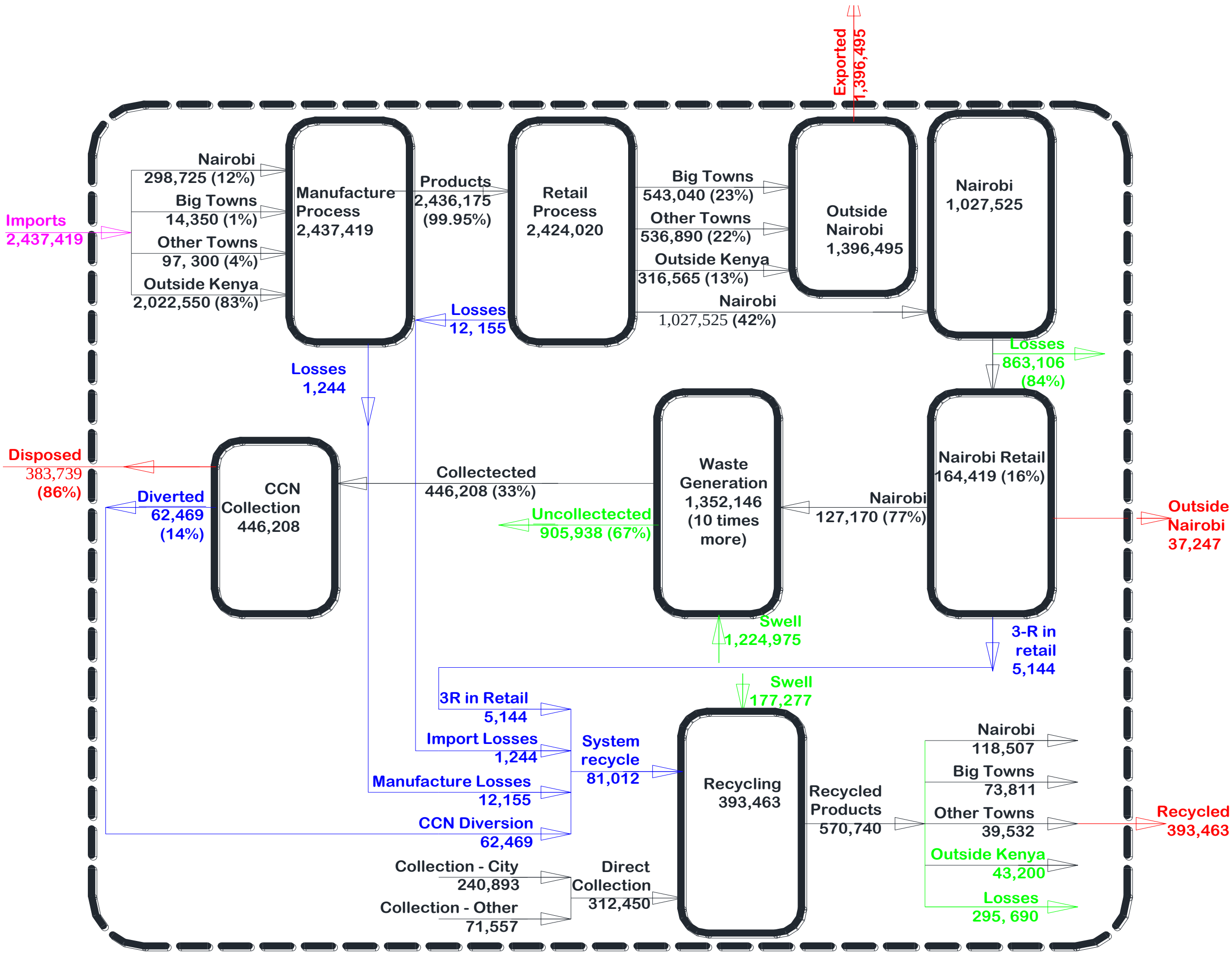

Figure 4-27: Flow of plastic materials(kg/wk) within the study boundaries

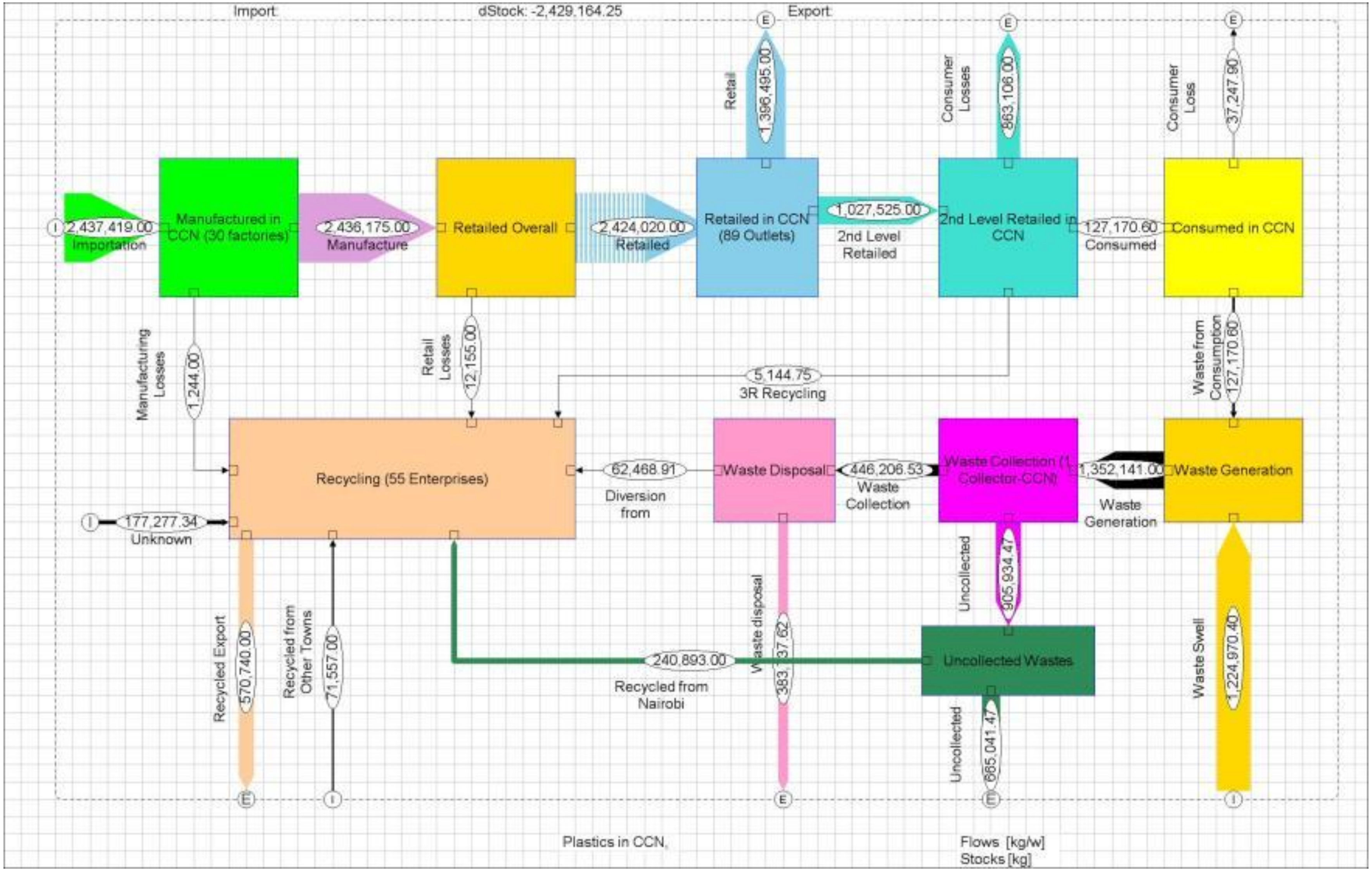

Figure 4-28: Plastic Materials flow (kg/wk) within the Study Boundaries as Analysed in STAN

The main advantages of the mass balance models was that uniform methodology, reproducible results and a comprehensive knowledge base for generation, pathways and accumulations of plastic materials was arrived at enabling accountability in supporting plastics management decisions. The case study promotes understanding of origins and sinks of plastic materials with in the study boundaries having achieved goals as follows:-

- Ability to track plastic substances through the supply chains.
- Identified data gaps in tracking the movement of plastic materials.
- Provision of information to guide decisions. In this case, 24.36 % of plastic materials that entered the study boundaries were not tracked at the exit.
- Increased opportunity for identification for plastic materials for recovery

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

1) The study has idealized and quantified the production, the transfer, accumulation and waste generation and disposal flows of the common plastic resins. The flows are industrial manufacture, retail and consumption, plastic waste generation at residential and commercial sources, collection, recycling and final disposal in terms that allowed for the mass balances of plastics for Nairobi City to be written.
2) The identified and compiled industrial production from manufacture was 2,436,176 kg/week and plastic waste quantities generated from retail and consumption of the various common plastic resins was 1,352,141.00 kg/week.
