RECYCLING OF PLASTIC WASTES IN KENYA: A SURVEY

BARUTHI O. MUGAMBI

"A thesis submitted to the Department of Mechanical Engineering of the University of Nairobi in partial fulfillment of the requirements for the degree of Master of Science (Industrial Engineering option) in Mechanical Engineering"

OCTOBER 2001

DECLARATION

I, Onesmus Mugambi Baruthi, hereby declare that this thesis is my original work and has not, to the best of my knowledge, been presented for examination in any other university.

------------------ 27th Sept. 2002.

SIGNATURE DATE

APPROVAL

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

FIRST SUPERVISOR: DR. KAMAU GACHIGI

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

DATE: 27TH SEPT. 2002

SECOND SUPERVISOR: ENG. DAVID M. MUNYASI

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

DATE: 27TH SEPT 2002

DEDICATION

This scholarly work is dedicated to my parents, Mr. Patrick Baruthi and Mrs. Beatrice Baruthi for their invaluable parental role through my formative period to my current status.

TABLE OF CONTENTS

AKNOWLEDGEMENTS

I wish at the outset, to state that a study of this nature required and received guidance of unwavering and conscientious form. This was unreservedly given by the Eng. David Munyasi, Dr. Kamau Gachigi and the late Dr. Gabriel E. Ekanem, all of the Department of Mechanical Engineering of the University of Nairobi, from the beginning to the successful completion of the study. Their kind and friendly supervision when carrying out the research and during the write up of this report is highly appreciated.

Secondly I wish to express my heartfelt gratitude to the University of Nairobi for offering me a two-year M.Sc. Scholarship without which this work would not have been made. I am indebted to the Ministry of Education for granting me research permit. Further I wish to acknowledge Mr. P. Orawo and Mr. J. Wambua both of Kenya Association of Manufacturers (KAM) and Mrs. L. Oyake of Nairobi City Council (NCC) for their assistance in getting valuable information during my research. I also wish to acknowledge Mr. Stephen Kathurima for his assistance in scanning of various photographs, which are included in this report. Special thanks go to managers of various institutions dealing with plastics for sparing time and responding to my research questions. Special recognition goes to (a) Mr. Anil Shah of Skyplast Manufacturers, and (b) Mr. Hemal Shah of Drums & Containers ltd. who provided me with in-depth and sincere information regarding secondary plastic wastes recycling. Also I would like to acknowledge, the cooperation of members of staff of the department of mechanical engineering for giving me priority in using the department's computers. To all those innumerable others who directly or indirectly assisted me in various stages in the preparation and write up of this thesis, I say: may the almighty God bless you.

The acknowledgement would be rather incomplete if I do not point out my gratitude to my colleagues in the M.Sc. part I Class of 1998 with whom we encouraged one another all along. Last but not least, sincere gratitude goes to my younger brother and sister, Mutembei and Kawira respectively for their life-long determination in encouraging me to take studies seriously.

Mugambi O. Baruthi.

LIST OF TABLES

TABLE NO. & TABLE DESCRIPTION — PAGE NO.

LIST OF FIGURES

FIGURE NO. & FIGURE DESCRIPTION PAGE NO.

LIST OF PLATES

MAP

LIST OF ACRONYMS & ABBREVIATIONS

APC	American Plastics Council
APME	Association of Plastic Manufacturers of Europe
CBOs	Community Based Organizations
CBS	Central Bureau of Statistics
CBSWM	Community Based Solid Waste Management
COMESA	Common Markets for Eastern and Southern Africa.
CREEL	Center for Research and Education on Environment Law
CPI	Consumer price index
CWC	Clean Washington Center
DFE	Design for environment
DSD	Duales System Deutschland of Germany
EC	European Commission
EIA	Environment Impact Assessment
EMS	Environmental Management System
EPIC	Environment and Plastics Industry Council of Canada.
ESID	Ecologically Sustainable Industrial Development
GSRIs	Government Sponsored Research Institutes
HDPE	High Density Polyethylene
ICI	industrial, commercial and institutional
IOP (K)	Institute of Packaging (Kenya)
IPC	Investment Promotion Council
IPFs	Intermediate Processing Facilities
ISO	International Organization for Standardization
ISWM	Integrated Solid Waste Management
IUPAC	International Union of Pure and Applied Chemistry
KAM	Kenya Association of Manufacturers
KEBS	Kenya Bureau of Standards
Kg	Kilogram
KIRDI	Kenya Industrial Research & Development Institute
KRA	Kenya Revenue Authority

Ksh	Kenya shilling
LDPE	Low Density Polyethylene
LLDPE	Linear Low Density Polyethylene
MOU	Memorandum of Understanding.
MRC	Mukuru Recycling Center
MRFs	Material Recovery Facilities
MSS	Material Sorting Systems
MSW	Municipal Solid Waste
NCC	Nairobi City Council
NEC	National Environment Council
NEMA	National Environment Management Authority
NET	National Environment Tribunal
NGOs	Non-Governmental Organizations
NIC	Newly Industrialized Country
NIMBY	Not in my backyard
NRP	Nyalenda Recycling Project
PCR	Post-consumer recycled
PE	Polyethylene
PEI	Packaging and Environment Initiative
PET	Polyethylene Terephthalate
PETCORE	PET Container Recycling organization
PP	Polypropylene
PS	Polystyrene
PTA	Preferential Trade Area
PVC	Polyvinyl Chloride
PWGR	Percentage waste generation rate
3 Rs	Reduce, Reuse and Recycle.
R&D	Research & Development
SERC	Standards and Enforcement Review Committee
SIEP	Settlement Infrastructure and Environment Program
SITC	Standard Industrial Trading Code

SPI	Society of Plastics Industry of North America
TA	Terephthalic acid.
UNCHS	United Nations Center For Human Settlements
UNDP	United Nations Development Program
UNEP	United Nations Environmental Program
UNIDO	United Nations Industrial Development Organization
VCM	Vinyl Chloride Monomer
XRT	X- ray transmission
XRF	X- ray fluorescence
NIR	Near infrared

ABSTRACT

In this thesis, the researcher presents the findings of a survey on the recycling of plastic wastes in Kenya. The study was carried out between April 2000 and April 2001. The main aim of the study was to find the factors behind low recycling of plastic wastes in Kenya.

General literature on plastics and their various recycling aspects was reviewed. It was found out that plastic packaging has the shortest useful life span compared to other categories of plastic applications. The study was limited to plastic packaging materials as follows: polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET), polyvinyl chloride (PVC). The primary, secondary and tertiary plastic waste recycling technologies of the above was reviewed.

The research design was a qualitative survey where stratified sampling was used to obtain samples from the list of plastic processing industries as contained in Kenya's Directory of Industries 1998. An interview schedule in the form of an industrial questionnaire was the principal research instrument, which was administered to a selection of plastic processing firms. In addition to the industrial questionnaire, face-to-face and telephone interviews, and direct observation were used as methods of data collection. Both qualitative and quantitative data was collected with forty questionnaires being satisfactorily filled. The data was then analyzed and presented in the form of tables, figures, bar charts, pie charts, and photographs or in prose form.

The study found out that Kenya currently recycles about 9000 tons of post-consumer plastic wastes per annum with polyethylene (PE), polypropylene (PP) and PVC as the main polymers recycled. These polymers are mainly used in manufacturing of rigid packaging containers. Most of the recycling activities, especially of post consumer plastic wastes, are carried out in the informal sector. Only the mechanical recycling option is practiced due to lack of other appropriate recycling technologies. Most of the recycling activities are carried out manually and where equipment is used, they are not designed for

effective recycling. Over 92 per cent of the interviewed firms carry out primary recycling of their internally generated wastes under 'free market' conditions.

In future, improvement in the general conditions for plastic recycling is expected due to regulations and other measures in preparation. These measures include improvement in the environment for recycling of not only plastic wastes but also other industrial wastes as entrenched in the constitution as Environment Management and Coordination Act of 1999. Other measures include voluntary agreements and contracts between the government and the packaging industry.

For further improvement of recycling of plastic wastes various recommendations have been suggested in this study to the main players in plastic recycling industry. It was recommended that the government put in place appropriate policies for enhanced recycling. The main policies it should target are as follows; awareness creation, provision of relevant incentives and putting in place appropriate legislative and regulatory measures. It has been further recommended that the plastic industry practice design for recycling when designing their plastic products for effective recycling of the resulting wastes. The main areas that it should target during the design process include; selection of recyclable materials, material compatibility and material identification. And finally it has been recommended that the recycling industry perform necessary process modifications for effective recycling operations. Main areas they should target in their process modifications include; property testing of recycled product, effective mixing of the melt and recycling process monitoring.

CHAPTER ONE: BACKGROUND INFORMATION

1.1 INTRODUCTION

From a historical viewpoint, the development of plastics can be regarded as one of the most important technical achievements of the twentieth century. In just 50 years plastics have permeated virtually every aspect of our daily lives, paving the way for new inventions and replacing materials in existing products. The success of these materials has been based on the properties of resilience, resistance to moisture and chemicals, photo and biodegradation, and the fact that they can be molded into any desired form.

The plastic industry in Kenya has been growing at a steady rate since 1993, with product diversification and entry of new firms into the industry (Kenya Government, Economic Survey 1997). This has been attributed to the increased use of plastics as packaging materials both at industrial and retail levels. This is due to affordability for consumers when compared with other packaging materials. Consequently this has resulted in increased plastic wastes generation.

Stricter global environmental legislation and controls governing waste disposal and the increasing quantities of solid wastes in general, have all contributed to increased costs of solid waste management services offered by most urban authorities. Solid waste management operations currently absorb between 30 and 50 per cent of most local government's operating budget. Even at such high level of expenditure, the level of solid waste service is low and only 5 percent to 70 percent of the solid wastes are collected. As living standards increase so also does the demand for improved environmental and economic benefits. Unsanitary practices including crude dumping become unacceptable to a better-educated and well-informed public. Plastic discards represent a substantial part of municipal and domestic solid waste pollution due to their volume and visibility. The exhaustion of traditional disposal sites, and the 'not in my backyard' (NIMBY) syndrome, are causing establishment of new landfill sites to become increasingly difficult for political reasons.

Kenya recently enacted environmental legislation, Environmental Management and Coordination Act of 1999 for putting into place a framework for environmental management (Kenya Gazette, 1999). The act encourages waste recycling as a way of managing all wastes generated by Kenyan industry. In cases where pollution has occurred the polluters will have to pay heavy penalties for environmental restoration according to 'polluter pays principle'. In the absence of local virgin plastics for manufacturing, recycling of plastic wastes if well coordinated would secure hundred of jobs in the informal sector as well as saving on foreign exchange expenditure for the country. If plastics recycling was combined with existing activities to recover materials such as paper and scrap metal, a wide range of recycling activities would occur with considerable benefits for Kenya.

As Kenya tries to achieve the objective of being a newly industrialized country (NIC) by the year 2020, environmental responsibility must be incorporated in the industrialization mix. In order to achieve this, existing and new plastic industries must adopt the Eco-efficiency and sustainability principles for ecologically sustainable industrial development (ESID). This will involve among other things environmentally sound management of wastes as a matter of priority. Businesses dealing with plastic products rarely have an environmental management system (EMS) for managing their business wastes. In Kenya, the plastic wastes are usually disposed off together with other residues. Although the plastic percentage is minor in terms of weight fraction compared to other types of residuals, it is important to keep in mind some aspects that make the rational disposal of plastic wastes necessary:

- Due to their low density, plastic products (films, bottles etc) occupy a greater volume in relation to the rest of the residuals generating a much bigger volume of the waste. This implies the necessity for very big spaces for disposal and high probability of causing litter.
- The slow degradability of the plastics because there are no efficient biological agents that accelerates the process of reincorporating them to the carbon cycles (Stanners and Bordeau, 1995).

- The probability that the current plastic fraction in the municipal wastes will increase due to population growth and globalization, and the consequent changes in habits of life, with a great tendency to use non-returnable plastic materials in areas of great consumption: excess of wrapping in supermarkets, food containers, etc.
- The useful life of the plastic products is in general very short. 40 % of the products have a useful cycle life of 1-month (Bisio and Xanthos, 1995).

This study looks into recycling as a plastic waste management option in Kenya.

1.2 INTEGRATED SOLID WASTE MANAGEMENT (ISWM)

Modern waste management starts with the generation of solid waste and covers every aspect through to final disposal. For planning purposes, it is convenient to consider the overall process consisting of the following five basic activities or elements.

- Waste generation and characterization (type, quantity and composition).
- Waste handling and separation, storage and processing.
- Waste transformation.
- Waste transportation.
- Waste disposal.

Modern ISWM encompasses "the control of generation, storage, collection, transfer, transport, processing and disposal of wastes in a manner that is in accord with the best principles of public health, economics, engineering, conservation, aesthetic and other environmental considerations"(Tchobanoglous et al, 1993). In developing an ISWM plan, it is necessary to select appropriate techniques, technologies and management programs for each of the elements, as well as their connections and interfaces.

Although the material extraction industry generates society's largest amount of solid waste, it receives the least attention. Almost all ISWM work is concerned with the industrial, commercial and institutional (ICI) sectors and the household sector, because these are the most visible waste generators and impact the public directly.

1.3 ISWM HIERARCHY

ISWM hierarchy consists of the following elements listed according to their order of desirability: source reduction, recycling, wastes transformation and landfill (Gainer & Associates, 1991).

1.3.1 SOURCE REDUCTION

This is the most effective way to reduce the quantity of waste, the cost associated with its handling, and its environmental impacts. Waste reduction may occur through the design, manufacture, and packaging of products with minimum toxic contents, minimum volume of material, or a longer useful life. Waste reduction may occur at the household, commercial or industrial facility through selective buying patterns and the reuse of products and materials. Due to many opportunities of reuse of plastic articles, reuse plays a key role as a source reduction method for plastic wastes in many developing countries such as Kenya. This is because it is cheaper to repair a used than to buy new or recycled article for similar reuse purposes.

1.3.2 RECYCLING

Recycling involves; (a) the separation and collection, (b) the preparation of these materials for reuse, reprocessing and re-manufacturing, (c) the reuse, reprocessing, and re-manufacture of these materials. The primary benefits of recycling are the conservation of natural resources and landfill space. However the collection and transport of materials requires substantial amounts of energy and labour and historically most recycling schemes are financially subsidized.

1.3.3 WASTE TRANSFORMATION

Involves the physical, chemical, or biological alteration of wastes. Typically, the physical, and biological transformation that can be applied to municipal solid waste

(MSW) are used, (a) to improve the efficiency of solid waste management operations and systems; (b) To recover reusable and recyclable materials; (c) To recover conversion products (e.g. compost) and energy in the form of heat and combustion biogases. The transformation of waste materials usually results in the reduced use of landfill capacity. The most eco-efficient transformation method is used.

1.3.4 LANDFILLING

Ultimately something must be done with, (a) the solid waste that cannot be recycled and is of no further use, (b) the residual materials remaining after solid waste have been separated at a material recovery facility (MRF), (c) the residual matter remaining after the recovery of conversion products or energy. Landfill involves the controlled disposal of wastes on or in the earth's mantle and it is by far the most common method of ultimate disposal for waste residuals.

The hierarchy can be conceptualized as a pyramid (see figure 1.1) with three levels: source reduction is on top, recycling and composting in the middle; and incineration and landfill at the bottom. Notice however that the top level, source reduction, is the smallest. This reflects the unfortunate fact that, while source reduction and recycling are the preferred methods of dealing with materials, we still actually treat the majority materials through the method of last resort, landfill and incineration. The goal then is to achieve a transition not only in what is preferred, but how the materials are actually treated. Conceptually the aim is to invert the pyramid (see figure 1.2), keeping source reduction on top, but now with the point of the pyramid down signifying that the materials are handled in the preferred manner. When compared to the environmental risks associated with landfill or incineration, recycling is the preferred solid waste management strategy.

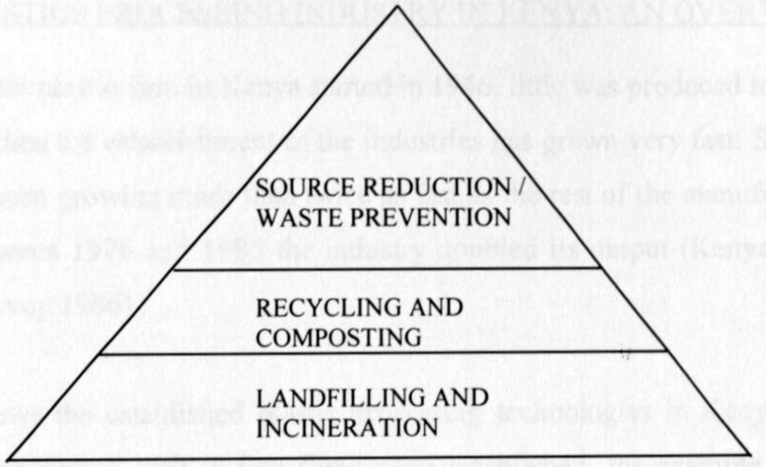


Figure 1.1: Current status of ISWM.

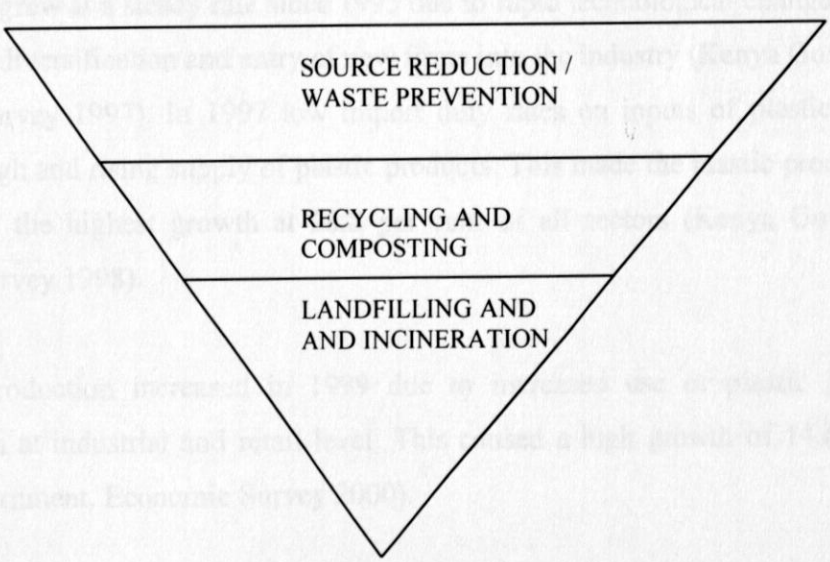


Figure 1.2: Desired goal for ISWM.

1.4 THE PLASTICS PROCESSING INDUSTRY IN KENYA: AN OVERVIEW

Though the first plastic firm in Kenya started in 1946, little was produced locally until the 1960s. Since then the establishment of the industries has grown very fast. Since 1971, the industry has been growing more than twice as fast as the rest of the manufacturing sector such that between 1976 and 1985 the industry doubled its output (Kenya Government, Economic Survey 1986).

Table 1.1 shows the established plastic processing technologies in Kenya by 1982. In some of the processes, only a few firms were established, for example, one firm did calendering, as was the case with fabric coating, sheet extrusion, lamination, and vacuum forming, while two did compression moulding. There were three producers of plastic pipes. For all other fabrication methods, more than three firms were established per process (Mwangi, 1982).

The industry grew at a steady rate since 1993 due to rapid technological changes coupled with product diversification and entry of new firms into the industry (Kenya Government, Economic Survey 1997). In 1997 low import duty rates on inputs of plastic products resulted to high and rising supply of plastic products. This made the plastic products sub-sector record the highest growth at 28.8 per cent of all sectors (Kenya Government, Economic Survey 1998).

Packaging production increased in 1999 due to increased use of plastic packaging products both at industrial and retail level. This caused a high growth of 14.6 per cent (Kenya Government, Economic Survey 2000).

Records from the Ministry of Trade and Industry show that Kenya currently has about 150 plastic processing firms with capacities ranging from 1000 to 8000 tons per year. The most common plastic processing technologies are blow molding, injection molding and film extrusion. Most of these firms are located in Nairobi and Mombasa, with a few in

Kisumu, Eldoret and Nakuru. Figure 1.3 shows the distribution of plastic industries by end use market.

PROCESS		EXAMPLES OF PRODUCTS
Calendering		Vinyl asbestos floor tiles
Coating		
	Fabric coating	Coated fabrics
	Wire coating	Cables and telephone wires
Extrusion		
	Conduit extrusion	Conduits
	Film extrusion	Film
	Pipe extrusion	Pipes
	Sheet extrusion	PVC floor tiles
Foaming		Mattresses, pillows and cushions
Lamination		Formica sheets (only high pressure laminates)
Moulding		
	Blow moulding	Containers, bottles
	Compression moulding	Plates, cups, ash trays
	Injection moulding	Cassettes, ball pens, containers
	Rotational moulding	Boxes, dustbins, plastic cone-shaped rod, markers, tanks
Vacuum forming		Sanitary ware
Weaving		Polypropylene woven sacks

Table 1.1: Processing methods and plastic products in Kenya.
Source: Mwangi, 1982.

Figures 1.4a and 1.4b gives a summary of the main local plastic production over the last 6 years. The figures show upward growing trend in local production of plastic products.

The plastic industry mainly produces goods made of polyvinyl chloride (PVC), polyethylene (PE), polystyrene (PS), and polypropylene (PP) with average consumption of 14000 tons per annum (Kenya Government, Investment Promotion Council (IPC), 1994). Most of the local production is consumed locally although about 10 per cent is exported, mainly in the preferential trade area (PTA) region in Africa commonly now referred to as Common Market for Eastern and Southern Africa (COMESA).

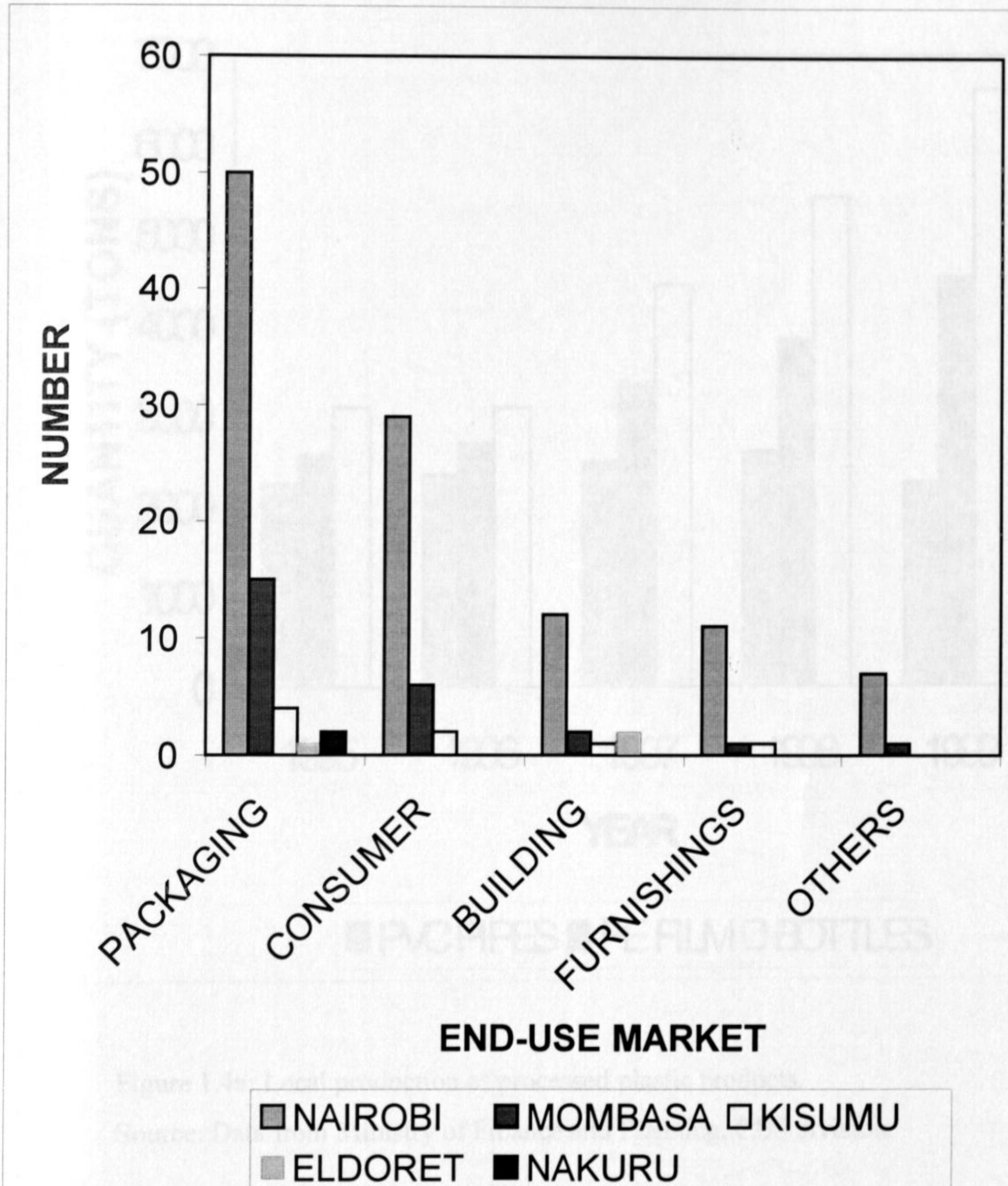


Figure 1.3: Distribution of plastic processing firms in Kenya by end-use market.

Source: Data from Ministry of Trade and Industry.

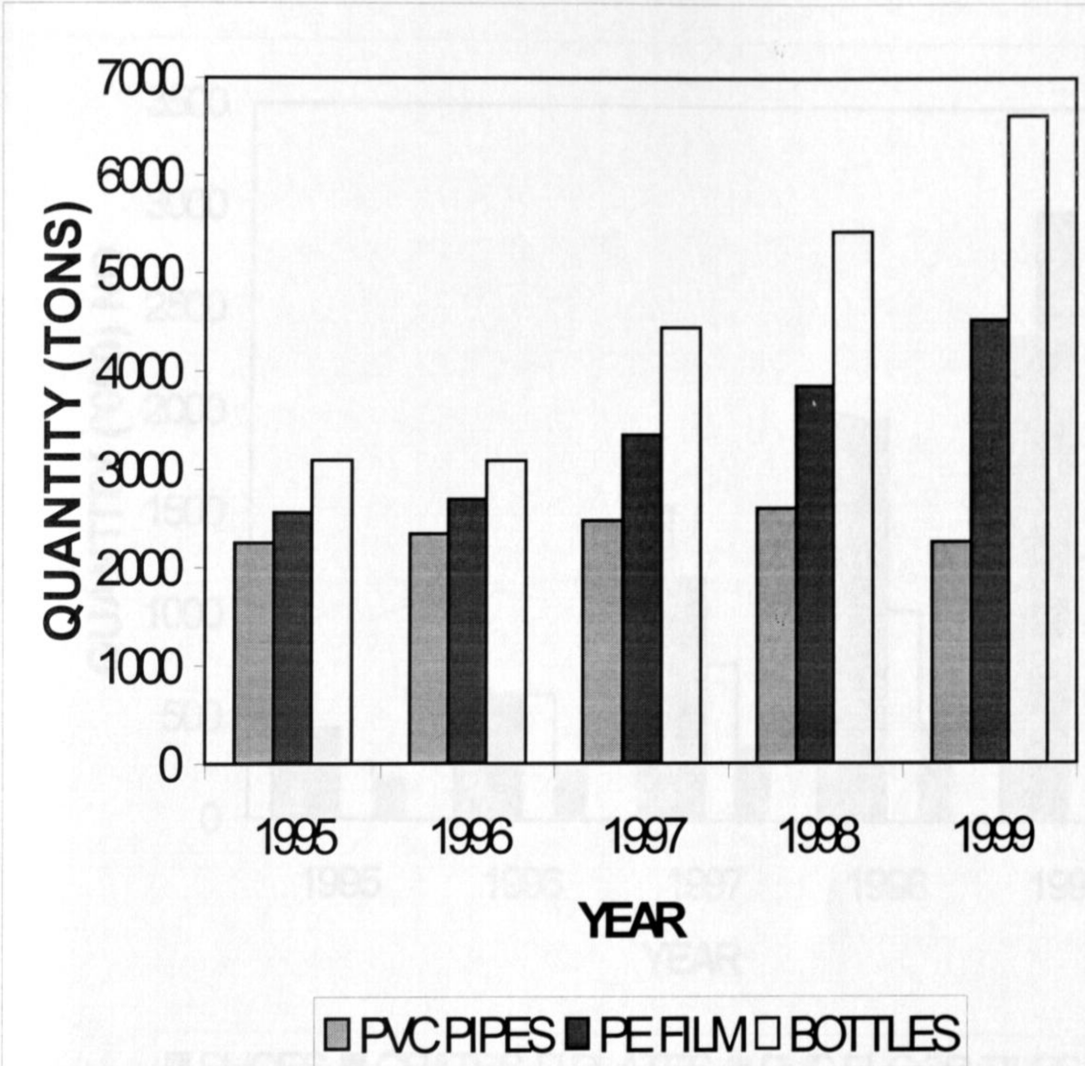


Figure 1.4a: Local production of processed plastic products.

Source: Data from Ministry of Finance and Planning, CBS division.

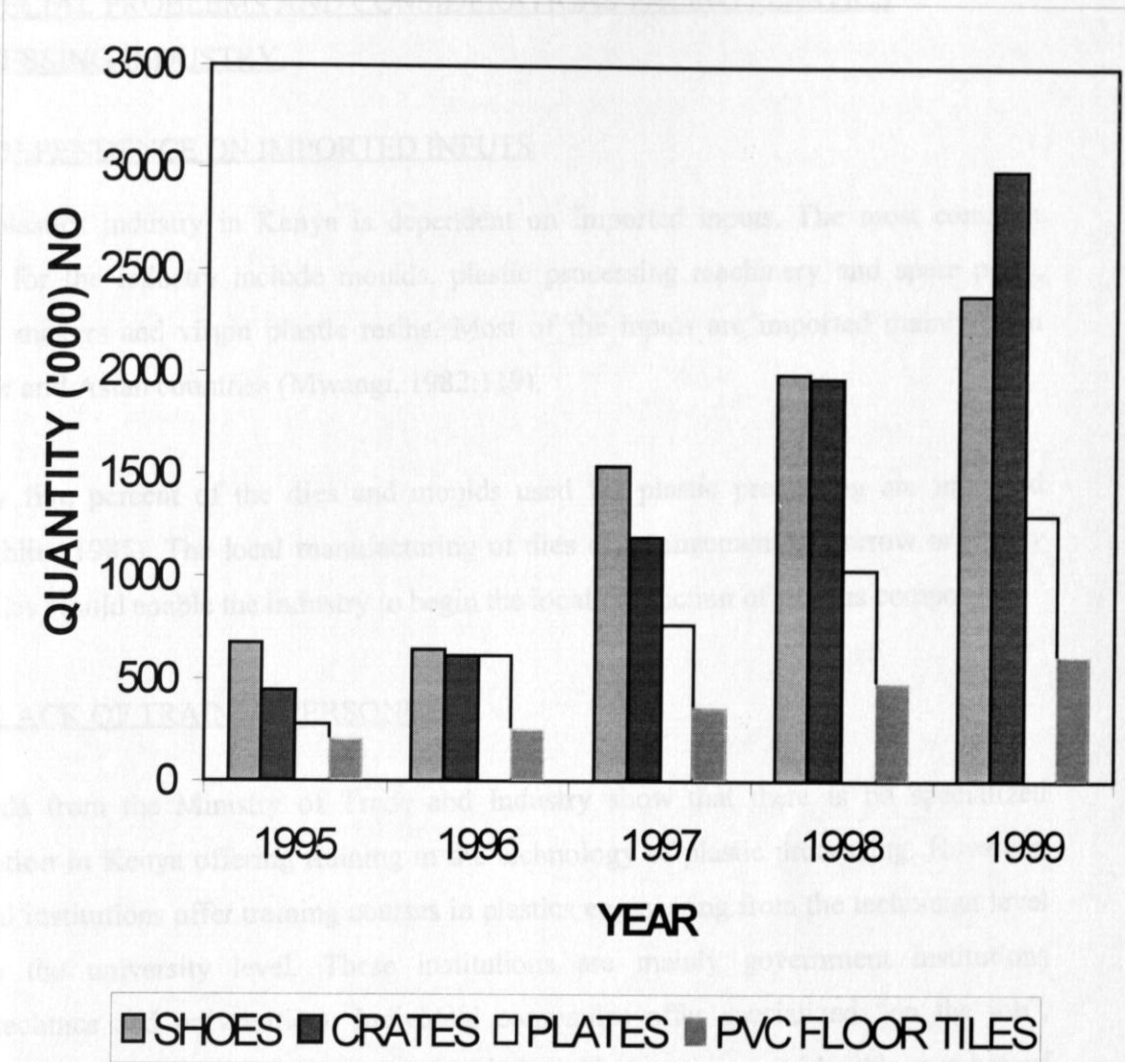


Figure 1.4b: Local production of processed plastic products.

Source: Data from Ministry of Finance and Planning, CBS division.

1.5 SPECIAL PROBLEMS AND CONSIDERATIONS FACING PLASTICS PROCESSING INDUSTRY.

1.5.1 DEPENDENCE ON IMPORTED INPUTS

The plastics industry in Kenya is dependent on imported inputs. The most common inputs for the industry include moulds, plastic processing machinery and spare parts, mould makers and virgin plastic resins. Most of the inputs are imported mainly from Europe and Asian countries (Mwangi, 1982:119).

Ninety five percent of the dies and moulds used for plastic processing are imported (Coughlin, 1985). The local manufacturing of dies or arrangement to borrow or jointly own dies would enable the industry to begin the local production of various components.

1.5.2 LACK OF TRAINED PERSONNEL

Records from the Ministry of Trade and Industry show that there is no specialized institution in Kenya offering training in the technology of plastic processing. However, several institutions offer training courses in plastics engineering from the technician level up to the university level. These institutions are mainly government institutions (polytechnics and universities). Individual companies offer specialized "on the job", training in the technology of plastic processing. However, a considerable number of Kenyans have been trained abroad in the technology of plastic processing in various institutions scattered all over the world. Those already in the plastics industry have also been sent abroad for training by the individual companies or through scholarships awards from donor agencies through the government. The availability of a well-educated and trained workforce is critical to the success of Kenya's industrialization process. Apart from entrepreneurship and managerial skills, there are equal requirements for operational, technician and artisan skills at the shop floor level. There also needs to be a proper ratio of technicians and artisans to engineers and designers.

1.5.3 INFRASTRUCTURAL LIMITATIONS

The inadequate state of Kenya's physical infrastructure acts as a major disincentive to potential investors and threatens the realization of industrialization. The availability of infrastructure and its efficient operation are major determinants to the cost of production, quality and timeliness of response to products and service demands. Electricity supply is crucial to plastics processing. The main constraints with regard to electricity supply are voltage fluctuations and power breakdowns. Electrical fluctuations and breakdowns damage equipment and create production losses. Most industrial activities also need clean, adequate and reliable water supplies. The lack of sufficient good quality water has been the cause to untold suffering as well as serious environmental degradation. The quantity and standard of water treatment must therefore be high enough to meet industrial requirements.

1.6 SCOPE OF THE STUDY

Plastics can be divided into two general categories: thermoplastics and thermosetts. A thermoplastic is a plastic that can be softened or melted by heating but regain their original properties once cooled again. On the other hand, a thermosett is plastic that solidifies or sets on heating, and which on further heating, it does not melt, but decomposes. The thermosetting property is usually associated with a cross-linking reaction forming a three dimensional structure. Products made from thermosetting resins cannot be reshaped once they have been fully cured. There are two categories of thermoplastics: commodity and engineering grade plastics. Because engineering plastics have high mechanical properties such as impact strength, they are mainly used in manufacturing of durable plastics. This study is specifically confined to resin types used in manufacturing commodity grade plastics. These resins are also known as plastic packaging materials.

Table 1.2 shows estimated life span of commodity and engineering plastic products by application. The table shows that packaging has a higher generation rate of the waste due to its short life span compared to other plastic applications. More so the used packaging plastics are the commonly recycled plastics because they are usually available in single polymer types, in large quantities, and are readily sortable and cleanable in form. More so they are generated in large quantities and in a limited number of locations, mostly commercial and industrial enterprises.

APPLICATION	ESTIMATED LIFE (YEARS)	PLASTIC CATEGORY
Transportation	11	Engineering grade
Packaging	< 1	Commodity grade
Building & construction	25	Engineering grade
Electrical & electronics	15	Engineering grade
Furniture & fixtures	10	Engineering grade
Consumer & institutional	5	Engineering grade
Industrial machinery	15	Engineering grade
Adhesives and other	4	Engineering grade

Table 1.2:Estimated life span (in years) of selected plastic products.
Source: Curlee, 1986:80.

The percentage composition of plastic waste by plastic type is as follows: high-density polyethylene (HDPE) (18 %), low-density polyethylene (LDPE) (42 %), PVC (11 %), PP (12 %), polyethylene terephthalate (PET) (5 %) PS (11 %), others (1 %).

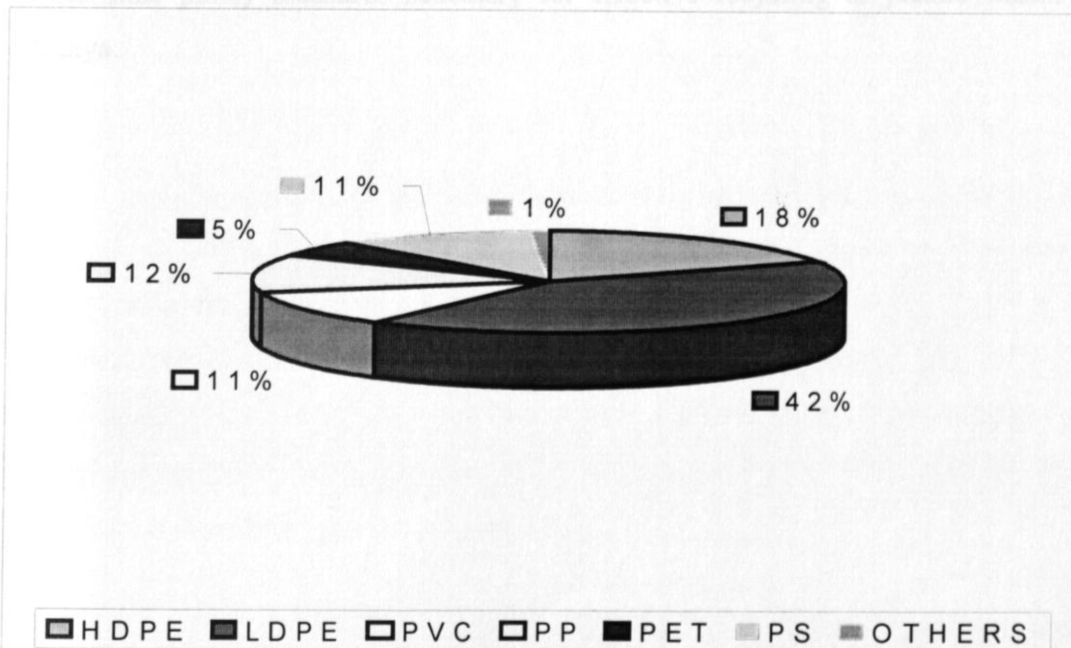


Figure 1.5: Classification of plastic waste by kind. Source: Ehrig, 1992.

This classification as shown in figure 1.5 is not very dependent on the place in the world (Ehrig, 1992). This study is limited to the above plastic packaging resins.

1.7 OBJECTIVES OF THE STUDY

The researcher sought answers to the following questions.

1. What factors lead to low recycling of plastic waste in Kenya?
2. What are the economic and policy considerations in recycling of plastic waste?
3. Who are the major generators of plastic wastes in Kenya?
4. What are the benefits of recycling of plastic waste in Kenya?

In order to arrive at those answers the research objectives specifically were to:

1. Identify recyclable plastic waste and their sources.
2. Determine the viability of existing technologies for recycling plastic waste.
3. Identify economic and institutional barriers to plastic recycling in Kenya.
4. Determine policy measures necessary for effective recycling of plastic wastes in Kenya.

CHAPTER TWO: LITERATURE REVIEW.

2.1 PLASTICS

The word 'plastic' means a material that is solid in its finished state and, at some stage in its manufacture or in its processing into finished articles, can be shaped by flow. Therefore, the origin of plastic forming can be traced back to the processing methods of natural high polymers such as lacquer, shellac, amber, horns, tusks, tortoise shell, as well as inorganic substances such as clay, glass, and metals. Because most natural high polymer materials are not uniform in quality and lack mass productivity in many cases, they are in particular not easily processed into better quality artificial materials such as celluloid, synthetic rubber, ebonite and rayon. Presently, plastics are defined as synthesized high polymers, and consequently substances made of above natural materials are precluded (Saechtling, 1987). To be specific the American Society of Testing and Materials (ASTM D883) gives definition of a plastic as follows;

A material that contains as an essential ingredient an organic substance of large molecular weight is solid in its finished state and, at some stage in its manufacture or in its processing into finished articles can be shaped by flow.

2.2 PLASTICS PRODUCTION

Polymer and monomer production is mainly carried out by petrochemical industries using output from oil refineries. The output fraction comprises complex mixtures of predominantly unreactive saturated hydrocarbons. The first processing step in converting such fractions into feedstock suitable for petrochemical industry is cracking. Essentially a cracker performs two functions (a) reducing the complexity of the input mixture into a smaller number of low molecular mass hydrocarbons and (b) rendering the hydrocarbons unsaturated so that they become more reactive.

Cracking is a three-stage process as shown in figure 2.1 below. Although it is possible to identify schematically the three processes, in practice they behave as a single unit.

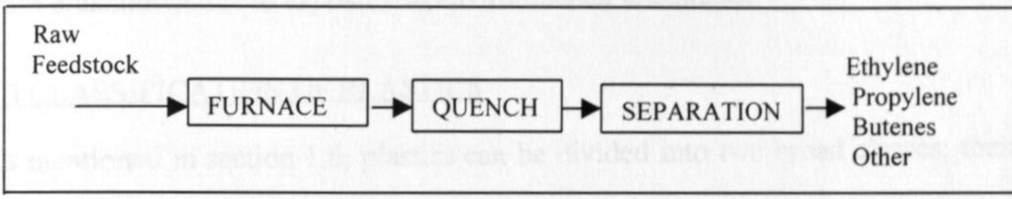


Figure 2.1: Schematic flow chart of the principal operation in cracking.

The raw hydrocarbon feed from the refinery is fed to the furnace section where it is raised to a high temperature. The reaction products that are formed depend upon the composition of the feed, the temperature of the furnace and the time that the hydrocarbons are held within the furnace (residual time). The cracker operator chooses temperature and residence time to optimize product mix from a given feed.

Upon leaving the furnace, the hydrocarbon gas is quenched to inhibit further reaction. It is then passed to the separation stage where the individual hydrocarbons are separated from one another by fraction distillation.

The principal products from the cracker are ethylene (C_2H_4), propylene (C_3H_6) and a mixture of butene (C_4H_8) isomers. Usually there will be some hydrogen and a number of other hydrocarbons, some of which will be separated. Others will be fed back to the furnace and yet others will be used as fuel.

These small molecules, called monomers are then chemically bonded into chains called polymers. Different combinations of monomers yield polymeric resins with different properties and characteristics. Combination of monomers produces copolymer with further property variations. The resulting resins may be molded or formed to produce several different kinds of plastic products with applications in the major markets. The variability of resin permits a compound to be tailored to a specific design or performance requirement. This is why certain plastics are best suited for some applications while others are best suited for entirely different applications. For instance impact strength measures the ability of a material to withstand shock loading; heat resistance protects the resin from exposure to excessive temperatures; chemical resistance protects the resin from breakdown due to exposure to environmental chemicals.

