Recycling of Solid Waste in Khulna City

by

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Declaration

This is to certify that the thesis work entitled "Recycling of Solid Waste in Khulna City" has been carried out by S. M. Moniruzzaman in the Department of Civil Engineering, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above thesis work has not been submitted anywhere for any award of degree or diploma.

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To

My beloved parents for their love

and

my dearest wife, for her continuous support and encouragement

ABSTRACT

Solid waste recycling approach is a part of sustainable and effective waste management system for most cities of the world. In the course of achieving proper solid waste management, many efforts in developing countries especially in Bangladesh have been focused on waste collection and disposal. Although institutionally the waste recycling part of waste management has been ignored, many individual dealers and house-to-house waste collectors have undertaken the recycling part of waste management as a source of income from long ago in Bangladesh. The purpose of this study is to investigate and analyze the potential of traditional recycling of solid waste in Khulna, the third largest city in Bangladesh.

The study revealed that the private sector is playing an important role in Khulna in recycling of solid waste. This private sector comprises a chain constituted by house-to-house waste collector (Feriwala), waste bin collector (Tokai), recyclable dealers (small, medium and large recyclable dealers) and industries at the top. It is estimated that at present 1312 tokais are working in Khulna city who collect waste from dustbins and disposal sites. On the other hand feriwalas are playing a very important role in the recycling process. They are the buyers of separated recyclable items stored for selling at the primary source (household). This study shows that there is more than 695 feriwalas involved in the chain of recycling network of Khulna. This estimate has been based on the information provided to by the recyclable dealers, feriwalas and brokers. They purchase materials include bottles, broken glasses, tin cans, containers, newspaper, magazines, aluminium utensils, iron items (construction rod, sanitary fittings etc.) in exchange of money, or sweets. The tokais and feriwalas then approach small recyclable dealers (SRD) who accept all types of waste and pay them accordingly. The study shows that there are 277 SRDs in Khulna city. The SRD then approaches medium recyclable dealer (MRD) to sell particular kinds of waste. From the field investigation it is found that there are 140 MRDs in Khulna. The MRD usually deals in more than two kinds of specific wastes and passes these recyclable wastes to the large recyclable dealers (LRD) who essentially specialize in specific wastes. There are about 33 LRDs in Khulna. The recyclable wastes are finally then passed on to the recycling industries (RI). The study revealed that there are 31 recycling industries in khulna.

The study revealed that 7.2 % (37.23 tons/day) of the total generated waste or 53.2 % of the recyclable waste or 84.6 % of readily recyclable solid waste is recycled daily and more than 4500 people are working in the private sector activity relating to waste recycling in Khulna. Private sector deals mainly with the non-biodegradable wastes and some slowly biodegradable wastes. Recyclable waste collected by private sector includes paper, glass, plastic, aluminum, iron, tin, bones and tyre. Except bone, paper plastic and tyre all other retrieved materials are transported to industries located in Dhaka, Jessore, Kushtia, and Barisal as raw materials for new products.

Three approaches were subsequently proposed to evaluate the possibility of formalizing the unorganized waste trade. It was concluded that it is possible to organize the sector without loss of employment. This proposal seems economically sustainable, as recovered costs of the recycled waste would far exceed expenses.

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Abbreviations

BBS	Bangladesh Bureau of Statistics
CBO	Community Based Organization
DOE	Department of Environment
EPA	Environmental Protection Agency
Feriwala	Local name; House to house waste collector
KCC	Khulna City Corporation
KDA	Khulna Development Authority
LRD	Large Recyclable Dealer
MRD	Medium Recyclable Dealer
MSW	Municipal Solid Waste
NGO	Non Governmental Organization
RSW	Recyclable Solid Waste
RI	Recycling Industry
SDS	Secondary Disposal Site
SRD	Small Recyclable Dealer
Tokai	Local name; Waste bin collector

Units of Measurement

gm	Gram
kg	Kilogram
m	Meter
kg/day	Kilogram per day
ton/d	Ton per day
Tk.	Taka
kg/cap/day	Kilogram per capita per day
gm/residence. day	Gram per residence per day

CHAPTER ONE

INTRODUCTION

1.1 General

Solid waste is useless and unwanted materials coming from production and consumption of human and animal activities. Management of solid wastes has continued to be a major problem and a big challenge in most urban centers particularly the rapidly growing cities in developing countries. Environment was not an issue in a third world country like Bangladesh and solid waste management was definitely not the prime concern of environmentalists and the government because of less waste generation during the past decades. Solid waste generation is increasing due to rapid urbanization, industrialization and population growth.

Recycling is the process through which solid waste can be used again. The situation in developing countries is different from the developed world, where several governments had greatly initiated increased recycling of the domestic solid wastes by the end of the last millennium (Poulsen et al., 1995). In order to enhance waste recycling and thus promote a more sustainable approach towards solid waste management, various studies on solid waste recycling and reuse have been carried out and reported in various countries in developing world. Solid waste recycling has been found out to be currently acceptable as a sustainable approach towards solid waste management. This is desirable from environmental, economic and social points of view. According to Diamadopoulos et al., (1995), if solid wastes are not recycled, the space in landfills would be exhausted very fast and necessitate the construction of new ones. Seik (1997) and Kaseva and Gupta (1996), have also reported that solid waste recycling reduces environmental damage and is an import-substitution economic activities which also saves energy, conserves resources and saves waste collection and disposal costs.

Recycling of municipal solid waste (MSW) is now recognized as the most environmentally sound strategy for dealing with recyclable part of waste following only the preventive strategy of source reduction and reuse (EPA, 2004). Developed countries like USA, recover as much as 30% of the total waste (EPA, 2004). In 1951, the percentage of urban population was only 4.33% of total. Since then rising trend has continued reaching around 24% by the year

2001(BBS, 1997). One of the directly related consequences of population growth in urban area is the increase in waste generation. Rapid deterioration of environmental quality of the municipal areas is generally occurring with the conventional system of collection, transportation and crude dumping of solid waste. As such, the urban solid waste management has become a major concern for the cities and towns of Bangladesh.

Khulna, the third largest city of Bangladesh, has a waste generation rate of 520 tones/day (Waste Safe, 2005). Khulna City Corporation (KCC) is dealing with collection, transportation and dumping of waste from city area to Rajbandh. In order to deal with prevailing situation in a planned way, proper study is required to analyze the urban waste recycling scenario of Khulna. It is necessary to quantify the amount of recycled waste, recyclable part of waste as well as the current recycling practices to identify the problems and future prospects.

1.2 Background of the Study

Study on solid waste recycling and reuse is an important approach in waste management in Bangladesh. A limited study for Khulna city has been carried out. The potential for waste recycling could be expanded. Although there is currently no formal body or organization, which coordinates this activity, a large number of individuals, business organization and industries, has been involved. Biological system is created by Allah and already exists in nature. The engineers and the scientists have been increasing efficiency of the biological system to treat the biologically degradable solid waste and water. Similarly the recycling processes already exist in our society, which one has to understand first to increase the efficiency of the process. It is an important responsibility of the engineers for the better management of the solid waste. Solid waste management in developing countries should no longer be viewed from a narrow perspective of collection and disposal, instead it should be seen as a part of issues arising out of rapid urbanization due to natural growth as well as rural to urban migration. Solid waste management strategies in many developing countries ought to be reorganized to include a separate collection and processing system for waste recycling. That can work parallel with the conventional systems operated by municipal bodies that are responsible for waste collection transportation and final disposal. This approach results into not

only the reduction of quantities of wastes to be disposed of, but also increase employment and thus income for the disadvantaged urban poor.

The pattern of waste recycling in Khulna as well as in Bangladesh is still unknown because a very few study in this field was carried out. Therefore an attempt has undertaken with the following objectives to know the present situation and amount of solid waste recycling in Khulna, to increase its efficiency and also to suggest important recommendations for further improvement to make it efficient and organized.

1.3 Objectives of the Study

The main objective of this research is to develop a model for increasing the efficiency of present recycling process and organizing the waste trade economically in Khulna. However, the specific objectives of this research work can be outlined as:

1. To get a clear scenario of solid waste recycling pattern of Khulna city.

2. To identify the composition of solid waste in different categories and determine their potential for recycling.

3. To determine the quantity of recyclable and recycled waste and impact of recycling on economy.

4. To propose an approach to evaluate the possibility of formalizing the unorganized waste trade.

1.4 Scope of the Study

This study provides the information and data about the present situation of solid recycling practices in Khulna city. The data of recyclable solid waste (RSW) collection amount, buying and selling prices of RSW at every stage, number of waste collectors, dealers and industries

involved in recycling process are collected. The total quantity of recycled waste and number of people involved in recycling activities are determined through this study. The physical composition of solid waste at one dustbin and one secondary disposal site are measured just to compare with previous studies and to find out the percentage of RSW in the total waste stream. The existing facilities and problems for recycling, options for improvements in Khulna city of Bangladesh are analyzed through this study for economically and technologically feasible and sustainable waste recycling. The study also highlights the several options of organizing the present recycling process and proposes some models for efficient recycling. All these findings will help to select a model of solid waste recycling to cope with the present situations with better environmental considerations. It will help the planner, environmentalist and engineer to choose an economically, technically as well as socially sound alternatives for better solid waste recycling in Khulna. In this study the recycling of mainly non-biodegradable and slowly biodegradable waste is considered. Some seasonal variation of solid waste composition, collection, and recycling are not measured.

1.5 Organization of the Thesis

The thesis presents literature review, data analysis and findings of the study in seven chapters and five annexure, as stated below. In addition, a bibliography of related publications has been presented.