3) There are data losses that opened up gaps of essential quantities. Whereas the manufacturer's data showed 1,027,525.00 kg/week, the retailers' weekly sales data showed 164, 419 kg/week, thereby an 84% loss in data accountability. The plastic waste generation showed a 32% increase from manufactured quantities, at 1,352,141.00 kg/week. The CCN recovery through collection and final disposal was 446,206.53 kg/week and 383,737.62 kg/week respectively. Plastic waste materials recovery from recycling was 393, 462.66 kg/week. Overall there is a 25 % data gap comparing weekly production quantities (1,027,525.00 kg) and combined weekly recovery from final disposal and recycling (777,200.28 kg/week).
4) There was a diminishing trend in comparable data – while manufacturing data was clearly, in seven resin categories, retailed plastic and plastics waste data was in mixed resins and therefore data tracking in plastic resin categories was lost. Reasonable assumptions were made in order to proceed with the mass balance.
5) Regular statistics on plastic wastes do not exist, not with CCN, KEBS, KAM or NEMA. Available data is individually, independently spread with the various actors. The data recorded and compiled by key actors is deficient in establishing and tracking the seven resin categories in terms of collection rates, transfer rates and final disposal.
6) The rate of plastic wastes removal rate by the CCN which has been operational for more than three decades is 37% (383,739 kg/week). This compares well with that by recycling enterprises at 39% (393, 463 kg/week) in spite of having been operational for only two

years. Many private owned enterprises have taken up the opportunity presented in plastic wastes recycling enterprise.