2.3 CLASSIFICATION OF PLASTICS

As mentioned in section 1.6, plastics can be divided into two broad classes: thermosetts and thermoplastics.

2.3.1 THERMOSETTS

These are plastics where linear long or branched polymer chains are held together by covalent bonds. These resins once cured and set cannot be remelted. For processing, initially a linear polymer precursor is synthesized. Cross-linking and curing reactions are then brought about after a curing agent has been added into a mould. Thermosetts are valued for their durability and strength and are primarily used in automobiles and construction, although applications such as adhesives, inks and coating are significant. Their applications reach far beyond those mentioned here.

2.3.2 THE THERMOPLASTICS

This class of plastics comprises linear or branched chain polymers without covalent bonding between the chains. The attractive forces between these linear molecules are Van der Waal's forces. These weak secondary-bonding forces permit thermoplastics to soften when exposed to heat and return to their original condition when cooled back down to room temperature. When a thermoplastic is softened by heat, it can then be shaped by extrusion, molding or pressing. Thermoplastics offer versatility and a wide range of applications. They make up the greatest share of plastics used in packaging because they can be rapidly and economically formed into any shape needed to fulfil the packaging function. The following is a further description of the different types of thermoplastic polymers, the packaging resins, since it is this class that avails itself to recycling.

2.4 PACKAGING RESINS

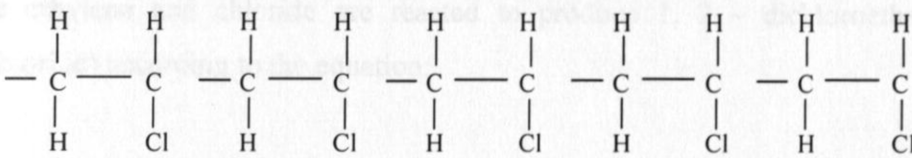
Commonly used packaging resins are PVC, PET, HDPE, LDPE, PP, and PS whose major properties and applications are given in Table 2.1.

RESIN	PROPERTIES	PACKAGING APPLICATIONS	RECYCLED PRODUCTS
PET	Clarity, strength/toughness, barrier to gas and moisture, resistance to heat	Plastic soft drink and water bottles, beer bottles, mouthwash bottles peanut butter and salad dressing containers, ovenable film, and ovenable pre-prepared food trays.	Fiber, tote bags, bottles, clothing, furniture, carpet
HDPE	Stiffness, strength/toughness, resistance to chemical and moisture, permeability to gas, ease of processing, ease of forming	Milk, water and juice containers, trash and retail bags, liquid detergent bottles, yogurt and margarine tubs, cereal box liners	Liquid laundry detergent containers, drainage pipes, oil bottles, recycling bins, benches, pens, dog houses, floor tiles, picnic tables, lumber, mail box posts, fencing
PVC	Versatility, ease of blending, strength/toughness, resistance to grease/oil, resistance to chemicals, clarity	Clear food packaging, shampoo bottles, medical tubing, wire and cable insulation	Packaging binders, decking, paneling, roadway gutters. mud flaps, film and sheet, flooring, cables, speed bumps, mats
LDPE	Ease of processing, barrier to moisture, strength / toughness, flexibility, ease of sealing	Bread bags, frozen food bags, sqeezable bottles (e.g. honey, mustard)	Shopping envelops, garbage can liners, floor tiles, furniture, film and sheet, compost bins, paneling, trashcans, landscape, timber, lumber.
PP	Strength/toughness, resistance to chemicals, resistance to heat, barrier to moisture, versatility, resistance to grease/oil	Ketchup bottles, yogurt containers and margarine tubs, medicine bottles	Auto battery cases, signal lights, battery cables, brooms and brushes, ice scrapers, oil funnels, landscape borders, bicycle racks, rakes bins, pallets, sheeting trays
PS	Versatility, insulation, clarity, easily foamed	Compact discs jackets, food service applications, grocery store meat trays, egg cartons, aspirin bottles, cups, pallets	Thermometers, light switch plates, thermal insulation, egg carton, vents, desk trays, rulers, license plate frames
OTHER	Dependent on resin or combination of resins	Three and five gallon reusable water bottles, some citrus juice and ketchup bottles	Custom products, plastic lumber.

Table 2.1: Properties and applications of packaging resins.
Source: SPI, 2001.

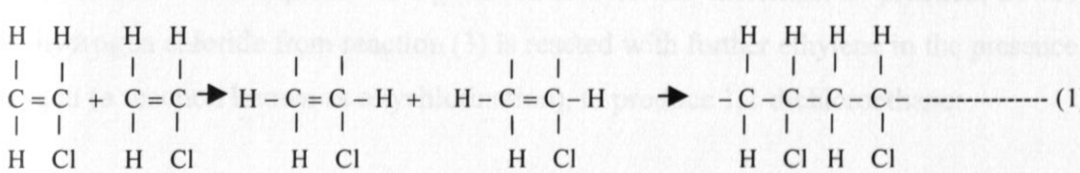
2.4.1 POLYVINYL CHLORIDE (PVC)

PVC is a chlorinated hydrocarbon polymer. The structure is similar to that of polyethylene (see page 29) except that alternate carbon atoms in the main chain have one of their hydrogen atoms replaced by a chlorine atom to give a structure shown below



Structure of polyvinyl chloride

The polymer is produced from vinyl chloride by a process essentially similar to that used in the production of polyethylene, polypropylene and polystyrene. That is, the double bond between carbon atoms in the vinyl chloride molecule is opened and neighboring molecules combines with each other to produce a long chain molecule. Schematically the reaction is as shown by equation 1 below:



Vinyl chloride PVC

The starting raw materials for (vinyl chloride monomer) VCM and PVC are crude oil and natural gas for the hydrocarbon part of the molecule and naturally occurring sodium chloride (and to a lesser extent, potassium chloride) for the chloride part.

The hydrocarbon feedstock is converted by cracking ethylene as described in section 2.2. The sodium chloride is electrolyzed as an aqueous solution to produce chlorine with sodium hydroxide and hydrogen as a co-polymer according to the equation:

$2NaCl\ (aq) + 2H_2O\ = 2\ NaOH\ (aq) + Cl_2\ (g) + H_2\ (g)$.

The ethylene and chloride are reacted to produce 1, 2 – dichloroethane (ethylene dichloride) according to the equation:

$C_2H_4\ (g) + Cl_2\ (g) = C_2H_4Cl_2\ \ (g)$------------------------(2)

The 1,2 – dichloroethane is then decomposed by heating in a high temperature furnace when it produces vinyl chloride and hydrogen chloride according to the reaction:

$C_2H_4Cl_2\ \ (g)\ \ = C_2H_3Cl\ (g) + HCl\ (g)$ -----------------(3)

If the process were stopped at this stage, it is clear that 50 % of the input of chlorine would be lost from the system and unless there was sufficient demand for hydrogen chloride, this would represent a significant loss of raw materials. In practice, however, the hydrogen chloride from reaction (3) is reacted with further ethylene in the presence of oxygen (a reaction known as oxychlorination), to produce 1,2-dichloroethane:

$C_2H_4\ (g) + HCl\ (g) + \frac{1}{2}\ O_2\ (g) = C_2H_3Cl\ (g) + H_2O\ (l)$ ---------------(4)

The dichloroethane produced by reaction (4) is now decomposed according to reaction (3). Matching the direct and oxychlorination steps can show the overall reaction shown by adding together equation (2), (3), and (4) as:

$2C_2H_4(g) + Cl_2\ (g) + \frac{1}{2}\ O_2\ \ (g) = 2\ C_2H_3Cl\ (g) + H_2O\ (l)$. ------------(5)

As can be seen, the chlorine is now completely used by the overall process.

The industrial process for the production of VCM and PVC is shown in Figure 2.2. It should be noted that producers of PVC do not all carry out the complete sequence of operations shown. Many buy commodities such as sodium chloride, chlorine, hydrogen chloride, dichloroethane and even vinyl chloride monomer on the open markets and operate only at the later stages of the process.

Early PVC processing technology was based on established rubber moulding processes and the products that could be manufactured were limited to those using heavily plasticized polymer. The main problem was the inability to convert the polymer into usable products without severe thermal degradation because of the tendency of the polymer to de-hydrochlorinate at elevated temperatures. It was not until the discovery of suitable stabilizers that processing technology advanced to the point where the full potential of the polymer could be realized. Nowadays, by choosing suitable stabilizers and plasticizers, the polymer can be converted into a wide variety of products as diverse as plastisols, which provide the seals in some closures, through coated fabrics used in architectural applications, films and sheets for use in packaging applications and extruded pipes and section for use in building applications.

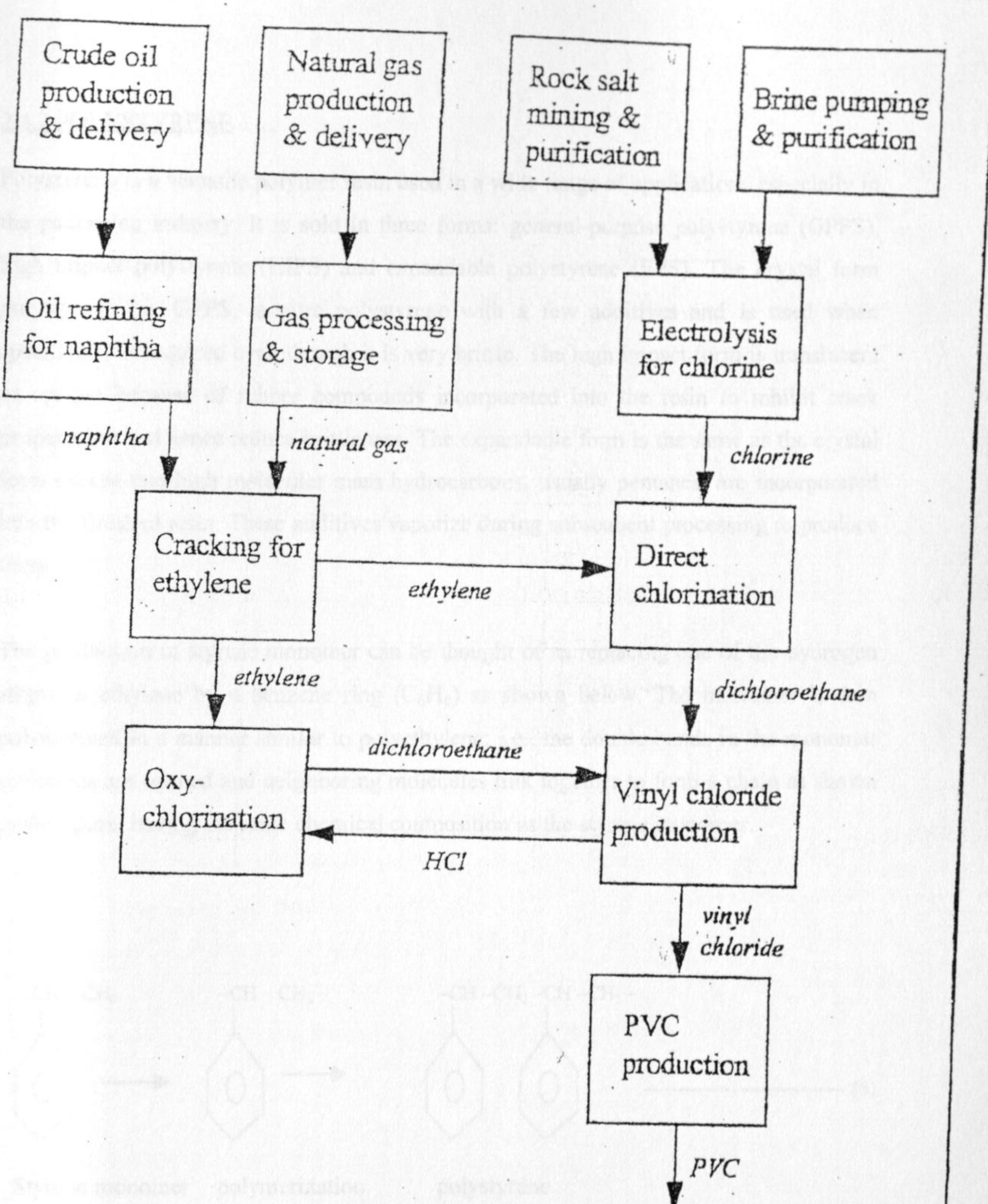
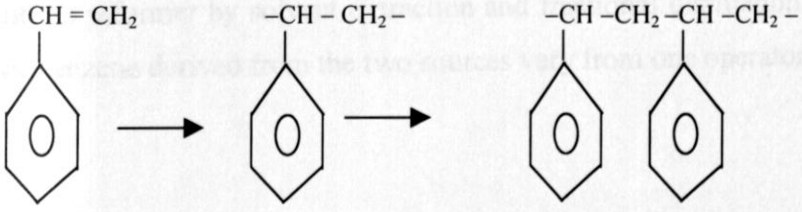


Figure 2.2: Schematic flow diagram for the production of VCM & PVC. Source: Boustead, 1999.

2.4.2 POLYSTYRENE

Polystyrene is a versatile polymer resin used in a wide range of applications especially in the packaging industry. It is sold in three forms: general-purpose polystyrene (GPPS), high impact polystyrene (HIPS) and expandable polystyrene (EPS). The crystal form polystyrene i.e. GPPS, is pure polystyrene with a few additives and is used when specifically is required even though it is very brittle. The high impact form is translucent or opaque because of rubber compounds incorporated into the resin to inhibit crack propagation and hence reduce brittleness. The expandable form is the same as the crystal form except that high molecular mass hydrocarbons, usually pentanes, are incorporated into the finished resin. These additives vaporize during subsequent processing to produce foam.

The production of styrene monomer can be thought of as replacing one of the hydrogen atoms in ethylene by a benzene ring (C_6H_6) as shown below. The monomer is then polymerized in a manner similar to polyethylene; i.e., the double bonds in the monomer molecules are opened and neighboring molecules link together to form a chain as shown in the figure, having the same chemical composition as the styrene monomer.



---------------------------------- (6)

Styrene monomer   polymerization   polystyrene

In practice, the production route from crude oil and natural gas is as shown in the figure 2.3. Crude oil refining produces a fraction known as naphtha, which contains a mixture of high molecular weight, saturated hydrocarbon of various compositions. This is converted into smaller group of unsaturated hydrocarbons by cracking in a process in which the naphtha is heated to high temperature in the absence of air, maintained for a short time at this temperature and then very rapidly cooled back to a low temperature when all of the reaction stops and the mixture of products is essentially fixed. The resulting mixture is then separated into its constituent components by distillation producing principally ethylene, propene, mixed butene and a number of other compounds, which find uses elsewhere in the petrochemical plant either as feedstock or fuels. The precise mixtures of products from cracking are determined by a number of factors such as cracking temperatures, residence time and the nature of the feedstock. The operation of the cracker can often be adjusted to produce the required mix of products. Natural gas is also converted into ethylene, propylene, butene and other products by cracking. Although benzene is usually present in small quantities in crude oil, its direct extraction is usually uneconomical. However, one by-product of naphtha cracking is a liquid usually referred to as pyrolysis gasoline, which is high in unsaturated aliphatic and aromatic hydrocarbons. The benzene fraction in the pyrolysis gasoline can be extracted by repeated distillation.

Benzene is also produced directly from naphtha by a process known as catalytic reforming. The basic feedstock is converted into a mixture of products of which the principal components are benzene, toluene and xylene (the process is referred to as the BTX process). Benzene and other aromatics are isolated in the pure state from the output of the reformer by solvent extraction and fractional distillation. The relative proportions of benzene derived from the two sources vary from one operator to another.

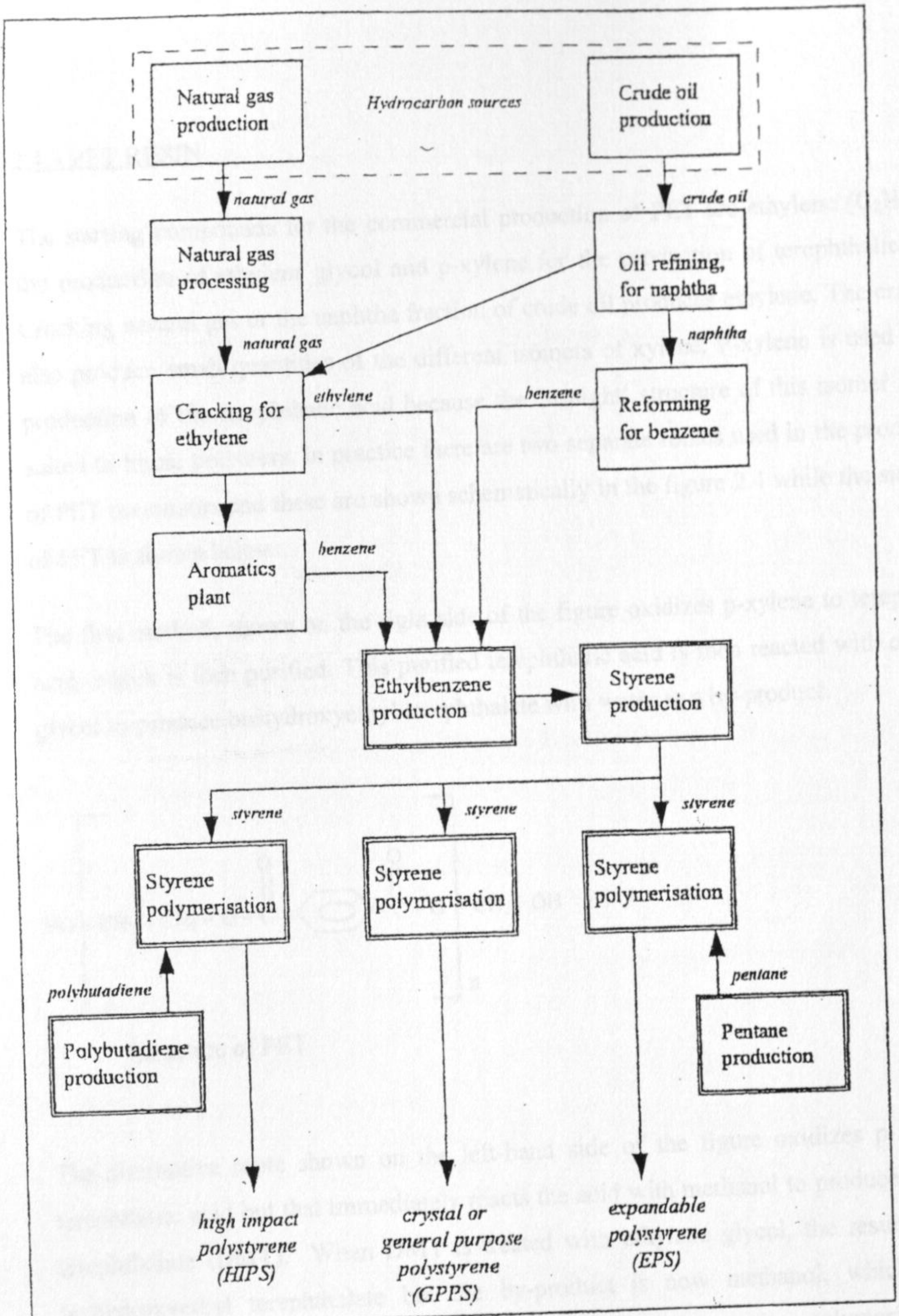


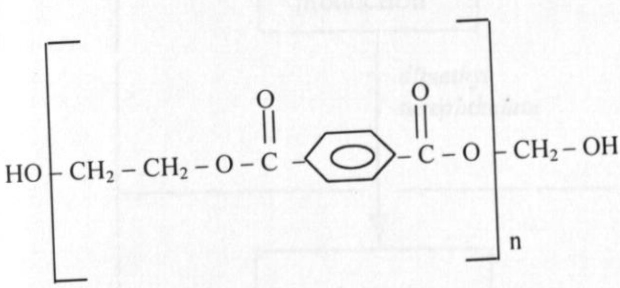
Figure 2.3: Sequence of operations used in the production of the different forms of polystyrene from crude oil and natural gas.

Source: Boustead, 1999.

2.4.3 PET RESIN

The starting compounds for the commercial production of PET are ethylene (C_2H_4) for the production of ethylene glycol and p-xylene for the production of terephthalic acid. Cracking natural gas or the naphtha fraction of crude oil produces ethylene. The crackers also produce small quantities of the different isomers of xylene. P-xylene is used in the production of the terephthalic acid because the 'straight' structure of this isomer is best suited to linear polymers. In practice there are two separate routes used in the production of PET precursors and these are shown schematically in the figure 2.4 while the structure of PET is shown below.

The first method, shown on the right side of the figure oxidizes p-xylene to terephthalic acid, which is then purified. This purified terephthalic acid is then reacted with ethylene glycol to produce bishydroxyethyl terephthalate with water as a by-product.



Structure of PET

The alternative route shown on the left-hand side of the figure oxidizes p-xylene to terephthalic acid but that immediately reacts the acid with methanol to produce dimethyl terephthalate (DMT). When DMT is treated with ethylene glycol, the result is again bishydroxyethyl terephthalate but the by-product is now methanol, which can be recovered and reused. The monomer produced by either route is then polymerized in the liquid phase to produce amorphous polyethylene terephthalate. A second polymerization in the solid state increases the molecular weight of the polymer and produces a partially crystalline resin that can be used to produce bottles via injection moulding and stretch blow moulding.

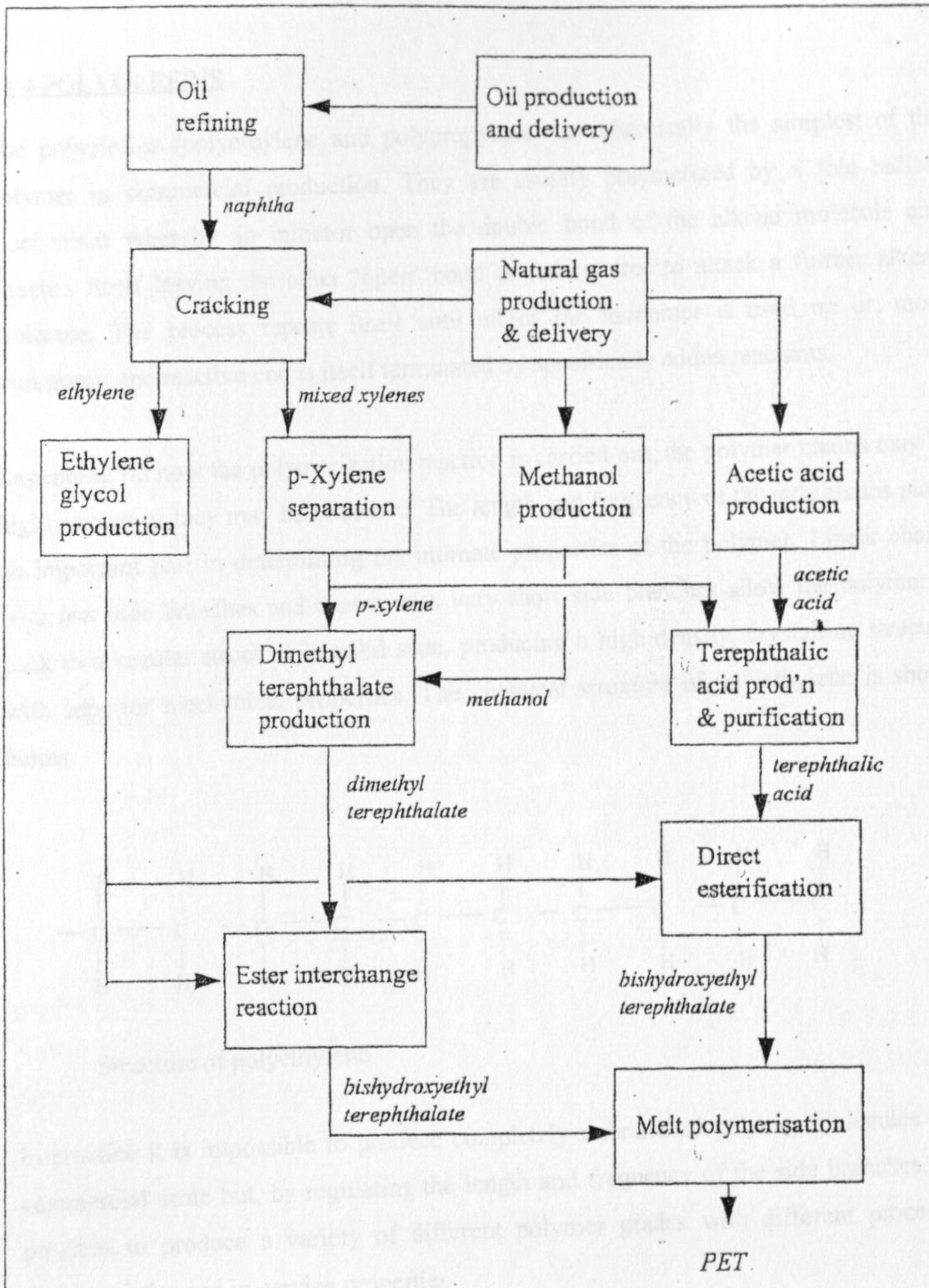
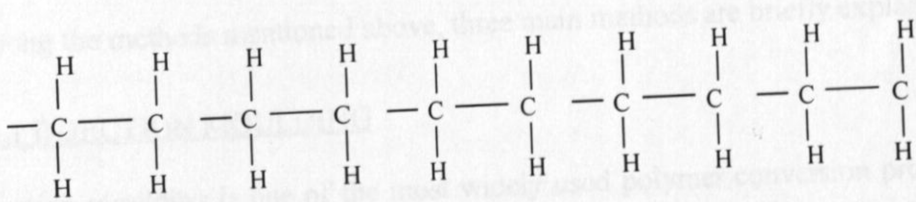


Figure 2.4: Schematic diagram showing the routes to amorphous polyethylene terephthalate. Source: Boustead, 1999.

2.4.4 POLYOLEFINS

The polyolefins (polyethylene and polypropylene) are chemically the simplest of the polymer in commercial production. They are usually polymerized by a free radical mechanism whereby an initiator open the double bond of the alkene molecule and attaches itself leaving the other 'open' bond or radical free to attack a further alkene molecule. The process repeats itself until all of the monomer is used up or, more commonly, the reactive end is itself terminated by specifically added reactants.

Depending on how the polymerization reaction is carried out, the polymer chains may be highly linear or they may be branched. The length and frequency of the side chains plays an important part in determining the ultimate properties of the polymer. Linear chains with few side branches and chains with very short side branches allow the polymer to pack in a regular structure in solid state, producing a high density, crystalline structure with superior mechanical properties. The chemical structure of polyethylene is shown below.



Structure of polyethylene

In practice it is impossible to produce completely unbranched polymer molecules on a commercial scale but, by regulating the length and frequency of the side branches, it is possible to produce a variety of different polymer grades with different processing characteristics and in-service properties.

The polyethylene available commercially can be divided into three main groups: low density polyethylene (LDPE), high-density polyethylene (HDPE) and linear low-density polyethylene (LLDPE). LDPE is produced in a high-pressure process and contains a high

2.5 PLASTIC FORMING PRODUCTION PROCESSES

The main plastic forming methods are shown in table 2.2 below

SERIAL NO	MOLDING PROCESS	EXAMPLES OF PRODUCTS
1	Extrusion process	Pipe, etc
2	Injection molding	Bucket, housing of office automation equipment
3	Blow moulding	Container, bottle
4	Vacuum forming	Pack case for eggs (thin film product)
5	Pressure forming	Suitcase (thick sheet product)
6	Roto moulding	Tanks
7	Inflation process	Film, sack
8	Calendar process	Film, sheet
9	Fluidized bed process	Tub
10	Compression molding	Electric parts: Plugs, switches
11	Transfer molding	Package molding for integrated circuit

Table 2.2: Plastic-molding processes and examples of their products.
Source: UNIDO, 1995:2.

Among the methods mentioned above, three main methods are briefly explained below.

2.5.1 INJECTION MOULDING

Injection moulding is one of the most widely used polymer conversion processes and is capable of producing almost any component. In injection moulding, the polymer resin together with any additives are heated until molten and injected into water-cooled mould. Once solid, the mould is opened and the component ejected after which the cycle is again repeated. Irrespective of the type of machinery used, the sequence of events in the injection moulding process can be represented as a time cycle as shown in the figure 2.5 below.

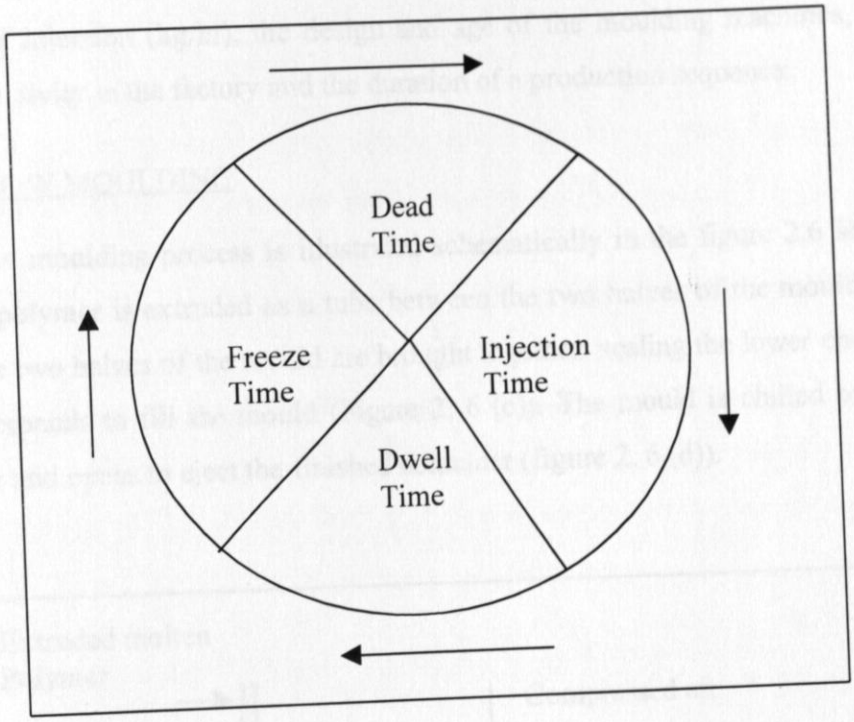


Figure 2.5: The time cycle in injection moulding.

The four elements of the cycle are:

1. Injection time – the time taken to fill the mould with molten polymer.
2. Dwell time – the time period during which the mould is full but remains under pressure.
3. Freeze time – the time required for the moulding to set or freeze sufficiently to allow the moulding to be removed without damage.
4. Dead time – the time required for the mould to open, for the moulding to be removed and for the mould to close again.

In practice, the setting process starts during the dwell time and continues during the freezing time so that the boundary between these two phases of the operation is blurred. Achieving the correct proportion for these four elements of the moulding cycle is the key to ensuring that good quality mouldings are produced in the shortest time thereby making the most effective use of the moulding machine. It is important to recognize that the performance of injection moulding factories can be very variable because of factors such as rate of injection (kg/hr), the design and age of the moulding machines, the general level of activity in the factory and the duration of a production sequence.

2.5.2 BLOW MOULDING

The blow moulding process is illustrated schematically in the figure 2.6 shown below: Molten polymer is extruded as a tube between the two halves of the mould (figure 2. 6 (a)). The two halves of the mould are brought together, sealing the lower end of the tube, which expands to fill the mould (Figure 2. 6 (c)). The mould is chilled to solidify the polymer and opens to eject the finished container (figure 2. 6 (d)).

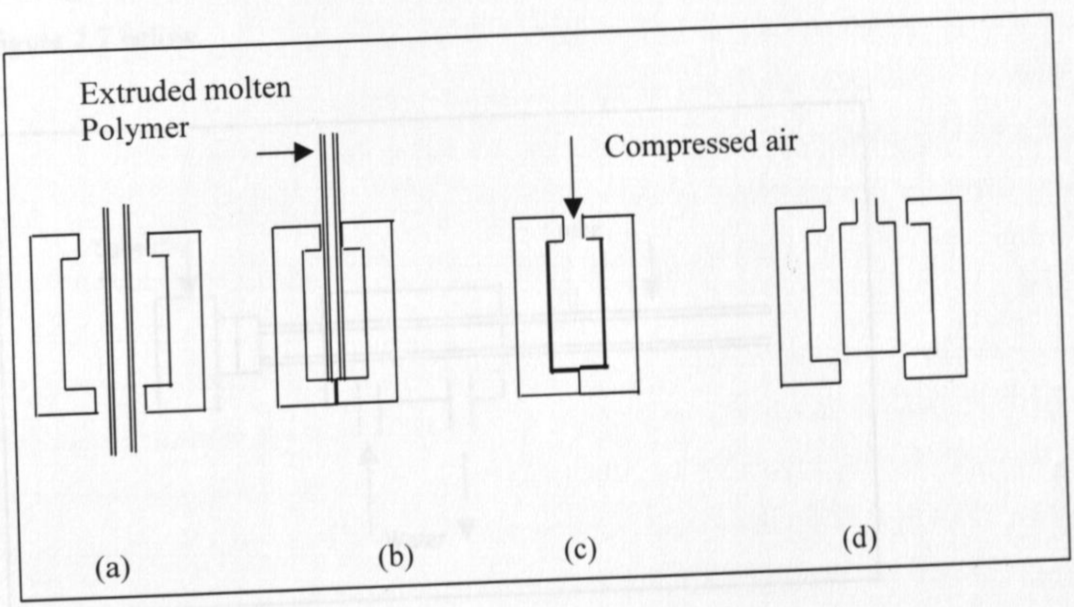


Figure 2. 6: Stages in the production of blow moulded containers.

In practice, the mould may consist of more than two parts depending on the complexity of the container to be blown, and may mould more than one container at the same time, but the general principles of the figure are still followed.

2.5.3 EXTRUSION MOULDING

When the plastic material is heated in the heating cylinder, in general, the position of screw is fixed during extrusion moulding process. Therefore a resin that is made plastic is discharged continuously from the die. The discharged resin is moulded into the basic shape and formed with the sizing die, cooled and finally solidified. The receiving equipment serves an auxiliary function of receiving extruded products. The products are cut or wound up according to the characteristics and purpose of use. This moulding method is suitable for moulding sheets, and films with uniform cross-section.
In pipe extrusion the molten polymer is extruded through an annular die and cooled by passing through a water trough. The processing sequence is shown schematically in figure 2.7 below.

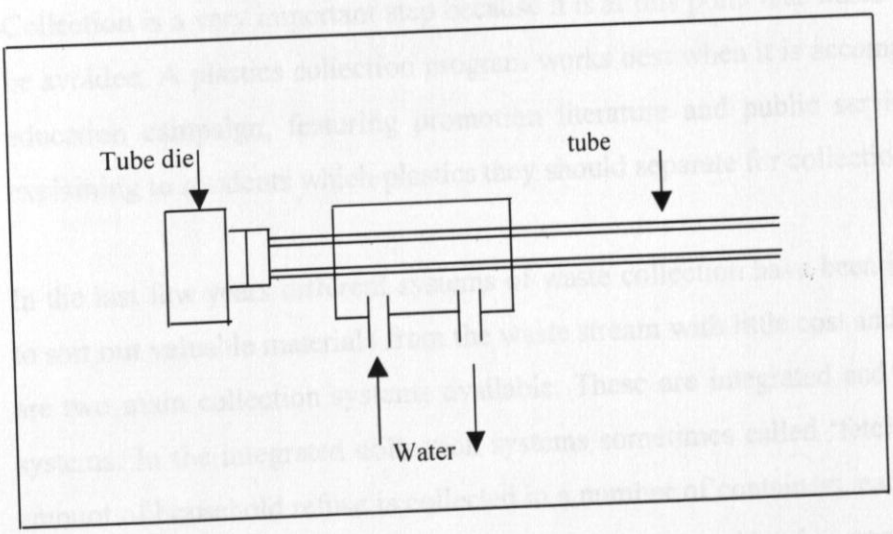


Figure 2.7: Schematic diagram of pipe extrusion.

2.6 RECYCLING OF PLASTICS

2.6.1 RECYCLING INFRASTRUCTURE

Plastics waste is generated at all stages of the plastic life cycle including the producer, compounder, wholesaler, retailer, packager and consumer. Of the total waste generated, about 60% is post-consumer waste, mainly packaging materials (Drain et al, 1981). There are myriad different types of plastic wastes, but for simplicity they may be divided broadly into the following four categories. The first category consists of single grades of plastics that have not been contaminated and can be incorporated into the process from which it originated. The second category consists of single grades of plastics that have been contaminated and cannot be incorporated into the process from which it originated and therefore has to be further processed for different end-use applications. Third category consists of mixed plastic waste stream with known composition and essentially free of non-plastic contaminants. The last category consists of randomly collected or municipal refuse that is contaminated with non-plastic materials. As with other recyclables, infrastructure for recycling plastic waste consists of collection, handling, reclaiming and end-use as major components (APC, 2001).

2.6.2 COLLECTION

Before plastics are recycled, they are collected or recovered from the waste stream. Collection is a very important step because it is at this point that waste contamination can be avoided. A plastics collection program works best when it is accompanied by a public education campaign, featuring promotion literature and public service adverts clearly explaining to residents which plastics they should separate for collection (APC, op cit.)

In the last few years different systems of waste collection have been introduced in order to sort out valuable materials from the waste stream with little cost and high purity. There are two main collection systems available. These are integrated and additive collection systems. In the integrated collection systems sometimes called 'fetch systems' the total amount of household refuse is collected in a number of containers, each for different type of material. The materials are collected simultaneously with other waste.

Additive collection systems are operated independently from the conventional waste collection. They are based on the readiness and cooperation of the customer to transport the valuables to a container located at a central area. These systems are also called the 'bring system'.

2.6.2.1 The fetch systems

To establish such a system in an area, a number of containers are used. The number ranges from systems using two up to five or even more containers with simultaneous or alternative removal with combined or separated collection of different materials. One-way sacks can also be used. Common fetch collection system is curbside system.

Curbside collection

In curbside collection system consumers separate plastic containers and other recyclable from their household refuse. The plastic containers are placed in the consumers recycling bin and set out at the curbside for collection- usually to be picked up the same as regular refuse collection.

There is rapid growth in number of households with curbside collection especially in Belgium where 40 to 60 % of targeted recyclable are returned through this program with low contamination (Petcore, 2001).

2.6.2.2 The 'bring system'

The 'bring' system works through a number of containers being placed at strategic areas. The consumers must deposit the materials into those containers. Plastic materials are collected separately from other deposited materials. The problem with bring system is that high motivation by the public is necessary. The number of containers and their distance from individual households also influences the success of the system. Popular systems used for collecting bottles include drop-off, buy back centres and return vending, refill and deposits systems (Petcore, op cit).

(i) Drop-off locations

The public drops off their plastics in collection containers located at convenient points. About 10 to 15 % of available recyclables are usually recovered by this method but can be higher with good participation rates. However contamination levels can be as high as 10 - 30 %.

In Italy over 40 % of the population now has access to some 24,500 PET 'igloo'. Bottle banks for PET are becoming well established in countries such as Switzerland (over 12,000 drop off points), France (over 5,000 sites) and the UK (over 1,500 sites).

(ii) Buy-back centres

Plastic containers and other recyclables are purchased from consumers through a recycling operation. This method provides an incentive for consumers to separate and bring back their recyclables. About 15 to 20 % of available recyclables are usually recovered through this system.

(iii) Return vending

In this collection system machines are placed in accessible places into which consumers can insert plastic containers such as bottles and receive coupons or tokens in return. This method achieves similar return rates as buy back centres.

(iv) Refill and deposit

Bottles are sold with refundable deposits that are redeemable on return of the bottle to participating retail sites. Deposits may be both refillable and single-use plastic containers. This approach is common in Scandinavian countries, the Netherlands, Germany, Switzerland and Austria.

2.6.3 SORTING

After plastics are collected, they are delivered to a handler for sorting (if necessary) and densification. Most collection programs today are multi- material, commingled programs. This means that plastics are collected with other recyclable such as glass and aluminum. In these programs plastics will need to be separated or sorted from the other materials using materials recovery facilities (MRFs). Material sorting systems (MSS) can be categorized into three categories: macrosorting systems, microsorting systems, molecular sorting systems (Lund, 1993).

2.6.3.1 MANUAL SORTING SYSTEMS

The overriding best practice in manual sorting systems used at plastic intermediate processing facilities (IPFs) is adequate training of plant personnel in identifying characteristics that will usually distinguish plastic containers by different resin types. Manual sorting systems are generally of two types: positive and negative sort systems. In a positive system, the desired resin types are removed from a stream of plastic containers being carried over a conveyor system. In a negative sort system desired resin containers are left in the conveyor system and unwanted materials or contaminants are removed from the conveyor line. To facilitate manual sorting, simple tests and two main types of resin identification codes are used. These simple tests and the codes; International Organization for Standardization (ISO) and Society of Plastics Industry (SPI)) are discussed below.

(a) ISO CODE

Identification marking of plastics is covered by ISO 11469. It specifies a uniform marking of products that have been fabricated from plastic material. ISO follows the International Union of Pure and Applied Chemistry (IUPAC) rules for abbreviation of natural and synthetic polymers. The abbreviated terms for the basic polymers may be supplemented by up to four symbols to differentiate between or among modifications of polymer, if desired. Such symbols indicate special characters of the polymer such as brominated (B), expanded (E), plasticized (P), unsaturated (U) and other. The ISO coding system is exemplified below;

PE – LLD - Linear low-density polyethylene.

PS - HI - High impact modified polystyrene.

PVC – P - Plasticized polyvinyl chloride.

(b) SPI CODE

SPI introduced its code in 1988 to meet the recycler's needs for a method of identifying plastic material used in packaging. The SPI code is simpler than the ISO standard implying that it contains less information. The overwhelming majority of plastics packaging are made with one of six resins. The SPI resin identification code therefore assigns each of these resins a number from one to six. This number is featured inside a triangle of chasing arrows with the resin abbreviation printed underneath. A seventh code identified as other than the main six, or denoting that the polymer is made of a combination of more than one resin. Figure 2.8 below illustrates the SPI coding system.

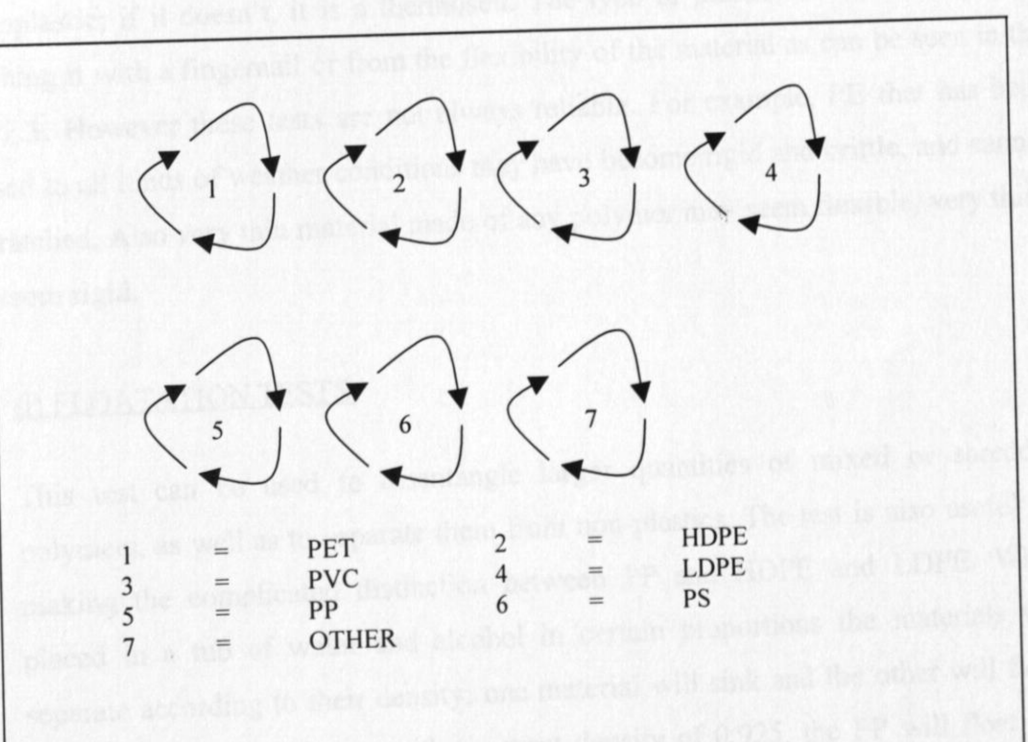


Figure 2.8: SPI packaging resin identification codes.
Source: SPI, 2001.