Chapter 1 : This chapter includes general introduction, background, objectives, and scope of the study.

Chapter 2 : Literature review covering details about waste recycling system, advantages of waste recycling, source and types of solid waste, physical composition of solid waste. Brief reviews of relevant literatures are also discussed.

Chapter 3 : The methodology and overview of study areas including general information are described.

Chapter 4 : This chapter describes the present status of solid waste in Khulna such as generation and composition of solid waste, percentage of RSW. The existing solid waste management practices and involvement of KCC are described here.

Chapter 5 : This chapter aims to present the detail of results of interview on different groups involved in recycling including residential status, life style working conditions of waste collectors. This chapter also presents quantity recycled, percentage of recycling and the processes of recycling in different industries and the existing recycling pattern in Khulna.

Chapter 6 : This chapter presents the market price mechanism, value addition to the recyclable solid waste and proposes approach with mass balance to organize the private sector involved in recycling.

Chapter 7 This chapter includes precise conclusions of the findings as an outcome of this study and provides a number of recommendations for improvement of present situation and for future research.

References : A list of relevant publications and reports, which may be useful for any future study in this context, is included at the end of the main chapters.

Annexure : Necessary Annexure are provided.

CHAPTER TWO

LITERATURE REVIEW

2.1 General

As noted in the previous chapter the objectives of the study are to get a clear scenario of solid waste recycling pattern, identify the recyclables, determine the quantity of recycled waste and impact of recycling on economy and propose an approach to evaluate the possibility of formalizing the unorganized waste trade of Khulna. The literature review, therefore, has focused on different aspects of recycling which exist throughout the world. The advantages, components and different programs of recycling, the estimation method for waste quantity recycled and measures of recycling performance are described here. Sources, types and composition of solid waste are also described in this chapter.

2.2 Sources and Types of Solid Waste

Solid wastes comprise all the wastes arising from human and animal activities. The term solid waste means all-inclusive, encompassing the heterogeneous mass of throwaways from the urban community as well as the more homogeneous accumulation of agricultural, industrial, and mineral wastes (Tchobanoglous et al., 1993). Sources of solid wastes in a community are in general related to land use and zoning. For convenience, waste is classified according to their sources.

Although any number of source classifications can be developed (Tchobanoglous et al., 1993), the following categories are useful for Bangladesh: (1) residential. (2) commercial & institutional (3) construction, (4) municipal services, and (5) industrial

Typical facilities, activities, or locations where wastes are generated associated with sources and types of solid wastes are described in Table 2.1

Table-2.1 Typical solid waste generation facilities, activities, and locations associated with sources and types

Source	Typical facilities, activities or location where the wastes are generated	Types of solid wastes
Residential wastes	Single family and multi family dwellings, low, medium and high rise apartments etc.	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, tin cans, aluminum, other metals, ashes, special wastes (including bulky items, consumer electronics, yard wastes, batteries), household wastes
Commercial	Stores, restaurants, markets, office buildings, hotels, motel, print shops, medical facilities and institutions etc.	Paper, cardboard, plastics, wood, food waste, glass, metals, special waste, hazardous wastes etc.
Institutional	Schools, hospitals, prisons, governmental centers	As above in commercial
Construction & demolition	New construction sites, road repair sites, razing of buildings, broken pavement	Wood, steel, concrete, dirt etc.
Municipal services	Street cleaning, landscaping, catch basin cleaning, parks and beaches, other recreational areas	Special wastes, rubbish, street sweepings, landscape and tree trimmings, general wastes from parks and recreational areas
Treatment plant sites	Water, waste water and industrial treatment processes etc.	Treatment plant wastes principally composed of residual sludges.
Municipal solid waste (MSW)	All of the above	All of the above
Industrial	Construction, fabrication, light and heavy manufacturing, refineries, chemical plants, lumbering, mining power plant demolition etc.	Industrial process wastes, scrap materials, special waste, hazardous wastes and non- industrial wastes including food wastes, rubbish etc.
Agricultural	Field and row crops, orchards, vineyards, dairies, feedlots, farms etc.	Spoiled food wastes, agricultural waste, rubbish, hazardous wastes.

(Tchobanoglous et al., 1993)

2.3 Composition of Solid Waste

Composition is the term used to describe the individual components that make up a solid waste stream and their relative distribution. The composition of solid waste differs for different countries and regions. Developing countries have generally high food and yard wastes whereas developed countries have a large fraction of paper and plastic content (Dhussa et al., 2000). Identification of waste composition is crucial for the determination of recyclable solid waste (RSW), for evaluating recycling programs and plans and taking essential health precautions.

Urban wastes can be subdivided into two major components- organic and inorganic. In general, the organic components of solid waste can be classified into three broad categories: putrescible, fermentable, and non-fermentable (Diaz et al., 1996). Putrescible wastes tend to decompose rapidly and unless carefully controlled, decompose with production of objectionable odors and visual unpleasantness. Fermentable wastes tend to decompose rapidly, but without the unpleasant accompaniments of putrefaction. Non- fermentable wastes tend to resist decomposition and therefore, breakdown very slowly. A major source of putrescible waste is food preparation and consumption. As such, its nature varies with lifestyle, standard of living, and seasonality of foods. Fermentable wastes are typified by crop and market debris.

The composition of MSW in six major cities of Bangladesh is as follows: the food and vegetables waste ranges from 68 to 81%, while paper and plastic are 7.2 to 10.7% and 2.8 to 4.3% respectively (waste safe, 2005). The remaining portions are rubber, cloth, metal, tin glass, dust and others. The fermentable portion is normally very high as compared to other portions in Bangladesh. In Bangalore, India the putrescible portion is 75.2% and paper, metal, glass, plastics/ rubber/leather, textiles and ceramics/dust/stone are 1.5%, 0.1%, 0.2%, 0.9%,3.1% and 19% respectively (Diaz et al., 1996). In Australia the putrescible portion is 23.6% and paper, metal, glass, plastics/ rubber/leather and ceramics/dust/stone are 39.1%, 6.6%, 10.2%, 9.9% and 9% respectively (Diaz et al., 1996). The principles difference between waste generated in developing nations and those generated in industrialized countries is the higher organic content characteristic in developing nations. Now from the composition of solid waste which portion is recyclable is important.

2.4 Defining Recyclable Solid Waste (RSW)

Determining the quantity of RSW generated, by whatever method of separation, first requires a determination of what is to be considered as RSW and how recycling performance is measured. Recycling programs can be compared if data are standardized, but in general, they are not. Consistent, standard, and meaningful measurement terminology is needed if communities are to effectively plan and assess their recycling programs. It would be wise to state at the outset of a program what will be counted as RSW. Scenarios for the quantification of recyclables may include the following (Tchobanoglous et al., 1993):

- All of the materials collected at curbside
- Those materials actually sold to market
- All recyclables collected and processed at an material recovery facility (MRF)
- Only those recyclables that are sold to market after separation and processing, with residues that are generated at the MRF subtracted from the total.

2.5 Overview of Recycling

During the 19805, recycling took on much greater significance than just providing an alternative method for treatment of our solid waste (Tchobanoglous et al., 1993). In the United States, the recycling rate for municipal-solid waste (MSW) is about 22 percent, not including composting, based on estimates by Franklin Associates (U.S. EPA, 2001). However, the goal of 50 percent diversion by 2000 is close to being achieved in California. One significant trend is the emergence of a greater number of mandatory and voluntary programs for the source separation of recyclable materials. These so-called curbside programs require the participation of residents to separate recyclable materials into one or more fractions for collection. In 1989, 1042 curbside programs existed in 35 states (Tchobanoglous et al., 1993). Almost 15% (more than 467.65 tons/day) of inorganic fraction of the waste is recycled in Dhaka city, Bangladesh (Sinha, 1993). Nearly 17.4% (1287.44 tons/day) is recycled by around 89,600 recyclists in Delhi, India (Mittal, 2005). The RSW are generally paper, plastic, glass, aluminum and other metals.

2.6 Advantages of Recycling

Recycling is widely assumed to be environmentally beneficial and conducive to sustainable economic development. The advantages of recycling can be classified as:

1. Economic advantages: These include reduction of cost of solid waste management, saving of energy in terms of electricity and fuel, reducing foreign importation, generation of employment, and reduction in health care costs and saving in cost to other public utilities.

2. Environmental/Ecological advantages: These include soil or other natural resources conservation such as control of erosion and soil moisture.

3. Social advantages: Creating employment for scavengers, and cutting down littering.

4. Other benefits: Prolonging the life of the local landfill sites due to reduction of waste amounts arriving at the landfills. Encouraging expansion and development in the waste utilization industries.

2.7 Quantities and Composition of Recyclables

Between 1960 and 1990, U.S. MSW production rose from 2.7 to 4.51b per day per capita (Tchobanoglous et al., 1993). For the period from 1990 to 2000, MSW generation increased from 205 million to more than 230 million tons per year (Table 2.2). The estimates given in table 2.2 include residential, commercial, and institutional solid waste. While per capita daily generation rates may be leveling off population increases will continue to increase overall volumes of waste produced into the future.

Growth in the quantities of waste generated is not the only problem contributing to the present problems associated with solid waste management. The composition and complexity of materials in the current waste stream may be more of a problem than the volume or weight

produced. Recycling must deal with not only the vast quantity of bottles, cans present in affluent U.S. society waste stream but also the considerable complexity of the highly engineered products (Tchobanoglous et al., 1993).