7) The recycling enterprises are outside of the "formal" waste management system and yet, at no cost to the formal sector and with additional licensing levies charged on them, they provide livelihoods to huge numbers, and save the city as much as 39% per cent of its plastic waste management budget by reducing the amount of waste that would otherwise have to be collected and disposed of by the city.

5.2 RECOMMENDATIONS

The following are recommendations based on data obtained, aimed to inform and motivate policy changes with respect to plastic products so that environmental problems are reduced.

1) The recycling rate shows significant results achieved by the private driven, informal sector enterprise that ought to be promoted. The informal sector's point of entry is at the plastic waste collection stage. Authorities such as City County of Nairobi ought to build on the foundation offered by the private enterprise to increase further the collection and recycling rates. This can be achieved by developing legal and institutional framework as well as policies that support and give incentives to accelerate private sector growth and operations by addressing the following:-

    - Legal framework that offers duty waivers for recycling machines,
    - Legal and institutional framework that sets up designated plastic recycling zones that offer collective benefits
    - Evaluation/introduction of recycling licensing criteria and tipping fees on certain plastic resin wastes at final disposal sites,
    - Establishment of drop off points for waste plastics by consumers so that recyclers use them as collection depots,
    - Enforcement of waste sorting into reasonable plastic categories at domestic, commercial and other generation points, at the waste transfer and material recovery stations and at the disposal sites in order to ease the recycling effort and rid the city streets of scavenger cartels.

2) The KEBs should develop, update and enforce standards for plastic recycling as well as plastic material identification and labelling coupled with awareness and education for consumers and plastic waste handlers' on the same. This will benefit the retailers,

consumers and collection crew for ease of recycling and aid in estimation of mass of plastic products.

3) Data is power in that without data collection and management systems, it will always be difficult to account for plastic material movement. Future studies and industry would benefit from having up-to-date data that closes the gaps in plastic material flows within the study boundaries. Establishment of a system of continuous data collection, recording and management by the various key actors, namely; manufacturers, retailers, collection and disposal and recyclers together with identification of a repository/custodian institution for this data is an essential.
4) The mass balance study reveals the need for education, lobbying and awareness creation towards establishment of respective umbrella bodies for retailers and recyclers whose key mandates would be policy advocacy and data collection, collation and compilation among others.
5) This mass balance case study ought to be periodically updated in future, as part of a regular exercise of data collection and material tracking applicable to inform policy and legislative directions. Further work can be carried out as mass balance studies for individual plastic resins such as PET, PVC and PS

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APPENDICES

Appendix 1. Survey Tool used for Plastic Manufacturing Plants

PART A - ORGANIZATION DETAILS

1. Enumerator's Name________________________________
2. Name of the Respondent Organization________________________________
3. Where are you located________________________________(Street Name)
4. For how long has the Organization existed________________________________
5. Designation of respondent________________________________
6. Organization's address________________________________

PART B – PRODUCTION DETAILS

1. What Plastic resins do you manufacture/import? (Tick appropriate)
   - ☐ High-Density Polyethylene (HDPE)
   - ☐ Polyethylene TelePhthalate (PET)
   - ☐ Low-Density Polyethylene (LDPE)
   - ☐ Polypropylene (PP)
   - ☐ Polystyrene (PS)
   - ☐ Polyvinyl Chloride (PVC)
   - ☐ Others, (Please Specify)____________________
2. Where do you source the raw materials used in the manufacture/imports?
   - ☐ Within Nairobi______________%
   - ☐ Mombasa, Nakuru, Kisumu, Thika or Eldoret________________%
   - ☐ Other towns in Kenya ________%
   - ☐ Outside Kenya______________%
3. What's your average weekly production/importation?________________(Kilograms kg)
   - ☐ High-Density Polyethylene (HDPE)
   - ☐ Polyethylene TelePhthalate (PET)
   - ☐ Low-Density Polyethylene (LDPE)
   - ☐ Polypropylene (PP)
   - ☐ Polystyrene (PS)
   - ☐ Polyvinyl Chloride (PVC)
   - ☐ Others, (Please Specify)____________________
4. To what use are your plastic products put?
   - ☐ Packaging material
   - ☐ Carrier bags
   - ☐ Other Finished consumer product
   - ☐ Raw materials for other products
   - ☐ Others, (Please Specify)____________________

PART C – DESTINATION DETAILS

1. How long does it usually take, for procured raw materials to exit the organization?_____(wks)
2. Where is your common target market? (Please indicate percentage)
   - ☐ Within Nairobi______________%
   - ☐ Mombasa, Nakuru, Kisumu, Thika or Eldoret________________%
   - ☐ Other towns in Kenya ________%
   - ☐ Outside Kenya______________%
3. Are you involved in recycling or Re-use of your plastic products? *Yes (__)* *No (__)*
4. If yes what percentages do you recycle/re-use? ____________________%

PART D – OPINION

1. What Challenges do you encounter in management of industries and wastes for your type of plastics? ________________________________
2. What policy developments would you recommend in relation to production and management of your type of plastics? ________________________________
3. What's your take concerning an umbrella trade association for plastic manufacturers? Do they have a niche interest not represented by KAM?