(c) SIMPLE RESIN IDENTIFICATION TESTS

Some simple tests using basic equipment can provide adequate information for identification (Vogler, 1984). Not all of them are easy to carry out, but most work reasonably well. A rule of the thumb is " if in doubt, test. If still in doubt, throw it out". However, further explanations of some of these tests described in the Table 2.3 are needed and follow here.

To make general distinction between thermoplastics and thermosetts, take a piece of wire just below red-hot and press it into the material. If it penetrates, the material is a thermoplastic; if it doesn't, it is a thermosett. The type of plastic can be identified by scratching it with a fingernail or from the flexibility of the material as can be seen in the table 2.3. However these tests are not always reliable. For example, PE that has been exposed to all kinds of weather conditions may have become rigid and brittle, and cannot be scratched. Also very thin material made of any polymer may seem flexible, very thick may seem rigid.

(i) FLOATATION TESTS.

This test can be used to disentangle larger quantities of mixed or shredded polymers, as well as to separate them from non-plastics. The test is also useful for making the complicated distinction between PP and HDPE and LDPE. When placed in a tub of water and alcohol in certain proportions the materials will separate according to their density; one material will sink and the other will float. For, example, in a mixture with an exact density of 0.925, the PP will float and HDPE will sink; in one with a density of 0.93, LDPE will float and HDPE will sink. Note, however, that the floatation test is not exact enough to distinguish between PP and LDPE, since their densities can overlap. In this case the fingernail test and the visual appearance of the material may be more conclusive indicators.

Another floatation test using pure water and salt can be used to distinguish between PS and PVC, both of which sink in pure water.

YMER	FLEXIBILITY	IN WATER	RELATIVE DENSITY	BURNING	SMELL ON BURNING	SCRATCHES WITH FINGER NAIL	CAN IT BE PERFECTLY TRANSPARENT	NOTES
DPE	Very flexible	Floats	0.9-0.92	Blue flame with yellow melts and drips burning droplets	Like candle wax	Yes easily	no	has a waxy feel intermediat e densities between 0.92 and 0.96 also exists
IDPE	Much less flexible than LDPE. Film crackles when bent	Floats	0.96	Ditto	ditto	Yes with difficulty, especially when cold weathered	no	Very tough, hard to tear.
PP	Hard to bend but does not break when bent	Floats	0.90-0.91	Yellow flame with blue base. can drip burning droplets	Ditto but less strong	no	no	very strong, form an almost unbreakabl e height if folded
PVC	Rigid PVC is brittle plasticized PVC can be very flexible	Sinks	1.2-1.6	Yellow, sooty smoke, doesn't continue to burn if removed from frame	Pungent hydrochlo ric acid. danger do not inhale	Rigid PVC-non-flexible plasticized PVC-yes	yes	Touch with a red-hot copper wire to flame. green flame indicates PVC or other polymer containing chlorine

Table 2.3: Simple tests to distinguish some commonly recycled polymers.

When a specific amount of salt is added into the water the PS will float to the surface, while the PVC and dirt will remain on the bottom of the container. The amount of salt need not be measured, but may be determined by experience.

(ii) BURNING TEST.

This test is carried out as follows. Cut a 5 cm long sliver of the plastic material, 1 cm wide at one end, and tapering to a point at the other. Hold the sample over a sink or stone, and light the tapered end. The color and smell of the flame can be used to tell the type of polymer. PVC can be confirmed by touching the sample with a red-hot copper wire and returning the wire to the flame; it should burn with a green flame. Burn off all residues before repeating the test with the same wire.

2.6.3.2 AUTOMATIC SORTING SYSTEMS

Major AutoSort technologies in use today include optical, X-ray transmission (XRT), X-ray fluorescence (XRF) and near infrared (NIR). The X- ray sortation is commonly used in plastic bottle sortation and is discussed below.

X- RAY SORTATION

Auto- sort technologies based on X- ray detection are generally considered to be the most reliable binary sort method used in sorting of PVC and PET plastic bottles. Figure 2.9 below illustrates how this sortation is done.

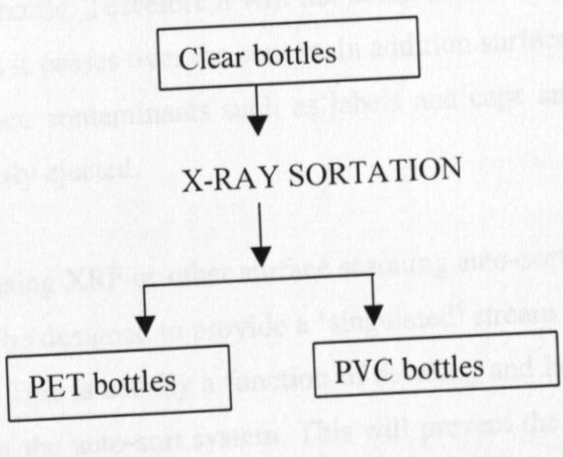


Figure 2.9: Separation of mixed clear plastic bottles.
Source: Petcore, 2001.

The X-ray sensors detect the presence of chlorine atom found in PVC bottles, which is absent in PET bottles. There are two kinds of X- ray detectors currently available. The first is XRT and the second is XRF. XRT signal passes through a bottle and is read by a sensor on the other side. Because XRT signals passes right through a bottle, they ignore such items as labels than other detection systems. This technology has additional benefits in that it can read the chemical content of bottles when they are stuck together, which is a common occurrence when bales are packed too densely. For example if a PVC bottle is stuck to the bottom of a PET bottle as it passes over the sensor, the signal will pass through the two bottles and detect the PVC bottle and eject both bottles from the stream.

The principal drawback to XRT system is that flattened or partially flattened bottles can scatter the detection beam, which prevents the sensor from getting a reading on the other side. This can make the XRT system to eject good bottles that it cannot read. A good way to prevent losses of PET bottles that may result from this or from bottles that are stuck together being ejected is to physically separate rejected bottles by hand and pass them through the system again.

In XRF detection system, the X-ray detection signal bounces off the bottle surface and the reflected signal is read by the sensor. The limitation with all surface-scanning techniques is that they will not detect a PVC bottle that is shielded from the signal by another bottle. Therefore it will not detect a PVC bottle that is stuck to the back of a PET bottle as it passes over the sensor. In addition surface-scanning signals might be affected by surface contaminants such as labels and caps and may cause the PET bottles to be incorrectly ejected.

When using XRF or other surface scanning auto-sort technologies, it is important that the system be designed to provide a 'singulated' stream of bottles passing over the signal and sensor. This is usually a function of debaling and how well bottles are separated prior to entering the auto-sort system. This will prevent the shielding effect described above that can allow PVC to stay in the PET bottles stream. Because x-rays are a form of radiation precautions must be taken to protect workers from exposure. An x-ray sorting system should include sophisticated shielding to eliminate worker exposure to any danger resulting from x-ray radiation.

2.6.3.3 MICROSORTING SYSTEMS

A microsorting system involves separating polymers by type after they have been shredded and chopped into small pieces of approximately 1/8 to 1/4 inch in diameter. Microsorting systems can be subdivided into dry and wet methods. Dry methods are cheaper in investment and operating costs than wet methods, but they create dust problems and explosion or fire hazards. Moreover the recovered fractions are still contaminated with dirt or organic materials. Wet methods are more expensive; they yield a cleaner product, but give rise to a wastewater treatment problem. One dry and a wet micro sorting methods are respectively discussed below.

(i) ELECTROSTATIC SEPARATION

Electrostatic separation operates on the principle that when two dissimilar materials are brought into contact, an electronic charge will be transferred so that one of the materials becomes positively charged while the other becomes negatively charged. The polarity of the charge that develops on any particular type of material depends on the other materials that it comes into contact with. This is in accordance with the triboelectric series that dictates which material will take a positive charge and which will take a negative charge when two materials are 'rubbed' against each other. A short version of that series as it pertains to polymers is shown in the table 2.4.

In the second table (table 2.5), if PVC and PET are contacted together, PVC will be charged negatively and PET positively. Similarly, if PP and PE are contacted, PP will charge negatively and PE positively. To effect a separation of mixed plastics, the plastics must be dry and ground to 5.5 mm size. The particles are then agitated together to provide many contacts so that charging of the individual particles can occur. After charging, the particles are allowed to fall through a strong horizontal electric field so that the positively charged particles will be deflected towards the negative electrode and vice versa. The separated materials are collected and evacuated from the bottom of the apparatus. The process is very cost-effective since the only energy is to provide particle-to-particle contacts for charging and to lift the material to sufficient height. Experiments conducted on a laboratory scale have achieved purities of 99 % (Brown, 1998).

ABRIDGED TRIOELECTRIC SERIES FOR POLYMERS	
PVC	negatively charging plastics
PET	↓
PP	
PE	
PS	positively charging plastics

Table 2.4:Triboelectric series.
Source: Brown, 1998.

INITIAL COMPOSITION OF MIXTURE		SEPARATED COMPOSITION AND RECOVERY	
Polymer	Composition, %	Composition, %	recovery
PVC PET	50.0 50.0	99.2 99.9	80.3 89.1
PET PVC	99.0 1.0	100.0 6.5	75.2 80.0
HDPE PP	50.0 50.0	99.9 99.7	90.6 92.6
HDPE PP	75.0 25.0	99.1 94.2	91.4 96.7
PP PE	50.0 50.0	94.1 98.8	96.2 91.9
HDPE PP PS	42.5 42.5 15.0	92.0 96.1 99.6	72.2 90.7 73.8
PP PS	5.0 95.0	30.9 99.9	95.0 85.1

Table 2.5: Separation results for virgin plastic mixtures.
Source: Brown, 1998.

(ii) SINK-FLOAT SEPARATION

This is a cost-effective method whereby the separation is based on densities (ρ) of different plastics. Water is a suitable fluid to separate floating organic from sinking inorganic material. Water/alcohol mixtures of suitable density have been tested as a means of sorting plastics according to their various types. The sink/float diagram below illustrates how sink-floatation separation operates as described in section 2.6.3.1(c (i)).

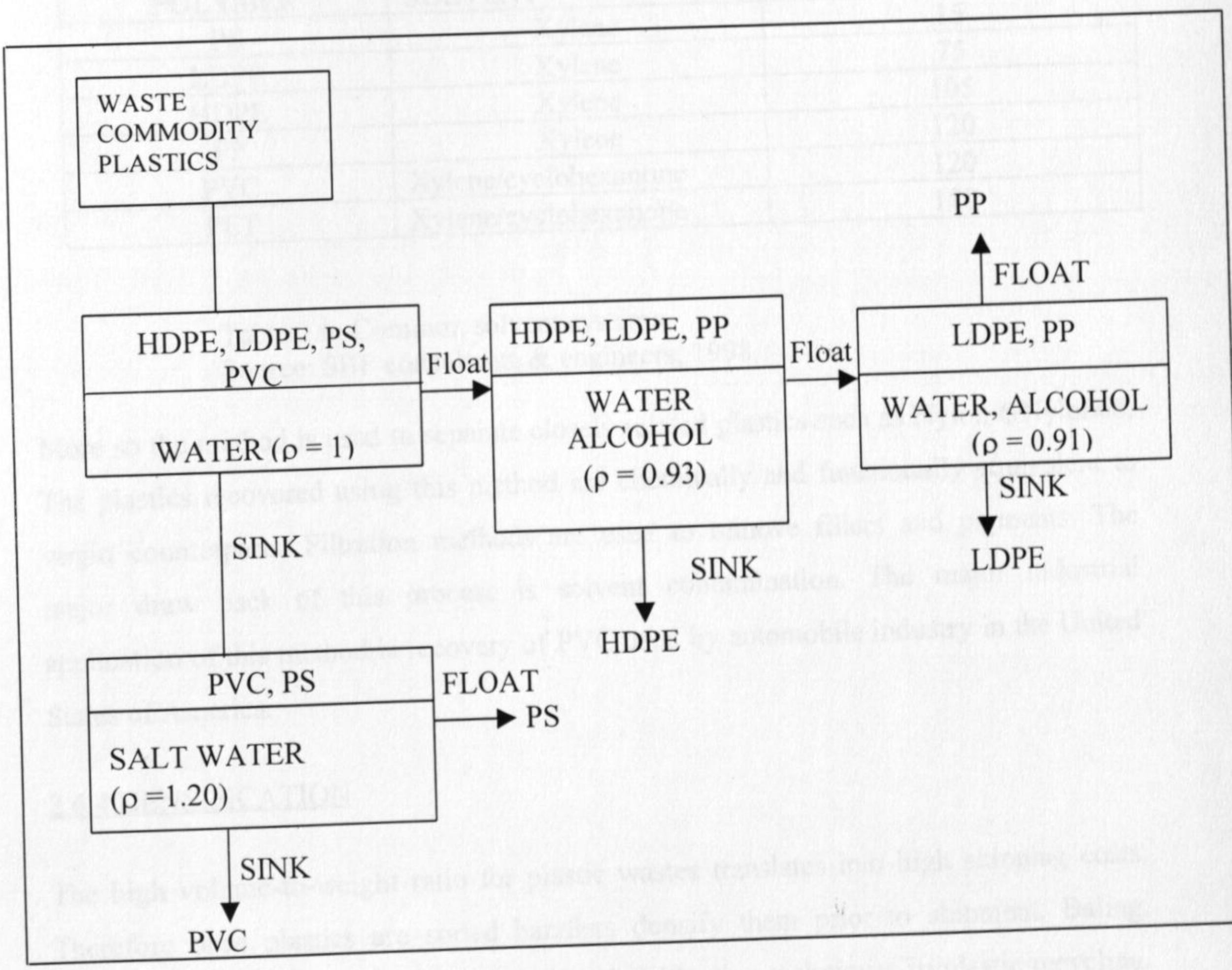


Figure 2.10: The float-sink separation diagram.
Source: SBP consultants & engineers, 1998.

2.6.3.4 MOLECULAR SORTING

A study done at Renselaar Polytechnic has shown that it is possible to separate out six or more polymer types, one from the other, by dissolving them all in a suitable solvent system and taking advantage of temperature point at which each polymer would dissolve in the solvent (Drain et al, op cit.). Table 2.6 below shows some suitable solvents that could be used for molecular sorting.

POLYMER	SOLVENT	TEMPERATURE (^{O}C)
PS	Xylene	15
LDPE	Xylene	75
HDPE	Xylene	105
PP	Xylene	120
PVC	Xylene/cyclohexanone	120
PET	Xylene/cyclohexanone	180

Table 2.6: Common solvent systems.
Source: SBP consultants & engineers, 1998.

More so the method is used to separate closely related plastics such as Nylon 6/Nylon66. The plastics recovered using this method are chemically and functionally equivalent to virgin counterparts. Filtration methods are used to remove fillers and pigments. The major draw back of this process is solvent contamination. The major industrial application of this method is recovery of PVC used by automobile industry in the United States of America.

2.6.4 DENSIFICATION

The high volume-to-weight ratio for plastic wastes translates into high shipping costs. Therefore once plastics are sorted handlers densify them prior to shipment. Baling, shredding and agglomeration are the major densification techniques in plastic recycling. Shredding is the most common densification technique and is discussed below. Figure 2.11 illustrates principle of operation of a shredder.

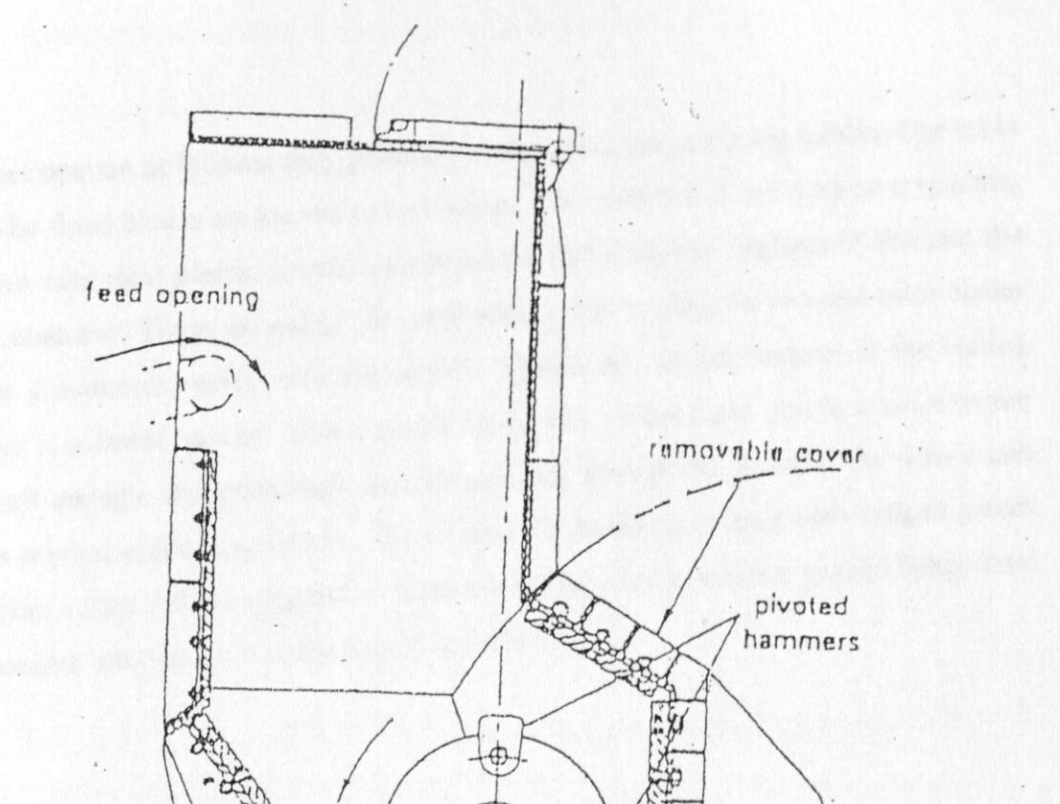


Figure 2.11: Principle of operation of a shredder.

Shredders operate as follows; they generally contain two sets of cutting blades. One set is fixed. The fixed blades are known as bed blades. The other set is mounted on a spinning rotor that cuts rigid plastic containers against the bed blades as material is fed into the cutting chamber. These are called the rotor blades. The number of bed and rotor blades used in granulators varies with the specific equipment. At the bottom of the cutting chamber is a metal 'screen' with a specific hole size. When rigid plastic containers are cut small enough, the granulated material will fall through the holes in the screen and enter a regrind evacuation system. The product of shredding is irregularly shaped pieces of plastics called flakes or regrind. A blower could be used to remove ground flakes from the shredder after which it is discharged into boxes.

2.6.5 RECLAMATION

Reclamation is the step where sorted and densified plastics are converted into reclaimed pellets. The specific process utilized by reclamers will depend in large part on the reclamer's confidence in the quality of the plastics coming into the facility and the application into which the recycled plastic will be used. Pellets are made by melting plastic and extruding the melt into thin strands through a filter to sieve oversized solid contaminants. The extrudate is then chopped into small uniform pieces.

2.6.6 END-USE

Once the plastic is in pellet or flake form, it is sold to manufacturers to be made into final plastic products. It is important to keep in mind that one or more of these elements of the recycling infrastructure may be performed by the same recycling organization.

2.7 FACTORS INFLUENCING PLASTICS RECYCLING

Whether plastics are dumped or recycled for their material or energy contents depends on a number of interacting factors, the major ones of which are: political, ecological, economical, market development and technological.

2.7.1 ECOLOGICAL AND POLITICAL FACTORS

The decreasing availability of low-cost dumping sites, social pressures on environmental pollution, the increasing cost of raw materials and energy, and the growing appreciation of the world's finite reserves have resulted in government's involvement in waste generation, waste disposal and the recycling of the constituents of the waste streams. The problems of waste are universal, but the solution of each country probably will depend on the waste generated per capita and its composition, the population and the population densities, land mass and the availability of appropriate sites for dumping at suitable freight costs.

It is the task of the governments to analyze national problems and suggest or enforce solutions. One hopes that governments will guide their respective countries to adopt appropriate and sensible programs for plastic disposal and recycling, always remembering that what appears to be both technically and economically feasible is not fixed for all time, but depends on general economics and markets.

Also even if not profitable in economic terms, a promotion of recycling is justified when it provides environmental advantages. There are two criteria that are used to 'measure' the environmental advantages of recycling. These are life cycle assessments and health risks associated with recycling (European Commission (EC), 2000).

(a) LIFE CYCLE ASSESSMENTS.

Life cycle assessment (LCA) is a technique for assessing the environmental aspects and potential impacts associated with a product by,

- compiling an inventory of relevant inputs and out-puts of a product system
- evaluating potential environmental impacts associated with those inputs and outputs
- interpreting the results of the inventory analysis and impact assessment phases in relation to objectives of the study.

LCA studies the environmental aspects and potential impacts throughout a product's life (i.e. cradle-to-grave) from raw material acquisition through production, use and disposal (ISO, 1998). Figure 2.12 show the three stages of LCA study.

STAGE 1: An inventory stage – where the aim is to provide a detailed description of the inputs of raw materials and fuels into the system and the outputs of solid, liquid and gaseous wastes from the system (see figure 2.13).

STAGE 2: An interpretation stage – where the inventory results are linked to identifiable environmental problems.

STAGE 3: An improvement stage – in which the system is modified in an attempt to reduce the environmental impact.

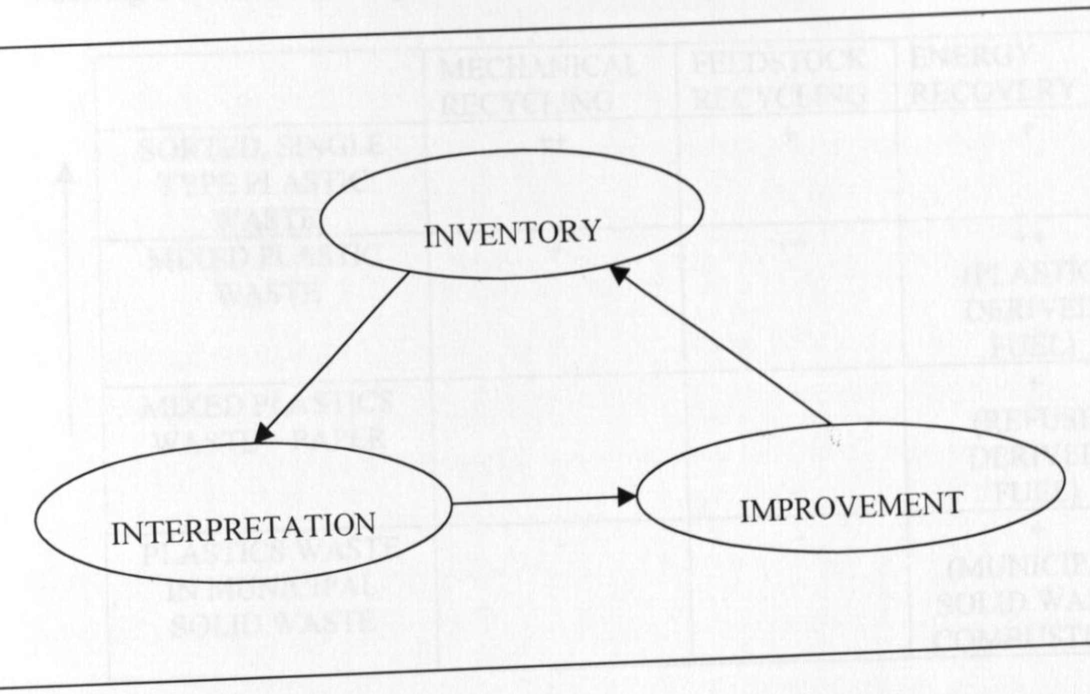


Figure 2.12: The three main stages of a life-cycle assessment.
Source: Boustead, 1999.

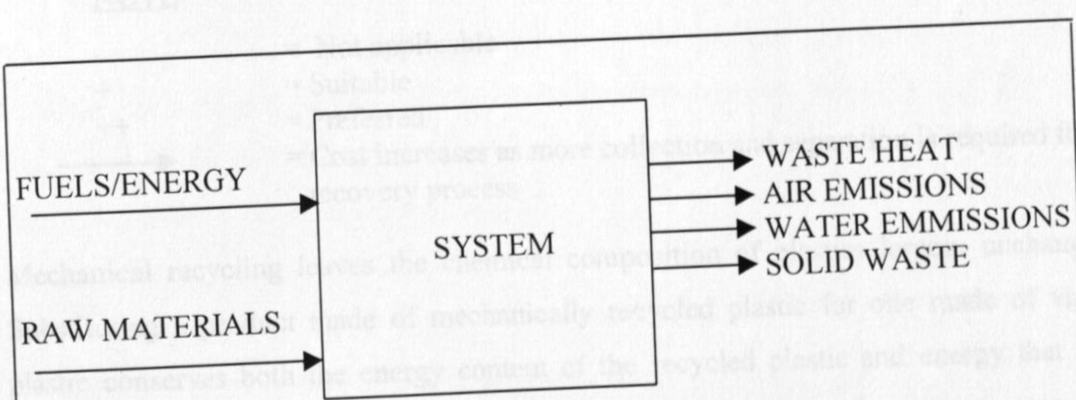


Figure 2.13: Schematic diagram of an industrial, life cycle system.
Source: Boustead, 1999.

A German study on various recovery options for packaging waste has given rise to the following LCA results (see figure 2.14 below).

	MECHANICAL RECYCLING	FEEDSTOCK RECYCLING	ENERGY RECOVERY
SORTED, SINGLE TYPE PLASTIC WASTE	++	+	+
MIXED PLASTIC WASTE	+	++	++ (PLASTIC DERIVED FUEL)
MIXED PLASTICS WASTE + PAPER	-	-	+ (REFUSE DERIVED FUEL)
PLASTICS WASTE IN MUNICIPAL SOLID WASTE	-	-	+ (MUNICIPAL SOLID WASTE COMBUSTION)

Figure 2.14: Eco-efficiency of various recovery options.
Source: Hyde and Kremer, 1999.

NOTE

– = Not applicable
\+ = Suitable
++ = Preferred
→ = Cost increases as more collection and separation is required for recovery process

Mechanical recycling leaves the chemical composition of plastics largely unchanged. Substituting a product made of mechanically recycled plastic for one made of virgin plastic conserves both the energy content of the recycled plastic and energy that was originally used in its manufacture. Feedstock recycling exploits the energy content of plastic by converting them into new raw materials. Energy recovery exploits the energy content of plastics by generating electricity and heat.

Because mechanical recycling of waste plastics into substitutes for virgin plastic products is only suitable for single resin waste fraction, an environmentally acceptable recycling strategy would stipulate mechanical recycling for single-resin fraction, and feedstock recycling or energy recovery for the mixed plastic fraction. In view of the environmental drawbacks, such a strategy would not favour mechanical recycling of waste plastics into substitutes for wooden and concrete products (Hyde and Kremer, 1999).

(b) HEALTH RISKS ASSOCIATED WITH RECYCLING

Collection, sorting and treatment are not associated with specific 'new' risks related to the exposure of workers and environment to hazardous substances. General risks like accidents in transportation processes or accidental fires in material stores do exist. Possible specific risks of mechanical plastics recycling are related with toxic substances in the recycling material, e.g. heavy metals and other additives. Some PVC products contain heavy metal stabilizers which are toxic (cadmium and lead compounds especially).

2.7.2 ECONOMIC FACTORS

In the plastics industry the raw materials cost can be between 50 and 70 % of the total cost hence it is imperative to reduce waste and where possible recycle scrap and waste. The economic success of certain plastics operations, such as bottle blowing, vacuum forming and extrusion, depend on the intrinsic value or production costs of the material.

They depend on the cost of collection, segregation, and decontamination and on the potential markets for the recycled material. As the separation and segregation of plastic elements from municipal refuse is frequently done in conjunction with other constituents, such as glass, metals and paper, it is difficult to assign the true costs to the recovery and treatment of the various plastic elements.

The high cost of separation, segregation and decontamination of plastics in post-consumer wastes could be drastically reduced by pre-segregation at household level. This would require the cooperation of householders, separate storage bins for various types of plastics, separate collections by local authorities and central storage facilities for different plastics.

Unfortunately, raw materials and energy costs have been cyclic in nature and it is thus difficult for companies and governments to justify capital investment for recycling equipment and facilities. The increasing upward trend in the price of oil increases the price of virgin raw materials directly as a source of raw material and indirectly as a source of energy for processing and transportation. It may well be that we are entering a period when there will be financial incentives for the recycling of plastics.

Plastics not only have a good cost performance ratio but also require for their manufacture less oil or oil equivalent than metal, wood, paper. Thus, in terms of raw material and energy costs it would appear that replacing plastics with the more conventional materials would not be economical. There are, however, social changes and consequences associated with the use of plastics and these should be taken into account in the overall economic or energy balances.

2.7.3 MARKET DEVELOPMENT FACTORS

Homogeneous thermoplastic scrap can be recycled in-plant with virgin material or processed into granules by an independent recycler and sold to the processing industry as a cheaper replacement for virgin material. There is essentially no market for dealing in heterogeneous plastic waste of materials made from recycled plastics.

The key to the secondary recycling plastics, especially from post consumer waste, is the development of suitable markets for the recycled materials and their products. These products should have known or predictable specifications or performance capabilities. In the past, recycled material had to compete in the market with relatively inexpensive virgin raw materials. The increasing price of oil may favor the use of recycled material, but if it is to be used in place of virgin material, the price differential must be favorable. This price differential is necessary to offset the probability of lower production rates and interrupted production runs caused by the poorer quality feed material, and to incorporate processing additives and stabilizers. For recycled material to gain general acceptance its price will probably have to be about 20-25 % less than prime grade virgin material (Drain et al, op cit.). It is doubtful if the economics of recycling post-consumer wastes could support such a low price. It would appear therefore, that if plastics are to be recycled for their material contents, the products should not be in direct competition with those produced from virgin raw materials.

2.7.4 TECHNOLOGICAL FACTORS

The achievable quality of the recyclates depends greatly on the degree of contamination of the collected plastic wastes. In order to produce high-quality recyclates it is necessary to have the plastic wastes collected by type of application. With this in mind the recycling technologies can either be categorized as primary, secondary or tertiary.

2.7.4.1 PRIMARY RECYCLING

The primary recycling of clean, uncontaminated, single type plastic scrap and waste is comparatively easy and is practiced widely. The recycled scrap or waste is either mixed with virgin material at various ratios to assure product quality or used as a second grade material. The recycling is best done "in-house", when transportation and handling costs are minimized and where the history of the waste can be controlled, thereby eliminating, or at least limiting, contamination. Only thermoplastics are directly reprocessed.

The scrap or waste should be kept clean and it may have to be separated from the packaging media and segregated in terms of colour. Generally, the waste will have to be stored, preferably having undergone some form of bulk reduction; the bulk density in the form of waste film or fiber can be 15-20 times less than polymer granules. The conditions and duration of storage may be important to limit chemical changes in the polymer. The American Plastics Council (APC) recommends the following maximum duration for unprotected outdoor environment for various resins (see table 2.7).

RESIN	DURATION IN MONTHS
PET	6
HDPE	1
PVC	6
LDPE	1
PP	1

Table 2.7: Maximum safe duration for plastics left unprotected from UV-radiation.
Source: APC, 2001.

During processing or in-service use, a plastic may undergo chemical reactions that can affect its physical properties. If these physical properties are affected to any extent the plastic may become unsuitable for its original use and will have to be downgraded. One example of this is the reaction of polyolefins with oxygen both at elevated temperatures (thermal oxidation) and during exposure to ultra-violet light (photo-oxidation). This oxidative degradation results in a decrease in molecular weight, a build-up of hydroxyl and carbonyl compounds and a loss of tensile strength in solid materials. Trace quantities (typically< 0.1 %) of anti-oxidants and ultra-violet stabilizers are incorporated into polyolefin packaging material to prevent, or at least limit, thermal oxidative degradation during processing and photo-oxidative degradation during use. It is very probable that during primary or secondary recycling the hydroxyl and carbonyl compounds and any additives will be recycled and remain in the resultant polymer matrix. With mixed materials, even of the same plastic type, this could pose problems of compatibility and accelerated oxidation.

If contaminated or heterogeneous plastic waste is to be recycled as high-grade material, then a suitable cleaning-separation process must be included in the recycling system. A variety of such processes do exist, but as yet most have been operated only on a small scale, either for their technical or economic evaluation. Although, in general, such processes exploit differences in density between plastics or between plastics and their associated contaminants, processes do exist that utilize differences in other physical or chemical properties, such as differential wetting characteristics or solubility in a solvent or mixture of solvents. The development of appropriate and economical processes that can cope with the numerous industrial combinations of contaminants and plastic mixtures could assist greatly in the overall economics of both primary and secondary recycling.

A particular cleaning-separation process can be used for either primary or secondary recycling, depending on the composition and constituency of the feed material. In practice, however, the processes are used either "in-house" for primary recycling to remove specific contaminants from the otherwise homogeneous plastic material or for the secondary recycling of plastics from mixed wastes by removing contaminants or separating plastics into generic types. The details and limitations of the cleaning and separation equipment are discussed in the following section. The industrial practice of primary recycling is based on size reduction technique done by various types of granulators such as cryogenic grinders and plastic compactors.

2.7.4.2 SECONDARY RECYCLING

Secondary recycling utilizes plastic waste unsuitable for direct reprocessing through standard equipment. This is due to contamination that affects effective processability and predictability of properties of processed products using equipment designed for processing uncontaminated virgin resins.

Two approaches are applied during secondary recycling. One approach is to separate the plastics from their contaminants and then segregate the plastics into generic types, one or more of which is then recycled into products that generally compete with products produced from virgin or primary recycled material. The other approach is to separate the plastics from their associated contaminants and recycle them as a mixture without segregation.

(a) SECONDARY RECYCLING BY TYPE

Methods available for the separation of plastics into types depend on, shape, density, surface properties and selective dissolution; they include (i) air classification; (ii) hydrocycloning; (iii) flotation-sedimentation; (iv) froth flotation and (v) solvent extraction (Drain et al, op cit.).

Many techniques are available for the separation by type of the major thermoplastics. Selection of a technique for commercial use depends on the capital and running costs of the additional equipment, particularly if a drying stage is necessary (Drain, 1981).

(b) SECONDARY RECYCLING OF PLASTIC MIXTURES.

Recycling of mixed plastic wastes in the ratio in which they are normally found in collected waste offers advantages in that complex, energy consuming, separation processes are eliminated. Unfortunately, many of the commonly used plastics are virtually incompatible and this means that the mechanical performance of the products fabricated from mixed plastic waste are often inferior to the original components of the waste when used separately.

Two practical approaches to the problem have been the modification of plastic waste to improve its mechanical properties and the designing special equipment capable of processing mixed plastics.

MODIFICATION OF MIXED WASTE.

The compatibility of polymers refers to their miscibility, on a molecular scale, in the solid state. Such miscibility occurs only when the Gibbs free energy of mixing is negative and hence it is a rare event for high molecular weight polymers to be mutually soluble on a molecular level. The table 2.8 below shows resin-to-resin compatibility.

POLYMER TYPE	LDPE	LLDPE	EC	HDPE	PP	PS	PVC
LLDPE	1						
ETHYLENE COPOLYMER (EC)	1	1					
HDPE	1	1	1				
PP	4	2	2	4			
PS	4	4	4	4	4		
PVC	4	4	(2)	4	4	4	
PET	4	4	(3)	4	4	4	4

1 = EXCELLENT COMPATIBILITY
2 = GOOD COMPATIBILITY
3 = FAIR COMPATIBILITY
4 = NOT COMPATIBLE
( ) = COMPATIBILITY DEPENDS ON COMPOSITION

Table 2.8: Resin compatibility matrix.
Source: ReTAP, 1997.

The efficiency of conventional high-speed production processes such as extrusion, blow moulding and injection moulding depends upon the constituency of the feedstock and this limits the use of mixed or contaminated plastics. The presence of impurities, whether they are a second type of plastic or otherwise, can seriously affect the production rates or can result in products with inferior performance or appearance.

The size, position and morphology of the domain structures that are formed when incompatible polymers are mixed, and which can affect the mechanical properties of the blend, can be influenced by the mixing operations. However, even expensive processing technology cannot eliminate the problem of the interface generation between the domains of different polymers. The lack of adhesion between the polymer phases in the blend causes substantial loss in property. Resin compatibility can be improved in three ways: alter composition of the blend so that a region of better properties is entered; introduce an additive that will improve the adhesion between the polymer phases in the blend; and introduce a non-plastic component.

(i) CHANGING PROPERTIES OF PLASTIC MIXTURES.

Changing the composition of a three, or more, component plastic mixture, to achieve a more favorable composition poses certain practical problems. Either a proportion of one or more of the components would have to be selectively removed from the mixture, or an additional quantity of one or more of the components would have to be added, either from a primary recycling process or as virgin material. The consequences of these alternatives would have to be considered in the overall economics of the process.

(ii) ADDITION OF COMPATIBILISERS.

Compatibilisers are additives that improve the physical properties of blends of incompatible polymers by promoting adhesion at the domain interfaces, thereby permitting the transmission of stresses from one phase to another. Chlorinated polyethylene (CPE) is such a compatibiliser. It is available with different proportions of chlorine, typically CPE 36, CPE 42, and CPE 48, where the numbers refer to the percent of chlorine.

(iii) ADDITION OF A NON-PLASTIC COMPONENT.

Chemical cross-linking can improve the physical properties of mixed plastics. Polyethylene may be cross-linked by compounding it with peroxide and heating the mixture. Typical peroxides that have been used are: dicumyl peroxide and di-t-butyl peroxide. The addition of a cross-linking agent to an incompatible plastics blend not only cross-links the polyethylene components, but also improves adhesion between the separate phases.

SECONDARY RECYCLING EQUIPMENT DESIGN REQUIREMENTS

The following are requirements for a commercially successful secondary recycling operation based on processing commingled plastics (Smith, 1978).

- The machine has to be capable of subjecting the plastic mixture to a high shear rate at high temperature for a short time period. High shear processing is necessary in order to achieve good dispersion. Short residence time is required in order to avoid material degradation caused by high temperatures.
- The product has to be manufactured in one step. The cost of a two-step process (e.g. homogenizing and pelletizing followed by extrusion) is usually too high to make it economically attractive. The raw material for a given product should have a fairly constant composition. This is required in order to produce products with consistent material properties. In addition, studies have shown that product properties are often dependent upon material feedstock composition.
- Output must be maximized. High production rates are necessary in order to minimize costs such as machine time and overheads.
- Proper selection of the product must be made. The mechanical properties of products made from mixed plastic wastes are generally low. Because of non-uniform colors and poor surface finishes, the appearance is often poor. This makes it difficult for mixed plastic products to compete with products made from virgin materials. However, they can compete with a variety of wood and concrete products where these properties are acceptable. In many cases the mixed plastic products offer properties that are inferior to the original materials.

SECONDARY RECYCLING PROCESS DESCRIPTIONS

THE "REVERZER" PROCESS

The reverzer process was developed by the Mitsubishi Company and is one of the earliest methods for producing commingled plastics products. The process basically consists of material preparation, extrusion and forming. Commingled waste plastics are fed into and mixed in an extruder where rapid melting and homogenization occur. A vertical screw plunger discharges the material into the mold. The mold is then cooled in a water bath or in a water spray tunnel. The reverzer process can manufacture products by three systems: intrusion molding, extrusion, and compression molding. With auxiliary equipment, the reverzer process is capable of producing a variety of shapes and sizes.

(i) INTRUSION (FLOW) PROCESS

A number of manufacturers, process commingled materials by intrusion processes, many based on the Klobbie process. The Klobbie system consists of an extruder, several rotating molds and a tank of cooling water. The commingled material is mixed and melted in the extruder and then is forced into one of the molds. After the mold is filled, the carousel rotates allowing another mold to be filled. The filled mold passes through the tank of chilled water allowing the mold to cool, and then is ejected. The process features high throughput and has the ability to produce thick-walled moldings such as pallets, as well as linear profiles such as plastic lumber products.

(ii) COMPRESSION MOLDING

The recycloplast system has proven to be the most successful technology based on the compression molding process. The process mixes commingled plastics with other materials, melting the materials by a friction process. An extruder presses the material into pre-measured, roll-shaped loaves. The loaves are then conveyed to a press-charging device, which fills a sequence of compression molds. Products are cooled, ejected onto a conveyor and then carried to storage. The process has high throughput and is capable of producing a variety of thick-walled products such sack pallets, grates, benches, and composting boxes. However, the plant size is large and capital investment is high.

(iii) CONTINUOUS EXTRUSION

Continuous extrusion of mixed plastic waste is very similar to technologies used in continuous pipe manufacturing. The systems have the ability to produce hollow profiles and foamed products. These techniques save materials costs and may provide a weight-saving advantage in certain applications. In addition, the system can produce profiles of varying lengths, such as very long profiles. However, continuous extrusion systems require more space than other systems because they require straight cooling sections. The system requires long cooling times in order to avoid temperature gradients, which can create, voids and profiles faces that contract inwards. Therefore the capacity of this system may be lower than the other molding systems.

2.7.4.3 TERTIARY RECYCLING

Tertiary recycling is the generic name given to processes by which plastic material is converted into energy or recoverable chemical products. The energy content of the waste plastic material may be recovered, at least in part, once only by burning the waste plastic material in air (incineration). Useful chemical products or fuels may be recovered from the plastic material by heating it in the absence of air (pyrolysis) or by depolymerisation (e.g. hydrolysis).

(a) INCINERATION

Plastics have a high-energy equivalent value (Table 2.9) and, except for fire retardant grades, burn readily; they are thus a potential source of energy. A typical value for polymers found commonly in household waste is 38 megajoules per kilogram (MJ / kg), which compares favorably to the equivalent value of 31 MJ / kg for coal (Eulalio et al, 2001).

This represents a valuable resource raising the overall calorific value of domestic waste which can then be recovered through controlled combustion and reused in form of heat and steam to power electricity generators. Table 2.10 gives some successful incineration projects.

RESIN	HEAT OF COMBUSTION (kJ/kg)
HDPE	46300
PVC	17500
PP	46500
PET	22700
PS	41700
LDPE	46300
OTHERS	36800

Table: 2.9: Heats of combustion for some common polymers.
Source: Eulalio et al, 2001.

NAME OF TECHNOLOGY	DESCRIPTION	STATUS
HT incineration process	Technology: high temperature incineration in a rotary kiln. Technology developed for the thermal destruction of hazardous waste. A feasibility study was carried out by three companies (Steinmuller, Sulzer Chemtech, Sulzer EscherWyss)	Technology proven
Cementa process (Sweden)	In 1995 4600 tons of fuel were substituted by plastic waste	Commercial

Table 2.10: Some successful incineration projects.
Source: Tukker et al, 1999.