Table 2.2 Generation and recycling of municipal solid waste

Year	Generation. 10^6 tons	Percent of generation
		Recycling
1960	88.1	6.4
1970	121.1	6.6
1980	151.6	9.6
1990	205.2	14.1
1994	214.4	19.7
1995	211.4	21.4
1997	219.1	21.6
1998	223	21.7
1999	229.9	22.1

Source: U.S. EPA (2001).

2.8 Steps of Recycling

Recycling is treating things that have already been used so that they can be used again. It is the reprocessing of wastes, either into the same material (closed loop recycling) or a different material (open loop recycling). Steps of solid waste recycling are those components, which need to be address for a successful waste recycling. These involve (1) the recovery of materials from the waste stream, (2) intermediate processing (3) transfer and transportation, and (4) final processing, to provide a raw material for manufacturers or an end product. The intermediate processing of mixed wastes and of source-separated wastes to recover materials involves a series of unit processes. The number of unit processes depends upon the degree of source separation of the wastes, as well as the types of materials to be recovered. The schematic diagrams of these tiers are shown in Figure 2.1. In the following sections these are discussed briefly.

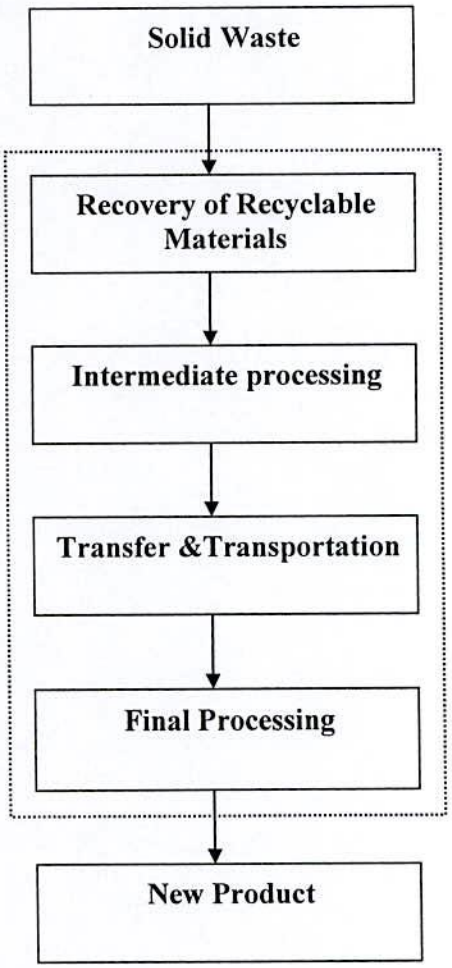


Figure 2.1 Typical components of waste recycling steps

2.8.1 Recovery of Recyclable Materials from Solid Waste

There are three main methods that can be used to recover recyclable materials from solid waste (Tchobanoglous et al., 2002).

1. Collection of source -separated recyclable materials by either the generator or the collector, with and without subsequent processing.
2. Mixed recyclables collection with processing at centralized materials recovery facilities (MRF s).
3. Mixed solid waste collection with processing for recovery of the recyclable materials from the waste stream at mixed –waste processing or front–end-processing facilities.

2.8.1.1 Collection of Source -Separated Recyclable Materials

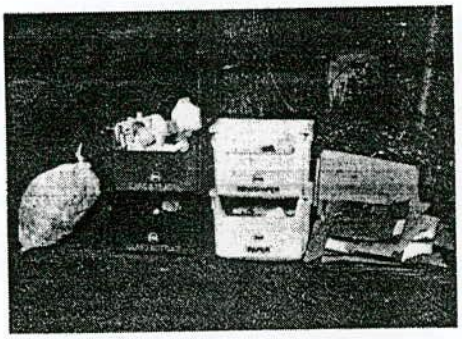
The separation of recyclable materials into individual components, either by the generator or at curbside by the collector, is known as source separation. The setout of source-separated recyclables at curbside is depicted in Figure 2.2a. The separated materials can be collected individually in single-compartment trucks, or more commonly, they are collected at the same time in a specially designed multi compartment-recycling vehicle. The segregated components are then transported to a consolidation site for further processing and subsequent shipment to markets (Tchobanoglous et al., 2002).

Usually, in the case of small communities, there is no further processing at the consolidation site. Processes such as can flattening, glass bottle crushing, and paper baling are performed by local scrap and paper dealers or collectors who prepare the materials as necessary for final markets. In larger communities, each component may be further processed at the consolidation site and/or directly marketed to an end user when the materials meet buyers' specifications. Drop-off centers, buyback centers, and bottle-bill return stations are variations of the source separation approach.

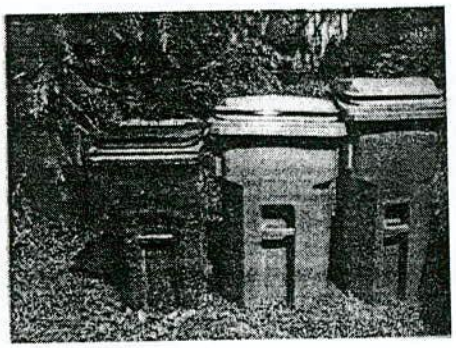
2.8.1.2 Collection of Mixed Recyclable Materials

Recyclable materials set out at curbside for combined collection are shown in Fig. 2.2a and 2.2b. The generator only needs to separate recyclable materials from non recyclable. Newspapers are often kept separate from the rest of the mixed recyclables to prevent contamination and to improve collection vehicle efficiency.

The recyclable materials are transported to an MRF where they are gated into each recyclable component (glass, metal cans, plastic bottles, etc). Processing actions at MRFs can vary from facilities with relatively low mechanization, depending primarily on the manual sorting of waste materials, to highly mechanized automated sorting processes. A variation of the mixed collection approach to recycling is the use of blue bags is a mixed-waste collection program. The color blue was chosen because it is distinctly different from the typical black or green trash bag, and studies have shown that the blue bag can be easily identified in a mixture of trash bags (Tchobanoglous et al., 2002). Mixed recyclables are placed in the bags by the generators.



(a)



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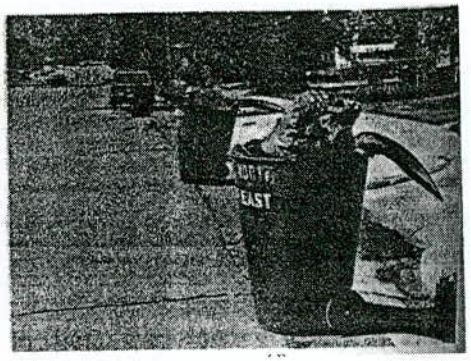
(c)



(d)

FIGURE 2.2 Waste materials set out for curbside collection: (a) source-separated recyclable materials are placed in three separate containers (one for paper, one for glass, and one for cans and plastics), cardboard is bundled for collection with recyclable materials, residual non recyclable wastes are placed in separate containers, and yard wastes are placed in the street for collection with specialized collection equipment; (b) waste collection system employing three separate large containers [one for non recyclable materials (container on left), one for mixed recyclable materials (container in center),and, for yard wastes (container on right)]; (c) mixed recyc1ablematerials received at a materials recovery facility for sorting; and (d) mixed wastes in a single large (90 gal) container (Tchobanoglous et al., 2002).

The blue bags are taken along with trash bags to a central processing plant where the blue bags are hand-separated from the trash and sent to a commingled recyclables processing facility for materials recovery. The bags can be filled with paper, mixed metals, plastic, and/or glass, depending on the design of the program. The objective of this type of program is to take advantage of the reduced collection costs of mixed-waste collection while still implementing an MRF that processes only the mixed recyclables, not the entire solid waste stream.

2.8.1.3 Collection of Mixed Solid Waste

In the third approach to recycling, there is no segregation of recyclables from other waste materials. Mixed wastes (including recyclables) are set out at curbside (Fig. 2.2c), as would be done for land filling or incineration. One collection vehicle is required for collection of the mixed waste-normally, the familiar packer truck. The mixed waste is then transported to a central processing facility, which employs a high degree of mechanization, including separation equipment such as shredders, magnets, and air classifiers to recover the recyclables. Mixed-waste processing of recyclables is also known as front-end processing or refuse-derived fuel (RDF) processing of MSW.

2.8.2 Intermediate Processing

Processors receive post consumer material from collection centers or brokers in bales. Pre-sorted bales are broken open and dump onto a conveyor for final sorting, size reduction and separation, cleaning and washing. For example PETE bottles are manually sorted by color, undesired plastics are removed. Sophisticated systems to sort by color and remove labels automatically are currently being developed and tested in USA (Tchobanoglous et al., 1993). Cans are often mixed with non-ferrous materials when they are delivered, must be separated. Broken glass bottles can be separated from unbroken one to crush for using as raw material.

2.8.3 Transfer and Transportation

Transfer and transportation involves two steps: (i) the transfer of wastes from the smaller collection vehicle to the larger transport equipment and (ii) the subsequent transport of the wastes, usually over a long distance, to a processing and disposal site. The transfer usually takes place at transfer station. Waste transfer stations are facilities where municipal solid waste is unloaded from collection vehicles and briefly held while it is reloaded onto larger long-distance transport vehicles for shipment to landfills or other treatment or disposal facilities. By combining the loads of several individual waste collection trucks into a single shipment, communities can save money on the labor and operating costs of transporting the waste to a distant disposal site. They can also reduce the total number of vehicular trips traveling to and from the disposal site. Although waste transfer stations help reduce the impacts of trucks traveling to and from the disposal site, they can cause an increase in traffic

in the immediate area where they are located. If not properly sited, designed and operated they can cause problems for residents living near them. For transportation, although motor vehicle transport is most common, rail cars and barges are also used to transport wastes.