   ____
4. What are your organization's prospects of future growth in production? *Increase (__) Decrease (___) No Change (___)*

Appendix 2. List of Manufacturing Plants Sampled

	Ref	Name	Location	Age (yrs.)	Respondent	Organization's address
Zone E	01	General Industries Ltd.	Pemba Street	7	Supervisor	_
Zone D	02	Premier Industries Ltd	Baba Ndogo	11	Supervisor	P.O. Box 22460-00400 Nairobi
	03	Recycling Enterprises	Kariobangi South	10	Owner	P.O. Box 47105-0016 Nairobi
	04	Afro Plastics Ltd.	Baba Ndogo	30	Supervisor	P.O. Box 34190-00100 Nairobi
Zone C	05	Complast Industries Ltd.	Sasio Road off Lunga Lunga	15	Production Manager	P.O. Box 78313 Nairobi
	06	Sumaria industries	Industrial area Migwani Road	33	Production Manager	P.O. Box 42565Nairobi
	07	General plastics Ltd	Funzi Road off Enterprise Road	37	Production Manager	P.O. Box 10032 Nairobi
	08	Packaging Industries Ltd (PIL)	Nadume Road off Lunga Lunga Rd	25	Production Manager	P.O. Box 48811 - 00100 Nairobi
	09	Roto Moulders ltd	Industrial area, Enterprise Road	20	Production Manager	P.O. Box 26393- 00504 Nairobi
	10	Kentainers Ltd. Nairobi (tanks)	North Airpport Road Embakasi	17	Production Manager	P.O. Box 40168- 00100 Nairobi
	11	Mamba tanks	Industrial area, Enterprise Road	12	Production Manager	P.O. Box 73346 Nairobi
	12	Ken Aluminium Products Ltd	Lunga Lunga Rd	33	Production Manager	P.O. Box 78012-00507 Nairobi
	13	Adix Plastics Ltd	Sasio Road off Lunga Lunga	11	Sales Manager	P.O. Box 22276-00400 Nairobi
	14	Crown Industries	Industrial area, Enterprise Road	26	Director	P.O. Box 40119 Nairobi
	15	Metro Plastics Limited	Nadume Road off Lunga Lunga Rd	25	Sales Manager	P.O. Box 78485-00507 Nairobi
	16	Techno Plast Ltd.	Nadume Close off Lunga Lunga Rd	17	Sales Manager	P.O. Box 45424-00100 Nairobi

	Ref	Name	Location	Age (yrs.)	Respondent	Organization’s address
	17	Kenpoly Industries Ltd.	Along Lunga Lunga Rd	34	Production Manager	P.O. Box 30032-00100 Nairobi
	18	Teepee Brush Manufacturers Ltd.	Along Lunga Lunga Rd	35	Sales Manager	P.O. Box 48865 Nairobi
	19	General Industries Ltd.	Lusaka Road	39	Production Manager	P.O. Box 41682-00100 Nairobi
Zone B	20	Kevian Kenya Ltd	Off Ngong Road	8	Sales Manager	P.O. Box 25290-00603 Nairobi
	21	Flexpac International	Near Magana Flowers off Naivasha Road	16	Production Manager	P.O. Box 63318-00619 Nairobi
	22	Africa Polysak Ltd	Maasai Road, off Mombasa Road	11	Sales Manager	P.O. Box 18869-00500 Nairobi
	23	NCT Middle East FZE	Waiyaki way	13	Sales Manager	P.O. Box 78443-00507 Nairobi
	24	Sarrchem Int.	ABC Place , Waiyaki Way	10	Sales Manager	P.O. Box 63289-00619Nairobi
	25	Vitafoam Products	Along Mombasa Rd	44	Sales Manager	P.O. Box 18094-00500 Nairobi
	26	Polymed E.A.	Panari Sky Centre Mombasa road	11	Sales Manager	P.O. Box 100479-00101 Nairobi
	27	Kevnoe Plastics EPZ	Ndege Road, Karen	10	Production Manager	P.O. Box 198-00502 Nairobi
	28	Safepack Ltd	Maasai Road, off Mombasa Road	15	Sales Manager	P.O. Box 39060 Nairobi
	29	Sanpac Africa Ltd.	Mombasa Road opposite JKIA	21	Sales Manager	P.O. Box 39080 Nairobi
	30	Talani plastics	Off Mombasa Road	8		P.O. Box 48594-00100 Nairobi
Zone A						