(b) PYROLYSIS

It is the physical and chemical decomposition of organic materials caused by heating in oxygen free or oxygen deficient atmosphere. This process sometimes called destructive distillation, drives off volatile components and leaves a char consisting of carbon and quite often a fairly large ash content. By varying temperature, it is possible to vary the properties of liquid or gaseous products. Table 2.11 below shows some pyrolysis projects

TECHNOLOGY NAME	DESCRIPTION OF TECHNOLOGY
Akzo process	Technology: fast pyrolysis in a circulating fluidized bed system (two reactors) with subsequent combustion. Research at Akzo started in 1992;technology chosen was based on Battelle process. Experiments with 100% PVC waste have been carried out with promising results. Process conditions: hot circulating sand bed, steam at 700 – 900 °C Input: mixed waste including high percentage of PVC waste; Input quality: shredded waste Output: HCL, CO, H2, CH4 depending on the feedstock composition, other hydrocarbons, fly ash
BASF cracking process	Technology: liquid phase thermal cracking (pylolysis / depolymerization) Technology was developed to process DSD waste. Due to lack of waste no large-scale plant was built and pilot plant was shut down. Process conditions: ca. 400° C Input: plastics waste Input quality: max. 8% PVC Output: HCl, petrochemical gaseous and liquid feedstock;

Table 2.11: Some pyrolysis projects.
Source: Tukker et al, 1999.

(c) CHEMICAL RECYCLING

Chemical recycling, also called chemolysis is the use of a chemical to break down the backbone of the polymer. Of all packaging resins chemically recycling is mostly used to recycle post-consumer PET bottles. This is because all other available recycling methods deteriorate properties for it to be recycled back to bottles of desired properties. Due to above facts chemical recycling methods commonly applied to PET bottles are described below.

(i) CHEMICAL RECYCLING OF PET

Chemical recycling is an established method for recovery of PET waste. However, equipment costs are high and require large turnovers to be economically viable (Petcore op cit.). The selection of the most appropriate process is dependent upon the quality of the available feedstock and demand for intermediates formed. Glycolysis and methanolysis are unable to remove colours added to PET feedstream during original formulation, and therefore require additional purification steps.

(ii) GLYCOLYSIS

Glycolysis involves the breakdown of the polymer backbone by the action of glycols under elevated temperatures and in the presence of catalyst. Reaction of recovered PET with excess ethylene glycol under pressure at around 200^{o} C reverses the polymerization reaction to give bishydroxyethylterephthalate (BHET) and short chain polymers of just a few repeat units. The BHET formed is purified by melt filtration under pressure to remove physical impurities and treatment with carbon to remove chemical impurities.

(iii) METHANOLYSIS

In methanolysis, the polymeric backbone is cleaved by the addition of methanol. Treatment of PET with methanol, under pressure at around 200^{O} C in depolymerisation, giving dimethyl terephthalate (DMT) and ethylene glycol (EG).

The DMT is purified by distillation and crystallization to give a high quality intermediate, which may be used to make new PET. Once refined the EG may be used for a variety of applications including antifreeze and PET production.

(iv) HYDROLYSIS

Polymers containing carbonyl functions can be cleaved back to monomers by hydrolysis

PET may be hydrolyzed by treatment with water, acids or caustic soda to give terephthalic acid (TA) and ethylene glycol, which require purification before, re-use. Commercial hydrolysis is less well established than either glycolysis or methanolysis.

(v) SAPONIFICATION

PET may also be hydrolyzed by treatment with alkali. Two processes have been suggested for commercialization: "Recopet"(France) and "Unpet"(USA).

"Recopet" is a multistage process, in which PET flakes are saponified, filtered and dyes extracted before TA is precipitated and sodium sulfate and EG extracted.

The "Unpet" process produces EG and disodium terephthalate which are then heated to evaporate off the EG and reduce organic impurities to carbon dioxide and water. The disodium terephthalate is obtained by filtration from aqueous solution.

2.8 ECONOMIC AND INSTITUTIONAL INCENTIVES AND BARRIERS TO PLASTIC RECYCLING

There are several groups of decision-makers that individually or collectively decide if plastic waste will be recycled or disposed off (Curlee, 1986). Figure 2.15 illustrates identification of those different private or public decision-makers. The first group is plastic manufacturers; resin producers, converters, fabricators, assemblers, and so forth. Manufacturers' decisions are important on two fronts- first, in their decisions to recycle r dispose of their own manufacturing waste, and second, in the way they design and produce products that contain plastics. Certain product designs will obviously be more amenable to recycling than others.

The second group is consumers. Consumers contribute to recycling mainly by diverting plastic wastes away from the municipal stream. The possible streams can be divided into three parts: (1) segregated plastics that are returned to retrieve a deposit (such as PET beverage bottles), (2) segregated plastics that are diverted because they are contained in products that are recycled to retrieve some other materials (such as steel, copper and other metallic from automobiles and electrical and electronic equipment), and (3) the municipal waste stream. In the first case, the final question of recycling or disposal is given to the waste processor. In the second case, the question is posed to the firm that recycles the product that contains plastics. If the plastics enter the municipal stream, the question is posed to the public-sector decision-maker. The public-sector decision-maker also, of course, affects the private sector's incentives to recycle through the regulations and legislation.

To examine more closely the particular incentives and barriers faced by the different decision-makers, it is convenient to categorize the decision-makers according to their common incentives and barriers to recycle or dispose of their waste, or contribute to the recycling process. In the first group there are three sets of decision-makers: (1) manufacturers in their role as producers of manufacturing plastic waste, (2) private-sector processors of post consumer plastic wastes and (3) private sector processors of wastes containing plastic parts. Manufacturers in their role as producers of plastic products comprise the second group. The third group is composed of consumers of products containing plastics. Consumers contribute to recycling by diverting their plastic waste away from the municipals waste stream (MWS). The final group is composed of the public sector as a regulator of private sector actions that could impact on the private sector's incentives and barriers faced by each group.

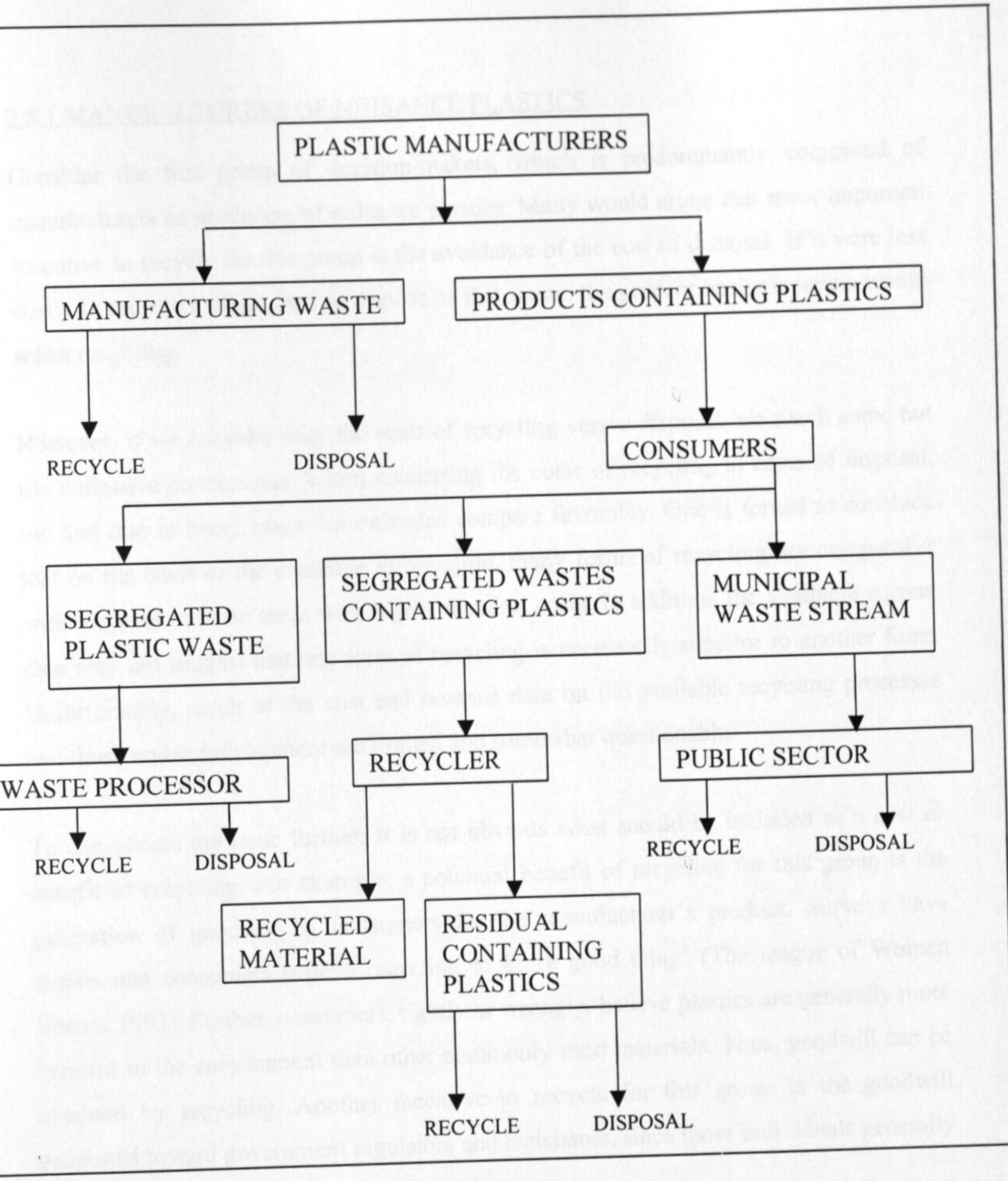


Figure 2.15:Flow diagram in decision making in plastics recycling.
Source: Curlee, op cit.

2.8.1 MANUFACTURERS OF NUISANCE PLASTICS

Consider the first group of decision-makers, which is predominantly composed of manufacturers as producers of nuisance plastics. Many would argue that most important incentive to recycle for this group is the avoidance of the cost of disposal. If it were less costly to recycle a waste than to dispose of that waste, the prudent businessperson would select recycling.

However, if we consider only the costs of recycling versus disposal, we reach some not too definitive conclusions. When comparing the costs of recycling to costs of disposal, we find that in many cases the estimates compare favorably. One is forced to conclude that on the basis of the available information, many forms of recycling are competitive with disposal in those areas with higher disposal costs. In addition, the available current data may not suggest that one form of recycling is necessarily superior to another form. Unfortunately, much of the cost and revenue data on the available recycling processes and those under development are limited and somewhat questionable.

To complicate the issue further, it is not obvious what should be included as a cost or benefit of recycling. For example, a potential benefit of recycling for this group is the generation of goodwill by consumers for the manufacturer's product. Surveys have shown that consumers believe recycling to be 'a good thing' (The league of Women Voters, 1993). Further, consumers, rightly or wrongly, believe plastics are generally more harmful to the environment than other commonly used materials. Thus, goodwill can be obtained by recycling. Another incentive to recycle for this group is the goodwill generated toward government regulators and legislators, since those individuals generally follow the preferences of their constituencies.

On the negative side, this first group of decision-makers faces several barriers or costs that may render an otherwise attractive technology unacceptable. The technological uncertainties of new and often untried recycling process may be severe. Market uncertainties are the second major problem and are divided into three different parts:

1. Insuring the availability of suitable waste in sufficient quantities.
2. Battling the potential bias against recycled goods by consumers.
3. Establishing distribution channels for the recycled goods.

Quite often recycled plastic products cannot compete with products made from virgin resins. Therefore, new distribution channels may have to be formed, or the firm that recycles may have to penetrate established but difficult- to- enters channels. Regulatory uncertainties are the third major barrier. Regulations and legislation may affect the relative costs of recycling and disposal by limiting certain options. Further, regulatory uncertainties may exacerbate the technological and market uncertainties by varying the climate in which the recycling operation must function.

2.8.2 MANUFACTURERS AS PRODUCERS OF PRODUCTS CONTAINING PLASTICS

Consider the second group of decision makers-manufacturers as producers of products that contain plastics. There is an incentive for this group to reduce the cost of plastic recycling, through product design and developing of recycling processes, thereby indirectly reducing the cost of discarding their products and thus spurring product demand. The more recyclable a product is, the more attractive and marketable that product becomes. Another incentive to contribute to recycling through product design and recycling process development is the generation of goodwill to consumers and government regulators, for the reason mentioned above.

On the barrier side there are the potentially higher costs of product design and manufacture and the costs of developing processes to recycle waste plastics. The manufacturer must balance the potential gains to be obtained from these actions with the expected higher costs associated with these measures that can enhance recycling.

2.8.3 CONSUMERS

There are three main incentives for consumers to divert their post-consumer plastic wastes away from the MWS. In some cases there is a direct incentive to divert the waste to claim the positive value of plastics, e.g. returnable beverage bottles. These incentives are usually the result of government actions that place a value on the plastic waste if it is diverted from the disposal stream. In other cases there may be an indirect incentive to divert the plastics (which may have no positive value) from the municipal waste stream to recycle other materials in the product containing the plastics-e.g. electrical equipment, which is recycled to retrieve its copper content. On another level, there may be an incentive to divert the waste to a recycling stream because of concern about the potential external costs-mostly environmental- imposed on the society by the disposal of plastic wastes.

On the barrier side it is often costly and inconvenient to source separate plastic wastes. Plastics are usually bulky and are very difficult to identify by resin type. Another important barrier is the cost and inconvenience of transporting the plastics to a collection point.

2.8.4 THE PUBLIC SECTOR AS THE PROCESSOR OF PLASTICS IN THE MUNICIPAL WASTE STREAM.

The public sector in its role as the processor of the general waste stream has two main incentives to recycle. The first is the avoidance of the direct cost of disposal. These are the same direct accounting cost considerations faced by the manufacturer when considering recycling. However, in addition to these direct costs of recycling or disposal, the public sector decision-maker must also consider the potential external or social costs associated with the various options. These external costs are mostly in the form of environmental degradation.

On the barrier side, the public sector decision-maker faces the same uncertainties as the manufacturer when deciding about manufacturing wastes. In addition, the uncertainties associated with environmental impacts must be a component of the optimal public decision.

2.8.5 THE PUBLIC SECTOR AS A REGULATOR OF PRIVATE SECTOR WASTES.

The first question that arises when considering this topic is why there should be public sector involvement. There are three main reasons. First, there may be market failures in the form of externalities: - i.e., costs or benefits that result from the production, use, or disposal of a good that is not borne by the parties making the economic transaction. Because these costs and benefits are not relevant considerations to the buyer and seller of the good, they are not included in the purchase price. The externalities that apply most in the case of plastic recycling are, as stated above, potential environmental pollution. Second, the disposal of most post-consumer wastes is subsidized in one form or another, which puts plastics recycling at a relative disadvantage as regards disposal. In virtually all cases, the consumer doesn't pay the marginal cost of disposal, which implies that there is generally no incentive to divert plastics from the general waste stream on monetary grounds. In other words, the consumer pays a flat rate fee for waste disposal; thus nothing is gained by reducing the volume of waste entering the waste stream. Third, recycling may also be put at a disadvantage because of regulations that may hinder recycling. These regulations include:

1. Tax inequities between virgin and recycled materials.
2. Zoning laws that may force recycling centers to be located far from waste sources.
3. Greater emphasis of research and development activities on virgin materials as compared to recycling process.
4. Regulations that may require products containing recycled plastics to be labeled as containing those materials.

Some have argued that there may be an undue bias against recycled plastics, because the way in which the labeling is done suggests that the product may be inferior.

There are therefore several reasons why the government or public sector may want to subsidize, in one form or another, the recycling of plastic wastes. Such subsidization must, however, recognize the intricacies of the incentives and barriers to recycling and set up incentive programs that address those intricacies. In many cases, several different groups must cooperate in order for recycling to be technically and economically feasible. Therefore, each group must have a net incentive to participate. Further, a social evaluation of the viability of plastics recycling must go beyond a consideration of the direct costs of disposal versus recycling. While external benefits may be gained from recycling, the potential social costs imposed by some recycling programs may be severe. All direct and external costs and benefits of the various options must be considered to determine the social viability of plastics recycling.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 INTRODUCTION

A survey research is a study in which data is collected from the members of a sample, for the purpose of estimating one or more population parameters. The research procedure employed is characterized by systematic collection of data from members of the given population through questionnaires and interviews. Surveys are normally intended to describe and report the way things are (Ogula, 1998:10).

Research methodology can be defined as 'systematic research procedures and techniques that help the researcher to avoid self-deception' (Prewit, 1975:1). This chapter addresses various methods and procedures that were used all the way from data collection to drawing of the final conclusions. It starts with a description of a sampling design, which is a systematic method of selecting actual respondents out of the potential subjects. The chapter further describes the types of data collected and still further points out the methods used in collecting the said data.

Additionally this chapter looks at the extraneous factors that influenced collection of raw data before finally looking at the types of data representation methods.

3.2 SAMPLING DATA DESIGN

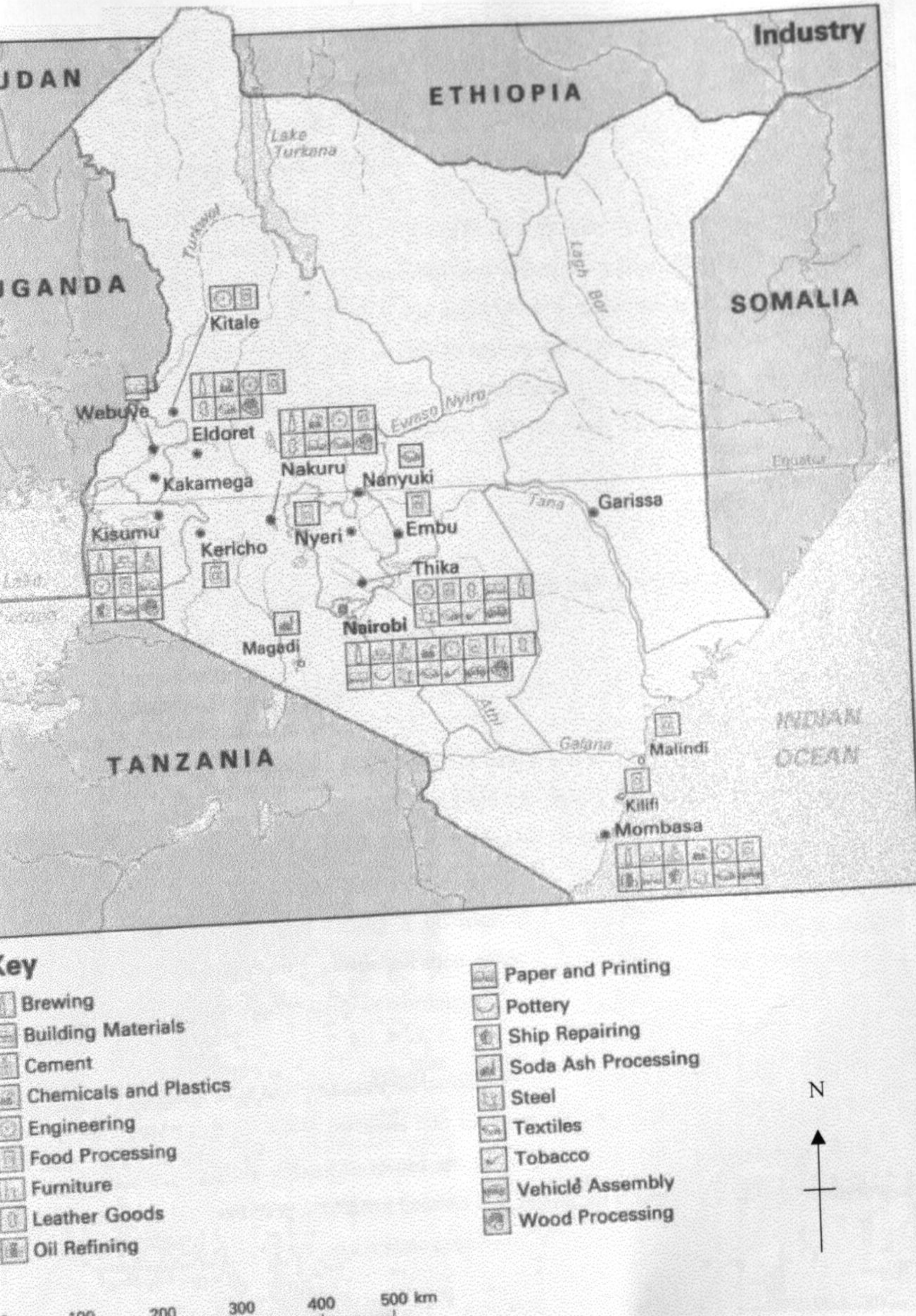
Qualitative research is defined as the systematic collection, analysis and interpretation of data in order to provide a description and an account of events and objects in their natural settings (Ogula, 1998:15).

This study involved qualitative research methods and was thus practical, having for the most part being carried out in the field. It basically employed the method of stratified sampling in which the population was divided into strata or categories from which random samples were drawn. Sampling was done using plastic firms listed in the directory of industries of 1998. The local plastic production was stratified as follows.

- Plastic packaging: bags, containers, sheets, trays, crates, bottles.
- Water tanks.
- Industrial and civil construction: pipes, conduits.
- Household plastic items.
- Recycled plastic granules.
- Footwear, ropes, woven bags, fabrics.

The population was all the above firms together with institutions in the informal sector dealing with recycling plastic wastes. Most of the above firms were located mainly around Nairobi (including Limuru, Ruiru, Thika, Athi River) and Mombasa, although a few were located in Kisumu, Nakuru, and Eldoret. Map 3.1 shows the locations of the above cities and towns). Firms were interviewed in the above locations irrespective of whether they were listed in the directory or not (see appendix three). Some firms in the directory were difficult to locate as they had either relocated, or were no longer processing plastic products or had changed name. Where the firms had ceased operating, other plastic processing firms were interviewed independently of whether they were included in the sample or not. This would compensate for the firms that were not interviewed due to reasons explained above.

An attempt was made to interview all established informal institutions (individually or collectively owned or informal) that process plastic waste. It was difficult to locate most of these institutions, as they did not exist in the directory. Assistance was sought from local community members to locate most of them. Others were located in areas such as inside the dumpsites and due to high security risks (mainly mugging and assault) were not interviewed. This did not affect the findings much as the scavenging activities in most of the visited municipalities were more or less the same. However all organized recycling institutions, especially community based organizations (CBOs), were interviewed.



Map 3.1: Kenya showing locations of major industries.
Source: Macmilan Education, 1999.

3.3 TYPES OF DATA COLLECTED

Both qualitative and quantitative data were collected. Qualitative data focused on the description of actual recycling processes and description of factors affecting recycling activities. Other qualitative information was collected from documentation in university libraries around the country as well as private and corporation libraries that proved to have documentation sources. Major sources of quantitative data were; Central Bureau of Statistics (CBS), Kenya Revenue Authority (KRA), and the plastic processing institutions.

3.4 METHODS OF DATA COLLECTION

Three main methods were used in data collection. These were interview schedule, face-to-face and telephones interviews and direct observation

3.4.1 INTERVIEW SCHEDULE

The interview schedule was the principal tool of data collection. It comprised a scheduled industrial questionnaire, which mainly consisted of questions relating to recycling of plastic waste. A copy of the questionnaire is attached in appendix four. The interview schedule was deemed appropriate because it made it possible to ask uniform questions of the same standard. Besides, where a question was not clearly understood by the interviewee, the face-to-face communication made it possible to elaborate or ask the same thing in a different language or wording.

Where the response given was seen as insufficient, this method helped to elicit further information by posing more questions into the same areas of interest. The method also gave the interviewee a chance to record spontaneous answers, which were hoped to be more informative and less normative because the respondent did not have plenty of time to dwell over and over again on the same question.

3.4.2 FACE-TO-FACE AND TELEPHONE INTERVIEWS.

This method was applied to officials of various interested groups who do not directly process plastics. These include officials of Kenya Association of Manufacturers (KAM), Nairobi City Council (NCC), Institute of Packaging (IOP)(K), community based organizations (CBOs) and government officials (particularly in the Ministry of Trade & Industry).

3.4.3 DIRECT OBSERVATION

This method was used in observing occurrences that were deemed necessary in drawing conclusions. Non-verbal behavior was observed here and the validity of the respondents' answers was assessed. Some counter questions were rendered necessary on the basis of this assessment. Data was thus substantially augmented.

3.5 EXTRANEOUS INFLUENCES ON DATA COLLECTION

Several problems were encountered in the field during the process of data collection, which were feared to produce adverse effects on the data collected. This was mostly in the formal plastic processing industries, which are predominantly privately owned businesses. In some of these firms the biggest problem was that the owners knew very little about plastic technology. This forced the researcher to 'hire' shop floor employees in the firm to assist in getting some of the responses from the owners. Even in cases where an employee was given permission to answer some of the questions, they feared giving answers in depth as he was constantly interrupted. They feared the risk of losing their jobs given that the research was carried out when both the private and public sectors were retrenching their employees. In cases where the proprietors were familiar with the questions, there was mistrust among them on who should answer the questionnaire. This forced skipping a firm occasionally not because there was no recycling taking place in the firm but because they were not fully convinced that the research was purely academic. This was so especially when one was forced to identify himself by showing the research clearance permit he was given by the government through the Ministry of Education.

Occasionally one was forced to memorize the questions in the questionnaire so as to administer it as a usual talk, only to go and record the responses immediately he stepped out of the plastic firm. Some of the proprietors feared showing the machinery and other equipment inventory, siting 'company policies' that prohibit giving such information to any outsider who is not their employee. It was understood later that the plastic processing is a very competitive industry and managers fear that crucial information might leak to their competitors.

Harassment by gatekeepers in the formal industry was a constant problem. Even in the cases where an appointment had been booked for interview through the telephone, some of the gatekeepers would not allow anybody inside the firm's premises. They demanded trivial details like when was the appointment made and by whom. Some even went to extent of lying that the concerned manager who deals with research matters was away only for one to find out later that it was a "hoax".

The research was conducted (from April 2000 to April 2001) during a power crisis that had hit hard the industrial sector due to power rationing. Most of the time was wasted moving from firm to firm only to find that due to lack of power many had been temporarily closed. Even when there was power, the management complained of lack of time to answer all questions, as they were 'busy' solving internal problems caused by power crisis. This was a reason mainly given especially when the respondent avoided questions related to financial or "clandestine" company dealings.

The study was conducted during one of the hottest period due to persistent drought. As most of firms were not readily accessible using motor vehicle means the researcher had to travel on foot from firm to firm. In addition, not only was the sun hot and scorching, dust constantly 'evaporated from the ground', this was made worse by wind blowing across industrial area tracks.

Another problem was high security risk posed by slum dwellers that reside in slums located in industrial area. The collectors who are mainly scavengers mainly caused this threat. Most of these collectors demanded money for the information they released. Other informal scrap dealers demanded money, since they have the misconception that researchers usually have a lot of money.

Despite of the above constraints, most of the sampled firms were interviewed. The firms that were found to carry out recycling on a large scale were interviewed at length and depth.

3.6 METHODS OF DATA PRESENTATION AND ANALYSIS

The main methods for data presentation and analysis were frequency tables, graphs and photographs (plates). Frequency tables were used to analyze data while most of the qualitative data was presented by use of flow diagrams, photographs. Quantitative data was presented by pie charts, bar charts, line graphs, histograms and tables.

CHAPTER FOUR: RESULTS AND DISCUSSION

After field work, the data collected by various techniques was summarized and analyzed. Data was presented in the form of tables, graphs and charts or in prose form. This chapter gives the results and discussion of various aspects of plastic recycling in Kenya.

4.1 PRIMARY RECYCLING

Plastic goods cannot be produced without generating waste; thus primary recycling especially for thermoplastics has been practiced since the establishment of the industry in Kenya. The desirable characteristic of primary waste is that the quality of plastics recovered for reprocessing is almost as high as that of virgin plastics. The reprocessing techniques include shredding, extruding and pelletizing, resulting in regrind or reprocessed pellets. These pellets are either used on their own or are often mixed with virgin pellets. Since all the virgin raw materials used to process plastic products are imported, recycling of the primary waste saves on cost of imported raw material used by the companies.

4.1.1 SOURCES OF PRIMARY WASTE

The main sources of primary waste for recycling is pre-consumer scrap found in thermoplastic processing industries. This is typically the cleanest of all plastic waste sources, because it has not been in contact with other materials, and can be recovered within a controlled environment. Pre-consumer scrap can be divided into either manufacturing or re-manufacturing scrap.

4.1.1.1 MANUFACTURING SCRAP.

Manufacturing scrap is material rejected along the processing line. This occurs during the normal machine operation or during process interruption either due to machine breakdown or power failures. Other manufacturing scrap is caused by defective equipment such as moulds, dies which results in products that do not meet customer specifications. Primary waste generation depends on the technologies used in plastic processing. Some firms only import second hand machinery that normally generates a lot of waste during normal operation. The major industrial processes that results in plastic waste generation are compounding, fabrication, conversion and distribution. In compounding plastic waste results when the base resin is being combined with additives and fillers to modify the processability and quality of plastic. Fabrication involves all plastic forming processes that are used in manufacturing of plastic parts. Modification of moulded part to final usable products constitutes the conversion process while distribution involves the process of delivery of finished products to their consumers. Table 4.1 below gives a summary of relative primary waste generation by the forty interviewed firms by process.

OPERATION	PWGR
Compounding	1-5
Fabrication	5-12
Conversion	4-30
Distribution	3-5

Table 4.1: Relative plastic waste generation by process.
Source: Own survey.

Note: PWGR refers to percentage waste generation rate.

The table gives the minimum and maximum generation rate from the forty out of all interviewed firms in the formal sector. The table shows that the main sources of plastic waste for primary recycling are the fabrication and conversion processes. The conversion process, which includes trimming, and other machining operations, gives the highest primary plastic waste.

4.1.1.2 RE-MANUFACTURING WASTE

These wastes arise when secondary operations such as bag printing produce off-grade products such as misprinted bags, products that are rejected by their customers etc. Printed inks limits the variety of colours that can be achieved from recycling of such type of waste. This scrap is then recycled like any other primary waste.

4.1.2 PRIMARY RECYCLING PROCESS

Most firms interviewed carry out on-site primary recycling to reduce liability for disposal of their wastes. During on-site recycling, the primary waste is collected and stored in clean plastic bags to avoid contamination that could affect their processability and the quality of recycled-content products. When enough waste is accumulated a shredder is used to grind them into a form known as regrind. Plates 4.1 and 4.2 below shows primary wastes stored in clean plastic bags before and after grinding respectively.

Depending on the polymer, process, and application of the products the regrind is mixed in varying proportions with virgin granules to manufacture end products using standard equipment that is normally used for processing virgin granules. Table 4.2 gives a summary of responses by primary recycling enterprises pertaining to primary waste. The table gives column wise details pertaining to an enterprise starting with year of establishment, resins, processing technology, percentage estimated primary waste generation rate and major primary products. The generation rate is an estimate because most of the firms interviewed do not bother to keep records of their waste. The estimate was given in comparison to the quantity of raw material usage. The table shows the percentage savings of the raw material costs a firm can achieve by practicing efficient primary recycling.

4.2 SECONDARY RECYCLING

In Kenya, secondary recycling is carried out using either post-consumer or contaminated and often degraded primary wastes. Unlike primary recycling where they are directly incorporated in the manufacturing processes together with virgin raw materials, secondary recycling requires various upgrading techniques (see section 4.2.3) to be able to achieve acceptable quality for further processing using standard equipment. Most of the firms in table 4.2 expressed their willingness to start large scale recycling of post-consumer wastes to cater for local market provided that favorable economic and technological conditions are put in place for competitive plastic processing. At initial stages, some companies had started small scale recycling pilot projects using locally available post-consumer wastes during the time of the research.

Plate 4.1:Pre-consumer plastic wastes.

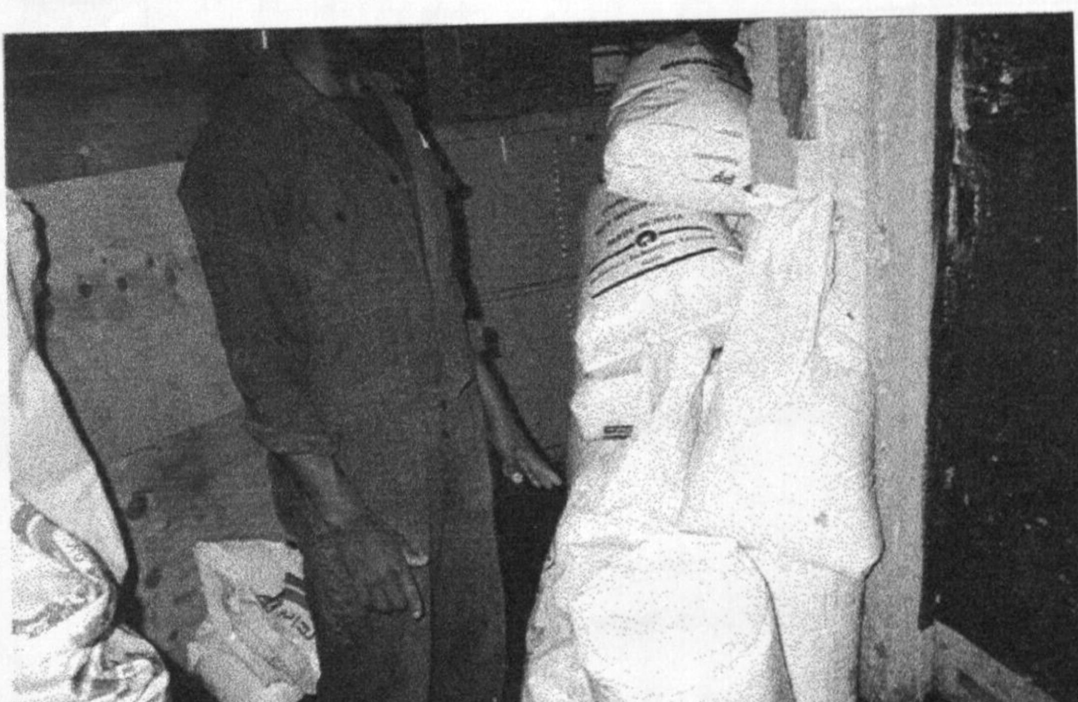


Plate 4.2: Granulated pre-consumer plastic wastes.

NAME OF FIRM	YOE	RAW MATERIAL	MAJOR PRODUCTION PROCESSES	PWGR (%)	PRIMARY PRODUCTS
Kenya suitcase manufacturers	1980	PVC	Injection molding	10	Shoe soles
Premium drums	1968	HDPE	Blow molding	1.5	Plastic containers.
Pearly Waters	1996	PET HDPE	Blow molding	12	Bottles, jars, caps
Polycans	1975	HDPE-blow HDPE-injection	Injection molding Blow molding	12	125ml-60 l containers
Raneem Plastic	1998	PP	Extrusion	15	Plastic mats
Polysack	N/A	PP	Extrusion	10	Plain/woven laminated bags
Bata Shoe	1940	PVC	Injection molding	1	Shoes, soles
Bobmil	1982	HDPE LDPE LLDPE	Film blowing	20	PE sheeting Bags, greenhouse sheeting
General plastics	1977	HDPE LDPE LLDPE	Injection molding Blow molding	20	100ml -5 l Containers
C & P Shoe	1982	PVC-suspension grade	Injection molding	4	Shoes, sole, PVC coated fabrics
NAS	1984	PS, HDPE, LDPE	Injection molding Film blowing	10	Battery boxes and lids, PE bags, crates, cups, mugs etc.
Polythene Ind.	1987	LDPE	Film blowing	5-10	PE bags & sheeting
Ashut Engineers	1986	HDPE, LDPE, LLDPE, PP	Injection molding Blow molding	20	Jerry cans, bottles
Polypipes	1976	PVC (K47)	Extrusion	4-5	Pipes
Blowplast	1995	HDPE-injection HDPE-blow	Injection molding Blow molding	10	5ml-20 l Containers.

Table 4.2: Some primary recycling firms. Source: Own survey.

Note:

PWGR refers to percentage waste generation rate.

YOE refers to the year of establishment, which could be either;

(a) When a firm started production.

(b) When a firm was sold to or brought by a new concern.

4.2.1 SOURCES OF SECONDARY PLASTIC WASTES

RESIN	MAIN SOURCES
Bottle-grade HDPE–natural	Yoghurt and milk bottles Post–industrial scrap
Bottle-grade HDPE–pigmented	Coloured detergent and soap bottles Post–industrial scrap
Film-grade LDPE and LLDPE	Film packaging Post–industrial scrap
Suspension-grade PVC	Plastic shoe and soles, hose pipes
Injection-grade PP	Battery casings, buckets, basins Post–industrial scrap
Film–grade HDPE	Agricultural film Post–industrial scrap

Table 4.3: Main sources of secondary waste.
Source: Own survey.

Table 4.3 gives the main sources of secondary recycled plastics while figure 4.1 gives the flow diagram of post-consumer plastic waste in Nairobi, where most recycling activities are well established. The figure shows that the post-consumer recycling activities have a complicated chain of operations.

This is mainly because of the following reasons:

- The waste quantities collected at the source are too small for direct sale to the reprocessing industry.
- The wastes often needs to be upgraded before they can be recycled.
- There is a long geographical distance between the collectors and location of recycling industries.
- Due to scattered sources of post-consumer plastics, the wastes pass through various processes before they reach the recycling industries for recycling.
- Most of the collectors do not have the financial and physical means to store, clean and then transport the wastes to established recycling institutions.

The figure shows that secondary waste recycling activities start from small waste dealers, who are established either in community neighborhoods or at the municipal dumping sites. Waste pickers (sometimes called scavengers) at the city or at the dumping sites usually sell the separated waste to a waste-dealer with whom they are associated.

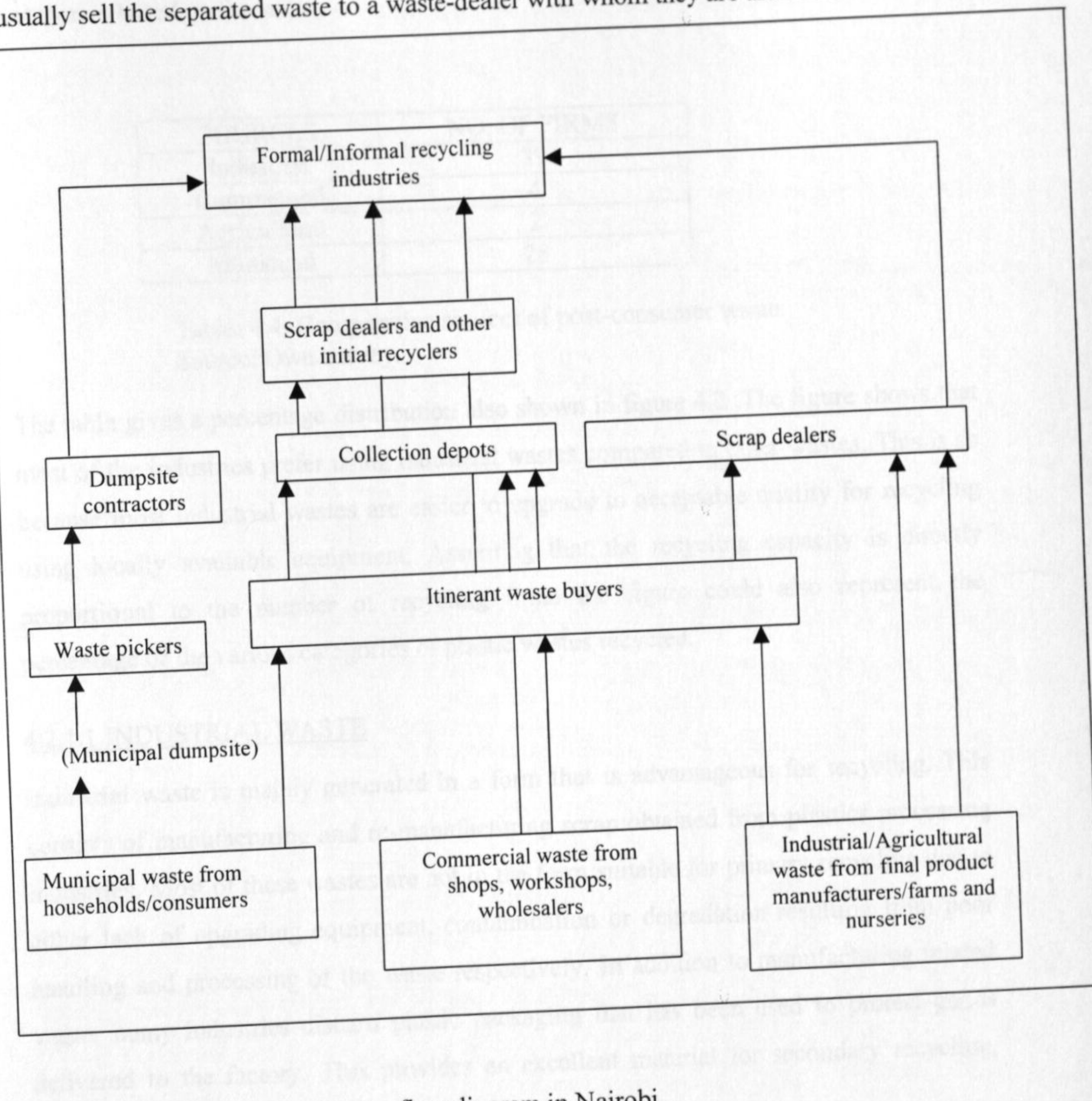


Figure 4.1 Post-consumer wastes flow diagram in Nairobi.
Source: Own survey.

Usually a group of scavengers is associated with particular waste dealers who act as their 'patron'. Various sources of post-consumer plastics for recycling can be categorized into five classes. These are industrial, municipal, commercial, agricultural and imported wastes. Table 4.4 below gives the relative number of firms recycling the various categories based on the survey.

SOURCES	NO. OF FIRMS
Industrial	37
Commercial	4
Agricultural	2
Municipal	28

Table: 4.4: Comparative sources of post-consumer waste.
Source: Own survey.

The table gives a percentage distribution also shown in figure 4.2 .The figure shows that most of the industries prefer using industrial wastes compared to other wastes. This is so because most industrial wastes are easier to upgrade to acceptable quality for recycling using locally available equipment. Assuming that the recycling capacity is directly proportional to the number of recycling firms the figure could also represent the percentage of the various categories of plastic wastes recycled.

4.2.1.1 INDUSTRIAL WASTE

Industrial waste is mainly generated in a form that is advantageous for recycling. This consists of manufacturing and re-manufacturing scrap obtained from plastics processing industries. Most of these wastes are not in the form suitable for primary recycling due to either lack of upgrading equipment, contamination or degradation resulting from poor handling and processing of the waste respectively. In addition to manufacturing related waste, many industries discard plastic packaging that has been used to protect goods delivered to the factory. This provides an excellent material for secondary recycling, because it is usually less contaminated and in ample supply.

4.2.1.2 MUNICIPAL WASTE

The local government (market, urban and town councils) is responsible for collection and disposal of municipal wastes because of their legislated responsibility to protect public health. This provides for government ownership of municipal wastes. Either local authorities or their private contracted firms manage municipal waste which includes plastic waste collected from streets, parks, collection depots and waste dumps. In all the towns visited, commingled collection of this type of waste is widespread. Most of these wastes end up in the municipal dumpsites where scavengers sort out recyclables.