2.8.4 Final Processing

Final processing includes sorting, size reduction, size separation, magnetic separation, granulation and washing, drying, densification, shredding, molding, die casting etc. to provide a raw material for manufacturers or an end product. For example plastic bottles are turned into small flakes by a granulator designed to cut clean chips without causing excessive heat. The chips are washed using hot water, detergents to remove labels. After they are washed, the flakes proceed to a settling tank, where PETE sinks to the bottom and lighter plastics such as HDPE float. After separation through drying and molding new products can be obtained.

2.9 Measures of Recycling Performance

Although difficulties remain in quantitatively measuring the performance of recycling programs on a consistent, standard basis, the following useful performance criteria have defined (Tchobanoglous et al., 2002):

1. Capture rate
2. Participation rate
3. Recycling rate
4. Diversion rate

2.9.1 Capture Rate

The term capture rate (also referred to as the source recovery factor) denotes the weight percent of an eligible material in the total solid waste stream actually separated for recycling. Capture rate applies to a single material, not recyclables in general. This measure of performance is of greatest importance in measuring the success of a separation collection program. Thus, for example, a capture rate for aluminum would be used to describe how much aluminum is captured by the community's curbside program versus how much is captured through the bottle-bill program.

2.9.2 Participation Rate

The term participation rate denotes the percent of households (or businesses) that regularly separate recyclables. For example, in a particular community, on a monthly basis, 75 percent of the citizens participate in the curbside program. Participation may be different on a weekly basis than on a monthly basis, as fewer residents may participation weekly. The participation rate does not indicate the quantities of materials recycled or what materials were recycled. The participation rate term may actually provide misleading information regarding the success or failure of a recycling program, but does provide some useful measure of the extent of household involvement in the community's recycling program.

2.9.3 Recycling Rate

The term recycling rate is sometimes used to denote the quantity of recyclables collected per household per unit of time (e.g., 35 lb/residence. month). The recycling rate normally addresses what was collected without regard to whether the material was act ally sold or what amount of contamination was present in the recyclables. The term recycling rate is sometimes quoted as a percentage of the total quantity of waste generated in the community.

2.9.4 Diversion Rate

Another performance factor in gauging the success of a recycling program is the diversion rate, which represents the weight of total solid waste that is not land filled (or not incinerated). Thus, if the objective of the program is to minimize the weight of solid waste (including processing residues and incinerator ash) sent to landfill through a combination of strategies (such as source reduction and recycling), the ultimate performance measure is the net diversion rate. Again, diversion is often reported as a percent rather than weight or volume. It may be more useful to determine the net volumetric diversion rate, as it is a better measure than weight to estimate the savings in landfill life achieved by the integrated program. Landfills fill up long before they get too heavy.

2.10 Estimation Method of Recycled Waste Quantity

Method I: Mittal (2005) in Delhi, India categorized the total quantity of recyclables collected daily into nine groups depending on the quality collected by men, women and children through each mode of the transportation. The numbers of men, women (in terms of percentage) was evaluated by field survey. With the help of these the average weight picked up by an average recyclists was evaluated as below:

Average daily weight picked up by an average waste collector
= (number of children ×recycle load carried by each child + number of men × recycle load carried by each man + number of women × recycle load carried by each child)/ total number of recyclists

Method II: Enayetullah & Sinha (2004) reported that there are more than 100 shops (recyclable dealers) in Khulna. They selected some sample recyclable shops and gathered information about recyclables collected per day by field survey on September 2004. Based on data of these selected dealers they reported daily quantity of recyclables collected by wholesale shops of Khulna was 12.06 ton/day.

2.11 Recycling Programs

There are many ways to implement a recycling program. The program can be either voluntary or mandatory. The materials to be recycled can include paper (newspaper, cardboard, mixed paper, etc.) glass, cans (aluminum, ferrous), and plastics (PET, HDPE, PS, PVC, PP, LDPE, etc.), as well as other items. According to Tchobanoglous (1993) the followings are some recycling programs

Unit Pricing-Based Systems

The concept of unit pricing, also referred to as pay-as-you-throw or variable rate, is dents pay a fee proportional to their waste generation. By assessing a fee on material for waste collection, residents can be encouraged to increase their participation and separation factors.

Off and Buyback Programs

Drop-off and buyback centers are centralized locations where a specified class of waste generators (typically residential generators) may voluntarily bring certain recyclable materials (Fig 2.3).

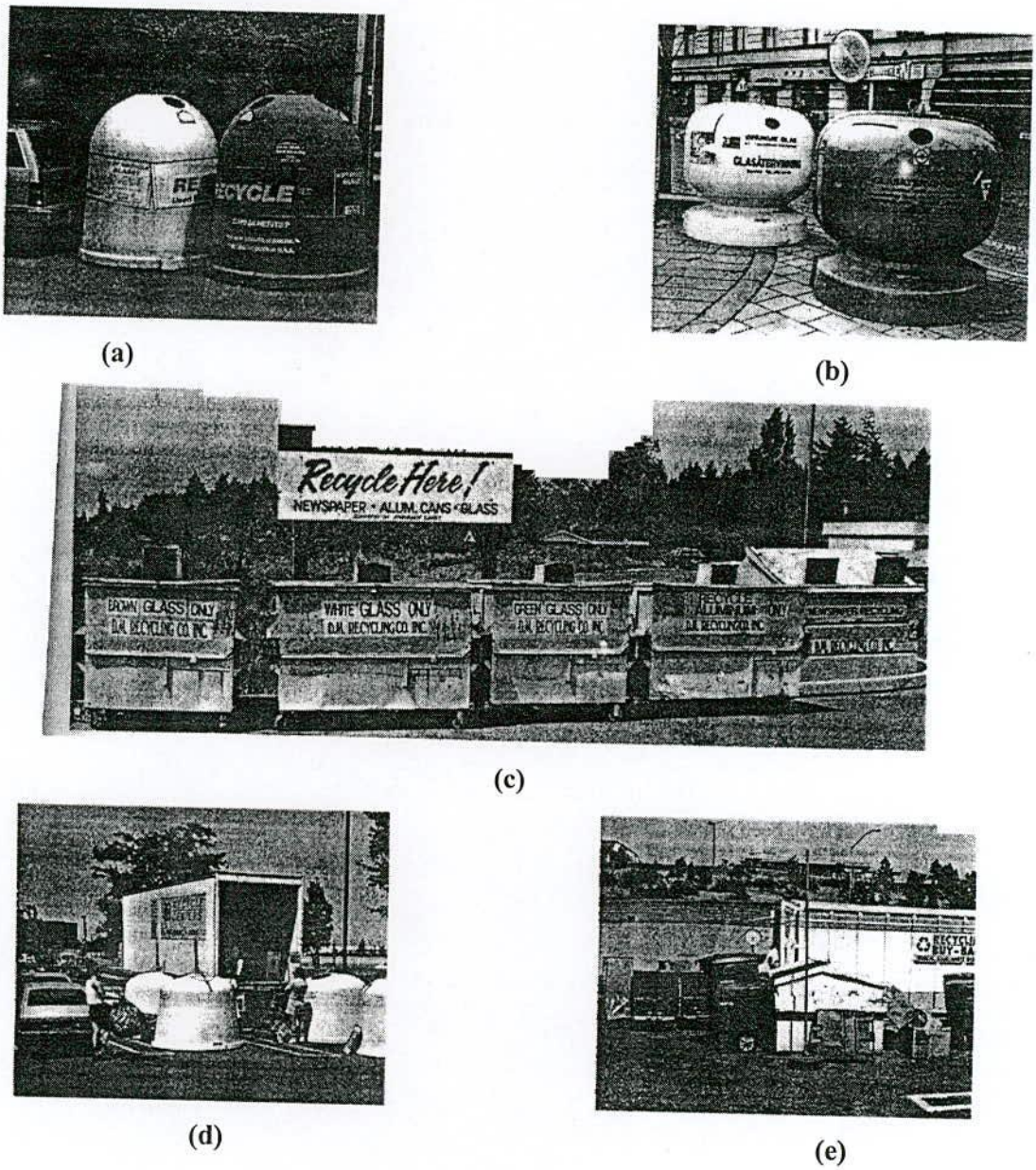


FIGURE 2.3 Typical examples of drop-off and buyback centers for the recovery of recyclable materials: (a) igloo-type in a residential area, (b) modified igloo-type in city center, (c) in rural area, and (d) and (e) buyback centers located near supermarkets.
(Tchobanoglous et al., 1993.)

One of the largest advantages of drop-off centers is that they are inexpensive to implement .A drop-off center can be as simple as several small-capacity containers that temporarily store the materials for regular pickup and transportation to market or a consolidation facility, or it can consist of drop-off at the central consolidation facility itself.

Bottle-Bill Legislation and Recycling

Before the first deposit laws were enacted in 1970, there was virtually no recycling of aluminum cans or plastic bottles; glass bottles were recycled at just 1 percent. Bottle-bill programs were implemented, not so much for their impact on materials recycling but rather because of the very positive impact they have on litter control. However, such legislation proved to be a part of many successful recycling programs. Columbia, Missouri, currently (in 2000) have mandatory bottle deposit legislation. In each case, the consumer pays a deposit on each container purchased and receives that amount as a refund when the container is returned for recycling or refilling. These bottle deposit bills primarily affect soft-drink beverage containers.