Appendix 3. Survey Tool used for Plastic Retail Outlets

PART A - ORGANIZATION DETAILS

1. Enumerator's Name____
2. Name of the Respondent Organization____________________________________
3. Where are you located____________________________________(Street Name)
4. For how long has the Organization existed________________________________
5. Designation of respondent____
6. Organization's address____

PART B – PRODUCTION DETAILS

1. What Plastic resins do you commonly distribute? (Tick appropriate)

- ☐ High-Density Polyethylene (HDPE)
- ☐ Polyethylene TelePhthalate (PET)
- ☐ Low-Density Polyethylene (LDPE)
- ☐ Polypropylene (PP)
- ☐ Polystyrene (PS)
- ☐ Polyvinyl Chloride (PVC)
- ☐ Others, (Please Specify)______________________

2. Where do you source the plastic products that you distribute?

- ☐ Within Nairobi_______________%
- ☐ Mombasa, Nakuru, Kisumu, Thika or Eldoret____________________%
- ☐ Other towns in Kenya _________%
- ☐ Outside Kenya_______________%

3. What's your average weekly distribution?___________________(Kilograms-Kg)

- ☐ High-Density Polyethylene (HDPE)
- ☐ Polyethylene TelePhthalate (PET)
- ☐ Low-Density Polyethylene (LDPE)
- ☐ Polypropylene (PP)
- ☐ Polystyrene (PS)
- ☐ Polyvinyl Chloride (PVC)
- ☐ Others, (Please Specify)______________________

4. To what use are your plastic products put?

- ☐ Packaging material
- ☐ Carrier bags
- ☐ Other Finished consumer product
- ☐ Raw materials for other products
- ☐ Others, (Please Specify)______________________

PART C – DESTINATION DETAILS

1. How long does it usually take, for procured raw materials to exit the organization?_____(wks)
2. Where is your common target market? (Please indicate percentage)

- ☐ Within Nairobi_______________%
- ☐ Mombasa, Nakuru, Kisumu, Thika or Eldoret________%
- ☐ Other towns in Kenya _________
- ☐ Outside Kenya_______________

3. Are you involved in efforts to reduce, recycle or re-use the plastic products that you distribute? *Yes (___) No (___)*
4. If yes what percentages do you recycle/re-use? __________________________%

PART D – OPINION

1. What Challenges do you encounter in management of your type of plastics and plastic wastes? ____
2. What policy developments would you recommend in relation to production and management of your type of plastics? ____
3. What are your organization's prospects of future growth in production? *Increase (__) Decrease (___) No Change (___)*

Appendix 4. List of Retail Outlets Sampled

Ref	Name	Location	Age (yrs.)	Organization's address
1	Tuskys OTC	Landhies Road	6	P.O Box 54280-00200 Nairobi
2	Maxcare Hardware	Ngara Road	1	
3	Wanjiru (Asam Limited)	River Road	20	
4				
5	Eastmatt stores	Mfangano Street	6	
6	Ebrahims Limited	Moi Avenue	10	P.O Box, 40897-00100 Nairobi
7	Nakumatt Haile-selasie	Haile-Selasie Avenue	1	P.O Box 78355-00507 Nairobi
8	Uchumi City Square	Aga Khan Walk	30	P.O Box 73167-00200 Nairobi
9	Jack N Jill OTC	Temple Road/ Race Course Road	25	P.O Box 47107 Nairobi
10	Arcos Matress Limited	Racecourse Road	6	
11	Brison Hardware Limited	Luthuli Lane	6	
12	Rumu Eletricals	River Road	8	
13	ENT Limited	Mwimbi Road	11	
14	Bini Wholesalers Limited Nairobi	Yatta Road	10	
15	Matunda Plastics Limited	Cross Road	10	
16	Lotus Enterprise Limited	Ukwala Road	15	
17	Gatogo Enterprise Limited	Ngara Road	15	
18	Naivas	Ronald Ngala	1	P.O Box, 61600-00200 Nairobi
19	Ukwala Bus Station	Haile-Selasie Avenue	3	P.O Box 34667-0200 Nairobi
20	Nakumatt Moi Avenue	Moi Avenue	1	P.O Box 78355-00507 Nairobi
21	Nakumatt City Hall	Wabera Street	1	78355-00507
22	Nakumatt Haile Selasie	Haile-Selasie Avenue	1	P.O Box 78355-00507 Nairobi
23	Tuskys Chap Chap	Muindi Mbingu Street	3	P.O Box 5428-00200 Nairobi
24	Nakumatt Lifestyle	Monrovia/ Moktar Daddah Street	5	P.O Box 78355-00507 Nairobi
25	Tuskys Imara	Tom Mbpoya Street	6	P.O Box 54280-00200