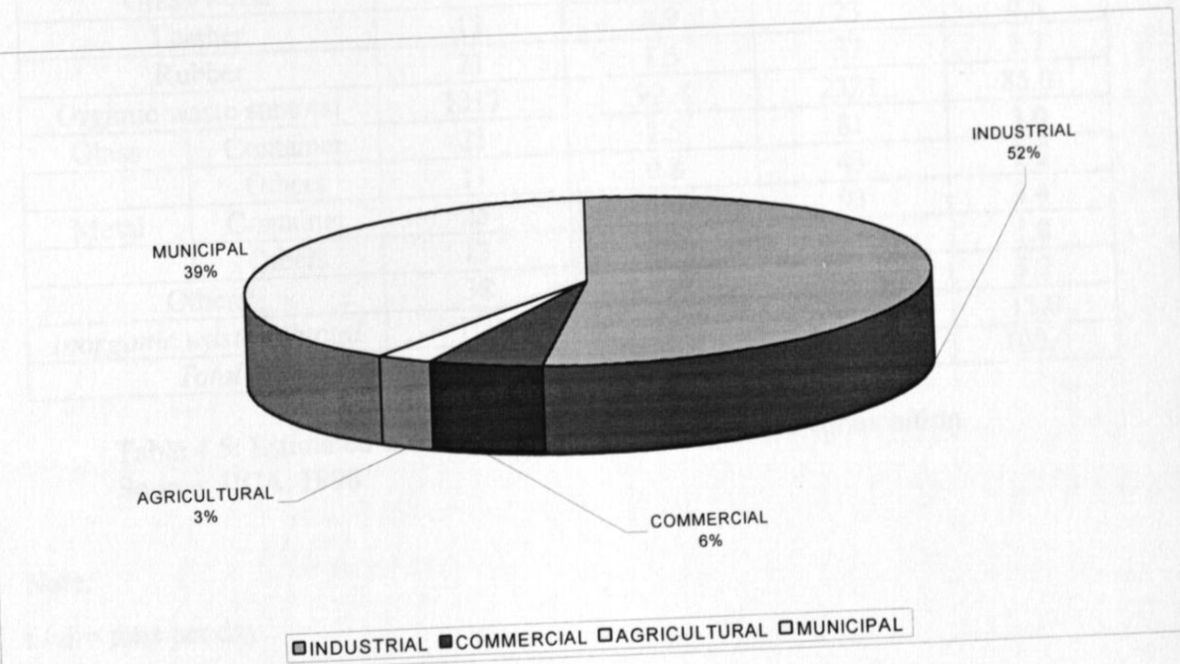


Figure 4.2: Relative sources of plastic waste in Kenya. Source: Own survey

Table 4.5 gives estimated composition of municipal waste in Nairobi City Council (NCC). The table shows that the generation of plastics in the municipal solid waste stream is expected to increase in future given the growing urban population and the adoption of western lifestyles. For the case of Nairobi, generation of plastic waste is expected to rise from 169 to 297 tons per day (JICA, 1998). This shows that in future municipal waste will continue to be an important source of plastic waste that could be upgraded for secondary recycling.

Composition		1997		2008	
		Amount (t/d)	(%)	Amount (t/d)	(%)
Food waste		734	51.5	1,293	47.4
Paper	Recyclable	206	14.5	363	13.3
	Other paper	41	2.8	71	2.6
Textile		38	2.7	67	2.5
Plastic	Container	67	4.7	118	4.3
	Other plastics	102	7.1	179	6.6
Grass/wood		96	6.7	168	6.2
Leather		13	0.9	23	0.8
Rubber		21	1.5	37	1.3
Organic waste subtotal		1317	92.4	2321	85.0
Glass	Container	21	1.5	81	3.0
	Others	11	0.8	43	1.6
Metal	Container	25	1.7	93	3.4
	Others	13	0.9	49	1.8
Others		38	2.7	143	5.2
Inorganic waste subtotal		109	7.6	410	15.0
Total		1426	100.0	2730	100.0

Table 4.5: Estimated municipal solid waste amount and composition.
Source: JICA, 1998.

Note:

t / d = tons per day.

4.2.1.3 POST-CONSUMER COMMERCIAL WASTE

Waste plastics in this group are products, which have served their intended use, usually packaging that has been discarded by a commercial business. The larger the quantity of waste produced by a commercial business, the higher the probability of developing a viable recovery program. Examples of principal generation points include supermarkets and warehouse and distribution centers.

4.2.1.4 AGRICULTURAL WASTE

In Kenya the major source of agricultural plastic waste is PE greenhouse sheeting, which is already sorted although most of the time is contaminated with soil. Other sources include packaging, PVC hoses and irrigation pipes.

4.2.1.5 IMPORTED WASTE

This category includes imported primary wastes or processed plastics that, due to their short useful life spans, end up becoming a source of wastes suitable for recycling. Table 4.6 show primary wastes by resin type imported between 1991 and 1999 while figures 4.4 and 4.5 show importation of processed plastics between 1994 and 1999

SITC[a]	*	1991	1992	1993	1994	1995	*	1997	1998	1999	TOTAL
57910000	0	0	0	18,000	121,055	109,161	0	21,735	0	0	269,951
57920000	0	19,584	4,600	0	0	0	0	0	0	0	24,184
57930000	0	500	36,000	500	46,398	17,800	0	24,040	42,620	11,4207	282,065
57990000	0	0	254	100	8	3,000	0	88,055	49,075	420	140,912
TOTAL	0	20,084	40,854	18,600	167,461	129,961	0	133,830	91,695	114,627	717,112

Table 4.6: Importation of plastic wastes in kgs.
Source: Data from Ministry of Finance and Planning, CBS division.

Note:

SITC[a]: In international commerce various commodities of trade are coded for easier identification and documentation. These codes are commonly referred to as standard industrial trade codes (SITCs), where a group of well arranged numbers are used. A comprehensive list of various classes of plastic products and their SITC used in this report is found in appendix one.

* For 1990 and 1996 there was no waste imported from the records.

4.2.2 SECONDARY RECYCLING BUSINESSES

The secondary recycling business can be categorized by major recycling activities as illustrated by a simple flow chart shown in figure 4.3 below. These enterprises consist of collectors, handlers, reclamers and end-users.

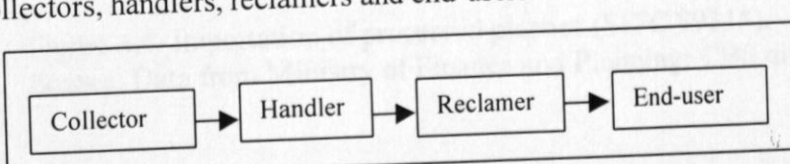


Figure 4.3: Simplified post-consumer plastics recycling flow chart.

Note:

For simplicity, the generators of plastic waste (homes, businesses) and brokers or exporters that direct flow of recovered plastic waste are not shown.

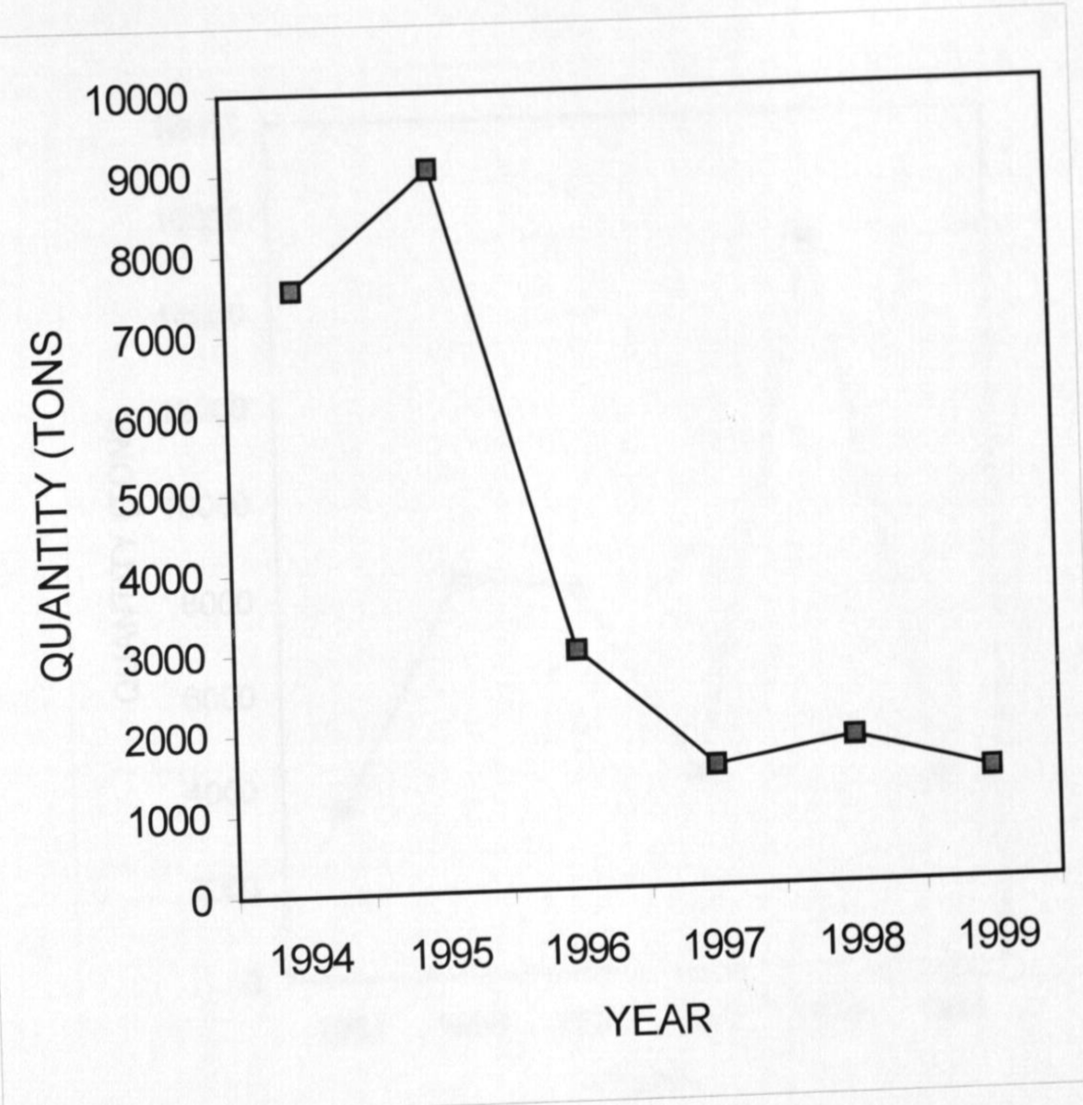


Figure 4.4: Importation of processed plastics (SITC 8931*).
Source: Data from Ministry of Finance and Planning: CBS division.

Note:

8931* includes the category of plastics whose SITC codes starts with 8931 as listed in appendix one.

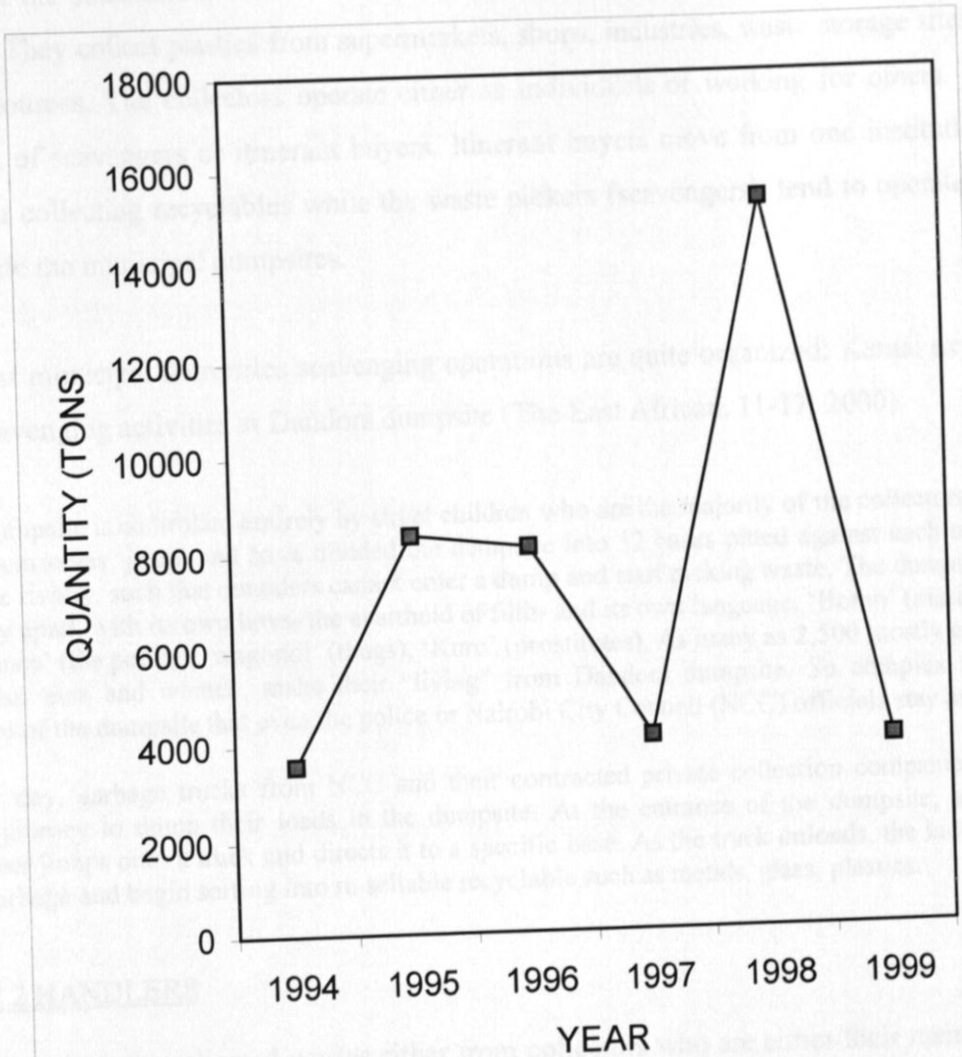


Figure 4.5: Importation of processed plastic products (SITC 582*).
Source: Data from Ministry of Finance and Planning: CBS division.

Note:

582* description of this category of plastic products is found in appendix one.

4.2.2.1 COLLECTORS

Most of the collectors involved in collecting plastics for recycling do so in the informal sector. They collect plastics from supermarkets, shops, industries, waste storage sites and other sources. The collectors operate either as individuals or working for others. They consist of scavengers or itinerant buyers. Itinerant buyers move from one institution to another collecting recyclables while the waste pickers (scavengers), tend to operate near or inside the municipal dumpsites.

In most municipal dumpsites scavenging operations are quite organized; Kantai explains the scavenging activities at Dandora dumpsite (The East African, 11-17, 2000).

The dumpsite is controlled entirely by street children who are the majority of the collectors. They call themselves 'jeshi' and have divided the dumpsite into 12 bases pitted against each other in intense rivalry, such that outsiders cannot enter a dump and start picking waste. The dumpsite is a society apart, with its own laws- the apartheid of filth- and its own language. 'Bomb' (marijuana), 'madanse' (the police), 'wagondi' (thugs), 'Kuro' (prostitutes). As many as 2,500 mostly children but also men and women, make their "living" from Dandora dumpsite. So complex is their control of the dumpsite that even the police or Nairobi City Council (NCC) officials stay away.

Every day, garbage trucks from NCC and their contracted private collection companies make their journey to dump their loads in the dumpsite. At the entrance of the dumpsite, a 'jeshi' member jumps onto a truck and directs it to a specific base. As the truck unloads, the kids assess the garbage and begin sorting into re-sellable recyclable such as metals, glass, plastics.

4.2.2.2 HANDLERS

Handlers buy the collected wastes either from collectors who are either their members or scavengers who mainly operate on an individual basis. They then sort and separate the plastics into various categories after which they organize for transportation to reclaimers or end users. In Kenya handlers could be categorized into two groups i.e. scrap dealers and CBOs.

(a) SCRAP DEALERS

These kinds of traders act as brokers between collectors and, either reclaimers, or end users. Most of these dealers are located at strategic positions such as municipal dumpsites, while others operate buy-back centres from where they purchase recyclable plastics. They have basic equipment such as weighing scales and mainly operate on a cash-on-delivery basis, thus providing fiscal incentive for collectors. Generally they have built simple and semi-permanent structures from which they operate their businesses while others operate under trees. Plates 4.3 and 4.4 illustrate a plastic handling business and plastic film scrap yard behind Kijabe Street in Nairobi respectively.

(b) COMMUNITY BASED ORGANIZATIONS (CBOs)

There are two CBOs currently involved in plastic recycling activities. Mukuru Recycling Center (MRC) deals with all recyclable commodities while Nyalenda Recycling Project (NRP) specializes in recoverable plastic wastes.

(i) MUKURU RECYCLING CENTER

Mukuru Recycling Center (MRC), located at the Dandora dumping site, was started by Father Alex Zanoteli of Kariobangi South Catholic Church in 1992, following initiation of community based solid waste management (CBSWM) by NCC. Due to the nature of their work and lifestyle, the community living in Korogocho slums found themselves marginalized and undermined by the surrounding society. The church's main aim for this community was to initiate a rehabilitation program that would improve/modernize their scavenging activities. The efforts were carefully channeled through a gospel outreach program, which slowly improved their characters to embrace human social morality. These efforts later culminated into a strong united garbage-recycling project.

MRC collects recyclable wastes from the Dandora dumping site, factories in industrial area, other places as far as Village Market on the other side of Nairobi. They also purchase recyclables from other scavengers who are not their members. Once enough plastic is gathered, they either deliver directly to recycling industries using hired vehicle or that of their customer. As a way of attracting and maintaining supply by scavengers they buy all the recyclable brought to their site using a cash-on-delivery basis.

Plate 4.3: Scrap yard behind Kijabe Street.

Plate 4.4: Plastic films in a scrap yard behind Kijabe Street.

United Nation Commission for Human Settlement (UNCHS) acts as adviser for MRC in an attempt to improve their activities through its Settlement Infrastructure and Environment Program (SIEP). For example in October 1999, the international agency facilitated the signing of an experimental working agreement between the group and Skyplast Manufacturers Ltd, a local recycling company based in Nairobi. Both organizations came up with memorandum of understanding (MOU) that MRC will provide 3 tons of properly sorted plastic waste of different types after every two days. Payment of MRC was to be done by cheque on a weekly basis, but due to failure by MRC to maintain the required recyclate standards the MOU terms were broken resulting in cancellation of the contract.

Currently MRC consists of two sub-groups, Mukuru 'A' and Mukuru 'B'. The first sub-group collects or buys recyclables like paper, plastic, glass, and scrap metal. It carries out essential preliminary sorting and separation of recyclables before finally selling them to recycling companies. The other subgroup is involved in composting and briquetting activities to manufacture compost fertilizers and white charcoal respectively.

(ii) NYALENDA RECYCLING PROJECT

Nyalenda Recycling Project (NRP) is a community plastic recycling project started by Pandipierri Catholic Mission in Kisumu in 1995. The objectives of the project were to improve the income of the poor local Catholic faithful while improving the community's living environment. The members of the community living around the project collect plastic waste from the environment and sell it on a cash-on-delivery basis to the project for processing. The project also buys plastic wastes from other sources such as from dealers located at places as far as Eldoret.

The project owns a second-hand shredder that crushes the waste plastics according to type into flakes before they are thoroughly washed and dried in the sun. After drying the plastic is then packed into 25-kilogram bags ready for sale to end users throughout the country for further processing into final products. The trustees of the church currently run the project and are in the process of contacting local NGOs such as Healthy Living for assistance while at the same time conducting vigorous community education and awareness campaigns to sensitize local residents about their activities.

4.2.2.3 RECLAIMERS

These kinds of business process waste plastics into pellets for sale to end-users. The amount and nature of processing depends on the quality of plastics they receive. The main recycling operations carried out by most reclaimers are shredding and granulating, washing, drying and then pelletizing. In Kenya, only Rainbow Plastics located in Nairobi specializes in reclaiming activities.

4.2.2.4 END USERS

The end users convert the recycled plastic pellets into new plastic products. Due to the low quality of available wastes, the pellets are blended and compounded with virgin granules and additives respectively to improve the properties of post-consumer recycled content products. The major problem facing end users is the lack of a consistent supply of secondary raw materials of uniform quality compared to virgin feedstock.

Table 4.7 gives some of secondary recycling companies. Column- wise the first to the last column gives the name of the enterprise, year of establishment, raw material, recycling technology and recyclates respectively.

FIRM	YOE*	RAW MATERIAL	RECYCLING PROCESSES	PRODUCTS
Rainbow Plastics	1990	Plastic waste objects: HDPE, LDPE, PP	Pelletizing	Secondary raw materials
Palson	1998	Plastic waste objects: HDPE-blow	Pelletizing Blow molding	Secondary raw materials, 20 l Jerry cans
Cable & Plastics	1978	Plastic waste objects: HDPE, LDPE	Pelletizing Blow molding Injection molding	House hold items
Modern Soap Factory	1965	Plastic waste objects: HDPE-blow, PP	Pelletizing Blow molding	Jerry cans
Arrow Plastics	1995	Plastic waste objects: HDPE, LDPE	Pelletizing Blow molding	20 l Jerry cans

Implast	1995	Plastic waste objects: LDPE	Pelletizing Film blowing	Packaging bags
Nairobi Plastics	1990	Secondary raw materials	Blow molding Injection molding	House hold items
Brush Manufacturers	1982	Plastic waste objects: HDPE, LDPE, PVC	Injection molding Extrusion	PE Sheeting, Domestic items, Brushes.
Skyplast	1987	Plastic waste objects: HDPE, PP	Pelletizing Injection molding Blow molding	Jerry cans, Basins Buckets.
Mukuru Recycling Center	1992	Plastic waste objects	Collection, sorting	Sorted plastic waste
Afrolite Ind.	1985	Plastic waste objects: PVC soles, Shredded PVC soles	Injection molding	Shoes, soles
Drums & Containers	1997	Plastic waste objects: HDPE, LDPE, primary waste from other companies	Pelletizing Blow molding	5 l -120 l Jerry cans
Comrade Engineering	1990	Secondary Raw materials	Injection molding	Motor vehicle bushes
Nyalenda recycling Project	1995	Plastic waste objects	Collection, sorting	Sorted plastic waste
Cosmo plastics	1978	Plastic waste objects: LDPE	Film blowing	Packaging bags
Kenpoly	1977	Plastic waste objects: HDPE-injection	Injection molding	Crates buckets, etc.
Talani	N/A	Plastic waste objects: HDPE, LDPE, primary waste from other companies	Pelletizing Blow molding	5 l -120 l Jerry cans
Plaspack	1988	Plastic waste objects: HDPE, LDPE,	Pelletizing	Regrind & pelletised polyethylene material
Rubi	N/A	Plastic waste objects: LDPE	Film blowing	Packaging bags
Phytec (EA)		Plastic waste-PE Sheeting e.g. greenhouse sheeting	Film blowing	PE Sheeting
Crown Ind.	N/A	Plastic waste objects: PVC soles, Shredded PVC soles	Injection molding	Shoes, soles
Topen Ind.	N/A	Plastic waste objects: PVC soles, Shredded PVC soles	Injection molding	Shoes, soles

Table 4.7:Secondary recycling businesses. Source: Own survey.

Note: YOE* Refers to the year of establishment.

4.2.3 SECONDARY RECYCLING TECHNOLOGIES

Figure 4.6 Schematically show flow chart of secondary mechanical recycling processes. The recycling processes involve collection, washing, sorting, densification, pelletizing and product manufacture. The order of the processes carried out depends on the quality and quantity of the waste.

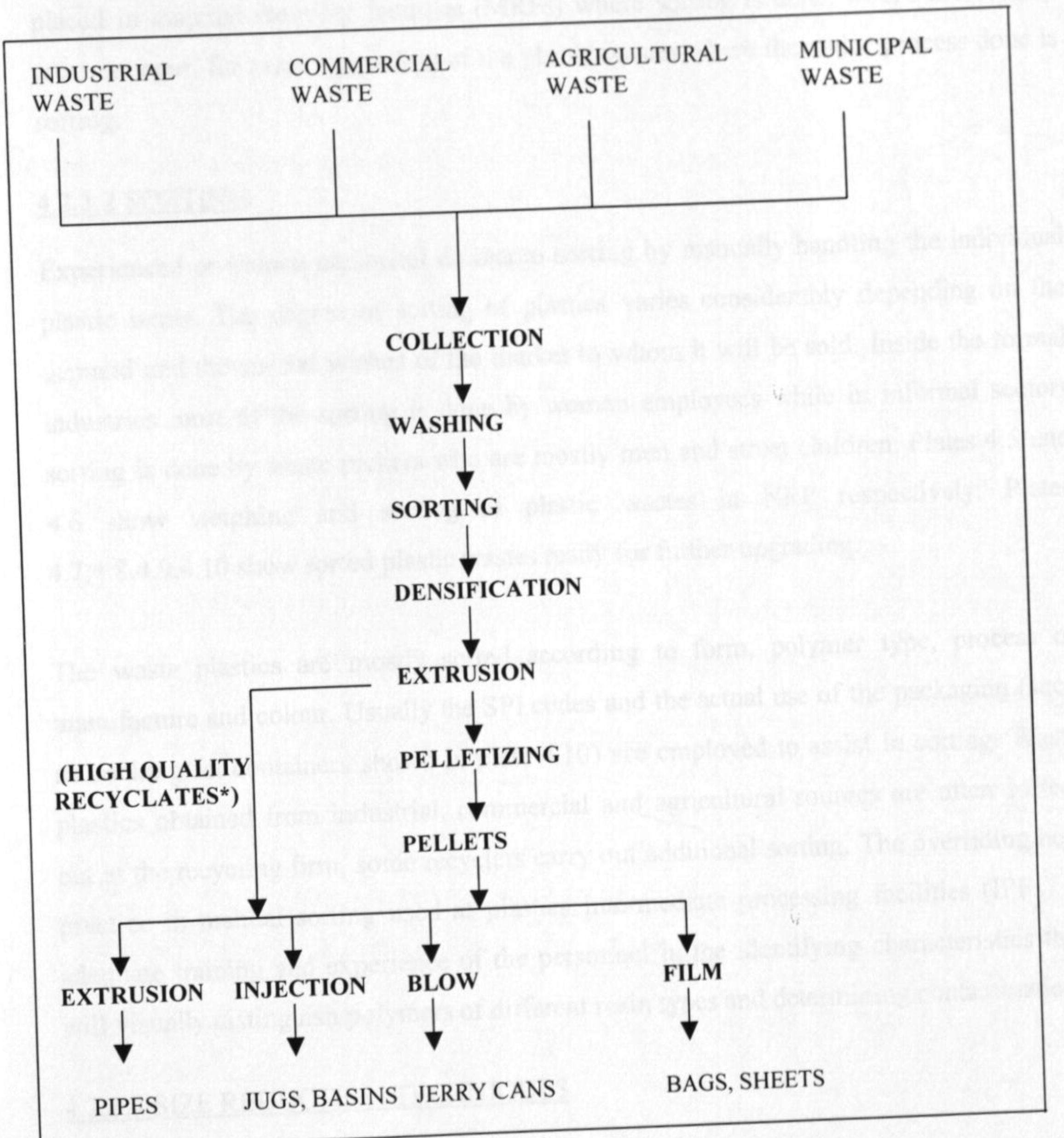


Figure 4.6: Mechanical recycling processes of secondary plastic wastes. Source: Own survey. Note: **HIGH QUALITY RECYCLATES*** are recycled plastic products that requires minimal upgrading processes during recycling process.

4.2.3.1 COLLECTION

The recycling process starts with the collection of plastic waste from various sources such as the municipal waste stream, industrial sources, agricultural sources and commercial sources. Collection is done manually, after which the waste is transported to the recycling enterprise. Generally after collection the wastes are weighed and thereafter placed in material recovery facilities (MRFs) where sorting is done. MRFs are usually areas set apart for easier upgrading of the plastic wastes where the major process done is sorting.

4.2.3.2 SORTING

Experienced or trained personnel do macro sorting by manually handling the individual plastic items. The degree of sorting of plastics varies considerably depending on the demand and the special wishes of the market to whom it will be sold. Inside the formal industries most of the sorting is done by women employees while in informal sectors sorting is done by waste pickers who are mostly men and street children. Plates 4.5 and 4.6 show weighing and sorting of plastic wastes in NRP respectively. Plates 4.7,4.8,4.9,4.10 show sorted plastic wastes ready for further upgrading.

The waste plastics are mostly sorted according to form, polymer type, process of manufacture and colour. Usually the SPI codes and the actual use of the packaging (such as cooking fat containers shown in plate 4.10) are employed to assist in sorting. Waste plastics obtained from industrial, commercial and agricultural sources are often sorted, but at the recycling firm, some recyclers carry out additional sorting. The overriding best practice in manual sorting used at plastics intermediate processing facilities (IPFs) is adequate training and experience of the personnel in the identifying characteristics that will visually distinguish polymers of different resin types and determining contamination.

4.2.3.3 SIZE REDUCTION TECHNIQUES

(a) CUTTING

This is needed for large items such as jerry cans and buckets, which are too large to fit the opening of the shredder. Cutting equipment range from hand tools to electricity powered saw depending on the capital investment of the recycling enterprise.

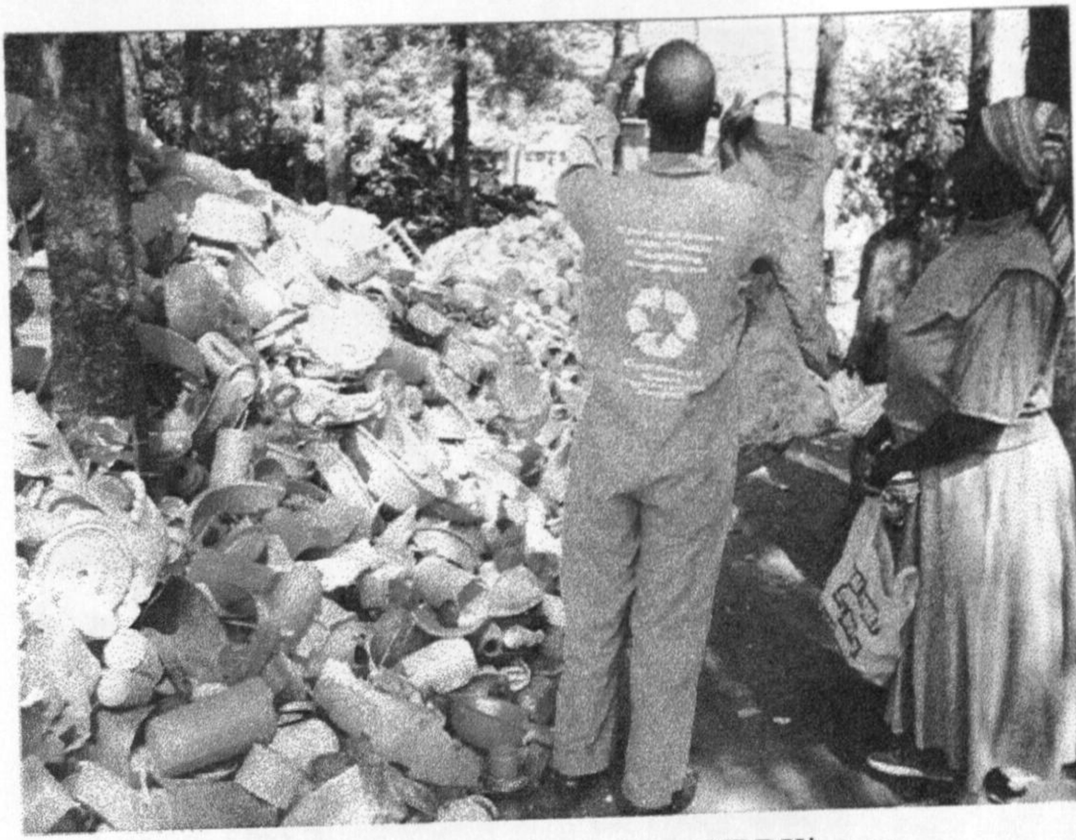


Plate 4.5: Weighing of plastic wastes at NRP,Kisumu.

Plate 4.6: Sorting of plastic wastes by women employees in NRP,Kisumu.

Plate 4.7: Sorted blow grade plastic wastes.

Plate 4.8: Sorted injection grade plastic wastes.

Plate 4.9: Grade sorted plastic wastes ready for shredding.

Plate 4.10: Sorted PP–injection grade 'chipsy' containers.

(b) SHREDDING

The product of shredding is irregularly shaped pieces of plastics called flakes. Plate 4.11, below shows a shredder being repaired to be available for granulating rigid plastic packaging by NRP. After shredding the flakes are ready for washing.

4.2.3.4 WASHING

It is important that the waste plastics are washed thoroughly, to remove particularly water soluble and sinkable contaminants. This is because clean waste materials fetch better prices and they improve the quality of the end recycled content product. In Kenya, most washing is done manually using special detergents in either concrete or open-ended plastic tanks. Plate 4.12 below shows concrete tanks used for washing plastic wastes in NRP. The three tanks shown are for the first, second and final washing respectively.

4.2.3.5 DRYING

After washing most of the drying of plastic wastes is done under the sun using raised wire meshed trays or ground laid plastic films. Plates 4.13 and 4.14 show the trays and dried flakes packaged in 25-kg bags ready for further upgrading respectively.

The informal recycling sector mainly concentrates on the above recycling processes, thus there is need for them to use well-designed recycling equipment and efficient recycling practices for them to manufacture recycled feedstock that can compete effectively with the imported ones.

4.2.3.6 OTHER RECYCLING TECHNIQUES

Pelletizing and product manufacturing are the final steps in the plastics recycling process. For high quality recycled content products, these processes require that the waste plastics first be sorted according to the polymer types. The use of pellets increases the efficiency of the product manufacturing process.

Plate 4.11: Shredder used by NRP in Kisumu.

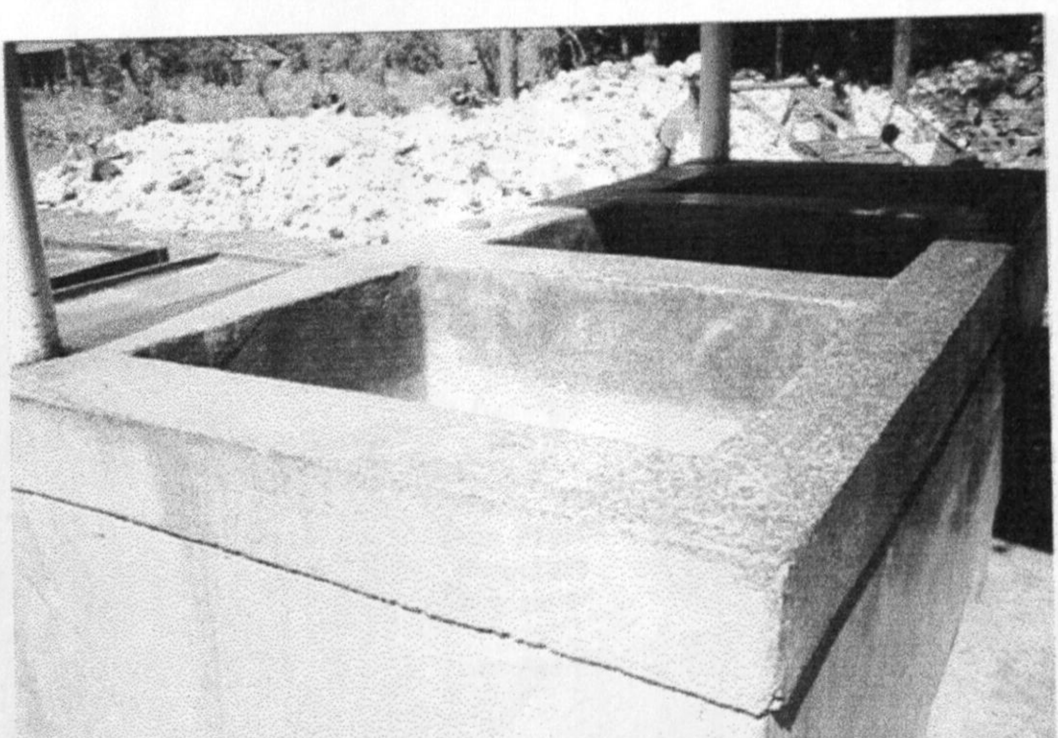


Plate 4.12: Concrete plastic washing tanks.

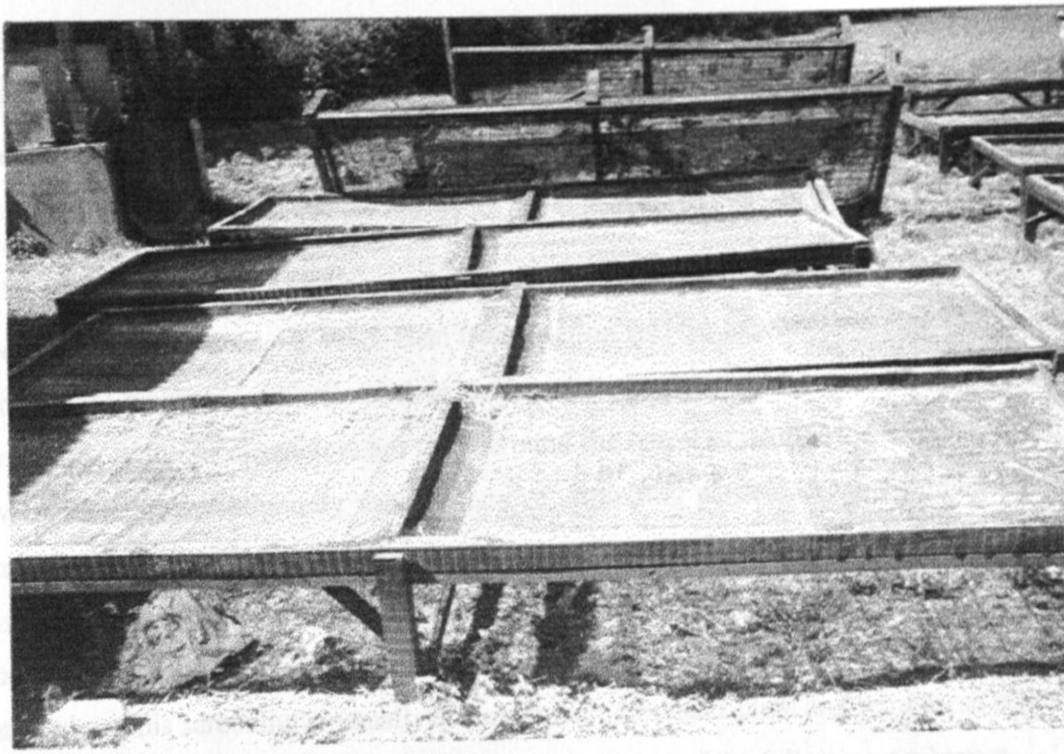


Plate 4.13: Raised trays used to dry washed plastic flakes.

Plate 4.14: Shredded flakes packaged in 25-kg bags in NRP.

(a) PELLETIZING

Shredded rigid plastic objects are subjected to the process of extrusion and pelletizing to produce plastic pellets. Figure 4.7 illustrates the extrusion and pelletizing processes carried out using a vent-type extruder shown in figure 4.8, which is described below.

The materials are picked up from the hopper by a rotating screw and are forced down the barrel to the extrusion die head. Heat from friction and the heating elements fitted around the barrel cause plasticization while the special geometry of the screw compresses the material. Water or air coolers are fitted around the barrel to control the melt temperature. Melt filtration is commonly used to remove unmelting particulate contaminants such as metals. Melt filtration process is generally done in extrusion equipment, where melt flow is continuous and pressure is relatively low and constant. During extrusion the solid contaminants are mechanically screened out of the recycled resin before the melt exits the extruder. This screening is usually achieved with a breaker plate and wire mesh screen. If no melt filtration is done solid contaminants cause any of the following problems;

- Inferior properties such as visible defects, and reduced mechanical properties.
- Plugging of small openings in converting equipment (e.g., nozzles in molding machines).
- Surface defects.
- Different and inconsistent properties in finished parts.

A basin of water or a ventilator then cools the extrudate that emerge from the extrusion die head. The extrudates supported by the rollers placed at the end of the water basin are then drawn by a mechanical system into a pelletizer. The pelletizer chops the strings into short, uniform, cylindrical, pellets that are ready for use as secondary raw materials by end users.

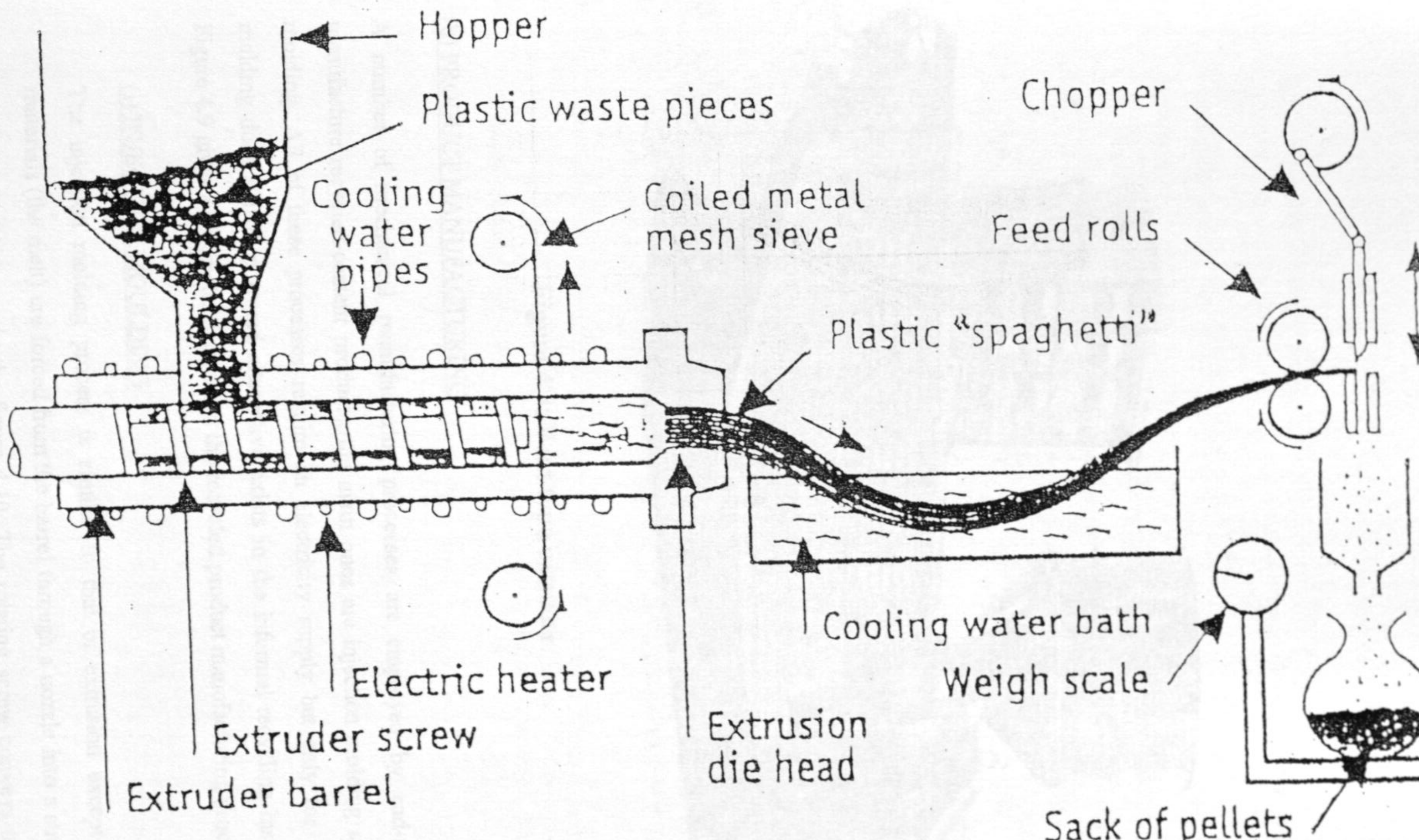


Figure 4.7: Extruder with a pelletizer.