2.12 Adding Value to Recovered Waste

The recovered waste has some economic value. In other words wastes having economic value in the market are reclaimed and salvaged in different ways. In the different steps of recycling process the value is added. Items like broken glass, metals and papers need to be reprocessed before selling (Kaseva, 2002). The average buying price at source for plastics in 1994 was about US$ 0.06 per kg in Malaysia (Nasir et al. 1996).

Ways of extracting and adding value to recovered waste materials are shown in Table 2.3

2.13 A Brief Historical Perspective

Traditionally, solid waste management is mainly concern with removal of municipal wastes by hauling and dumping them out of the city boundaries.

Table 2.3 Ways of extracting and adding value to recovered waste material

Extracting and adding value processes	Explanation and comments
Collection	Identification and picking of items or collecting mixed waste allows the sector to acquire the waste and turn it into a resource. Most primary materials recovered from refuse, such as paper, plastics, rags, metal, glass, and food leftovers, constitute a commodity as they all have a market price
Sorting	Main process that increases the value of the waste recovered. The deeper the sorting differentiation, the higher the value of waste. For instance, if plastic is grouped into one major category, its value is lower than when it is further separated into sub-categories of hard and soft, then HDPE, PET, LDPE, etc. Sorting according to color, size, shape and potential use or re-use of the materials so as to meet the end-users quality specifications
Accumulation of volume	Additional volume adds value: larger volumes command higher per-unit prices. The greater the quantity, the better bargaining power the trader has. For small quantities, transactions costs, such as checking quality, arranging transport and paying the seller, reduce the profit margin. Industrial feedstocks are massive in volume. It follows that storage space is required
Pre-processing	For instance: washing, changing in shape-cutting, granulating, compacting, baling
Small manufacturing craftsmanship	Creation of micro-enterprises that use the special skills of informal recyclers to transform recyclables into articles traded directly to the community and being affordable by the poor
Market intelligence	Proximity to markets where informal recyclers and traders conduct business allows for the flow of information which allows decisions to be made on accurate market prices, competitors, trading partners, etc
Trading	In informal or formal markets. Links to the secondary materials network are crucial. Traders should be financially capable to add and conserve value of recyclables. Difference between buying and selling should also provide buffer against risk

(Adapted from Scheinberg (2001a) and from Community and Institutional Development (CID), Cairo, private communication)

However, with the ever increasing tonnage of refuse due to the expansion of urban centers, which implies increased collection, transportation and disposal costs, recycling is currently

accepted as a sustainable approach to solid waste management. The problems are complex and challenging in today's society. For instance, in most of the countries collection generally includes the gathering of recyclable and the hauling of these materials to a processing center, a transfer station, usually near a landfill and to the final market destinations. If the distance from the location to the center is far, the transportation cost will be very high. Solving this problem is complicated because factors such as volume, weight, loading, unloading, cleaning, shipping costs for both rail and truck and fuel surcharges must be considered.

In developing countries like India and Bangladesh the recycling is carried out to a large extent. However, unlike the developed countries like USA, the recycling remains essentially an informal activity. The collection of solid waste is carried out by poor recyclists and the waste finally lands up at the recycling units through a hierarchy of dealers (Mittal, 2005). The city of Dellhi, the capital of India, alone is estimated to have more than 85,000 people (Data, 1997) engaged in such activities. Since no special support from the government has been forthcoming to encourage clean and organized recycling, it remains an activity within the informal sector (Mittal, 2005). To organize this activity Mittal (2005) proposed two models -
Model A: Regularize the services of all recyclists.
Model B: Regularize a few recyclists and equip them with tricycles.

CHAPTER THREE

METHODOLOGY AND OVERVIEW OF THE STUDY AREA

3.1 General

The chapter is divided into two sections. Section 3.2 describes the overall methodology employed in this research to know the pattern of recycling, estimate the quantity of waste recycled and other related issues regarding recycling. Section 3.3 and section 3.4 describes the general information such as location, layout, population, and socio-economic and environmental condition of the study area.

3.2 Methodology

In order to achieve the objectives of the study, the overall methodology being used in this study is as shown in Figure 3.1. According to Figure 3.1, the methodology can be divided into several sections, i.e. site selection criteria, data collection procedure and data analysis.

3.2.1 Sites Selection

At first reconnaissance surveys were done to find out the dealers and industries involved in recycling. After preliminary deskwork different areas were selected in Khulna where most of the recyclable dealers and industries and waste collectors are present.

3.2.2 Data Collection

Both primary and secondary data were collected in doing this research. Primary data, such as the opinion from waste collectors, recyclable dealers, industry workers and KCC officials through in depth interview. Secondary data, such as statistics and reports on the quantity of solid waste generated and its composition and management practices of Khulna were collected by searching previous study, books and journals.

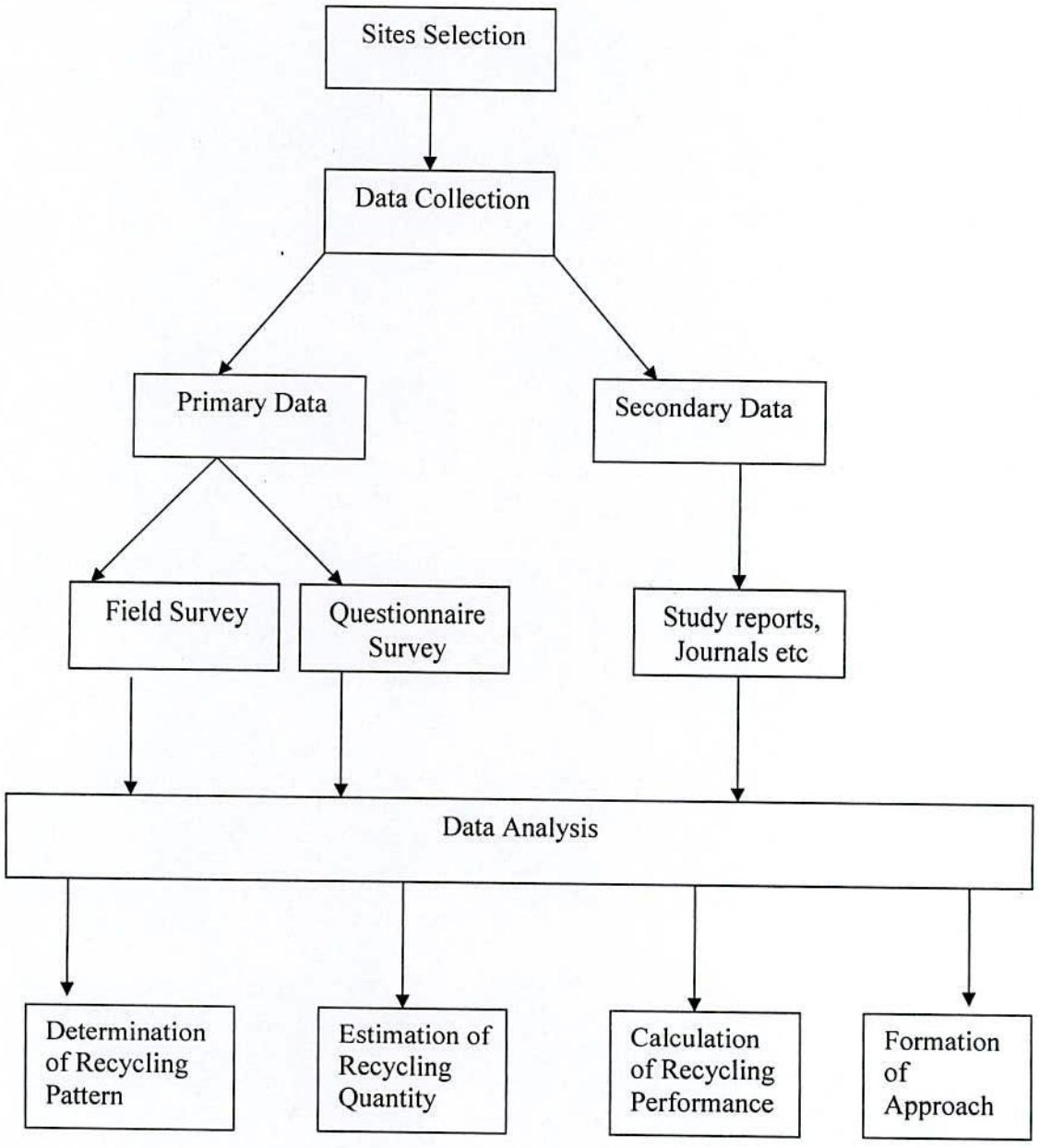


Figure 3.1 The Methodology of This Study

3.2.2.1 Primary Data Collection

A field survey was undertaken to provide a better insight to the nature and problems of recycling of solid waste. A set of questionnaires designed for waste collectors, recyclable dealers and workers of recycling industries were used to obtain information about the ongoing waste recycling pattern.

i) Determination of composition of solid waste: The composition of solid waste in a primary disposal site (dustbin) and a secondary disposal site were measured by weighing the different components of solid waste by weighing machine. The percentages of different components in total solid waste were calculated in percent by weight basis.

ii) Determination of number, category and recycling activities of waste collectors: Field surveys were conducted to determine the numbers and composition of the waste collectors' class. The criterion for the categorization of waste collectors into feriwala (men & women) and tokai were based on the mode of their waste collection, transportation, sex and age. Waste collectors were interviewed through questionnaire form for getting information about their recycling activities such as type, quantity, and selling prices of waste they collected and their waste collection and selling places. Waste collectors also provided information on the size of their population near the sites they represented, their daily income and living condition. More than fifty-five waste collectors of different study areas of Khulna were interviewed at their living and working places.