Ref	Name	Location	Age (yrs.)	Organization’s address
				Nairobi
26	Ramco Hardware Limited	Sheikh Karume Road	20	
27	Nikunj Wholesalers Limited	Ngwasi Ukwala Road	15	
28	Uchumi Koinange	Monrovia Street	12	P.O Box 73167-00200 Nairobi
29	Baba Ndogo Hardware	Baba Ndogo near the police station	1	020889600, P.O. Box 609-0618 Nairobi
30	New Ruaraka hardware	Baba Ndogo Road	20	0733511665, P.O. Box 51837-00200 Nairobi
31	Kikomba Mattresses Supermarket	Pumwani Road	10	0721806580, P.O. Box 51837-00200 Nairobi
32	Vimit Ltd	Pumwani Road	2	P.O. Box 18560-00300 Nairobi
33	Centroline Supermarket Ltd, Eastleigh	Eastleigh, section 1	15	P.O. Box 45149-00100 Nairobi
34	Lango Supermarket	Mlango Kubwa	7	P.O. Box 49887-00100 Nairobi
35	Arithi polythene bags & sweets	Eastleigh,	2	0726684935, 0720676675
36	Mesoro Supermarkets Ltd.	Buru Buru	15	0721896642, P.O. Box 54787 Nairobi
37	Bismillahi Design Shop	Eastleigh	4	0721997675
38	Banadir Minimarket	Eastleigh	3	0711623476
39	Balu Balu Enterprises	Kamukunji Rd	5	0728735684, P.O. Box 337337 Nairobi
40	Ngetcha Enterprises	Kamukunji Rd	20	0724484709
41	Gladys Supermarket (Mini)	Gikomba	8	0725134911, P.O. Box 13494 00200 Nairobi
42	Horyal Supermarket	Eastleigh	5	0727977777, P.O. Box 16201-00610 Nairobi
43	Dirie One Supermarket	Eastleigh	7	0720961598, P.O. Box 71701-00622 Nairobi
44	Mini-Bakeries	Isiolo road, off Enterprise Road	23	P.O. Box 17592 Nairobi
45	Sabmiz Enterprises Ltd	Off Dar-es-Salaam Rd, Industrial area	20	P.O. Box 18305-00500 Nairobi
46	Naivas Eastgate	Tena estate, along Outering road	3	P.O. Box 61600-00200 Nairobi

Ref	Name	Location	Age (yrs.)	Organization's address
47	Tumaini self-Service Ltd	Along Outering Road, next to Caltex	1	P.O. Box 339-00507 Nairobi
48	Gulf timber and hardware supplies	Along Enterprise Road	12	P.O. Box 41347-00100 Nairobi
49	Basco Paints Kenya Limited	North Airport Road, Embakasi	35	P.O. Box 34424-00100 Nairobi
50	Tusky's Embakasi	North Airport Road, Embakasi	0.5	P.O. Box 54280 Nairobi
51	Chandarana Supermarket	Yaya Centre	20	P.O. Box 14078-00800 Nairobi
52	San Jackson Electronics	Kawangware	5	P.O. Box 65021 Nairobi
53	Nakumatt Karen	Langata Road, Karen	6	P.O. Box 78355 Nairobi
54	Nakumatt Prestige	Ngong Road	8	P.O. Box 78355- 00507 Nairobi
55	Nakumatt Junction	Ngong Road	7	P.O. Box 78355- 00507 Nairobi
56	Nakumatt Galleria	Langata Road, Karen	1	P.O. Box 78355- 00507 Nairobi
57	Millenium Timber and Hardware	Dagorreti Corner, Ngong Road	6	www.mocality.co.ke/millenium
58	Rovek Ventures	Ngong Road	4	P.O. Box 86522 Nairobi
59	Waleg Hardware Ltd	Karandini Road	11	P.O. Box 24688 Nairobi
60	Uchumi Ngong Hyper	Ngong Road	11	P.O. Box 73167- 00200 Nairobi
61	Tusky's T-Mall	Langata Road	2	P.O. Box 54280 - 00200 Nairobi
62	Davester Enterprises	Langata Road	10	P.O. Box 25566- 00502 Nairobi
63	Uchumi Lang'ata Road	Langata Road	10	P.O. Box 73167 - 00200 Nairobi
64	Chandarana Supermarket, Lavington	Lavington green, - James Gichuru Road	18	P.O. Box 14078 - 00800 Nairobi
66	Uchumi Supermarket (Sipange Branch) Thika Road	Ruaraka	8	P.O Box 73167 Nairobi
67	Kibishi Jipange Hardware	Ruaraka Thika Road	8	P.O Box 32970- 00600 Nairobi
68	Jimco Hardware	Kahawa Sukari	4	P.O Box 427000-00100 Nairobi
69	Peflo Hardware	Kiambu Town Kiambu Road		P.O Box 44824 Nairobi