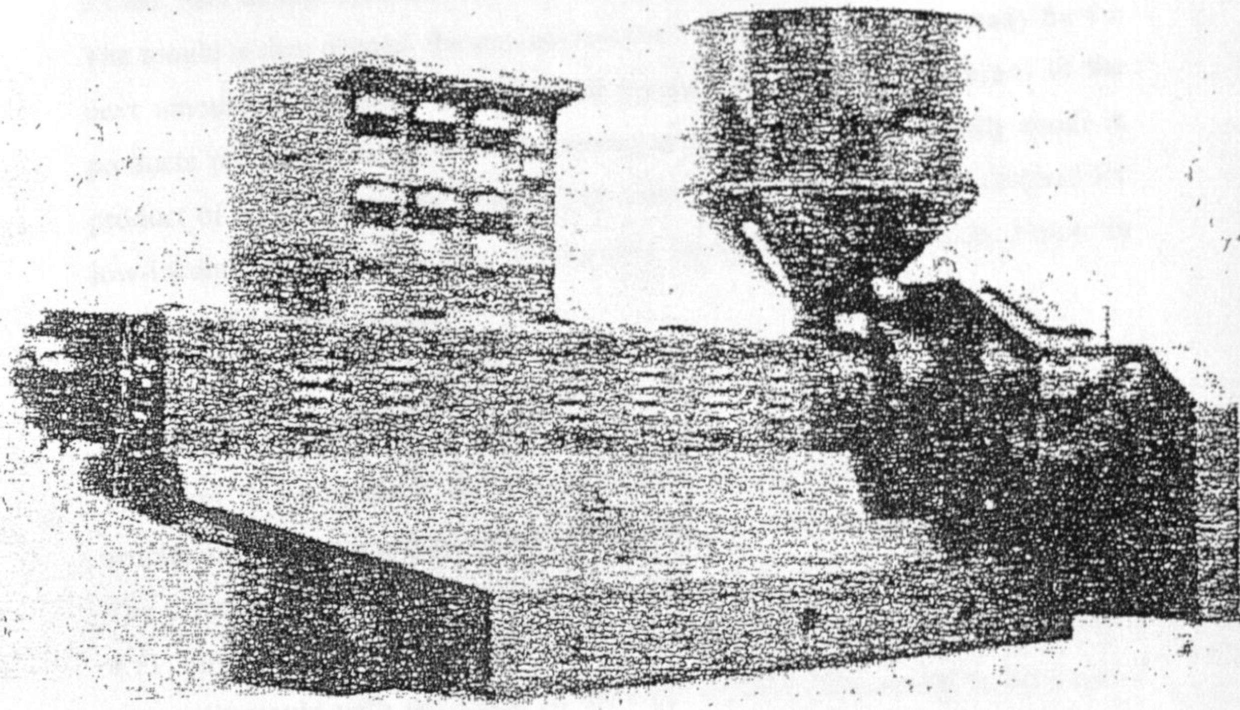


Figure 4.8: Vent-type extruder.

(b) PRODUCT MANUFACTURING

A number of mechanical manufacturing processes are employed by end-users to manufacture recycled-content products, the main ones are injection molding and blow molding. All of these processes require an electricity supply but only for injection molding does a hand powered alternative exists in the informal recycling institutions. Figure 4.9 gives a schematic diagram of the recycled product manufacturing process.

(i) INJECTION MOULDING

The injection molding process is similar to that of extrusion except that the materials (the melt) are forced from the barrel through a nozzle into a strong, split steel mould as shown in the figure 4.10. The rotating screw conveys the plastic forward and the heating elements plasticize it. The screw then stops moving, allowing the melt to accumulate in the front part of the barrel. When an adequate amount has accumulated, the screw moves forward again, pushing the melt into a closed steel mould. The mould is kept cool so that the material quickly solidifies. The mould is then opened, the product removed, and the mould made ready for the next amount of the melt. The shape of the mould determines the types of the products produced. Hand-powered molding is possible, but this usually result in product of poorer quality (e.g. caused by unequally applied pressure) destined for low-income consumer markets. Mechanized injection molding usually results in products of a better quality.

(ii) BLOW MOULDING

The term 'blow molding' is used to describe the process of producing hollow articles such as bottles, where the tops or bottom are narrower than the body itself. The principle of the process, which takes place in two stages, is shown in figure 4.11. First, a piece of plastic tube, or "parison" is extruded, and is then transferred to a split mould with the shape of the final product. The mould is then closed around the parison. Compressed air is blown into the open end to expand the parison to the shape of the mould. The formed shape is allowed to cool until the finished object solidifies, which is then ejected from the mould and the cycle is repeated.

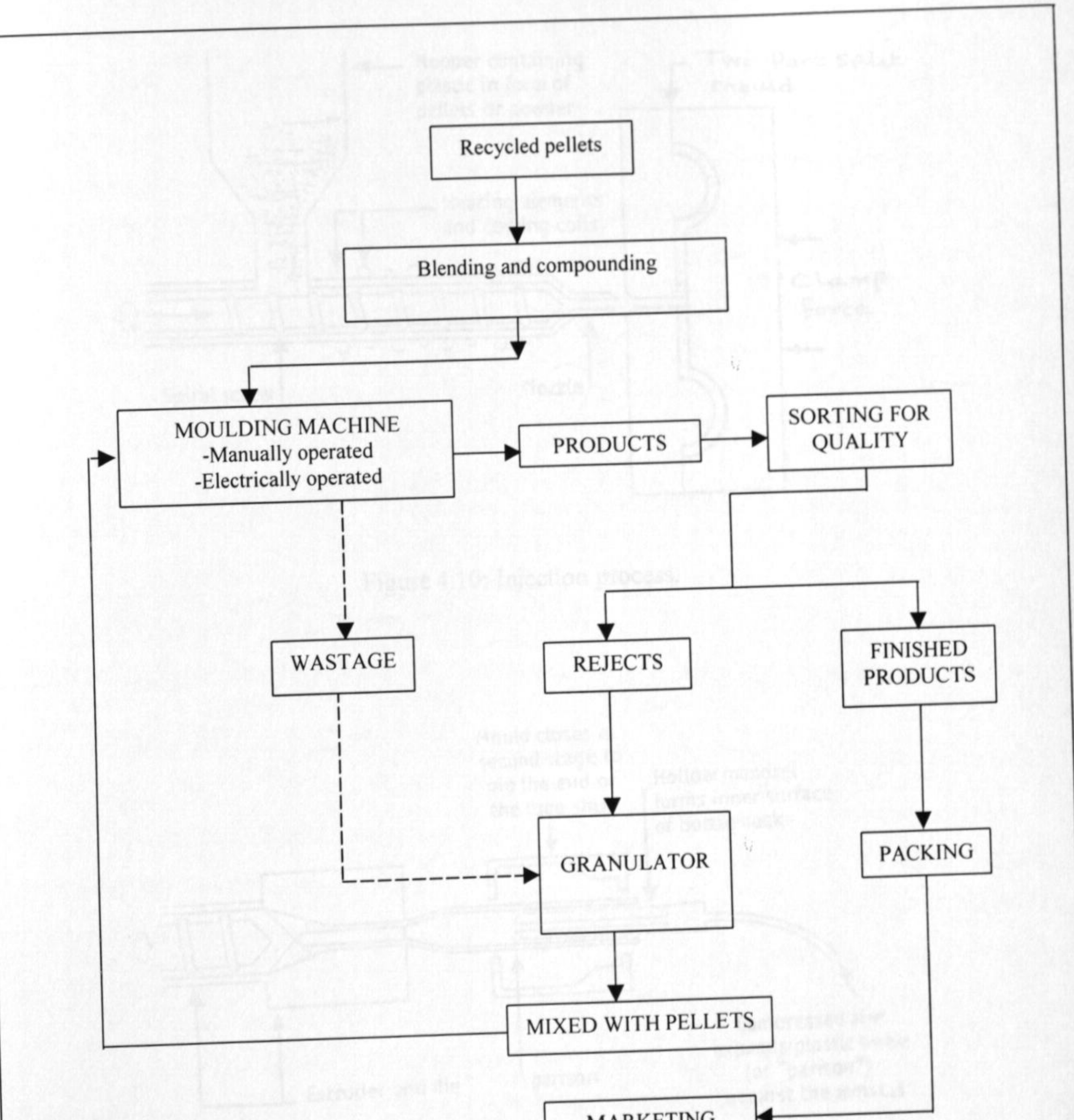


Fig. 4.9: Processes for plastic products from secondary raw materials.
Source: Own survey.

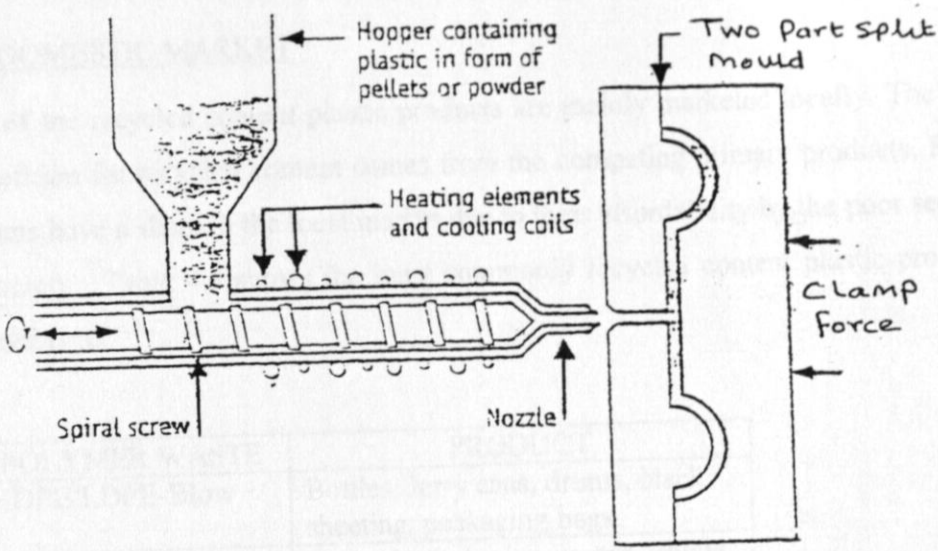


Figure 4.10: Injection process.

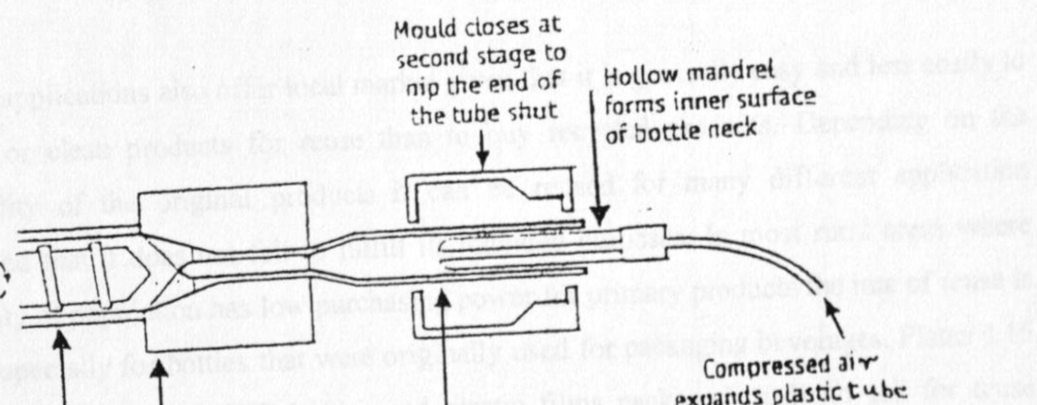


Figure 4.11: Blow moulding process.

4.3 MARKETING OF RECYCLATES.

4.3.1 DOMESTIC MARKET

Most of the recycled content plastic products are mainly marketed locally. The greatest competition for recycled content comes from the competing primary products. Recycled products have a share in the local market due to their affordability by the poor sections of the society. Table 4.8 shows the most commonly recycled content plastic products by polymer type.

POLYMER WASTE	PRODUCT
HDPE/LDPE-Blow	Bottles, Jerry cans, drums, black sheeting, packaging bags.
HDPE/LDPE-injection	Jugs, plastic basins, motor vehicle bushes, buckets, crates
PP-injection	Basins, buckets, plates.
PVC	Jerry shoes, soles

Table 4.8: Recycled content products.
Source: Own survey.

Reuse applications also offer local market given that it is generally easy and less costly to repair or clean products for reuse than to buy recycled products. Depending on the durability of the original products it can be reused for many different application provided that it does not fail to fulfill its intended purposes. In most rural areas where majority of population has low purchasing power for primary products the rate of reuse is high especially for bottles that were originally used for packaging beverages. Plates 4.15 and 4.16 below show PET bottles and plastic films packaged ready to sell for reuse purposes. This shows that in future reuse applications for plastics should be encouraged especially in many developing countries such as Kenya where efficient recycling technologies are either lacking or under-developed.

Plate 4.15: PET bottles packaged ready to sell for reuse purposes.

Plate 4.16: Plastic films packaged in baskets ready to sell for reuse purposes.

4.3.2 EXPORT MARKET

Recycled plastics do not have a large share of export market due to the poor quality of locally available wastes. However, one firm admitted exporting less than 10 percent of its processed recycled content products in the form of jerry cans to neighboring countries. Records from the Ministry of Planning and Finance show that some enterprises exported recyclates from Kenya as shown in tables 4.9 below. The table shows that plastic waste amounting to 290,833 kilograms was exported between 1990 to 1999.

SITC[a]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	TOTAL
57910000	0	0	0	0	0	47,000	58,000	660	0	0	105,660
57920000	0	0	0	0	0	0	0	0	0	0	0
57930000	0	0	0	0	20	13	0	0	24,000	0	24,033
57990000	250	28,000	28,060	28,396	22,456	14,350	14,575	7,205	15,150	2,698	161,140
TOTAL	250	28,000	28,060	28,396	22,476	61,363	72,575	7,865	39,150	2,698	290,833

Table 4.9: Export of primary plastic wastes in kgs.
Source: Ministry of Finance and Planning, CBS division.

Note:

SITC[a] the product categories denoted by these numbers can be found in appendix one.

4.3.3:BARRIERS TO MARKET DEVELOPMENT

In Kenya market for recycled plastic products is under-developed compared to that of primary products.

TOWN	MAIN POLYMER RECYCLED	RECYCLING CAPACITY ESTIMATE PER ANNUM (TONS)
Nairobi	PE, PVC, PP	5937
Mombasa	PE, PP	2800
Nakuru	N/A	N/A
Eldoret	PE, PVC	60
Kisumu	PE/PP	72

Table 4.10: Recycling capacity distribution
Source: Own survey

Note:

The values indicates the total recycling capacity of class 'A' secondary recycling firms in their respective town. The Class "A" constitutes of the firms whose at least 50 percent of their feedstocks constitute post consumer plastic wastes (see appendix five).

Table 4.10 gives percentage distribution of plastic recycling capacity that is also shown in figure 4.12. Comparing this total recycling capacity with the average annual resin consumption of 14000 tons, the figure shows under-utilization of locally available plastic processing capacity using standard equipment.

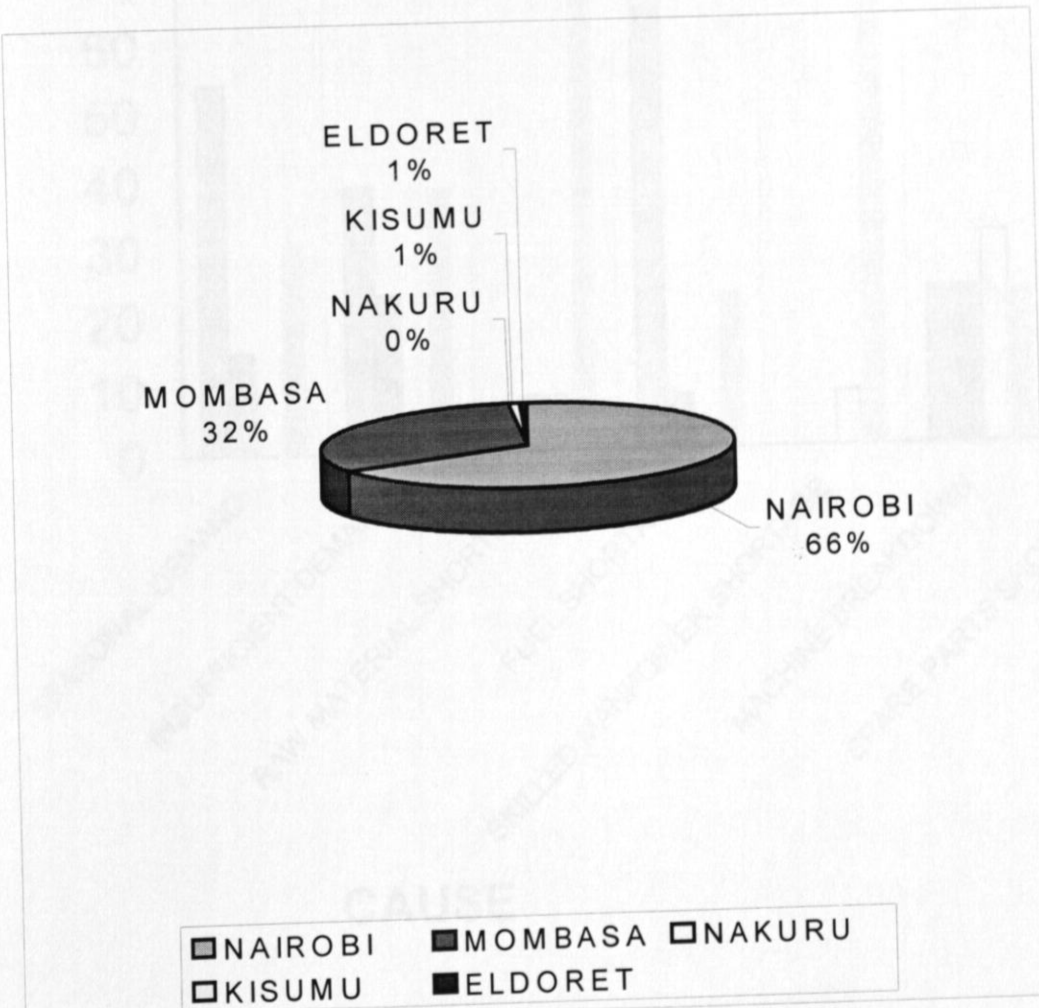


Figure 4.12: Relative distribution of secondary recycling capacity.
Source: Own survey.

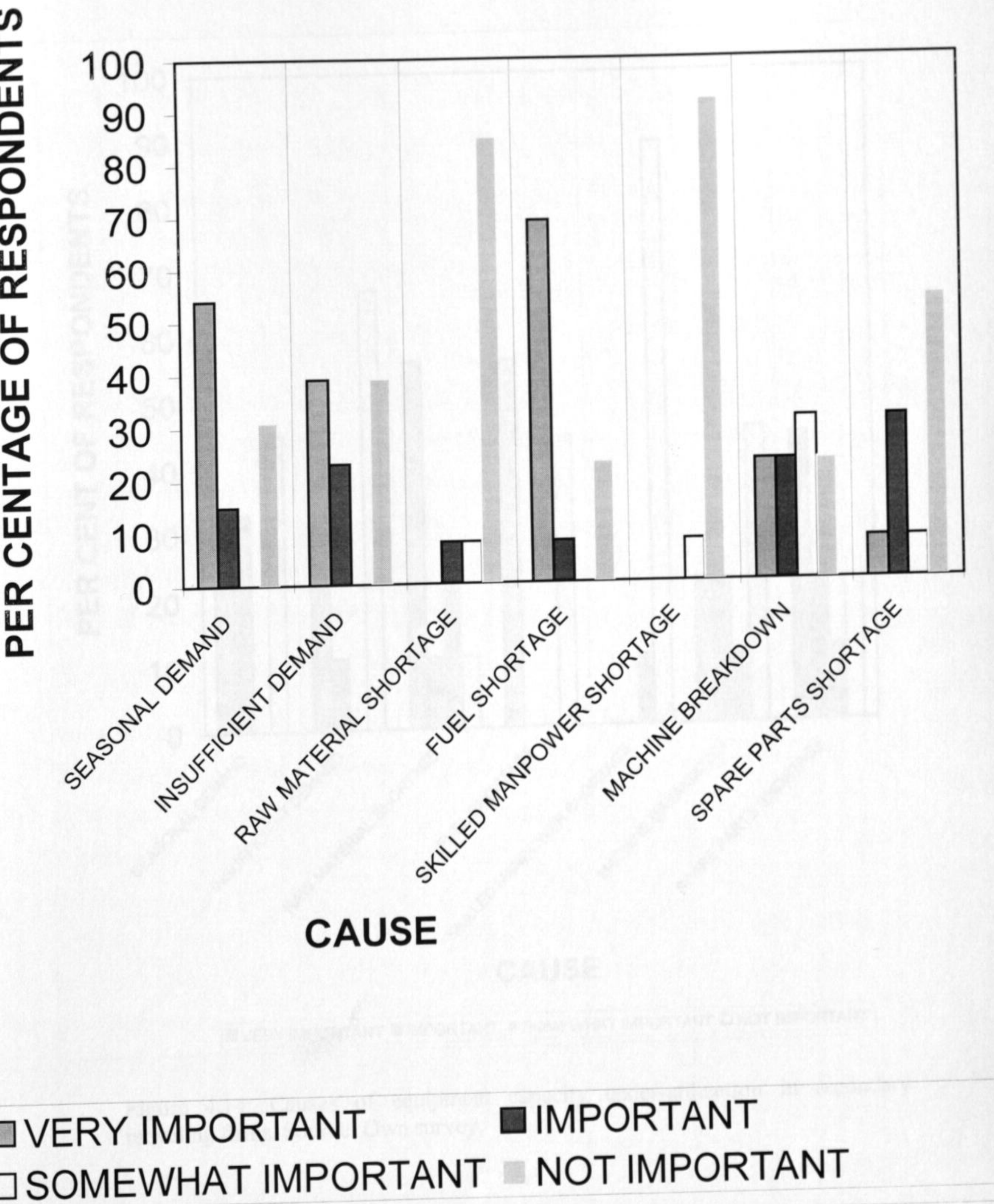


Figure 4.13: Causes of equipment capacity under-utilization by primary recycling firms.
Source: Own survey.

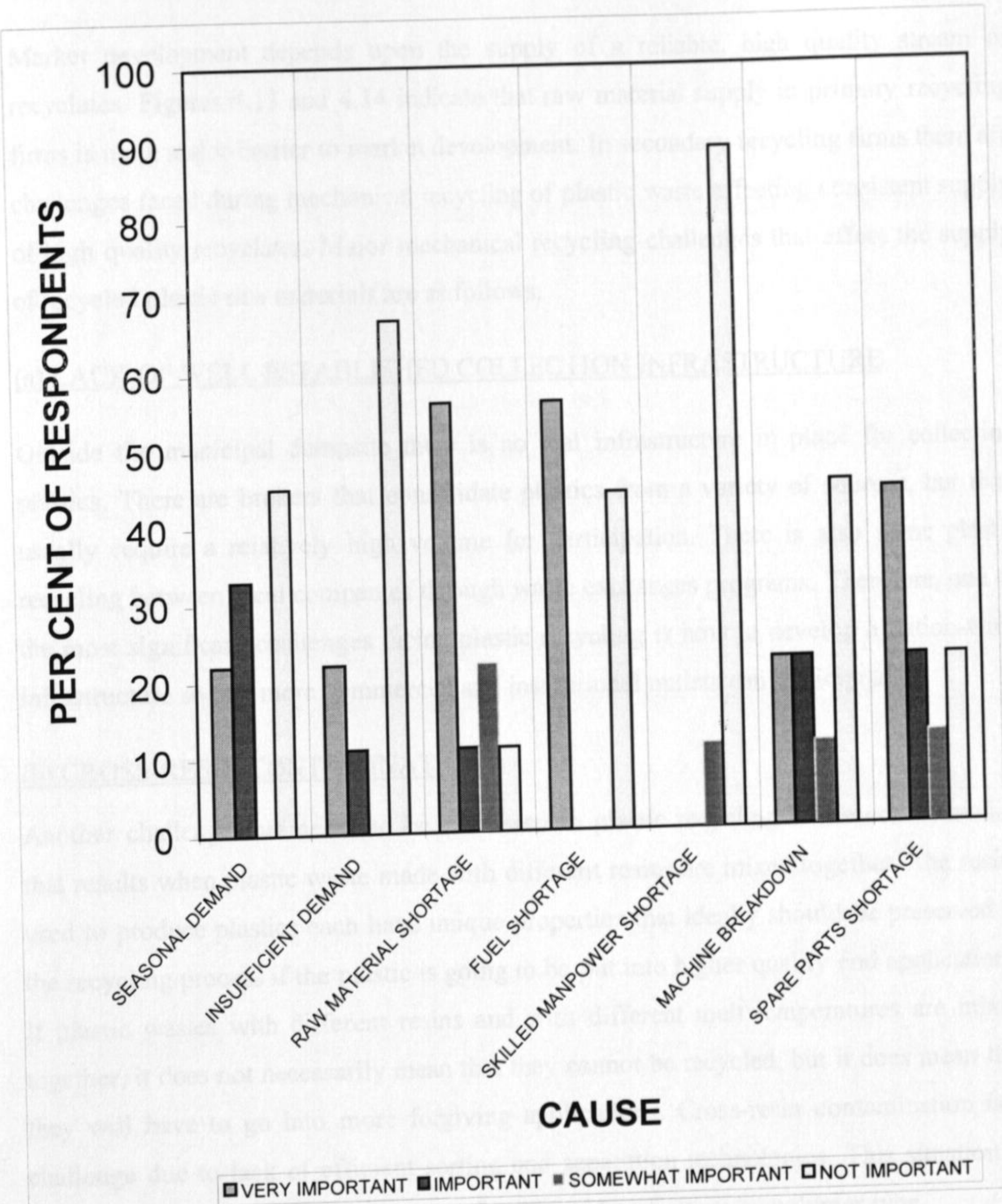


Figure 4.14: Causes of equipment capacity under-utilization in secondary recycling firms. Source: Own survey.

4.3.3.1 SUPPLY OF RAW MATERIALS

Market development depends upon the supply of a reliable, high quality stream of recyclates. Figures 4.13 and 4.14 indicate that raw material supply in primary recycling firms is not a major barrier to market development. In secondary recycling firms there are challenges faced during mechanical recycling of plastic waste affecting consistent supply of high quality recyclates. Major mechanical recycling challenges that affect the supply of recycled plastic raw materials are as follows.

(a) LACK OF WELL ESTABLISHED COLLECTION INFRASTRUCTURE

Outside the municipal dumpsite there is no real infrastructure in place for collecting plastics. There are brokers that consolidate plastics from a variety of sources, but they usually require a relatively high volume for participation. There is also some plastic recycling between local companies through waste exchanges programs. Therefore, one of the most significant challenges facing plastic recycling is how to develop a nation-wide infrastructure so that more commercial and institutional outlets can participate.

(b) CROSS-RESIN CONTAMINATION

Another challenge that needs to be addressed in plastic recycling is the contamination that results when plastic waste made with different resins are mixed together. The resins used to produce plastics each have unique properties that ideally should be preserved in the recycling process if the plastic is going to be put into higher quality end applications. If plastic wastes with different resins and with different melt temperatures are mixed together, it does not necessarily mean that they cannot be recycled, but it does mean that they will have to go into more forgiving applications. Cross-resin contamination is a challenge due to lack of efficient sorting and separation technologies. This situation is made worse by the inadequate labeling for easier identification by polymer type.

(c) TAPES AND LABELS.

Tapes and labels present challenges in plastic recycling mostly because they introduce different materials into the recycling system. For example, tapes can be made with different plastic resins or with other materials and they may have pigments, making them incompatible with the primary resin used in the plastic. Labels are problematic because they are commonly made of paper, which clearly is not compatible with plastic because it is an entirely different material.

(d) ADHESIVES

Adhesives show up in variety of forms. They are commonly used in the lamination process to bond two types of plastics together. They are also used on the back of tapes and labels that are secured in packaging.

Adhesives cause problems in plastic recycling in two ways. First they are designed to be used in the manufacturing process at certain temperatures that may be above those of some packaging material (like PE) and below those of others (like PP). Therefore, they could show up as unmelted particles and/or gels in the recycled product. Second, if adhesives do not melt fully, the remaining particles are small enough to pass through the filtering screens used in extruders. If the processor is making a recycled film product, the adhesive particles or gels appear as "sand" or tiny bumps, which adversely affect print quality.

(e) DYES, PIGMENTS AND PRINTING INKS

Dyes and pigments and printing inks present some challenges for plastic recycling since once they are in the plastic they cannot be removed. Therefore, the very presence of color limits the application in which recycled plastic can be used. It must be put back into products where color is not important or where dye can be used to mask the recycled material.

Printing inks present particular challenges in recycling because layers of dense and vivid colors are often screened one over the other, which dramatically increases the ratio of ink to material. Since dyes, pigments and printing of any kind limit the uses for recycled plastics, most recycled products in Kenya are limited to black colours.

(f) MOISTURE

Moisture is not a problem when washing recovered waste plastics. It is, however, a problem in dry processing systems for a number of reasons. First, moisture in plastics that are stored for long periods become a breeding ground for bacteria creating unpleasant smells which decrease the value of the material and makes the processing unpleasant if not more difficult. Second, moisture presents a handling problem when bags of packaged flakes open and moisture spills on the floor of the processing facility, creating a safety hazard. Third moisture is not plastic, and because markets pay by weight, they do not want to pay for water, which adds considerably to the weight of the material. In most of the informal enterprises negligence that causes improper drying and storage makes end users reject the recyclates.

(g) FOREIGN MATERIALS.

Anything that is not plastic presents challenges for plastic recyclers. Metal can cause serious problems with the grinding equipment, and clog extruder screens. Paper in particular form can make its way through the openings in extruder screens and end up as small lumps in recycled plastic. Other plastics are contaminants because they are in a form that is not easily handled by the recycling equipment and they increase the risk for cross-contamination. 'Dirt' stones and gravel, which are a particular problem in agriculture film, present difficulties for recyclers because they wreak havoc with the blades of the grinder, dulling them to the point where they can no longer be used (which reduces the efficiency of the recycling system and requires more replacements of the blades at considerable cost). For these reasons, contaminants need to be removed in order for plastics recycling to succeed.

Supply of recycled raw materials calls for joint ventures or partnership between waste collection authorities and the recyclers in order to establish viable collection schemes.

4.3.3.2 CONSUMER DEMAND.

Since most primary recycling enterprises sell their products to the packaging industry, the consumer demand for plastic packaging depends on demand for the goods to be packaged. Therefore the consumer demand for plastic packaging is more or less seasonal as indicated in figure 4.13.

Demand for recyclable plastics can be stimulated through government procurement policies. For example local government can require that a certain percentage of their purchased products be recyclable or made of recycled materials. What is needed to make them work is a serious, comprehensive government commitment to purchasing large quantities of recycled materials of all types. Another policy relates to recycling standards. In general, recycling standards require either that products or packaging be made of recyclable material, which means that the material reach a specified recycling rate, or that products or packaging consist of a certain percentage of recycled material. The advantage of recycling standards, if cleverly designed and applied, is that they provide a mechanism for coordinating public and private recycling activities and for establishing a broad-based recycling infrastructure.

Low quality end products/uses result due to low quality post-consumer plastic wastes. Cheaper prices and lack of awareness of recycled products currently attract consumption for recycled goods. Education of consumers about environmental benefits of recycled goods coupled with adoption of labeling standards could create a sustainable market.

4.3.3.3 TECHNOLOGY DEVELOPMENT

End use of recycled materials is dependent upon effective technology used during the recycling process. Expanding technology development programs, through government research laboratories, universities, and technology transfer programs, can promote market development.

Most of collection and handling processes for post-consumer waste is done manually due to the lack of effective technology. Reclamation processes are mainly done using imported second-hand equipment that has been upgraded using locally available spare parts. However, this equipment constantly breaks down due lack of technical know-how on effective operation and installation. This problem is mainly found in shredding equipment where the grinding blades break or become blunt. Insufficient capacity to recycle also affects the supply of the wastes.

The recycling industry needs new technologies to find alternatives to traditional markets. This will help to avoid direct competition with primary products. Plastic lumber for example, could be an alternative market for wood and concrete products in addition to establishing market for nuisance plastics. The survey revealed that the most common nuisance plastic wastes in Kenya are as follows; films, hazardous plastic wastes like medicinal wastes, battery acid plastic containers, degraded plastic wastes, unidentified plastic wastes, and PET bottles.

4.4 THE ECONOMICS OF RECYCLING

4.4.1 COSTS OF RECYCLING

The costs associated with plastics recycling can be divided into three main categories: raw material costs, production costs and transportation costs.

4.4.1.1 RAW MATERIAL COSTS

Each time recyclable waste changes hands in the waste recycling chain, value is added to it because inputs in terms of labor and capital go into the process and the waste changes form and utility. Scavengers input labour to separate recyclable from mixed and dirty garbage and into transporting it to the waste dealer. The dealer sorts, cleans, stores and transports the wastes to the wholesaler and the user industry. The user industry processes the waste into usable items for the consumer. The cost of recyclables at the dumpsite to a scavenger may be nothing besides time and effort, while the itinerant buyer might pay a nominal amount to commercial enterprises.

The competitiveness of the Kenyan manufacturers has been severely eroded since most of the raw materials imported by local manufacturers attracts between 5 % to 15 % import duty while other countries, especially those exporting to Kenya, have zero import duty on raw materials and other inputs. For example, in the footwear industry imported raw materials for making PVC shoe soles attract about 15 % import duty, according to one of the plastic footwear manufacturer. It has become cheaper to import finished goods than to manufacture the same locally, which is the trend that keeps the importers in a lucrative business at the expense of our local industries. High interest rates and a depreciation of the Kenyan shilling have tremendously increased the cost of imported raw materials in the recent years (Appendix two gives the consumer price index (CPI) between 1990 and 2000). Tables 4.12 and 4.13 show cost of imported virgin raw material and LDPE respectively.

RAW MATERIAL	SOURCE	DEALER
PVC	UK, Thailand, USA, Romania, Brazil, Jordan	Agrinco (k) LTD, Metchem (E.A), industrial distributors
PS	Saudi Arabia	N/A
HDPE	France, UK, Middle East, Kuwait, Saudi Arabia, Japan, Korea, Dubai	Mobil, Sabic, Agrinco (k) ltd.
PET	Korea, Saudi Arabia, India	N/A
LDPE	France, Saudi Arabia	Mobil, Sabic, Agrinco (k) LTD
LLDPE	South Africa, Saudi Arabia	Solvo-Chem
PP	Korea, Kuwait, Saudi Arabia	N/A

Table 4.11: Main sources of major packaging resins.
Source: Own survey.

This cost is expected to increase as consumption of the imported raw material is expected to increase as shown in figure 4.15.The situation has become worse with the COMESA's commitment to reduce the region's tariffs to 0 % on basic raw materials, 1 % on intermediate products and 2 % on finished items (Ministry of Trade and Industry). Most of our raw materials are sourced from non-COMESA countries as shown in table 4.11 and so as such our plastic industries cannot compete under such an uneven playing field.

SITC*	QUANTITY (KG)	VALUE (KSH)	MEAN PRICE (KSH/KG)
57111000	21,837,523	1,080,242,854	49.50
57112000	34,111,407	1,604,324,844	47.00
57211000	677,794	38,008,684	56.10
57219000	1,513,186	63,993,150	42.30
57311000	14,275,806	589,542,266	41.30
57312000	379,150	22,322,265	58.90
57313000	1,711,126	111,412,946	65.10
57433000	3,936,458	225,285,819	57.20
57511000	14,511,206	580,649,557	40.00
TOTAL	92,953,656	4,315,782,385	46.40

Table 4.12: Local consumption of virgin raw materials in 1999.
Source: Data from Ministry of Finance and Planning, CBS division.

Note:
SITC* the product categories represented by above codes can be found in appendix one.

YEAR	QUANTITY (KG)	VALUE (KSH)	MEAN PRICE (KSH/KG)
1994	14,535,068	525,625,534	36.20
1995	17,896,698	836,226,118	46.70
1996	18,938,766	996,086,855	52.60
1997	20,229,062	1,183,959,898	58.50
1998	20,817,603	1,027,622,398	49.40
1999	21,837,523	1,080,242,854	49.50
TOTAL	114254720	5,649,763,657	49.40

Table 4.13: Local consumption of LDPE for the last 6 years.
Source: Data from Ministry of Finance and Planning, CBS division.

POLYMER	SORTED	SHREDDED	PELLETIZED	PRIMARY WASTE	VIRGIN RESINS
HDPE-blow	2-4	15-25	20-40	50-60	58-80
HDPE-injection	2-3	15-17	20-30	N/A	68-90
LDPE-injection	2-3	15-17	20-30	N/A	
LDPE-blow	3-6	15-25	20-40	25-30	
PP - injection	3-6	19	30-40	N/A	60-65
PVC- suspension	20	40	N/A	N/A	55-80

Table 4.14: Costs of secondary feedstock (Ksh/kg).
Source: Own survey.

Note: N/A means the prices were not available due to the fact that plastic firms opt to perform on-site primary recycling of the polymer waste.

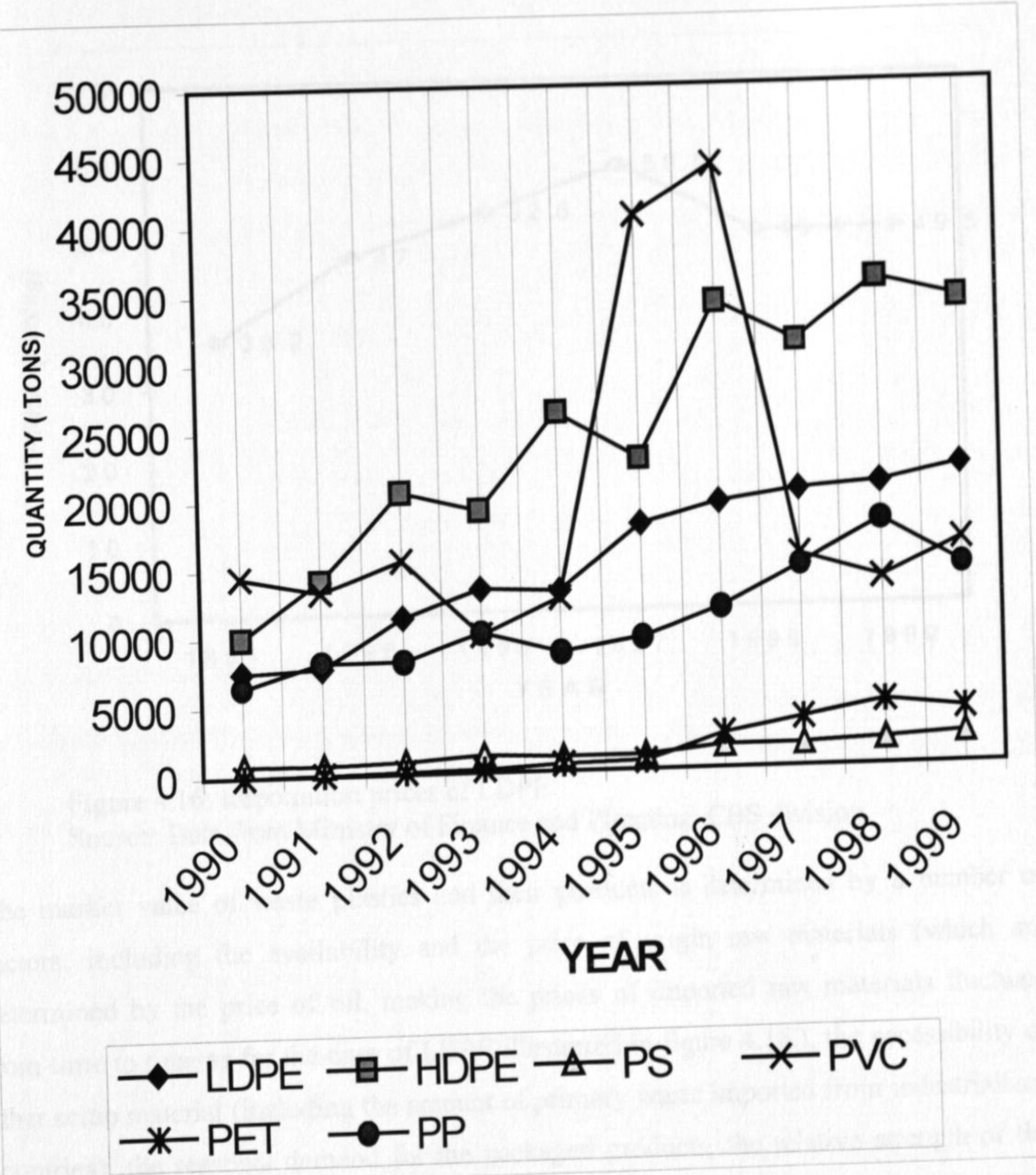


Figure 4.15:Local consumption of major plastic resins.
Source: Data from Ministry of Finance and Planning, CBS division.

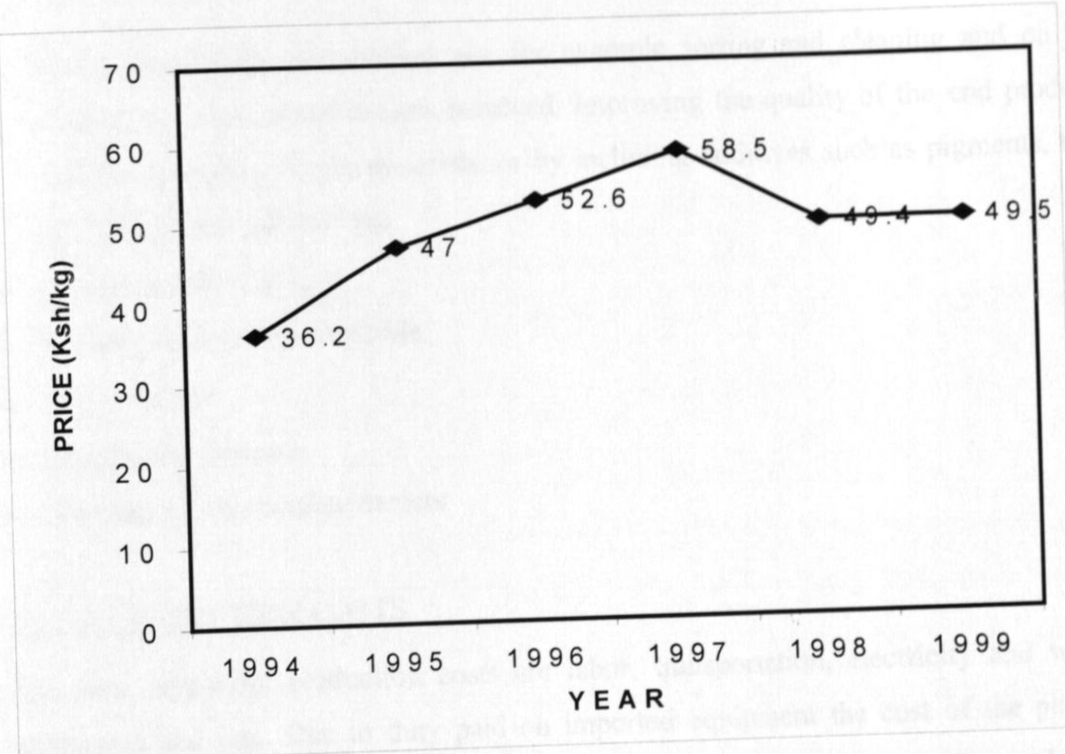


Figure 4.16: Importation prices of LDPE.
Source: Data from Ministry of Finance and Planning, CBS division.