iii) Determination of number, category and recycling activities of dealers: The work also involved surveys on recycling dealers of different study areas to get information on different aspects of the recycle trade chain. The numbers of dealers were determined by direct counting through field survey. Then the recyclable dealers were categorized into small, medium and large. The criterion for the categorization of dealers was based on the type and quantity of their recyclable solid waste (RSW) collection and processing. One hundred and sixty nine dealers of different categories were interviewed according to their willingness to give time, take pictures and give answers to questions of the questionnaire form. The information about the types, quantity, buying and selling prices, buying and selling places of RSW was collected. The dealers also provided information about the number of waste collectors with category supplying RSW to them, number of shopkeepers and workers involved in their recycling activities. From data based on the interviews averages of RSW collection/processing, buying and selling prices of RSW, number of collectors, shopkeepers, and workers were calculated. From these averages the total quantity of recycling and number of people involved

were calculated by extrapolating the averages of the collected data.

iv) Determination of number, category and process of recycling industries: The study involved surveys on recycling industries to get information on different aspects such as problems, prospects, procedure and quantity of recycling. The numbers of industries were determined by field survey. The recycling industries were categorized according to the specific type of RSW they recycle. Employees of fifteen industries were directly interviewed in the form of face-to-face interview. The questionnaires were shown in the appendix of this report. Direct interview were conducted to have more conversation with the final recyclers about the recycling procedure of a specific RSW, quantity of recycling, number of workers. The recycling processes of some industries were also observed during this survey. The information about buying price and source of RSW as well as the selling price and selling places of recycled product were provided. Indirect interviews (Face to face interview with employees of one industry about the same type of another industry) were conducted about other sixteen industries. Fewer questions were asked in indirect interviews than that in personal interviews. Questions asked in indirect interviews included the following:

- What is the name and location of the industry?
- What recyclable solid waste (RSW) do they deal with?
- What is the amount of RSW collection and from where it is collected?
- How many workers are there in their industries?
- What are the finish products and where do those go?
- What is the quantity of product?

The duration of indirect interviews lasted from 5 to 10 minutes.

v) Information about present management practices: The officials of conservancy section KCC were interviewed to know about present management practices of solid waste in Khulna. The information about the capacity with types and numbers of vehicle and involvement of NGOs for house-to-house waste collection were provided. Interviews were carried out with the KCC staff to learn about the official viewpoint of recycling also.

vi) Information about source separation: During field investigation an interview was conducted among sixteen families of different income groups regarding solid waste recycling pattern to create awareness, encourage in source separation and use recyclable products.

3.2.2.2 Secondary Data Collection

Secondary data such as total waste generation, per capita waste generation, composition, biodegradable and non –biodegradable portion, the percentage of waste having selling value of Khulna were collected from previous study reports, journals etc to find out percentage of recyclables in the total waste.

3.2.3 Data Analysis

The data was interpreted in a quite simple and straightforward way. The important points were noted, sorted and classified from the information obtained from observations and interviews.

3.2.3.1 Determination of Solid Waste Recycling Pattern

From the information obtained from observations and interviews the sources and ultimate destination of RSW, transportation mode and involvement of different groups of people in different stages were determined. Thus the overall scenario of waste recycling pattern were portrayed.

3.2.3.2 Estimation of Quantity of Recycling

i) Using method I: From the primary data the average collection capacity of an average category of waste collector was determined. The average numbers of waste collectors involved in each recycling dealer for supplying RSW were calculated from the face-to-face interview. The total numbers of waste collectors were determined by extrapolating the average. Now based on the average daily weight picked by an average waste collector the total quantity of waste recycled was determined by using method I as described in chapter two.

ii) Using Method II: The total quantity of waste recycled for each category of dealer who faced the direct interview was determined. The average quantity of recycling per dealer was calculated. The total quantities of recycling by the dealers were calculated by multiplying the average with total number of dealers like method II as described in chapter two.

3.2.3.3 Calculation of Recycling Performance

The different performance measures such as capture rate, participation rate, recycling rate and diversion are calculated. Capture was calculated by dividing the weight percent of an eligible material in the total waste stream. Participation rate was calculated by dividing the households that regularly separate recyclables by total household in percent. Recycling rate was calculated to denote the quantity of recyclables collected per household per unit of time. The diversion rate was calculated by dividing the weight of solid waste that is recycled and composted by the weight of total solid waste in percent.

3.2.3.4 Formation of Approach

To organize the activity and increase the efficiency of recycling some approaches were proposed with some variables; number of tricycles, number of waste collectors and amount of waste collection for analysis of cost and benefit. The separate mass balances were prepared for present recycling pattern and for the proposed approaches.

3.3 Different Study Areas of Khulna

Different study areas with description are shown in Table 3.1. Ward wise distribution of KCC with study areas is shown in Figure 3.2. The areas mainly Shiromoni, Fulbarigate, Daulatpur, Khalishpur, Shekhpara, Sonadanga, Gollamari and Labanchara were surveyed. Shiromoni, Lobochora and Khalishpur are industrial areas of Khulna . Almost all of the recycling industries are found in these three areas. Dowlatpur ,Shekhpara, Sonadanga, Gollamari are commercial areas.

Table 3.1 A description of different study areas

Location and Ward Number	Characteristics of the Ward	Number of Households	Population	Survey on Recycling Concern
Fulbarigate 2	Mainly low income households and some agricultural land	681	3,344	Recycling dealers & waste collectors
Dawlatpur 6	Located in city periphery. Mainly pre urban but some agricultural land.	963	4,728	Collectors, recycling dealers &industry
Khalishpur 9 & 12	Industrial area located along the river. many factory workers live here and there are a few slums	2,961	23,924	Recycling dealers, collectors &industry
Sonadanga 17	Planned housing in built up area with higher income households	1,334	8,416	Recycling dealers & industry
Shekhpara 20	It is mainly recyclable waste market area	1,077	5,708	Recycling dealers, waste collectors & industry
Gollahmari 24	Central area. Traditionally middle class and educated professionals live here	2,377	12,606	Recycling dealers
Lobanchora 31	Mainly low income Households with industries	2,998	14,721	Recycling Industry
Shiromoni & Other places -	-	-	-	Recycling industry, dealers and collectors

(KCC, 2007)

3.4 General Information of Khulna City

Khulna city, the third largest industrial city of the country, is located at the south-western part and situated on the banks of the Rupsha and the Bhairab rivers. It is a divisional

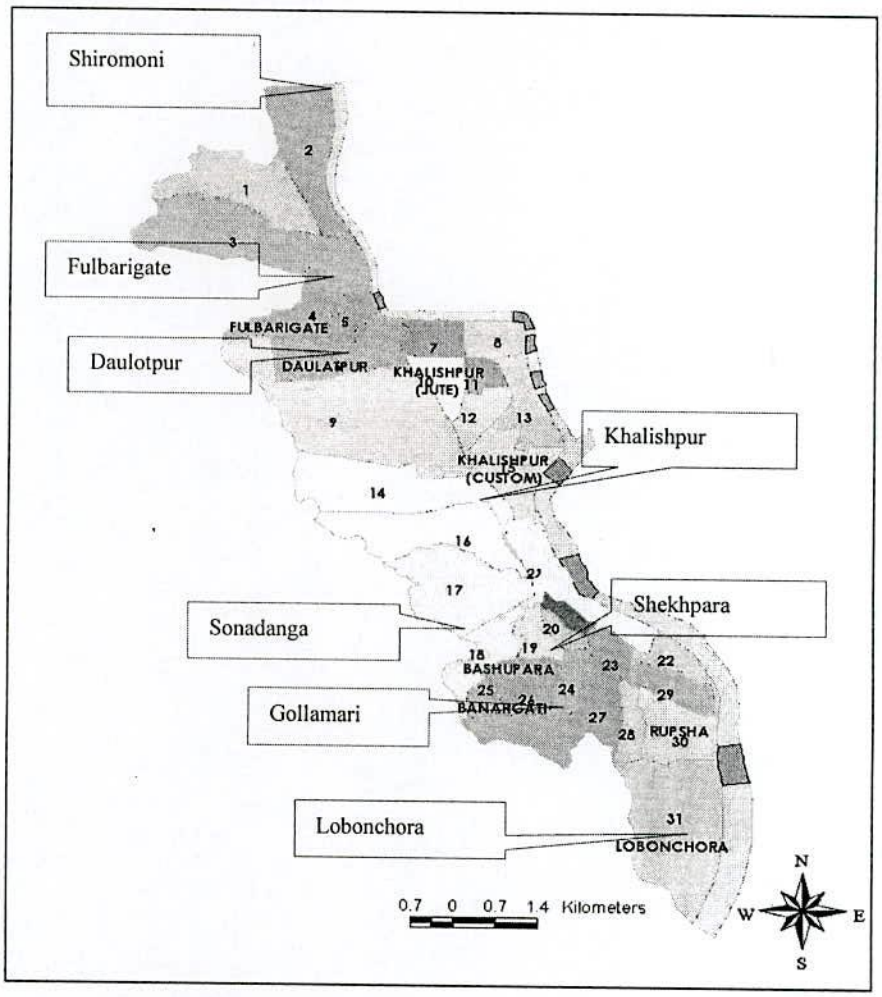


Figure 3.2 Ward wise distribution with study areas of Khulna city

headquarters, which serves as a gateway to the seaport of Mongla, the second largest seaport of the country. Khulna was declared a municipality in 1884, district headquarters in 1961, and a city corporation in 1984. Industrialization took place in the 1960s.