Ref	Name	Location	Age (yrs.)	Organization's address
70	Nyakio Hardware	Githurai 44	6	P.O Box, 62638-00200 Nairobi
71	Charma Enterprises	Githurai 45	20	P.O Box 76065- 00200 Nairobi
72	Sisbro Hardware	Woodvale Street Westlands	2	
73	Aliwoth Hardware	Ngara East- Muranga Road	6	P.O Box 22507 00400 Nairobi
74	Plumbline Hardware	Unga lane Westlands	10	P.O Box 66899 00800 Nairobi
75	M.K Hardware	Githurai 45	12	P.O Box 72682 20200, Nairobi
76	Kika Polythene	Kiambu Biashara Street	4	P.O Box 436 00900 Kiambu
77	Kassmart Supermarket Limited	Githurai 45 Thika Road	7	P.O Box 308 00610 Nairobi
78	3 in 1 Hardware	Ruaka Town	2	
79	Najacha Enterprises	Ruaka Town	5	P.O Box 63159 00619 Nairobi
80	Stanmatt Soko Limited	Githurai 45 Thika Road	5	P,O Box 51618 00200 Nairobi Tel. 0722347477
81	Chandarana Supermarket	Ngara Road	1	P.O Box 14078 00800 Nairobi
82	Kamindi Supermarket	Kiambu Town Kiambu Road	20	P.O Box 675 0200 Kiambu
83	Home Choice Investments	Ngara Road	4	P.O Box 921 00621 Nairobi
84	Cleanshelf Supermarket	Kiambu Town Kiambu Road	10	P.O Box 1828 Kiambu
85	Uchumi Supermarkets, Westlands Branch	Westlands	30	P.O. Box 73176 Nairobi
86	Uchumi Supermarkets, Sarit Centre	Westlands	15	P.O. Box 73176 Nairobi
87	Nakumatt Westgate	Westlands, Mwanzi Road	4	P.O. Box 78355-00507 Nairobi
88	Nakumatt Ukay	Westlands	17	P.O. Box 78355 Nairobi
89	Cocorico Polythene	Githurai 43	0.5	P.O. Box 30852 - 00100 Nairobi

Appendix 5. Survey Tool used for Plastic Recycling Enterprises

PART A - ORGANIZATION DETAILS

1. Enumerator's Name____
2. Name of the Respondent Organization____________________________________
3. Where are you located__________________________________(Street Name)
4. For how long has the Organization existed_____________________________
5. Designation of respondent____
6. Organization's address____

PART B – PRODUCTION DETAILS

1. What Plastic resins do you recycle/re-use? (Tick appropriate)
   - ☐ High-Density Polyethylene (HDPE)
   - ☐ Polyethylene TelePhthalate (PET)
   - ☐ Low-Density Polyethylene (LDPE)
   - ☐ Polypropylene (PP)
   - ☐ Polystyrene (PS)
   - ☐ Polyvinyl Chloride (PVC)
   - ☐ Others, (Please Specify)___________________
2. Where do you source the plastic materials that you recycling from?
   - ☐ Within Nairobi______________%
   - ☐ Mombasa, Nakuru, Kisumu, Thika or Eldoret________________%
   - ☐ Other towns in Kenya ________%
   - ☐ Outside Kenya______________%
3. What's your average weekly uptake (procurement) of plastic materials for recycling (Kg)?
   - ☐ High-Density Polyethylene (HDPE)
   - ☐ Polyethylene TelePhthalate (PET)
   - ☐ Low-Density Polyethylene (LDPE)
   - ☐ Polypropylene (PP)
   - ☐ Polystyrene (PS)
   - ☐ Polyvinyl Chloride (PVC)
   - ☐ Others, (Please Specify)___________________
4. To what use are your recycled plastic products put?
   - ☐ Remolded into Construction poles___________%
   - ☐ Shredded to Pellets for export_____________%
   - ☐ Compacted into bales for re-sale___________%
   - ☐ Resold in similar form__________
   - ☐ Others, (Please Specify)_________

PART C – DESTINATION DETAILS

1. How long does it usually take, for procured recycled materials to exit the organization?_____(wks)
2. Where is your common target market of recycled products? (Please indicate percentage)
   - ☐ Within Nairobi______________%
   - ☐ Mombasa, Nakuru, Kisumu, Thika or Eldoret________________%
   - ☐ Other towns in Kenya ________%
   - ☐ Outside Kenya______________%
3. Are you involved in re-use of your plastic products? *Yes (___)* *No (___)*
4. If yes what percentages do you recycle/re-use? ________________________%

PART D – OPINION

1. What Challenges do you encounter in management of recycling/re-use activities for your type of plastics? ____
2. What policy developments would you recommend in relation to recycling and re-use of your type of plastics? ____
3. What are your organization's prospects of future growth in production? *Increase (__) Decrease (___) No Change (___)*