The market value of waste plastics and their products is determined by a number of factors, including the availability and the price of virgin raw materials (which are determined by the price of oil, making the prices of imported raw materials fluctuate from time to time as for the case of LDPE illustrated in figure 4.16.), the accessibility of other scrap material (including the amount of primary waste imported from industrialized countries), the seasonal demand for the packaged products, the relative strength of the domestic economy, and government policies on trade, including import restrictions. The market for recovered plastics is characterized by a competitive structure a high degree of volatility, thus the demand and prices of waste plastics and reprocessed pellets can fluctuate enormously.

Table 4.14 shows costs of recyclable versus the cost of virgin raw materials in Kenya's recycling system. The table gives the minimum and maximum prices from the survey. The results show that there is discrepancy in payment and pricing of materials collected and sold by scavengers. The table shows clearly that the cost of raw materials depends on;

- The type of upgrading carried out, for example sorting and cleaning and on the number of intermediate dealers involved. Improving the quality of the end product, such as by adding virgin materials, or by including additives such as pigments, will also add to the material cost.
- Factory standard prices
- Quantity and quality available
- Polymer type
- Supply and demand
- Number of intermediate dealers

4.4.1.2 PRODUCTION COSTS

The most important production costs are labor, transportation, electricity and water, equipment and rent. Due to duty paid on imported equipment the cost of the plastic-processing equipment is high. Tables 4.15 and 4.16 shows the various sources and costs of plastic processing machinery between 1994 and 1999.

MACHINE	SOURCES
injection molders	Germany, Italy, India, Taiwan
extruders	Hong Kong, India, UK, Taiwan, France
blow molders	Japan, India, Germany, Italy
film blowers	India
printing machines	Korea, India, Germany
shredder	India, locally assembled
bag sealing machine	India Taiwan
weaving machines air compressors mixers chillers multi color printers	Italy

Table 4.15: Main sources of plastic processing machinery.
Source: Own survey.

TRADE IN PLASTIC PROCESSING MACHINERY	
Year	Value of equipment (Ksh)
1994	429,468,011
1995	843,159,657
1996	852,128,718
1997	592,221,478
1998	596,105,571

Table 4.16: Cost of imported plastic processing equipment.
Source: Ministry of finance and planning, CBS Division.

Note:
Records for costs of various types of machinery according to the country of origin are not available.

Generally it was difficult to obtain reliable data on production costs, since many recyclers especially informal entrepreneurs do not usually keep well-documented records. However two major recyclers gave the costs of various recycling processes per kilogram of recyclate as follows:

ACTIVITY	Skyplast (KSH/ KG)	Arrow (KSH/ KG)	Average cost KSH/ KG)
Collection	10	12	11
Cleaning	2	3	2.50
Sorting	2	2	2
Transporting	3	2	2.50
Drying	2	4	3
Other	1	2	1.50
TOTAL	20	21	20.50

Table 4.17: Costs associated with processing of post consumer plastics.
Source: Own survey.

The further extension of plastics recycling activities to include product manufacturing basically means that higher investments will be needed in machinery, and that these will incur greater expenditures on spare parts and maintenance. Also a product-manufacturing machine will consume considerably more electricity (by the large motor) and more water (for continuos cooling) than a shredding machine. The necessary moulds for product manufacturing also add to the production costs.

Some potential ways of reducing electricity and water costs could be through the installation of high efficiency motors and variable speed drives coupled with proper sizing and improved maintenance of processing equipment. Opportunities to conserve water include counter-current washing, filtration and reuse of water at earlier stages of the process, and reuse of cooling water in the washing process.

4.4.1.3 TRANSPORTATION COSTS

Transportation costs constitute a considerable proportion of overall production costs, especially in the case of bulky low-density plastics. One way to reduce the costs of transporting such waste plastics is through densification either by cutting or shredding. The site of the recycling plant should therefore be carefully chosen in order to minimize transportation costs. Currently recycling institutions use two ways of reducing transportation costs. Informal recycling enterprises uses handcarts while formal industries use modified motor vehicles. Plates 4.17 and 4.18 show these transportation means respectively.

4.4.2 BENEFITS OF RECYCLING

4.4.2.1 ECONOMIC BENEFITS

Plastic recycling in Kenya is carried out under free market conditions. By 'free market' conditions is meant that the recycling is carried out for economic reasons without legal obligation or subsidization. Under 'free market' conditions recycling is an economically profitable operation, where economic profitability means that the achievable price for the recyclables are higher than the gross cost of plastic recycling including collection, transport, sorting and treatment operations. The need for plastic waste recycling is driven by a variety of economic benefits, which includes financial as well as employment creation. By manufacturing recycled content products industries saves on the cost of imported raw material. Recycling of plastics brings about job creation and economic development through collection, reclaiming, handling activities. This is in the areas of sales, administration, marketing, clerical, engineering, laborer, technical, and other positions.

Plate 4.17: Locally fabricated handcart.

Plate 4.18: Modified motor vehicle.

Table 4.18 below gives direct jobs created by various recycling enterprises located in the five towns visited.

TOWN	CBO	RECYCLING FIRMS
NAIROBI	51	485
MOMBASA	N/A	57
NAKURU	N/A	0
KISUMU	12	10
ELDORET	N/A	80
Total	63	632

Table 4.18: Employment by major recycling institutions.
Source: Own survey.

Note:
N/A refers to the fact that these towns had no organized community recycling organizations that could provide data.

Emergence of recycling industry as a sector of the economy makes plastic processing industry more competitive compared to other industrial sectors in contribution to the industrialization process. Table 4.19 gives relative establishment of major secondary recycling industries and other plastic processing industries.

YEAR	ΣX_1	ΣX_2
1960-under 1963	3	0
1963- under 1966	7	0
1966- under 1969	9	0
1969- under 1972	19	0
1972- under 1975	31	4
1975- under 1978	40	4
1978- under 1981	48	5
1981- under 1984	65	7
1984- under 1987	81	10
1987- under 1990	81	11
1990- under 1993	82	15
1993- under 1996	83	16
1996- under 1999	147	30

Table 4.19: Relative cumulative frequency distribution of establishment of secondary recycling firms versus total number of plastic processing firms.
Source: Own survey.

Note:
ΣX_1: Number of plastic firms.
ΣX_2: Secondary recycling firms.

Figure 4.17 illustrates that secondary recycling industry is relatively a young industry although it shows upward growing trend while figures 4.18 gives the relative distribution of classes 'A' and 'B' respectively. The researcher categorized class 'A' secondary recycling firms as those recycling firms that utilize over 50 % raw materials from secondary sources while the other firms that are not included in the above definition comprising of class 'B' firms. Recycling industry supplies secondary raw materials to plastics processing industry. This makes plastic industrial sub-sector more competitive and more sustainable. Figure 4.19 shows percentage distribution of secondary recycling firms in the five towns.

Secondary recycling industry converts recyclables from disposable wastes to commodities of trade. For example in 1996, MRC collected recyclable amounting to 1,018 tons worth of ksh.1.55 million (JICA, 1998). This makes materials collected in recycling programs not garbage or waste any more.

4.4.2.2 ENVIRONMENTAL BENEFITS

The environmental aspects of plastic waste recycling have two sides. First recycling reduces the volume of the waste that has to be dumped resulting to an extended life of existing landfill sites. The second effect of recycling is the saving of natural resources used during extraction of raw materials. This adds significantly and in a positive way to ecologically sustainable industrial development (ESID).

Rigid plastic containers made of either HDPE, LDPE, PP are commonly recycled. These containers rarely contribute to the solid waste pollution in towns with established recycling infrastructure such as Kisumu and Nairobi. For nuisance plastic waste especially contaminated packaging films, have contributed to solid waste pollution in form of litter. Solid waste pollution downgrades the status of a town, which contribute either directly or indirectly to bad economic effects, such as tourism sector of the economy. One consequential effects of solid waste pollution is the recent downgrading of Nairobi from a 'B' to a 'C' working station by United Nations.

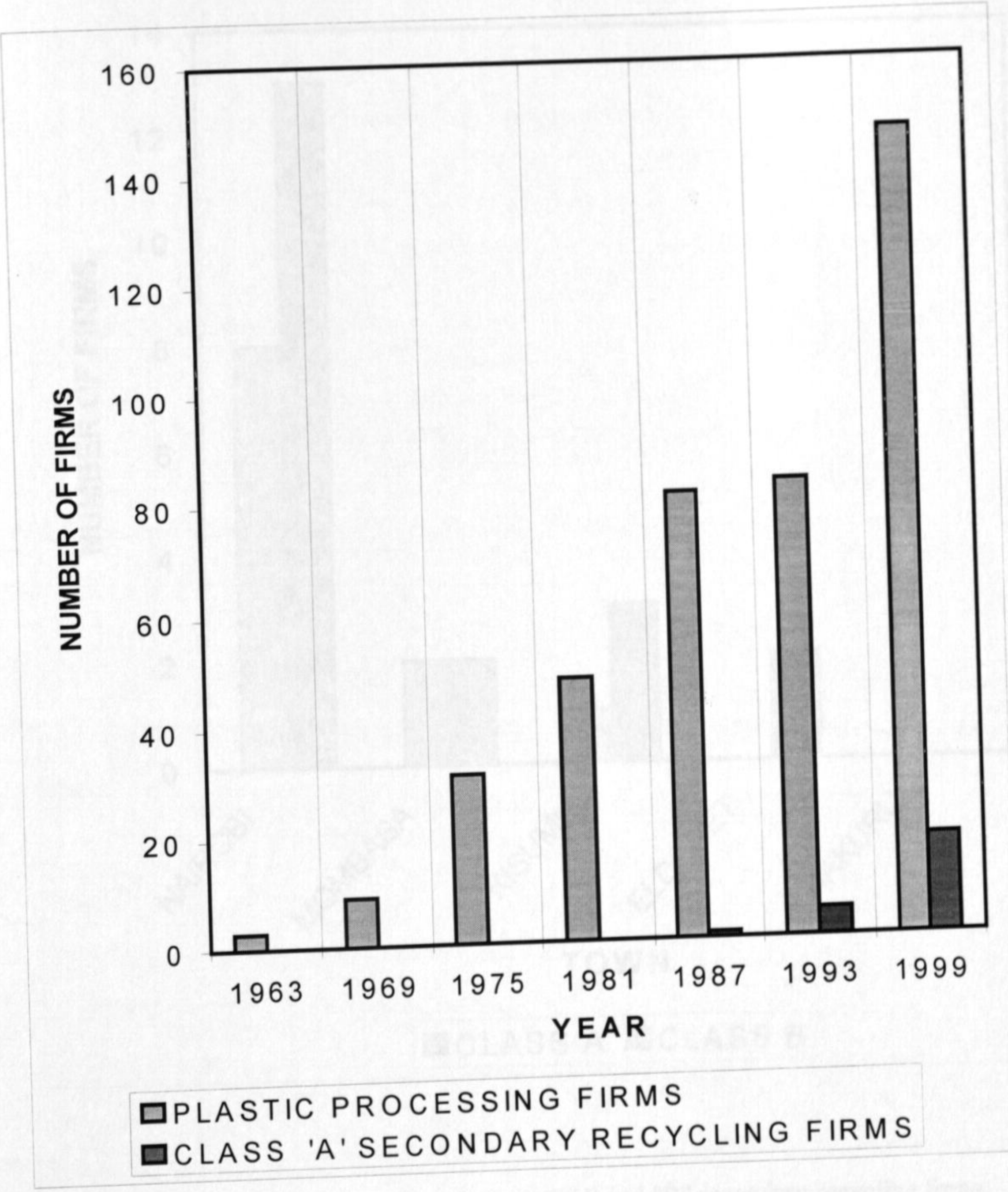


Figure 4.17: Relative establishment of major secondary recycling firms versus total number of established plastic firms. Source: Own survey.

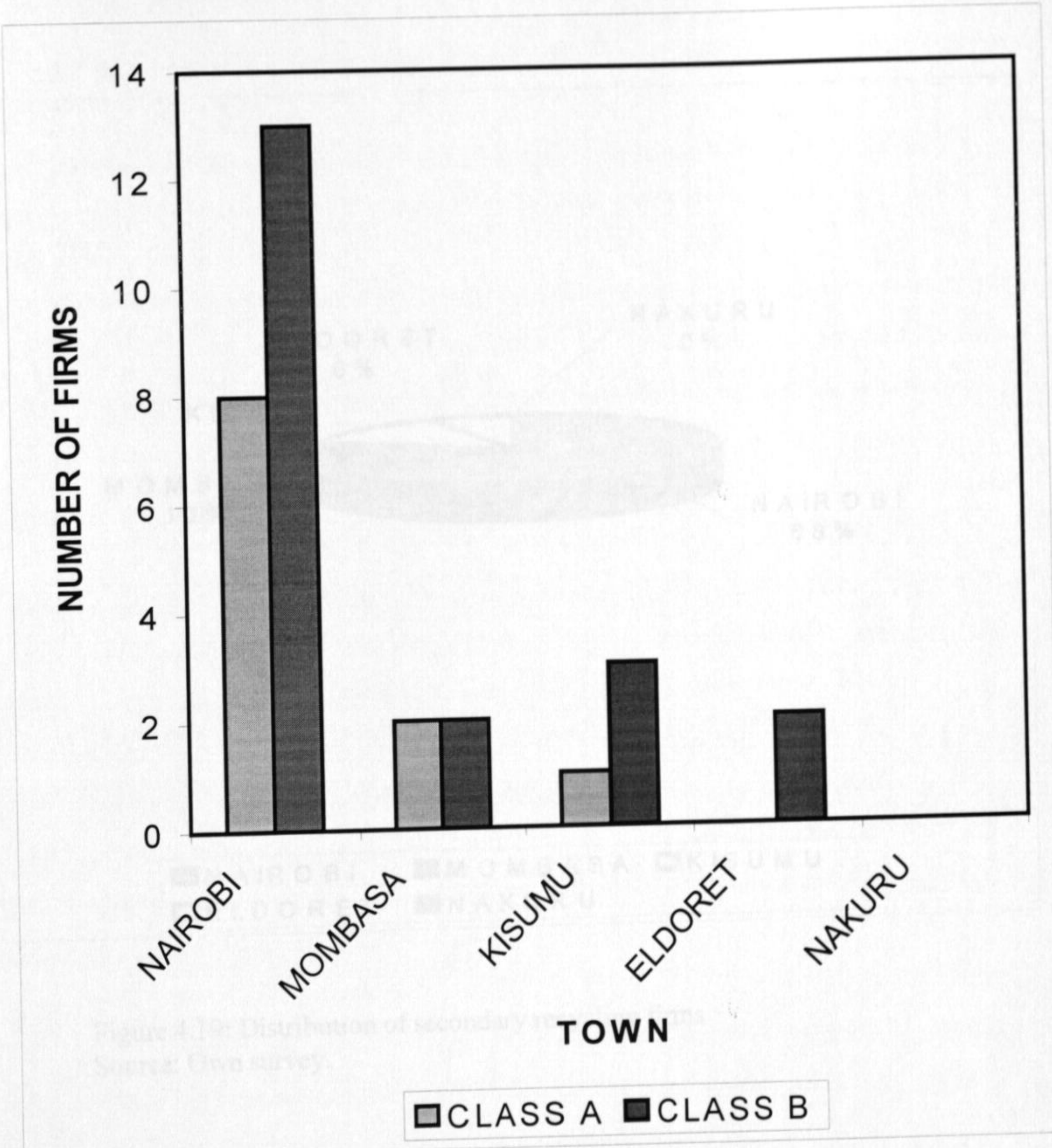


Figure 4.18: Relative distribution of classes "A" and "B" secondary recycling firms.
Source: Own survey.

Note:
The firms belonging to the above classes are listed in appendix five.

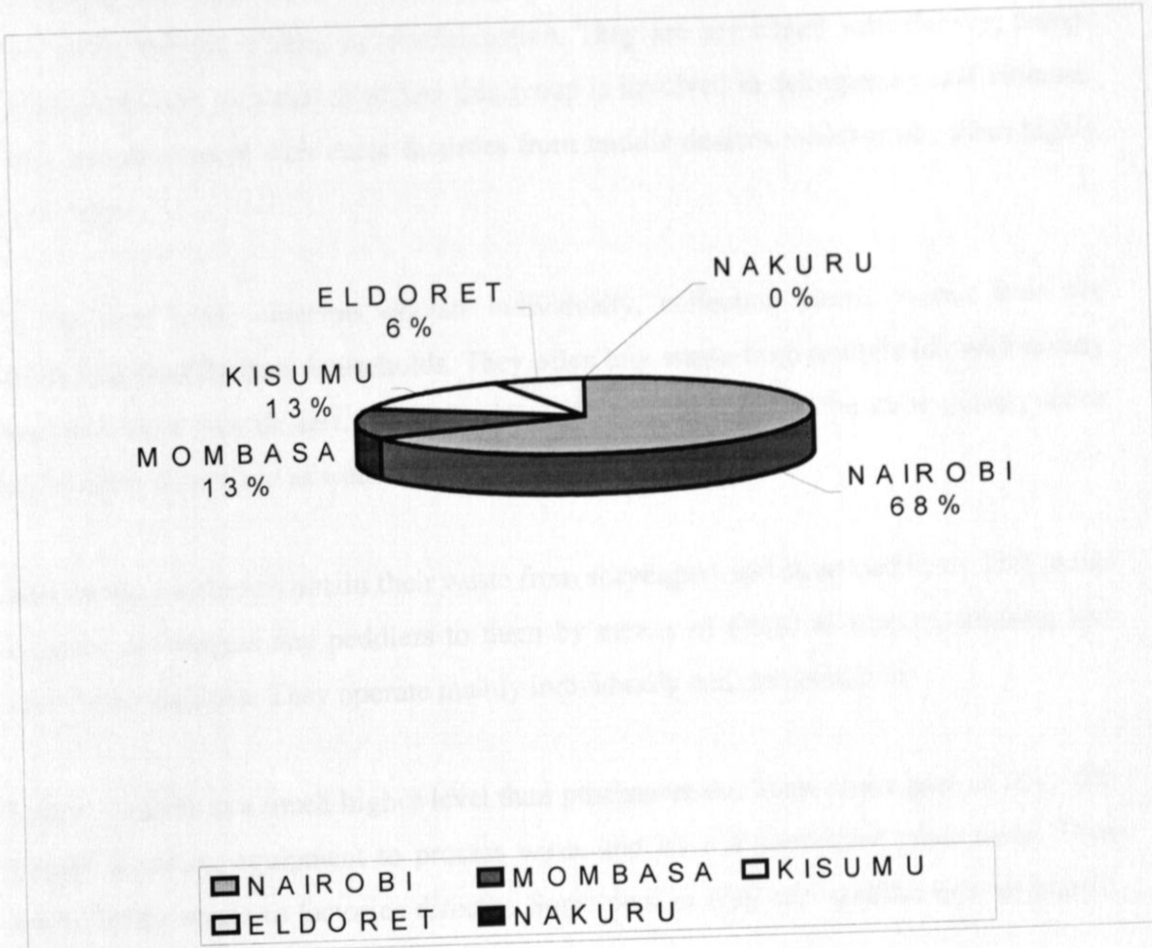


Figure 4.19: Distribution of secondary recycling firms
Source: Own survey.

4.4.2.3 SOCIAL BENEFITS

There are different social groups involved in the waste recycling process, which includes door-to-door collectors, formal waste collectors, street scavengers and dumpsite scavengers. On top of this, a large number of people find employment as dealers and traders in plastic waste or recycling equipment that derive the production materials from secondary sources.

Scavengers are the poorest group of the underprivileged community. They live in-groups, throughout the towns or on the dumping sites with family members participating in scavenging activities. Their status is very low and their living conditions are appalling. They often become victims of discrimination. They are associated with thieves, tramps and vagrants and, as a matter of fact this group is involved in delinquency and violence. These people receive their basic facilities from middle dealers, which make them highly dependent.

On the next level, itinerants operate individually, collecting plastic wastes from the streets and directly from households. They often buy waste from households with money borrowed from their dealers. They are obliged to sell the waste to the same dealer, which makes them dependent as well.

Small-scale purchasers obtain their waste from scavengers and street peddlers. This group obligates scavengers and peddlers to them by means of financial support, housing and other basic facilities. They operate mainly individually and independently.

Traders operate at a much higher level than purchasers do. They own a plot of land with storage facilities, equipment to process waste and have a permanent labor force. They supply bulky waste to factories directly. Some deal in only one specific type of plastic, others deal with different categories.

With adequate upgrading of the recycling sector the number of people finding employment could increase tremendously and at the same time improving their working conditions and social status.

4.5 THE PLASTIC PACKAGING AND ENVIRONMENT INITIATIVE (PEI)

IOP (K) and KAM have initiated a project dubbed 'plastics packaging environment initiative (PEI), 1998'. The PEI's aim is to take a proactive role and address the issue of plastic packaging waste without legislative approach. This is in relation to the policy of IOP (Mugera (ed.), 1998).

"The institute from the start is aware of the importance of keeping the earth safe to live in and will endeavor to prevent environmental degradation. The concern of the environment is no longer the preserve of Europe or America".

The PEI's recycling objectives include;

(a) Consumer education towards responsible disposal of waste packaging.

(b) Setting up recycling programs for used packaging.

(c) To participate in the enactment of informed and appropriate legislation on packaging and environment.

4.5.1 PEI PROJECTS

4.5.1.1 COLLECTION PROGRAMS

This project entails the positioning of large green cages 2m × 2m × 2m at conveniently situated sites around the country which provide the communities with a facility in which to place all plastics wastes. Consumers will be educated and encouraged putting their waste here. Each cage will have somebody in charge of it. The collected waste will be sorted out, graded and cleaned where necessary and sold to specialist recyclers. To participate as a company its name will be written on the cage it donates. The recyclers will be expected to keep the statistics for monitoring to determine the quantity and type of materials being recycled.

4.5.1.2 AWARENESS CREATION PROGRAMS

(a) CONSUMER EDUCATION

The main theme is to inform consumers the importance of plastics packaging. Littering will be criminalized and should take its position as an anti-social activity like crimes in the penal code. Any plastic company can sponsor one or many of the following programs and company name/brand will be associated with it

Radio, T.V, School visits, university visits, training/seminars/workshops, publications-pamphlets, booklets, packaging days, community cleaning days, posters, educate administrators-chiefs, DO's, educate professional societies.

(b) RETAILERS EDUCATION

This sector needs to be educated to recycle plastics. They are a critical link to reducing packaging waste in the supply chain.

(c) INDUSTRY PROGRAMS

Marking of all plastics to speed up the sorting in the waste streams. IOP (K) will collaborate with Kenya Bureau of Standards (KEBS) to work on a timetable to do this. This will facilitate the exportation of Kenyan products. Imported products will have to comply with Kenyan standards.

4.5.2 GOVERNMENT ROLE UNDER PEI

Under PEI the government is to play a major role in the key areas as follows;

4.5.2.1 LOCAL GOVERNMENT

- provide land for incineration and for green cages
- enforce criminalisation of litter

4.5.2.2 CENTRAL GOVERNMENT

- incentive programs to encourage use of recycled materials.
- make recycled materials/content exempt from levies/taxes.
- avoid waste mountains.
- enforce criminalization of litter.
- provide land for incineration/green cages.

4.6 DISCUSSION

One of the most important issues to be addressed by the waste management authorities in Kenya is the development of policies and implementation of programs for the recycling of plastic waste to achieve sustainable urban development. These policies and programs are discussed below.

4.6.1 POLICY OPTIONS FOR MARKET DEVELOPMENT

Collection of recyclable is usually the responsibility of local government. Setting up of viable recycling programs could save the government substantial saving in terms costs of collection and disposal of the solid waste in general. Therefore this requires the government to play a leading role in recycling programs in areas such as establishing collection programs, setting up land for building MRFs, establishing policies that encourages recycling. Such policies could be in areas of awareness, incentives and legislation.

4.6.1.1 CREATION OF AWARENESS

(a) OBJECTIVES OF THE AWARENESS CREATION

The overall objectives of an awareness creation program should be to educate communities and industries on:

- The consequences of their behavior and activities on the local and global environment.
- The need for changes in their behavior and activities to prevent the degradation of the local and global environment.
- The availability of technologies, which can help to improve living conditions and preserves the local and global environment.

This is expected to sound alarm for the populace to adopt proper plastic waste management ethics.

(b) TARGET GROUPS FOR AWARENESS CREATION

The target groups for awareness creation programs should be the consumers and the industries.

(i) CONSUMERS

Plastic waste concerns everyone in society: the rich, the poor, the old, the young, men and women. Nevertheless, some segments of the consumers can influence consumption and plastic waste production behavior than others. The following segments of consumers could be given more attention to achieve a cost-effective solution:

- Women are the principal decision makers in the households in buying goods, they handle most plastic wastes in the household and ultimately decide to discard them
- The young generation, especially school children, who are more attracted to the modern way of life, and somehow, inappropriately belief that the modern way of life is synonymous with consuming more and wasting more.
- Richer people who feel proud from buying unnecessary products and wasting more than most other poor people can afford. This give others in society the wrong meaning of economic affluence

(ii) INDUSTRIES

All plastic industries large or small should be the target of awareness creation. However, streamlining industrial products and processes so that they are more environmentally friendly will be a gradual process because of the high cost involved in the modification of products and processes and because of other interests of larger industries.

Under these situations immediate and intensive focus should be on small-scale recycling industries. The target group should be the potential entrepreneurs who wish to establish small-scale recycling industries and also the existing small-scale recycling industries who wish to expand their operations.

(c) COMMUNICATION PROCESS

Awareness creation programs can be done through the media and through direct contact. The impact of using the media will be very much dependent on local cultural, economic and social conditions. A judicious selection and balance in the extent of use of the media are important for effective communication

Various studies have shown that the following are effective tools for communicating to communities about recycling programs (APC, 2001).

- Direct mail brochures printed on recycled paper.
- Local media such as local newspapers, television, radio, local celebrities or hold contests especially in local schools related to the program as a means of attracting media attention.
- Community information resources: using community organizations such as schools, churches, libraries, neighborhood /condominium associations, etc.
- Employee training: especially on the common mistakes made by recycling.
- Telephone information line/s.

4.6.1.2 DEVELOPMENT OF SUITABLE LEGISLATION AND REGULATIONS

It is becoming increasingly obvious that the current plastic waste disposal practices are often inadequate for today's needs .The review and analysis of policy and legislation demonstrates there are inadequacies that need to be addressed if objective of protecting the environment is to be met. These inadequacies are both legislation and institutional and include the fact that legislation is scattered over a wide range of statutes, the lack of capacity for enforcement, lack of comprehensiveness, low penalties, poor incentives and vaguely defined institutional responsibilities.

In an attempt to address the above weaknesses, parliament enacted the Environmental Management and Coordination Act of 1999 (Kenya Gazette, op cit.). The act aims to establish an institutional framework for the management of the environment and radically alters Kenya law on environmental management. The charges introduced by the 1999 act exist and, for the time being will apply alongside the other legal provisions relating to environment. They do not override or replace the other laws. Therefore the provision of the new act are set out alongside those of the other laws previously in existence.

The salient features of the act include:

- The establishment of a national environment management authority (NEMA) to coordinate environmental activities.
- The act introduces a compulsory requirement for an environmental impact assessment (EIA). EIA, the procedure for prior assessment of the environmental impact of a proposed development project, is by no means new in Kenya, as elsewhere. However, it had until recently not been a statutory requirement
- The act establishes a standards and enforcement review committee (SERC), as a sub-committee of NEMA. The committee will recommend standards in the field of water quality, air quality and waste management.
- The act sets up a national environment tribunal (NET) that is an attempt to set up an administrative mechanism for quick resolution.
- The act enhances penalties for environment offences, introduces the prospect of fiscal incentives and mechanism; and set up a national environment council (NEC) responsible for policy formulation and direction.
- The act widens public access to environment information by providing that any person may have access to information transmitted to the NEMA unless there are reasons to keep the information confidential.

4.6.1.3 USE OF INCENTIVES

Incentives, including disincentives, can be used to obtain positive results for promotion of recycling of plastic wastes. Such incentives or disincentives will not only help in maximizing waste recycling and waste reduction but will also improve working conditions in the sector.

Some incentives are financial whereas others have no cost implications. Financial incentives can be a direct cost to government or they can relate to policy and procedural matters to improve access to capital market by plastic waste recycling entrepreneurs.

Such incentives can be applied as short-term support to stimulate maximization of waste recycling and reuse.

Some of the incentives that could be applied are:

- A reduction in levies to households who participate in source separation schemes or alternately higher levies to those who do not participate.
- Offering capital and operating assistance.
- Market measures and regulatory actions.
- Lending opportunities to small-scale recycling industries and business such as soft loans with low interest rates to entrepreneurs who wish to establish small-scale industries or wish to expand and improve technology in the existing industries.
- Financial concessions to any other industries that wish to voluntary participate in maximization of plastic waste recycling.
- Tax exemption or tax relief to the recycling sectors.
- Guaranteed marketing of recycled products. One such step could be the purchase of locally recycled waste bags by Local Authorities.
- Levy of environmental tax on virgin raw materials and products, which deplete the natural resources and cause environmental degradation.
- Review and simplification of government regulations relating to establishment, operation and taxation of small-scale plastic recycling industries. Many small size recycling industries operate informally because they are required to pay purchase and sales taxes the same as any other manufacturing industry rather than pay as a recycler.
- Various non-cost incentives such as "green label" for environment-friendly products.
- Technology incentives like tax rebates to industries or other establishments that invest in plants, equipment and machinery for pollution control, recycling of wastes
- Tax disincentives to deter bad environmental behavior that leads to depletion of environmental resources or that causes pollution.

4.6.2 PLASTIC WASTE MANAGEMENT PROGRAMS

Suitable programs for enhanced plastic recycling includes:

- Reduction of the amount of the waste.
- Maximization of separation at the source.
- Promotion of small-scale recycling industries.
- Integration of recycling and formal plastic waste management.

4.6.2.1 REDUCTION OF THE AMOUNT OF WASTE

The volume of the waste increases while its composition changes with economic development. A reduction in the amount of wastes could be achieved by the following measures.

- Change of consumption patterns and lifestyles
- Use of more recyclable plastic materials
- Banning of waste import.

(a) CHANGE OF CONSUMPTION PATTERN AND LIFESTYLES

The initial price of development is the growing amount of waste having more complex composition. The complexity in the composition diminishes the possibilities for recycling. Both the volume and composition of the plastic waste generated by the consumers are highly influenced by life-styles and consumption patterns. Volume is further increased with the growth of the population. While intervention in the growth of the population is beyond the scope of promoting recycling, changing the population's consumption pattern is however the most important tool for addressing plastic waste management issues.

The changing of lifestyle and consumption patterns is a long-term process. This however can be structurally achieved on the basis of voluntary participation of the people. To achieve this there is need to introduce some form of economic incentives (or disincentives) to consumers to reduce the amount of waste.

(b) USE OF MORE RECYCLABLE PLASTIC MATERIALS

In the absence of environmental levies, the costs of environmental pollution, which form a significant part of the production cost in industrialized countries, are not paid for in most developing countries such as Kenya. This is a major reason why plastic industries prefer using virgin raw materials compared to using secondary raw materials. Additionally the industry is reluctant to invest in process and product modifications that will be required to use more recyclable wastes as their secondary raw materials. The other reason for less use of waste plastic materials is the poor quality of the waste available at present. Under these circumstances the use of more recyclable materials will only be possible with the development of legislation that forces industries to internalize the environmental costs as an integral part of production costs, and the strengthening of institutions responsible for development, implementation, monitoring and control of environmental policies and programs. With the establishment of NEMA in accordance with Environment Management and Coordination Act of 1999,environment legislation will be enforced to industries.

(c) BANNING OF IMPORTS

Despite the fact that the present potential of recycling is not fully exploited in Kenya, plastic wastes trading in the name of recycling is being practiced.

Often these wastes may be contaminated and pose severe health and environmental problems to the locality, apart from the reduction in value of locally generated waste. This diminishes the economic driving force for promoting plastic waste recycling in Kenya.

4.6.2.2 MAXIMIZATION OF SEPARATION AT THE SOURCE

At present the economic benefits of separation of wastes at the household levels in Kenya are not attractive enough to warrant a full recovery of recyclable plastic materials at the source. Substantial amount of the recyclable wastes are discarded by households which can only partially be retrieved by scavengers at communal bins, open dumps and designated dumping sites, and by the waste collectors when collecting and transporting the wastes. To derive the full benefit of plastic waste recycling, maximum separation of recyclables from municipal and industrial wastes should take place at the source itself for the following reasons:

- Availability of more unpolluted plastic materials.
- Increasing waste management efficiency.
- Employment creation and better working environment.

(a) AVAILABILITY OF MORE UNCONTAMINATED PLASTIC MATERIALS

Plastic wastes recovered from mixed garbage at communal bins and dumping sites are generally contaminated, and sometimes the nature of contamination may entirely be unknown. This poses serious health hazards to the waste collectors, scavengers and industry workers. Use of contaminated materials also diminishes the quality of products. Additionally product users may also be subjected to health hazards. These are some of the reasons, which inhibit most formal industries from using recyclable wastes as source material for their products. Plastic industries will be encouraged to use plastic wastes if cleaner wastes are made available to them (For example Brush manufacturers put cleanliness as a requirement when buying waste plastics for recycling). Furthermore the extra efforts required for cleaning and sorting the wastes would also be substantially reduced.

(b) INCREASING WASTE MANAGEMENT EFFICIENCY

Separation at the source will substantially improve the efficiency of plastic waste management on top of the increase in waste recovery. The waste management efficiency will be enhanced because of good results expected, some of which are given below;

- The volume of waste handled will be much reduced resulting in direct improvement in waste handling efficiencies.
- Waste collectors will waste less time sorting the wastes for themselves.
- The efficiency of the capital intensive collection vehicles will improve as waste collectors will waste less time sorting waste and collection vehicles will waste less time making detours to sell the items

- Littering in city streets as a result of reduced scavenging at communal bins and open-dumps will be reduced resulting in savings in collection time of the waste collectors and in the cost of street sweeping. This will keep the environment clean.

(c) EMPLOYMENT CREATION AND BETTER WORKING ENVIRONMENT

Separation at the source could provide more secure jobs with fewer risks for the health and better working conditions to many of the urban poor involved in waste recycling. By stimulating source separation in favor of street and dumpsite dumping, for scavengers as well as others who handle the municipal wastes, cleaner jobs will be provided to them.

4.6.2.3 PROMOTION OF SMALL-SCALE PLASTIC WASTE RECYCLING INDUSTRIES

Though, currently, bigger manufacturing industries appear to be the major users of recyclable plastic wastes, small-scale recycling industries may be more suitable for the following reasons:

- Siting of a big industry is principally governed by other factors such as availability of cheaper land, energy, transportation of primary raw material, market etc., rather than the availability of waste as secondary source of raw material. These factors make the industries unfavorably located from the standpoint of maximization of plastic waste recycling. The greater haulage distance increases the cost of transportation and decreases the source price of waste materials, which is a disincentive to the effective source separation of plastic wastes. A small-scale industry located close to the source of generation will be able to pay higher prices for the waste material and this could help promote source separation.
- The big industries have limitations of their own in recycling wastes, as wastes cannot be used beyond a certain proportion of the virgin raw materials unless the process as well as the product is modified. It is quite unlikely that such modifications will keep pace with the need for recycling of plastic wastes because of high initial costs in process and product modification.

To make use of the advantages of small-scale recycling industries, an appropriate option would be to promote small-scale waste recycling industries at the neighborhood level or as near to the source of generation as possible. In such cases the waste could be transported at lower costs by using transportation modes such as locally fabricated push carts, thus, allowing higher prices for households to create an extra incentive for source separation and collection.

The promotion of plastic waste recycling could mean enhancing the capability of existing industries as well as creating favorable conditions for the growth of such industries. The following initiatives can be taken to promote small-scale plastic recycling industries.

- Improvement of performance
- Increase of level of know-how
- Improvement of marketability

(a) IMPROVEMENT OF PERFORMANCE

Most of the small-scale plastic waste recycling industries in Kenya operate in the informal sector and therefore do not have an access to many of the benefits that their counterpart bigger industries in the formal sector have.

They do not have access to credit facilities and therefore operate with limited funds and as a consequence their production capacity is rather low. One of the major problems in upgrading this sector is the availability of funds for purchase of collected plastic waste, equipment and sites. Better access to credit facilities could improve the performance of existing small-scale industries and could be a catalyst creating many new industrial establishments. The current levels of interest rates charged on credit facilities deter many local and foreign investors. The existing rules and regulations governing the establishment and the expansion of the industry are too complex for an establishment with very rudimentary organizational structures. In this respect, the requirement of registration, including payment of taxes and fulfillment of regulations normally applicable to bigger industries also applies to small-scale recycling industries, which severely constrains the growth of small-scale recycling industries.

(b) INCREASE OF LEVEL OF KNOW-HOW

Most of the small-scale wastes recycling industries are based on innovative and indigenous technologies appropriate to local conditions, for example chewing of pellets to determine their quality. The availability of technical know-how on small-scale waste recycling processes is not apparently a limiting factor, although there exists ample scope for upgrading. Obviously, small-scale industries lack know-how on in-house organizational aspects and business skills. There is a low level of social and health awareness amongst the people working in small-scale recycling industries and therefore the working conditions for the labor are extremely severe and unhealthy.

At the present rate of recycling, technological improvement is not seen to be a serious concern, but in the near future, with the need for extended recycling practices, the need for technology improvement will emerge to improve the quality of the products for better marketability and sustained profitability.

(c) IMPROVEMENT OF MARKETABILITY

The marketability issue is concerned with both the recovered recyclable plastic wastes and the finished products from the wastes.

(i) RECYCLABLE WASTES

Availability of a steady and reliable market for separated plastic wastes is essential for effective performance of the entire recycling sector. But several negative factors affect the marketability of plastic wastes. For example, the demand driven nature of recyclable wastes because of the surplus labour in Kenya gives the industries, particularly the larger ones, an upper hand in determining the prices and being selective in the recycling wastes in terms of quality and quantity; and the extended recycling of the wastes directly conflicts with the interest of the producer of the basic raw materials. This implies that the waste recycling market cannot be left alone to market forces and regular intervention is necessary through legal or other tools to sustain the recycling efforts.

(ii) FINISHED PRODUCTS

The marketability of recycled products heavily depends upon their price and quality in relation to those products made from virgin raw materials. The quality of recycled products drops with every recycling step resulting in similar drops in prices of finished products. At present the users of recycled products are the poor section of the society because the products are cheap. However, with enhanced recycling practices the marketability of recycled products will have to be addressed through improvements in product quality.

4.6.2.4 INTEGRATION OF RECYCLING AND FORMAL WASTE MANAGEMENT.

Recycling and waste management activities form a set of interdependent activities. These consist of collection and separation of recyclable wastes and transport to recycling centers. This interdependency calls for integration of recycling programs with formal waste management authorities and requires recycling and reuse of waste to become an integral part of the comprehensive waste management plan. In the absence of this, an independent recycling program will not be sustainable.

The waste management authorities are often skeptical of such integration. A common argument put forward is that it would increase the cost of their operations, while the social and environmental costs and benefits are largely overlooked. Initially a recycling program may appear to add cost to the waste management (see section 4.4.1), but in the long run show significant economic, social and environmental benefits to the society (see section 4.4.2). The integration process involves the improvement of communication and the increase of management capability as discussed below.

(a) IMPROVEMENT OF COMMUNICATION

A recycling program involves and concerns numerous governmental and non-governmental agencies, the public and industry. For a successful recycling program, open communication among them is essential. One area of serious concern is the sharing of information among industries on the waste produced and the processes used by them. The waste of one industry could be a valuable resource to another industry. But due to the communication gap a lot of industrial waste products are disposed of at substantial financial and environmental costs. Another example of poor communication may be taken from the missing linkages between the formal waste management authority and the informal waste recycling sector. Experience by officials in the informal and formal sectors points that a substantial improvement in the present level of inter- and intra- agency as well as inter- and intra- sector communication is needed. Such communication must be established from the beginning of conceptualization of the program and follow through planning, designing, implementation, monitoring and evaluation of recycling program.

(b) INCREASE OF MANAGEMENT CAPABILITY

Integration of plastic waste recycling and reuse elements with formal waste management systems, which are generally based on traditional practices, will obviously bring a host of new management issues to be addressed. To deal with the new issues, the existing management capability in the waste management authorities will have to be remarkably improved.

4.7 FUTURE PROSPECTS

Recycling provides part of the solution to problems of what to do with the uncollected heaps of plastic waste found in the streets and around collection depots. It also offer opportunities for income generation and the improvement of environmental and health conditions. In Kenya plastic recycling offers good prospects mainly because of increasingly westernized consumption patterns. The demand for plastic products is growing, and so is the amount of plastic waste being generated as a result. Plastic recycling has some benefits: it can generate income, require relatively low levels of investment, can yield reasonable or high profits and involves a relatively technically uncomplicated production processes. With improved environment for investing, plastic recycling could definitely be one of poverty eradication strategies in Kenya given that special categories of post consumer waste such as automobile scrap, will become available for recycling in future.

CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY

The estimated total plastic recycling capacity in Kenya is about 9000 tons per year. This includes the recycling of main recyclable polymer resins; these are PE, PP and PVC. Comparing with plastic waste generation rate of Nairobi alone, the above recycling capacity is about 10% of the plastic waste generation rate.

Currently, only mechanical recycling technology is carried out in all the recycling activities. Due to lack of appropriate recycling technologies most of the recycling processes are carried out manually and where equipment is used, they are not specifically well designed for effective recycling. Combined with lack of plastic processing guidelines, this leads to low quality recyclates. This low quality makes processability, especially of post consumer recyclates alone difficult. Plastic raw materials from secondary sources are often blended with virgin resins and thereafter compounded with appropriate additives to improve the processability and quality of the recycled products. The existing recycling activities are concentrated mainly in the following areas as follows:

- Primary recycling of pre-consumer waste. This is because primary-recycling processes of clean plastic waste is economically profitable and is carried out under "free market conditions". Over 92 per cent of surveyed firms carry out primary recycling of internally generated waste.
- The recycling of post-consumer wastes is mainly limited to recycling of PE and PP rigid packaging containers and agricultural films. These waste streams have any of the following characteristics favorable for recycling.

  (a) Are easily sorted into single resin types.

  (b) Are available in large quantities.

  (c) Are easily decontaminated.

  (d) Are easily recycled using locally available standard equipment.

Recycling of post-consumer wastes is far from reaching economic competitiveness due to tedious upgrading operations required to improve the quality of recovered plastics. The achievable prices of the recyclates are often low. Another short term reason which is specific to the present situation is the "double squeeze" of the profitability of plastic recycling by low prices for virgin plastics on the other side and the lack of disincentive to discourage landfilling. There are no legal regulations that are qualified to enforce recycling. Additional limiting factor for plastic recycling is lack of technical standards or commercial processing guidelines for competitive market.