3.4.1 Location and Layout

Khulna is a divisional city in southwestern Bangladesh. It is situated below the tropic of cancer, around intersection of latitude 22.49° North and longitude 89.34° East (KCC, 2005). The location of Khulna district in Bangladesh is shown in figure 3.3. The physical shape of Khulna city is controlled by its geo-physical conditions. It is linear shaped city extending from southeast to northeast along the Bhairab-Rupsha River.

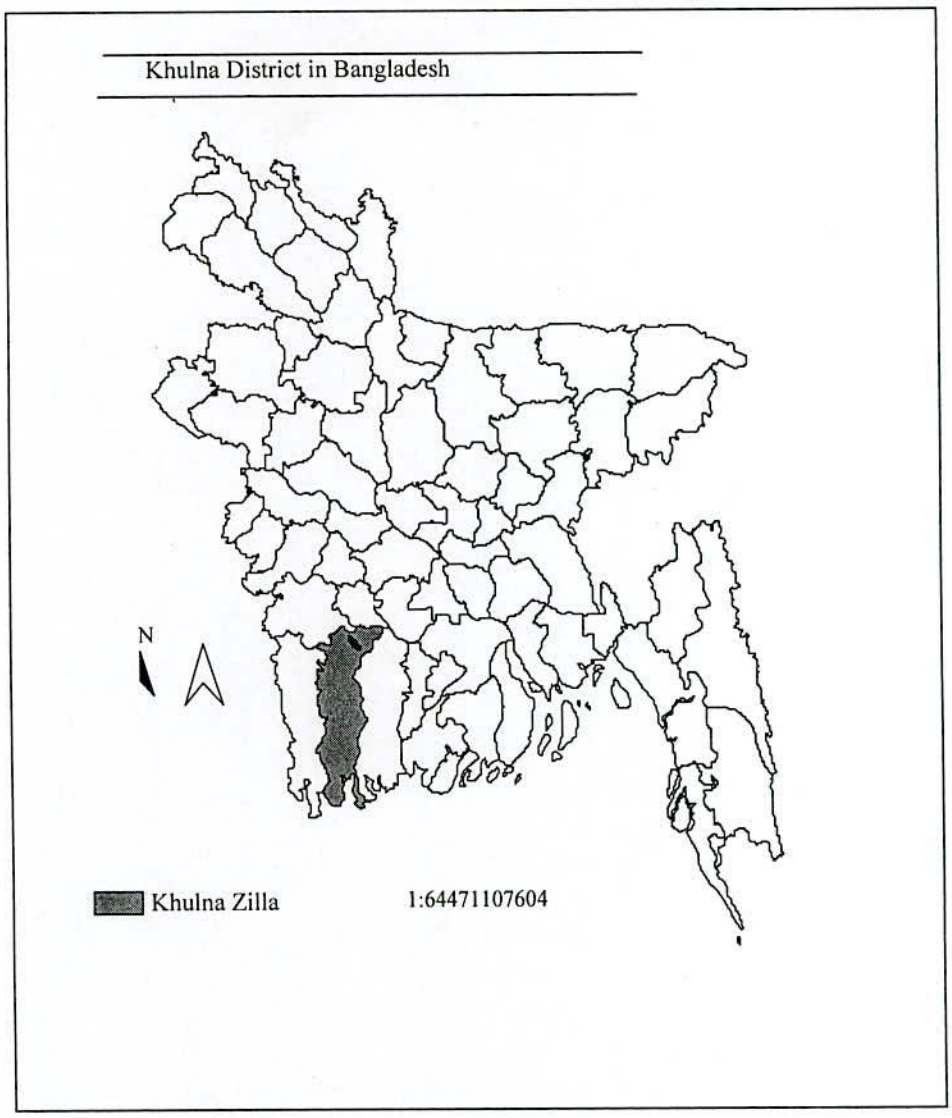


Figure 3.3 Location of Khulna district in context of Bangladesh (KDA, 2000)

The spontaneous nature of city growth and its shape are greatly influenced by the rivers (Bhairab-Rupsha) and Khulna-Jessore road. Surrounding districts are Satkhira, Bagerhat, Norial and Jessore. It lies along the Bhairab River. The city stands on the bank of Rupsha and has an important river port. It is connected by river, road, and rail to the major cities of the southern Gangetic delta. The layout of Khulna City Corporation with railway, highways etc are shown in Figure 3.4.

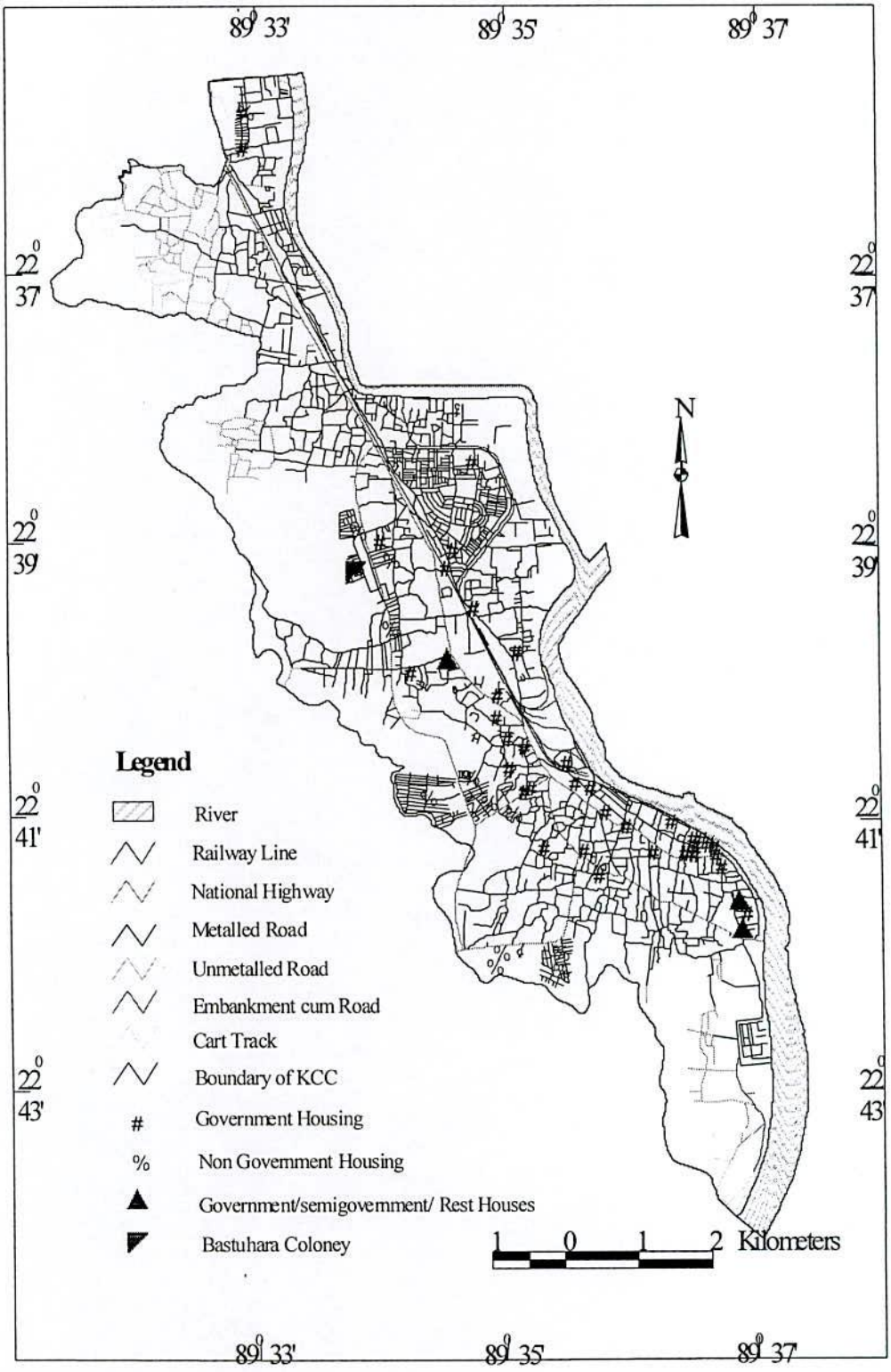


Figure 3.4 Layout of Khulna City Corporation (KDA, 2000)

3.4.2 Geography and Environmental Condition

The soil is alluvial as it is formed by the deltaic action of the Ganges, which brought sufficient mud. The land level is comparatively high and formed mainly by the deltaic action of the river Padma (Lower Ganges). Its elevation is 2.13m above Mean Sea Level. Climate in the Khulna city is moderate. Air is humid. Full monsoon is from June to September. During ebb tide the forest becomes bare by 1.82 to 2.13 m and at high tide the entire territory of the forest floats on water. The impact of urbanization in terms of mass poverty, gross inequality, high unemployment, under-employment, over-crowded housing and the proliferation of slum areas and squatters and general deterioration in overall environmental conditions have become the major concerns of policy issues. There is clear evidence that the potable water is in short of supply. The city also suffers from unhygienic sanitation conditions and high incidence of diseases. Annual average rainfall of Khulna 1715 mm, average temperature in summer is30°C and in winter is 15°C (DOE, 2005).

3.4.3 Demographic Characteristics

Khulna city is a densely populated area with 18,424 populations per square kilometer, 47 sq. km area and 31 wards (KDA, 2004). According to BBS (2001) census, total population in Khulna city area is 7,73,000. Khulna city, with a population of about 1.5 million as claimed by city authority in the year of 2005. Moderately rapid population growth (3.8%) is mainly due to large number of migrating people from rural areas of neighboring districts such as Satkhira, Bagerhat, Norial and Jessore. In 2002, about 48.45 percent of the total population was migrants. Most of the people (47.80%) migrate to the city for employment purpose (KDA, 2004). An imbalance in the gender ratio that is 118 males per 100 females. A relatively high literacy rate compared with other cities. A large proportion of people is engaged in private sector activity.