Appendix 6. List of Recyclers Organizations Sampled

	Respondent	Where located	Age (yrs.)	Designation	Organization's address
1	Jacob Otieno	Pemba Street	5	Owner	_
2	Jacob Otieno	Pemba Street	6	Owner	_
3	Jacob Otieno	Pemba Street	7	Owner	_
4	John Mwangi	Musindi Lane	7	Owner	_
5	Jane Nthenya	Workshop Road	8	Owner	_
6	Jane Nthenya	Workshop Road	8	Owner	_
7	Jane Nthenya	Workshop Road	8	Owner	_
8	Maurice Ouma	Factory Street	4	Owner	_
9	Samson Mwangi	City Stadium Roundabout	15	Owner	_
10	Maina	Musindi Road	6	Owner	_
11	Susan Wairimu	Irungu Riika Road	10	Owner	_
12	Susan Wairimu	Irungu Riika Road	10	Owner	_
13	James Maina	Irungu Riika Road	8	Owner	_
14	Susan	Kombo Munyiri road	6	Owner	_
15	John Musyimi	Rendille road	4	Owner	_
16	General Industries Limited	Factory Street	_	Supervisor	_
17	Hassan	Kirinyaga road	5	Owner	_
18	Hassan	Kirinyaga road	5	Owner	_
19	Jamlek kamau	Muthurwa raod	3	Owner	_
20	Jamlek kamau	Muthurwa raod	4	Owner	_
21	Jamlek kamau	Muthurwa raod	5	Owner	_
22	_	Kijabe Street	10	Owner	_
23	_	Kijabe Street	10	Owner	_
24	_	Kijabe Street	10	Owner	_
25	Wilson Saningu	Kirinyaga road	30	Owner	_
26	Wilson Saningu	Kirinyaga road	30	Owner	_
27	Wilson Saningu	Kirinyaga road	30	Owner	_
28	Wilson Saningu	Kirinyaga road	30	Owner	_
29	Jared	Kirinyaga road	5	Owner	_
30	Jared	Kirinyaga road	5	Owner	_
31	Jared	Kirinyaga road	5	Owner	_

	Respondent	Where located	Age (yrs.)	Designation	Organization's address
32	Kimani	Quarry Road	4	Owner	_
33	Mary Wambui	Quarry Road	5	Owner	_
34	Ann Kamau	Racecourse Road	6	Owner	_
35	James Maina	Racecourse Road	11	Owner	_
36	Reuben Maina	Racecourse Road	15	Owner	_
37	Stephen Muriuki	Factory Street	2	Owner	_
38	Stephen Mutua	City Stadium Roundabout	15	Owner	_
39	Msanii	Landhies Road	1	Owner	_
40	Jacob Kariuki	Landhies Road	2	Owner	_
41	Jackline Adhiambo	Baba Ndogo industrial area	0.5	Project Manager	_
42	Base	Baba Ndogo industrial area	1	Employee	
43	Base ya Vijana	Kware - Mathare North	2.5	Project Manager	_
44	Kwa Mama Njoro	Hamisi road, Eastleigh	2	Owner	_0720540588
45	Kwa Timo Base	Dandora	7	Owner	_0725120679
46	Pangani Base	Pangani Estate	20	Employee	_0721724679
47	Wachira Base	Eastleigh	1	Owner	_0716329290
48	Machokosh	Eastleigh	1	Owner	_0721720978
49	Wa Alex	Eastleigh North	2	Owner	_0729153502
50	Raunda Organization	Kariobangi/Dandora Roundabout	14	Project Manager	_0721609745
51	Premier Industries Ltd.	Baba Ndogo	11	General Supervisor	_0722511173
52	Boiler Base	Along Outering road	1	Owner	
53	Pemos Collectors	Enterprise Road Industrial Area	5	Sales manager	P.O. Box 63280-Nairobi
54	TeePee Brush Manufacturers ltd	Lunga Lunga	35	Sales manager	P.O. Box 48865-Nairobi
55	Ndung'u and Sons	Likoni Road	1	Owner	P.O. Box 78695-00507 Nairobi
56	Bruce Yellow Bins	Likoni Road	20	Owner	P.O. Box 79375-00200 Nairobi
57	December Waste Services	Likoni Road	3	Sales manager	P.O. Box 17952 Nairobi

	Respondent	Where located	Age (yrs.)	Designation	Organization's address
58	Obaa Waste services	Likoni Road	11	Owner	P.O. Box 17954 Nairobi
59	Ngong Dumpsite Recycle	Ngong Town - ngong Road	1	Owner	
60	Kawangware Recyclers	Off Gitanga Road	2	Owner	
61	Kibera Recyclers	Off Kibera Drive	2	Owner	
62	Hardy Recyclers	Off Lang'ata south Road	3	Owner	
63	Co-operative College	Maasai lane opposite Co-op College	1.5	Owner	
64	Karen Recyclers	Ngong Road	3	Owner	
65	Keti Chini	Githurai 44	12	Owner	
66	Kwa Davy	Westlands-Parklands Rd-Crescent Lane	3	Sales manager	_0721825349
67	680	Westlands-Crossway Rd off Parklands Rd	10	Owner	P.O. Box 72772-00200 Nairobi
68	Classic plastics	Ruiru town - Kiambu road at Prisons	4	Sales manager	P.O. Box 1101-00232 Ruiru
69	AgriPlast Kenya Ltd	Thika Road next to Clayworks	6	Sales manager	P.O. Box 39183-00623 Nairobi
70	Scrap dealer	Kiambu Town	2	Sales manager	