In future, improvement in the general conditions for plastic recycling is expected due to regulation and other measures in preparation. These measures include:

- Improvement in environment for recycling of not only plastics wastes but also other wastes as entrenched in the Environment Management and Coordination Act of 1999.
- Initiation of different voluntary agreements and contracts between the government and packaging industry through industry initiatives such as PEI.
- Recovery of the prices for virgin plastics are expected, following the usual price cycles and thus improving the economic conditions for plastic recycling.

Processing of plastic waste by the informal sector is already going on in Kenya's major towns. However the central and local government is not deriving the full benefits of plastic recycling due to the following constraints.

- Lack of potential policy instruments to further increase plastic recycling. These instruments range from statutory orders to prohibitions. Possible statutory regulations could include the source separation of recyclables, banning of landfilling of recyclable plastics.
- Lack of economic instruments for competitive plastic processing. Possible economic instruments could include 'hard' measures such as taxes or levies to discourage landfilling. 'Soft' measures for supporting the acceptance of existing and possible future recycling systems include creation of awareness to proper plastic waste management through information campaigns.

- Reluctance of local government to work in partnership with the informal sector. Often the municipal authorities consider the activities of informal sector as spread of litter, create an odor, nuisance and interfere with their operations and therefore believe the informal sector should be discouraged.
- Lack of support from the central government in research and development of small-scale recycling industry, with a view to improving recycling standards and product marketability. Government sponsored research institutes (GSRIs) such as Kenya Industrial Research & Development Institute (KIRDI) and standardization bodies like Kenya Bureau of Standards (KEBS) could jointly come up with plastic recycling guidelines.

5.2 CONCLUSIONS

Recycling of plastic wastes in Kenya is carried out under 'free market conditions'. This means that recycling is carried out for economic reasons without legal obligation or subsidization. No markets have been developed for new products applications based on waste plastics. Instead the same type of regularly available products are manufactured from waste plastics, although they are cheaper compared to primary products. In conclusion, plastics recycling industry in Kenya is characterized as follows:

- Most of raw materials used by plastics industry are imported. They are relatively expensive and so are the final products. The use of cheaper recycled secondary raw materials means that the raw material costs are reduced.
- The market for low-consumer items is extensive. Because of large number of low-income consumers, the level of acceptance of cheaper products is high.
- High unemployment and low labour costs mean that the labour-intensive manual processes involved in the recycling waste plastics, such as collecting, washing and sorting, makes plastics recycling economically feasible.
- There are no commercial processing guidelines or quality standards for recycled products.

- Large plastic processing industries rarely recycle post-consumer plastics because of their reluctance to modify their production processes to manufacture recycled content products.
- The technology used in the informal sector is in principle the same as that used in the formal sectors although most of the machinery used is often second hand or has been upgraded using locally available spare parts.
- Locally available recycling equipment is not well designed for effective recycling processes. This is illustrated by the fact that baskets are often used as baling equipment that makes transportation easier but does no facilitate effective sorting of plastic waste.

5.3 RECOMMENDATIONS

5.3.1 RECOMMENDATIONS FOR THE GOVERNMENT

5.3.1.1 RECOMMENDATIONS RELATED TO RECYCLING ACTIVITIES

(i) PLASTIC WASTE MANAGEMENT

The government and its relevant institutions such as KEBS in collaboration with appropriate organizations of the United Nations such as UNEP, UNIDO, should launch programs to demonstrate and improve recycling operations. These programs should, wherever possible, build upon existing or planned activities and should:

- Develop and strengthen national capacity in reuse and recycling of an increasing proportion of plastic wastes.
- Review and reform national waste policies to provide incentives for plastic waste reuse and recycling.
- Develop and implement national plans for plastic wastes management taking advantage of and give priority to reuse and recycling.
- Develop public education and awareness programs to promote the use of recycled content products.

(ii) DATA AND INFORMATION

The government should document information and research activities to identify promising socially acceptable and cost-effective forms of waste reuse and recycling relevant to Kenya. For example, supporting activities undertaken by CBOs in collaboration with the UNCHS and other international organizations. This support could include:

- Undertaking an extensive review of options and techniques for reuse and recycling all forms of plastic wastes. Policies for reuse and recycling should be made an integral component of national and local waste management programs.
- Assessing the extent and practice of waste reuse and recycling operations currently undertaken and identify ways by which these could be increased and supported.
- Increasing funding for research programs to test various options for reuse and recycling, including the use of small scale, cottage-based recycling industries.
- Producing commercial processing guidelines and best practices for plastic waste reuse and recycling.
- Identify potential markets for recycled products.

(iii) INTERNATIONAL AND REGIONAL COOPERATION AND COORDINATION

The government, through bilateral and multilateral cooperation, including through the United Nations and other relevant international organizations, as appropriate should:

- Undertake a periodic review of the extent to which Kenya reuse and recycle its plastic wastes.
- Review the effectiveness of techniques for and approaches to plastic waste reuse and recycling and ways of enhancing their application in Kenya.
- Review and update international guidelines for the safe reuse of plastic wastes.
- Establish appropriate programs to support small-scale waste reuse and recycling activities.

5.3.1.2 RECOMMENDATIONS RELATED TO MEANS OF IMPLIMENTATION OF ABOVE ACTIVITIES.

(i) SCIENTIFIC AND TECHNOLOGICAL MEANS

The transfer of technology should support waste recycling and reuse by the following means.

- Including the transfer of plastic recycling technologies, with bilateral and multilateral technical cooperation and aid programs.
- Developing and improving existing technologies, especially indigenous technologies and facilitating their transfer under ongoing regional and international technical assistance programs.

In facilitating the transfer of waste reuse and recycling technologies, the government could consider the following incentives options to encourage institutions, commercial establishments and industries to recycle plastic wastes.

- Offer incentives to local and municipal authorities that recycle the maximum proportion of their wastes.
- Providing technical assistance to informal waste reuse and recycling operations.
- Applying economic and regulatory instruments, including tax incentives to support the principle that generators of waste pay for their disposal.
- Providing legal and economic conditions conducive to investment in waste reuse and recycling.
- Implementing specific mechanisms such as deposit/refund systems as incentives for recycling.
- Promoting the separate collection of recyclable household plastic wastes.
- Providing incentives to improve the marketability of technically recyclable plastic wastes.
- Encouraging the development of markets for recycled goods by establishing environment awareness programs.
- Encouraging use of recyclable materials, particularly in packaging where feasible.

(ii) HUMAN RESOURCE DEVELOPMENT

Training is required to reorient current waste management practices to include waste reuse and recycling. The Kenya Government in collaboration with United Nation, other international and regional organizations such as UNIDO, UNEP, should undertake the following indicative list of actions;

- Including waste reuse and recycling in in-service training programs as integral component of technical cooperation programs of urban management and infrastructure development.
- Including the advantages and civic obligation associated with waste reuse and recycling in school curriculum and other relevant general education courses.
- Encouraging non-governmental organizations (NGOs), CBOs, women, youth and public interest group programs, in collaboration with local municipal authorities, to mobilizing community support for waste reuse and recycling through focused community-level campaigns.

(iii) CAPACITY BUILDING

Capacity building to support increased waste reuse and recycling should focus on the following areas

- Making operational national policies and incentives for plastic wastes management.
- Enabling local and municipal authorities to mobilize community support for waste reuse and recycling by involving and assisting informal sector waste reuse and recycling operations and undertaking plastic waste management planning that incorporates resource recovery practices.

5.3.2 RECOMMENDATIONS FOR THE CONSUMERS

- Become informed on the environmental and social impacts of plastics and practice the environmental shopping i.e. shopping with 3 Rs in mind.
- Participate in the implementation of waste management programs to manage their plastic wastes.
- Pay for appropriate programs to manage their wastes.

5.3.3 RECOMMENDATIONS FOR PLASTICS MANUFACTURERS

The plastic manufacturers should take account design for environment (DFE) when designing plastic products. This particularly includes design for recycling and the following areas should be taken into account.

(i) MATERIAL SELECTION

Careful selection of product materials helps facilitate part separation and sorting at the end of product life, increasing the feasibility of product recycling. The type of resin and additives selected can also enhance recyclability.

(ii) LESS MATERIALS

Using fewer materials to make new products reduce both the use of natural resources and the amount of material that needs to be recycled or disposed of at the end of the product life. While meeting product requirement, the different number of different plastics and non-plastic materials used in products, or in a product upgrades, should be minimized unless parts are clearly and accurately marked for material identification. Multiple recyclers will likely be processing the product material and they need to be aware of material selection changes. Changing materials without accurately marking the changed parts could result in contamination of recycled resin.

(iii) RESIN COMPATIBILITY

If more than one type of plastic is to be used within a product, recyclability will be enhanced if plastics are compatible for recycling together. If incompatible resins are to be used, designers should ensure that the material could be physically separated. It may also be helpful to select resins that have different specify gravities since many recyclers separate materials by differences in specific gravity.

(iv) RECYCLABLE MATERIALS

Design can facilitate recycling by selecting materials that can be used in internal 'closed loop' recycling processes. Plastic parts and enclosures should be designed to be recycled into the same part or into a different part within the same product wherever feasible. This approach helps provide an outlet for the plastic at the end of its life. Preferences can also be shown for materials that are readily recyclable externally. Because recycling markets and technology are changing rapidly, it is advisable for designers to periodically investigate recycling opportunities.

(v) CONTAMINANTS

Whenever possible, designers should select resin and design techniques to avoid using material that become contaminants in the plastics recycling process. Such materials include: labels, adhesives, coatings, finish.

(vi) USE OF RECYCLED PLASTIC

Using recycled plastic material creates outlets for recycled material, providing opportunities for recycling different products and making recycling more economically feasible. The use of recycled material also may conserve the use of natural resources and extends the life of the plastic. When using recycled plastic, companies should ensure that the material meets safety and performance criteria. Materials sample may need to be sent to an analytical lab for verification.

(vii) LIFETIME EXTENSION

Extending the life of a product delays its replacement and conserves natural resources. To accomplish this, products and parts can be designed to last enough or to be reused after appropriate servicing. Selecting a plastic material that can be best in accommodating repetitive reprocessing can extend particularly the life of plastic enclosures.

(viii) ADHESIVES

Adhesives (e.g. glues, epoxies) usually introduce a dissimilar, contaminating material to potentially recyclable parts. This may impact the quality and reusability of the recycled material for new application unless the adhesive can be removed easily or is thermally stable and compatible with the plastic to which it adheres. Designers should either look for adhesives that do not already affect recyclability or consider alternative fastening options.

(ix) MATERIAL IDENTIFICATION AND MARKING

Once molded, engineering plastics become very difficult to identify. Testing the material is time-consuming and not always conclusive. Marking can provide critical information to recycling facilities. Identifying not only plastic resins but also additives may necessitate changes in the recycling process.

Packaging materials should be marked according to SPI code. Designer may also wish to mark products with additional information that may facilitate product reuse and recycling. Knowing the grade of a plastic material at a part's end of life can facilitate its reuse and its resale to a recycling vendor.

A number of methods exist for marking information on plastic parts. Generally, marking through tooling is preferable to marking by labels, pad printing, bar coding or laser inscribing. Molded-in markings are one of the most environmentally conscious marking methods available since they require no use of other materials or chemicals, thus reducing the likelihood of contaminating the recyclable materials.

5.3.4 RECOMMENDATIONS FOR PLASTICS RECYCLING INDUSTRIES

Encouraging plastic processors to select processing methods that are the most efficient; minimize use and resin scrap; facilitates recycling of the end products; have the least effect on resin performance and provide the best balance of economics. The following areas should be targeted for improvement by the recycling industries.

(i) EFFECTIVE MIXING

A homogeneous material blend is important when mixing recycled resins with virgin resins (and other additives or colorants); both prior to introduction into the extruder, as well as during melt mixing within the extruder. Proper blending of materials prior to introduction into the extruder is important in any blended plastic extrusion process, but even more so for post-consumer recycled (PCR) and virgin blends. Therefore low tech premixing equipment may require closer attention during mixing to ensure a homogeneous feed stream into the extruder. The primary function of the extruder is to provide a continuous stream of uniformly molten polymer to the mould or die for configuring into a final shape. Melt mixing within the extruder is very important because of the different properties of the blended resin. For virgin/PCR blends a barrier screw, designed to accommodate blends of multiple materials, is recommended to achieve the requisite mixing.

To achieve proper melt mix in the extruder, low-shear mixing and controlled melt temperatures are very important. Low-shear mixing avoids degradation of the recycled resin. Since the recycled resin has already undergone at least one heat history, controlling melt temperature to prevent excessive heating is also important.

(ii) STRICT PROCESS CONTROLS

Strict process controls are critical in recycled/virgin blends, mostly to compensate for inconsistencies inherent with recycled resins. The most important controls are on feed stream consistency and contamination levels, mixing, filtration, and melt temperature.

(iii) PROPERTY TESTING

Property testing is important to meet customer standards, to provide quality control; to verify the manufacturing process, and to establish a history for new formulations and processing. Use of standardized tests is recommended for achieving results that are familiar and easily communicable.

5.3.5 RECOMMENDATIONS FOR FURTHER STUDIES

This research work is a major breakthrough in the study of recycling of plastic wastes in Kenya. But to reinforce these findings, the following areas are suggested for further research.

- Characterization studies of various plastics waste streams and their best practices for disposing them.
- Appropriate and cost-effective recycling process modifications for enhanced recycling by plastic manufacturing industries using locally available standard plastic processing equipment.
- Cost-effective plastics sorting and separation, and decontaminating systems.
- Developing standard methods and equipment for testing various properties of recycled products.

REFERENCES

APC: A primer on effective community recycling strategies: www.plasticsresource.com/recycle.ling-materials/recyclingkit/primer.html. Downloaded on 2/3/2001.

APC: information on municipal recycling programs, June 1999.

APME Reports: http//lca.apme.org/reports/htm/04.html: downloaded on 3/26/01.

Bisio, A and Xanthos, M: "How to manage plastics waste", Hanser publishers, New York, 1995.

Boustead, I: Eco-profiles of plastics and related intermediates', APME, Brussels, April 1999.

Brown, D: An industrial electrostatic separation process, EPIC, Ontario, Canada, 1995.

Corntreau-Levine, S. and UNDP: public-private partnerships for urban environment. Private sector participation in municipal solid waste services in developing countries. Urban management program discussion paper 13.Washington, World Bank. PP 5-20.

Coughlin, P: economics of scale, capacity utilization and import substitution: a focus on dies, moulds and patterns" Eastern African Economic Review, Vol.1 No. 1 (Renewed series), 1985.

Curlee, T. R: plastics recycling, economic and institutional issues. Conservation & Recycling vol. 9.no.4 PP 335-350,1986 Pergamon Journals, Great Britain.

Drain K.F, Murphy W.R and Olterburn M.S: polymer waste-resource recovery. Conservation & Recycling Vol.4. No. 4 PP 201-218,1981,Pergamon Journals, Great Britain.

Ehrig R.J (Ed.): plastics recycling- products and processes, Hanser publishers, New York, 1992.

Eulalio, A.C, Capiati J.N and Barbosa E.S: Municipal plastic waste, alternatives for recycling with a profit, Bahia blanca-Argentina, 2001.

European Commission: Mechanical recycling of PVC wastes, Milan Italy, January 2000.

Gainer & Associates: Establishing a waste reduction program at work. California Integrated Waste Management Board, January 1996.

Lund, H.F: The McGraw-Hill Recycling handbook, New York, 1993.

Heyde, M and Kremer, M: Recycling and Recovery of plastics from packaging in domestic waste. LCA-type analysis of different strategies. LCA Documents Vol.5, Ecomed Verlag, landsberg, 1999.

ISO: ISO14000 Meet the whole family, 1998,www.tc207.org.

Kantai, P: The treasure buried in Nairobi's dumpsites. The East African, Nairobi, December 11-17,2000.

Kenya Gazette: Environmental Management and Coordination Act, 1999,Government Printer, Nairobi, 1999.

Kenya Government: Economic Survey, Ministry of Finance and Planning, Central Bureau of Statistics Division, Nairobi, 1986.

Kenya Government: A guide for investors, Ministry of Trade and Tourism, IPC, Nairobi, October 1994.

Kenya Government: Economic Survey, Ministry of Finance and Planning, Central Bureau of Statistics Division, Nairobi, 1997.

Kenya Government: Economic Survey, Ministry of Finance and Planning, Central Bureau of Statistics Division, Nairobi, 1998.

Kenya Government: Economic Survey, Ministry of Finance and Planning, Central Bureau of Statistics Division, Nairobi, 2000.

Kirkwood, R.C. and Longley, A.J.: Clean technology and environment, Chapman & Hall, 1995.

Macmillan Education: The Macmillan primary schools atlas for G.H.C, English Press Ltd.Nairobi, Kenya, 1999.

Mugera S.K. (Ed.): the plastics packaging and environment initiative in Kenya: A joint initiative between Institute of Packaging and the Kenya Association of Manufacturers .A symposium report, Nairobi, September 1998.

Mwangi, H: the plastics processing industry in Kenya, 1982.

Ogula, P.A: A handbook on educational research, New Kemit Publishers, Nairobi, February 1998.

Paul T. W: Waste treatment and disposal, John Wiley & Sons, New York, 1998.

Petcore: Chemical recycling: www.petcore.org/recycle/chem.html. Downloaded on April 4, 2001.

APPENDICES

APPENDIX ONE: DESCRIPTION OF USED SITCs

SITC	DESCRIPTION
57111000	polyethylene having a specific gravity of less than 0.94
57112000	polyethylene having a specific gravity of 0.94 or more.
57211000	expandable polystyrene
57219000	other polystyrene
57311000	polyvinyl chloride not mixed with other substances.
57312000	other non-plastized polyvinyl chloride.
57313000	other plasticized polyvinyl chloride.
57433000	polyethylene terephthalate
57511000	polypropylene
57910000	waste, parings and scrap of polymers of ethylene.
57920000	waste, parings and scrap of polymers of styrene.
57930000	waste, parings and scrap of polymers of vinyl chloride.
57990000	waste, parings and scrap of polymers of other plastics.
89319990	other plastic articles for the conveyance or packing goods.
89319100	boxes, cases, crates and similar articles
89310900	articles for conveyance or packing of goods, of plastics sacks and bags of plastics other than ethylene.
8931	Articles for conveyance or packing of goods of plastics: stoppers, lids, caps and other closures, of plastics.
582	plates, sheets, foil, and strip, of plastics

APPENDIX TWO: CONSUMER PRICE INDEX (CPI)

YEAR	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CPI	34	40.7	52.7	76.9	99.2	100	108.8	121.9	129	132.4	104.1

Source: Ministry of Finance and Planning: CBS division.

APPENDIX THREE: LIST OF PLASTIC FIRMS INTERVIEWED OR GIVEN INDUSTRIAL QUESTIONNAIRES

NAIROBI FIRMS

NAME/ADDRESS	PHYSICAL LOCATION	TEL/FAX	PRODUCTS
1.Afrolite industries LTD Box 44037 Nairobi	Nairobi Enterprise Road	T-540638/540712	Jerry shoes, PVC soles.
2.Afro plastics (K) LTD Box 34190 Nairobi	Nairobi Off Baba Dogo Road	T-862041/2/5 F-862043	Plastic bottles, Jars &containers
3.Arrow plastics LTD Box 18519 Nairobi	Kikuyu Township	T-553346/8 F-555853	Plastics & By products
4.Bata shoe Co. (K) LTD Box 23 Limuru	Limuru Bata Estate	T- (0154) 71620 F- (0154) 71145	Plastic and leather plastic Car components, PVC shoes
5.Bobmil industries Box 48876 Nairobi	Nairobi Mombassa Road	T- 555412/ 541681	Plastic bags, sheeting,
6.Brush Manufacturers Box 48868 Nairobi	Nairobi Lunga Lunga Road	T- 533506/7 F-531770	Brushes, ropes sheeting,
7.Blowplast	Nairobi Funzi Road	T-558649/ 558792	Plastic containers
8.Comet plastics LTD Box 17905 Nairobi	Nairobi Homa Bay Road	557975/544256/7	Polythene and polypropylene Bags, tubing, Strapping.
9.Complast Industries LTD Box 78313 Nairobi	Nairobi Makungi Road	T-534037/8/9 F-530748	Plastic furniture and other plastics
10.C & P Shoe industries	Nairobi Mombassa Road	T-540722/3	shoes, soles
11.Crown Berger (Plastics division)	Nairobi Likoni Road	T-533603	Pipes
12.Drums & Containers	Ruiru	T-	J/cans, Drums.
13.Cosmo plastics LTD Box 46338 Nairobi	Nairobi Homa Bay Road	T-543066/7 F-553406	Polythene bags waxed paper Laminated Polypaper

14.Eslon plastics (K) LTD Box 41761 Nairobi	Nairobi Jirore Road	T-54148011/541677 F-552419	PVC pipes and & fittings, HDPE Pipes, Threaded Screen casings.
15.Implast Ltd.	Nairobi Lunga lunga Road	T-537735	Plastic bags.
16.General plastics LTD Box 10032 Nairobi	Nairobi Enterprise Road	T-530032/3/4/5 F-541559	plastic bottles & jars, shoes.
17.Haco Industries (K) LTD Box 43903 Nairobi	Nairobi Changamwe Road	T-530611/5/6 F-541083	Ball point pens, cloth pegs, rulers
18.Kenafric Shoe Ind. LTD Box 39257 Nairobi	Nairobi Off Baba Dogo Road	803032/1 802917/331719	PVC Shoes & soles
19.Kenpoly Manufacturers LTD Box 30032 Nairobi	Nairobi Lunga Lunga Road	T-542411/530511 F-540352, 530622	plasticware, bottles, jars, Stoppers, caps, Vacuum Flasks.
20.Kentainers LTD Box 42168 Nairobi	Nairobi Embakasi Road	T-823513/4/5 228106/7	Polythene tanks, containers and Waste manage-ment products
21.Megh Cushion Ind. LTD Box 18523 Nairobi	Nairobi Enterprise Road	T-534285 F-548860	Automotive seats & allied Trim products.
22.Mepal plastics (K) LTD Box 78040 Nairobi	Nairobi Lunga Lunga Road	T-554877/554905 F-554332	Plastic bags, tubing, sheeting And shrink film
23.Metro plastics (K) LTD Box 78485 Nairobi	Nairobi Lunga Lunga Road	T-540754/1027/8/9 F-545614	PVC pipes fittings.
24.Packaging Ind.Ltd Box 48811 Nairobi	Nairobi Lunga Lunga Road	T-530760 F-543109, 532653	Plastic Packaging material.
25.Pan plastics LTD Box 11971 Nairobi	Nairobi Baba Dogo Road	T-802305/9 F-802845	Plastic bottles jars, caps and
26.Packaging Industries Box 48811 Nairobi	Nairobi Lunga lunga Road	T-530760 F-543109	packaging Household items.
27.Polypipes LTD Box 59307 Nairobi	Nairobi Lusaka Road	T-543433/4/5 F-557453	PVC pipes&, fittings.
28.Polythene Ind. LTD Box 30467 Nairobi	Nairobi Mombassa Road	T-544204/5/6 F-543785	Plastic tubing sheets, bags.
29.Premium Drums LTD Box 78101 Nairobi	Nairobi Likoni Road	T-531297/531299 F-557083	Plastic Jerry cans.

30.Sumaria Industries Box 42565	Nairobi Migwani Road	T-750194 F-552138	jars, bottles, bags.
31.Rainbow plastic Ind. LTD Box 46470 Nairobi	Nairobi Lunga Lunga Road	541469	Recycled plastic granule.
32.Raneem Plastic Ind.	Nairobi North Airport Road	T-824808	Mats.
33.Roto Moulders LTD Box 26393 Nairobi	Nairobi Enterprise Road	T-531063 F-751188	Water storage Plastic tanks.
34.Sera Coatings (E.A) LTD Box 48425 Nairobi	Nairobi Lusingeti Road	T-556811 553634	PVC Coated Fabric and Sheeting.
35.Sunpac	Nairobi Off Baba Dogo Road	T-860602	Industrial plastics
36.Safepak industries	Nairobi Off Mombassa Road	T-535862	Containers
37.Sam G Plastics	Nairobi Kariobangi light industries	T-785021	Ground waste
38.Skyplast manufacturers	Tigoni Charpone Road	Tel.0154-76018	house hold containers
39.Sumaria Industries Box 42565	Nairobi Migwani Road	T-750194 F-7518556	Containers & bags
40.Ashut Engineers Box 44999 Nairobi	Nairobi Lunga Lunga Road	555100 F-803262	Plastic bottles, Jerry cans.
41.Talani Plastics	Nairobi Off Mombassa Road	T-	j/cans & Drums
42.Nairobi Plastics Box 49086 Nairobi	Nairobi Rangwe Close	T-545473	Plastic wares, conduits
43.NAS Plastics Box 19010 Nairobi	Nairobi Enterprise Road	T-433324	battery boxes, crates, Cups, bags
44.Tristar Bottlers	Ruiru	T-0151-55294/5	bottles
45.Vitafoam Products LTD Box 18094 Nairobi	Nairobi Mombassa Road	T-T-545441/2 F-542791	Foam mattresses, Pillows,Cushions
46.Yarena EPZ LTD Box 44174 Nairobi	Kitengela Athi River EPZ	566481 566224	Household. Plastic ware.

MOMBASA FIRMS

NAME/ADDRESS	PHYSICAL LOCATION	TEL/FAX	PRODUCTS
1.Cable & plastic LTD Box 86636 Mombasa	Mombassa Port Rieta Road	T-433329/449 F-434650	PVC Compound, Polystyrene.
2.Coast Plastics LTD Box 86636 Mombasa	Mombassa Chai Street	T-313045/223441 F-530748	Plastic goods, Jerry cans.
3.Elite Enterprises LTD Box 86420 Mombasa	Mombassa Muita Road	T-226092/227637	PVC shoes, Polythene bags.
4.Flexipack Industries LTD Box 95871 Mombasa	Mombassa Mozambique Road	T-226092, 227637	Plastic Packaging items.
5.Kenya suitcase Mfrs LTD Box 84658 Mombasa	Mombassa Miji Kenda Road	T-494418/495893 F-495778	travelling goods, plastic footwear,
6.Multiproducts LTD Box 82755 Mombasa	Mombassa Tangana Road	T-225783 F-315852	Polythene bags
7.Nitin Ind. Box 81033 Mombasa	Mombasa Mwangeka Road	F-494352	Plastic house- hold goods etc.
8.Packaging Mfrs (1976) LTD Box 98541 Mombasa	Mombassa Lumumba Road	T-434152/3/4 F-433234	Polythene bags, Propylene tubes.
9.Plaspack Co. Box 81064 Mombasa	Mombassa Changamwe Road	T-432347/8	Regrind & pelletized Polythene
10.Pearly Waters	Mombassa Gedeon Rimba Road	T-316816/7	bottles
11.Polycans LTD Box 90661 Mombasa	Mombassa Gideon Rimba Road	T-316288/9 F-221484	Plastic Containers
12.Rubi Plastic Ind. LTD Box 81072 Mombasa	Mombassa Lumumba Road	T-495542 F-491866	Polythene bags, Sheets and tubes.
13.Textile & Plastic Ind. LTD Box 83526 Mombasa	Mombassa Gedeon Rimba Road	T-312904 F-316095	Household plasticware, Shoes, bottles.
14.Tritex Ind. LTD Box 87447 Mombasa	Mombassa Bishop Makario RD. (Gedeon Rimba Road)	T-222593, 222243 F-224110	Polythene bags.
15.Twenties Mfrs LTD Box 81860 Mombasa	Mombassa Chonyi Road	T-493778/24086	Footwear.

KISUMU FIRMS

NAME/ADDRESS	PHYSICAL LOCATION	TEL/FAX	PRODUCTS
1.Bright Light products LTD Box 1340 Kisumu	Kisumu Busia Road	T-40071, 41903 F-44110	Household items.
2.Foam Mattress LTD Box 230 Kisumu	Kisumu Odera Street	T-22912/07,41367 F-43371	Foam mattress, Plastic products.
3.Kenby cables LTD Box 64 Kisumu	Kisumu Miwani Road	T-42767/45155 F-44628	PVC Cables.
4.Kenya Plastics Ind. LTD Box 954 Kisumu	Kisumu Nkuruma Road	T-20000	Plastic products.
5.Kisumu Polythene Ind. LTD Box 2360 Kisumu	Kisumu	T-22776	Polythene bags sheeting, tubes.
6.Nyalenda recycling Project Box 795 Kisumu	Kisumu	T-23797	Ground plastic waste

ELDORET FIRMS.

NAME/ADDRESS	PHYSICAL LOCATION	TEL/FAX	PRODUCTS
1.Mayson Kenya LTD Box 2595 Eldoret	Eldoret	T-32932	PVC Water pipes
2.Pyramid Packaging LTD Box 162 Eldoret	Eldoret Kipkaren Road	T-61660 F-61958	Plastic packaging
3.Shrunis plastics LTD Box 39514 Eldoret	Eldoret	T-62299	PVC products
4.Vishal Plastics LTD	Eldoret Kipkaren Road	T-32245/3166 F-32874	Polythene bags, Sheets, tubing.
5.Shiv Enterprises Box 241	Eldoret Kipkaren Road	T-62631	pipes,

NAKURU FIRMS

NAME/ADDRESS	PHYSICAL LOCATION	TEL/FAX	PRODUCTS
1.Kenya Flexo LTD Box 193 Nakuru	Nakuru Sungura Road	T-211370, 44893 F-210340	Thermoformed trays, bags
2.Plasticraft LTD Box 92 Nakuru	Nakuru Harry Thuku Road	T-212293/4 F-212711	Containers

THIKA FIRMS

NAME/ADDRESS	PHYSICAL LOCATION	TEL/FAX	PRODUCTS
1.Polysack LTD Box 1272 Thika	Thika Garissa Road	T-22954, 21536 F-30363	PP bags, sacks & fabrics

APPENDIX FOUR: INDUSTRIAL QUESTIONNNAIRE

INTRODUCTORY REMARKS

INDUSTRIAL QUESTIONNAIRE ON RECYCLING OF PLASTIC WASTES IN KENYA

(Strictly confidential)

Instructions for answering questions.

1. **This questionnaire consists of short and long questions.**
2. **You answer a question by either ticking your view/s or writing your answer/s in the spaces provided.**
3. **Your completed questionnaire should be mailed to the address shown below as soon as possible, but not later than** *June 2nd, 2000*. **Should you decide to mail the questionnaire, retain a copy of it.**
4. **Should you have views different from those expressed here, please write them down and mail to the address given below.**
5. **Mailing address is;**

BARUTHI ONESMUS MUGAMBI
POSTGRADUATE STUDENTS SECTION
DEPARTMENT OF MECHANICAL ENGINEERING
UNIVERSITY OF NAIROBI
P.O. BOX 30197
TEL. 334244 EXT. 28383,
NAIROBI.

Contact.

Person interviewed---
Name (optional)---
Designation---
Gender--
Telephone number--
Date--

1. Physical location.

Name of firm--
Street --
Town--
Year of establishment--

2. Recycling of waste plastics

Does your firm carry out recycling of waste plastics? Yes / No.

If **Yes**,

Which recycling does your firm do?

- Primary recycling (recycling of clean homogeneous plastic wastes)
- Secondary recycling (recycling of post consumer or heterogeneous plastic wastes)
- Tertiary recycling (recycling of plastic wastes to produce energy or for chemical material recovery)

Briefly explain the recycling process / processes carried out by your firm. Giving details of recycled products you manufacture.

----

3. Does your firm do secondary recycling? ---------------------Yes/No

If No continue from 5

What are the types of plastic wastes does your firm recycle? Give examples

(a) Thermoplastics e.g. Polyethylene---

-- (b) Thermosets e.g. Melamine-----------------------------

Where do you get waste plastics you recycle?

- Scrap dealers
- Collection depots
- Private houses
- Waste bins
- Refuse collection vehicles
- Municipal waste dumps
- Middle men

Others: ---

What problems do you face when acquiring plastic wastes or during your normal recycling operations? e.g. electricity failures during recycling processes

----

Which class of plastic wastes do you recycle?

- Industrial wastes
- Commercial waste e.g. supermarket wastes
- Agricultural wastes
- Municipal wastes
-

<u>Name of thermoplastic waste & Source</u>

<u>Give cost of following processes</u>
<u>(in the given order)</u>
<u>(Ksh / item)</u>

<u>Collecting</u> ***<u>Cleaning</u>*** ***<u>Sorting</u>*** ***<u>Transporting</u>*** ***<u>Drying</u>*** ***<u>Other costs</u>*** (Specify) ***<u>Gross cost</u>***

e.g. black 50 cc Polythene bags bought at Ksh. 2.00/Kg
Scrap dealers: Ksh.10 /Kg: Ksh.20 /Kg: Ksh. 30 /Kg: Ksh. 50 /Kg: Ksh. 25 /Kg: _: Ksh. 137/Kg

Give details of thermoplastic (recyclable) wastes found in the environment your firm does not recycle?

Recyclable plastic wastes	Reasons for not recycling
e.g. Polythene plastic bags	Contamination difficult to remove

What do you think should be done in general to reduce pollution due to plastic waste in our environment? What contributions can your firm make?

What are the factors affecting the price of waste plastics you recycle and their products?
e.g. buying unsorted plastic waste into different types.

What are the benefits of recycling waste plastics to your firm? Explain

e.g. savings on use of virgin raw materials

What do you think are prospects of plastic recycling industry in Kenya?

What do you think are the economic and institutional barriers to recycling of waste plastics and what do you think are the solutions?

e.g. lack of government incentives to plastic waste recyclers

What is the contribution of your firm to the country's economy?

What are general regulations that affect recycling of waste plastics in Kenya?

e.g. paying duty on imported plastic waste recycling machinery

What are the total savings in Ksh per ton of production for the last five years when recycling plastic wastes compared to using imported virgin raw materials?

YEAR	SAVINGS (Ksh/Ton)
1999	
1998	
1997	
1996	
1995	

What do you think should be done to increase effectiveness of the recycling process?

e.g. cleaning and drying of plastic wastes before feeding it to the recycling machinery.

What are the factors affecting the viability of your firm and what steps are your firm taking?

e.g. lack of markets for recycled plastics

Continue from 6

5 If your firm does primary recycling

What are the raw materials used in your firm?

RAW MATERIAL	SOURCE	DEALER	PRICE (Ksh./Kg)
For example, Thermoplastics e.g. Polyethylene (PE).	Imported: UK	Twiga Chemicals	Ksh. 60. /Kg

What steps are you taking to improve the marketability of your products? e.g. pressing for establishment of a law against discrimination of recycled products.

Give details of the following

Production processes	Products	Average Production / year	Production processes	Products	Average Production / year

7 What are Municipal Waste Management policies, health, labour or other regulations that affect your firm's recycling activities? What is your firm's opinion on them?

Growth of the industry

8 (a) What was your production in tons for the year 1999?

PROCESS	PRODUCTS	TONS
Extrusion		
Blow moulding		
Injection moulding		
Film moulding		
Others		

8 (b) Total production per year in tons: 1990-1999

Year	Extrusion	Blow moulding	Injection moulding	Film moulding	Others	Total
1990						
1991						
1992						
1993						
1994						
1995						
1996						
1997						
1998						

8 (c) Give a monthly breakdown of production in tons for 1999.

Monthly production in tones for 1999

Month	Extrusion	Blow moulding	Injection moulding	Film moulding	Others	Total
January						
February						
March						
April						
May						
June						
July						
August						
September						
October						
November						
December						

9 (a) Machinery Inventory.

	Purchase	Injection moulders			Capacity
Year	From: Kenya (specify) Imported (specify)	C.I.F. Value	make	model	Kgs/ hr

Give your comments:

9 b)

	Purchase	Extruders			Capacity
Year	From: Kenya (specify) Imported (specify)	C.I.F. Value	Make	model	Kgs/hr

Give your comments:

----

9 c)

	Purchase	Blow moulders			Capacity
Year	From: Kenya (specify) Imported (specify)	C.I.F. Value	Make	model	Kgs/hr

Give your comments:

9d)

Year	Purchase From: Kenya (specify) Imported (specify)	Film blowers C.I.F. Value	Make	model	Capacity Kgs/hr

Give your comments:

----

e)

ear	Purchase From: Kenya (specify) Imported (specify)	C.I.F. Value	Others Make	 model	Capacity Kgs/hr

Give your comments:

----

10 Production space

By reorganizing your use of the production space, by what % could you increase plastic processing equipment and still be efficient. ---------------------------------

Labour: shift information for 1999.

11 How many days do you work in a week? ---------------------------------

12 How many shifts do you operate in a day? ---------------------------------

13 Do machines shutdown during breaks? ---------------------------------

14 What is the total number of workers? ---------------------------------

Imports; plastic raw materials

15 Where do you obtain plastic raw materials? (Give details)

Large scale importer-------------------%

Local manufacturer--------------------%

Import-------------------------------?

If you import, do you buy from your central stores? -----------Yes/No

16 Description of workers over shifts.

Shift

Category of employees	No.	1st No.	2nd No.	3rd	Average wages per month (Ksh)
Managers					
Supervisors/Foremen					
Technicians;					
Skilled					
Semi-skilled					
Unskilled					
Operatives					
Others (Specified)					
Total					

Some causes of capacity under-utilization

17 Reasons for not utilizing full capacity over the last 24 months (1998/99). Please rank the following plus any other that you may have according to the order of importance.

A = Very important
B = Important
C = Somewhat important
D = Not important

Rank and Reason.

(i) Seasonal demand--
(ii) Insufficient demand---------------------------------------
(iii) Difficulties over raw material supply-------------------
(iv) Fuel shortages---
(v) Shortage of skilled manpower-----------------------------
(vi) (state category)--
(vii) Plant breakdown---
(viii) Difficulties in obtaining spare parts--------------------
(ix) Others: --

Repair and maintenance of machinery

18 Do you have a workshop? Yes/No

19. If **Yes** what are the main activities carried out in the workshop? ----------------------------------

20 Who repairs the machines? ----------------------------------

21 What are the most prevalent problems in repairing machines?

22 Are there any difficulties to obtain technicians with skills to repair the machinery? Yes / No

23. If **Yes**, how do you intend to remedy the situation? --
----

Availability of spare parts.

24. Where do you get the spareparts?

- Manufacture some of the spareparts? -----------------------
- Have them made by commercial machine shops? ---------------------
- Import directly? ------------ --
- Obtain from local importers? ---

25. What are the problems involved in getting spareparts? ---
----

----

26. If the buying of the plastic raw materials was controlled by the firms in the industry, by what % would you reduce C.I.F. on the raw materials due to freight and quantity order discounts? ------- %

27. Do you experience shortage of plastic raw materials? -------------Yes / No

28. If **Yes**, what causes the problem?

Possibilities of import substitution of plastic raw materials

29. Are there possibilities of producing plastic raw materials domestically? Yes / No

30. If **No** what factors hinder the production? --

--

31. Is there possibility of recycling plastic materials? --------Yes/No

32. What are the difficulties e.g. lack of machinery, etc.--

Importation of finished plastic products

33. Does Kenya import finished plastic goods? Yes/No

34. If **Yes** what are they? How does this affect your firm? --
----

Is there any possibility of producing these goods or some of them domestically? Yes / No

Explain: ---

Exports

35 Do you export? Yes / No

If **Yes**

a) What products do you export? --

----

b) To which country? ---

----

a) What % of your output do you export? --

----

36. Do you receive inquiries from other countries? Yes/No

37. Do you have program aimed at promoting exports? Yes/No.

If **Yes** explain them? --

Ownership

38 Who owns the firm?

(i) 100% local:

a) Government.
b) Asian.
c) African.

(ii) 100% foreign.

(iii) Joint venture:

Local private------------------------------%
Local Government--------------------------%
Foreign--------------------------------------%

(iv) Subsidiary of Transnational corporation----------------

(v) No idea.

(vi) Any other

39. Who are your competitors?

40. How do you intend to overcome competition in a liberalized economy?

APPENDIX FIVE: SECONDARY RECYCLING FIRMS

APPENDIX FIVE A: CAPACITY ESTIMATES OF M AJOR SECONDARY RECYCLING FIRMS.

FIRM	POLYMER WASTES	CAPACITY ESTIMATE (T/ Y)
Arrow	PE containers	60
Implast	PE containers/ films	350
Sam 'G' plastics	PP/PE containers/ films; PVC shoes and pipes	60
Talani	PE containers/ films	60
Skyplast	PP/PE containers	1560
Rainbow	PP/PE containers	360
Drums & containers	PE containers/films	1800
Palson	PP/PE containers	72
Rubi	PE containers/ films	1000
Plaspack	PE containers/ films	1800
Premier Industries	PP/PP Containers	1400
Topen Industries	PVC Shoe soles	1100

Note:

T/Y: Tons per year.

APPENDIX FIVE B: LIST OF CLASS "A" SECONDARY RECYCLING FIRMS.

FIRMS	YOE	PHYSICAL ADDRESSES
Rainbow plastics	1990	Lunga Lunga Road (NRB), Tel: 555831/541469
Palson	1998	Makasembo Road (KSM), Tel: 43361
Arrow Plastics	1995	Kikuyu Township Tel: 541192/3
Implast	1995	Lunga Lunga Road (NRB), Tel: 537435/36
Skyplast Manufacturers	1987	Charpone Road (Tigoni), Tel: 0154-76018
Mukuru Recycling Centre	1992	Dandora Dumping Site
Drums & containers	1997	Ruiru, Tel: 54282
Nyalenda Recycling Project	1995	Ring Road (KSM), Tel: 23797/22281
Talani Plastics	N/A	Mombasa Road (opposite Firestone)
Rubi Plastic Industries	N/A	Lumumba Road (MSA), Tel: 495542
Plaspack	1988	Refinery Road (MSA), Tel: 432347/8
Sam G Plastics	1991	Kariobangi Light Industries, Tel: 785621

Note:

N/A: Not available. YOE: Year of establishment.

APPENDIX FIVE C: LIST OF CLASS "B" SECONDARY RECYCLING FIRMS.

FIRMS	YOE	PHYSICAL ADDRESSES
Premium drums	1976	Likoni Road (NRB), Tel: 531297/531299
Comrade engineering	1990	Rabai Road (NRB), Tel: 783032
Brush	1976	Lunga Lunga Road (NRB), Tel: 558587/559297
Roto molders	N/A	Enterprise Road, (NRB), Tel: 552885/531063
Afrolite	1974	Enterprise Road, (NRB), Tel: 540638
Cosmos	1978	Homa Bay Road, (NRB), Tel: 543066/7
Phytech (E.A)	N/A	Westlands, (NRB), Tel: 740229
Viatu LTD	N/A	Kisumu Town, (KSM) Tel: 41355/22008
Bright light	N/A	Busia Road (KSM) Tel: 40071,41903
Shiv Enterprises	1996	Kipkaren Road (Eld.) Tel: 62631/61165
Cables & plastics	1978	Old Port Reitz Road, (MSA) Tel: 433329
Modern soap	1965	Lumumba Road, (MSA) Tel: 491450
Nairobi Plastics	1990	Rangwe Close, (NRB), Tel: 542421
Lolwe Plastics	N/A	Sabuni Road (KSM)
Kenpoly Manufacturers	1977	Lunga Lunga Road (NRB), Tel: 542411
Topen Industries	N/A	Lunga Lunga Road (NRB)
Premium Drums	N/A	Likoni Road (NRB)
Campos	N/A	Lunga Lunga Road (NRB)
Sunpac	N/A	Baba Dogo Road (NRB)
Eslon Plastics	N/A	Homa Bay Road (NRB)
Pyramid	N/A	Kipkaren Road (Eld.)

Note:

N/A: Not available

YOE: Year of establishment

Eld. : Eldoret

NRB: Nairobi

KSM: Kisumu

MSA: Mombasa