The mean family size of KCC area is found to be 5.60 persons. Slightly more than a third of the household are joint family type, while rest, 63.79% are single type (KDA, 2004). Due to diverse socio-cultural and other reasons during the one and half decades the scenario of social environment in Khulna city is markedly deteriorating. The main social problems of the city are terrorism; lack of adequate housing facilities for the poor; drug addiction; degradation of

moral values; lack of access to education for lower-income people; inadequate recreational facilities for the children; lack of comprehensive information on the social condition; and, unawareness of human rights at all levels especially by the poor. In KCC areas thee are about 120 slum areas are available in Khulna city (KCC, 2005). Peoples of adjacent district come here for job and working. Over the years, KCC has a wide variety of experiences of implementing different types of national and international agencies funded projects such as Slum Improvement Program funded by UNICEF; Drainage Improvement Project funded by Asian Development Bank (ADB); Environmental Mapping and Workbook funded by US International Agency for Development (USAID); Environmental Risk Management Action Plan funded by USAID, etc. KCC has also experience of working with different development partners such as NGOs, CBOs and private organizations in the areas of solid waste management and slum improvement.

3.4.4 Socio-Economic Condition

Khulna City is strategically located in an important hub as far as its development potentialities are concerned. The economy of a city can best be revealed through the income pattern of the city dwellers. The average household income per month is Taka 5,543 (US$ 90). It is equivalent to per capita yearly income of US$ 360.

The export of shrimp and the related activities such as shrimp processing, packaging, transportation, shipping, banking, insurance etc. have further reinforced the development of Khulna City to a great extent (KDA, 2004). The Export Processing Zone and the Airport will tremendously help to boost the overall socio-economic activities in Khulna city due to Rupsha Bridge.

The main socio-economic problems of the KCC are lack of job opportunities; market outlets for products produced through different micro-credit facilities; lack of capital; lack of adequate micro-credit facilities for the poor; lack of financial, technical and physical support facilities for informal sector's activities; local resources not properly exploited; lack of transparency in the allocation of the Annual Development Program (ADP) to the different agencies; and, lack of comprehensive information base of the city economy.

3.4.5 Land Use and Infrastructure

The small-scale private real estate business is flourishing day by day in KCC. The causes of the increment of the small-scale private real estate business and its impacts on the urbanization pattern of Khulna city in context of sustainable urban planning are mainly highlighted there. Due to the macroeconomic impact of globalization, the urbanization of the city is suddenly triggered up. To meet the needs of the increasing housing demand, private real estate companies have come forward with their own initiatives. Consequently, haphazard growth of this business is hindering the harmonic growth of the city. This business is growing in expense of deteriorated living environment, high traffic congestion, high land value and house rent etc. In observed land use composition with respect to the standard shown in draft structure plan map of KDA are stated in Table 3.2.

Table 3.2 Land Use Pattern in Khulna City

Land use parameter	% of the total land area shown in plan map of KDA	Actually found land area
Residential	40-65%	80-85%
Community facilities	5-10%	2.5-3.5%
Roads and streets	20-30%	10-12%
Open space (Parks and play grounds)	5-10%	0%
Shopping	5-10%	0%

(KCC, 2005)

Here it is seen that for maximizing the profit the private developers are selling more than 80% of the total project area (in terms of residential plot). Khulna Structure plan has proposed expansion area in the western side up to the Khulna Bypass Road. On the other side, the Bhairab-Rupsha River restricts city expansion. The largest segment of the expansion zone is around Rupsha Bridge (KDA, 2000).

CHAPTER FOUR

PRESENT STATUS OF SOLID WASTE AND ROLL OF KHULNA CITY CORPORATION

4.1 General

This chapter describes the generation rate, composition, biodegradable and non-biodegradable portion of solid waste of Khulna from previous study. This chapter also describes the composition of waste at dustbin and secondary disposal site obtained from the field investigation of this study. The quantity of recyclable solid waste is estimated. The management practices of solid waste by KCC are described here, obtained from interview with KCC officials.

4.2 Waste Generation and Composition in Khulna

Some previous studies were done to find out the waste generation in Khulna city. According to different studies per capita waste generation and total waste generation of Khulna are shown in Table 4.1

Table 4.1 Waste generation of Khulna city according to different studies

Reference study	Per capita waste generation	Total waste generation
Waste Concern (2000)	0.22 kg/day	201 tons/ day
New Age (2004)	0.23 kg/day	300 tons/day
Waste Safe (2005)	0.35 kg/day	520 tons/day

An extensive field survey was done in the six city corporations of Bangladesh by Waste Safe (2005). Therefore in this study 520 tons/day was considered reasonable for total waste generation in Khulna.

Several studies were done for estimating the waste composition of Khulna city also. The percentages of different composition of solid waste on the basis of generation sources are shown in Table 4.2.

Table 4.2 Physical composition of solid waste of Khulna according to different studies

Composition	A	B
Food and vegetable waste	78.9%	85.7%
Paper & paper products	9.5%	5.7%
polythene & plastic	3.1%	3.6%
Textile & woods	1.3%	-
Metal component	1.1 %	1.8%
Glass &ceramics	0.5%	2.5%
Rubber & leathers	0.5%	0.7%
Brick, concrete &stone	0.1%	-
Dust ,ashes	3.7%	-
Others	1.2%	-

Source: Column A: Waste Safe (2005), Column B: Raihan et. al. (2005)

The biodegradable portion was 91.4%, non-biodegradable portion 7.9% and others 0.7% (Raihan et. al.,2005). In this study the different components of waste and the recyclables collected by the collectors of a dustbin and a secondary disposal site (SDS) was measured on weight basis as described in Table 4.3. The survey was done just to make a correlation of waste composition with previous studies and to evaluate the percentages of waste that are readily recyclable. It was found that the collection of recyclables from dustbin (primary disposal site) is 10%, which is greater than that (7.6%) of SDS as shown in Table 4.3. This is because the recyclables were collected at every stage from household to disposal sites. Therefore the percentages of recyclables decreases from primary disposal site to secondary disposal site. The composition of solid wastes at a dustbin at Moylapota is shown in Figure 4.1 and the composition of solid waste of a SDS is shown in Figure 4.2.

Table 4.3 Physical composition and collection of recyclables at disposal sites

Location	P.T.I. More (SDS)		Collection	Moylapota(dustbin)		collection	Avg. (% by wt)
Component	(weight in kg)	(% by wt)	weight in kg	(weight in kg)	(% by wt)	weight in kg	
Food /Vegetable wastes	45.75	75.58	0	20.7	69	0	72.29
Paper	2.2	3.67	2	1.2	4	1	3.835
Plastics	0.3	0.5	0.3	0.6	2	0.5	1.25
Cloths	1.4	2.33	0	0.3	1	0	1.665
Glass	0.9	1.5	0.09	0.6	2	0.5	1.75
Metals	0.05	0.08	0.05	0.9	3	0.9	1.54
Polythene	2.2	3.67	2	0	0	0	1.835
Animal Bone	0.2	0.33	0.2	0.3	1	0.1	0.665
Dirt, ashes, bricks	3	5	0	3.6	12	0	8.5
Others	4.4	7.33	0	1.8	6	0	6.665
Total	60.4	99.99	4.64	30	100	3	99.995

(Field survey,2006)

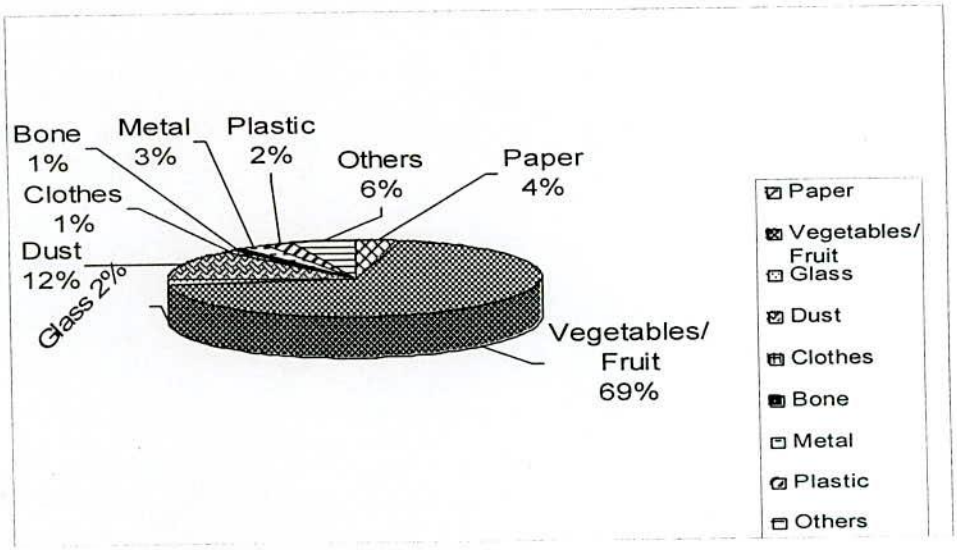


Figure 4.1 Percentage of physical composition of solid wastes found in a dustbin

Food and vegetables portion forms almost 69%, paper 4%, metal 3%, glass 2%, plastic 2% and bone 1%, clothes 1%, dust 12% and others 6% of the total waste (Fig.4.1).

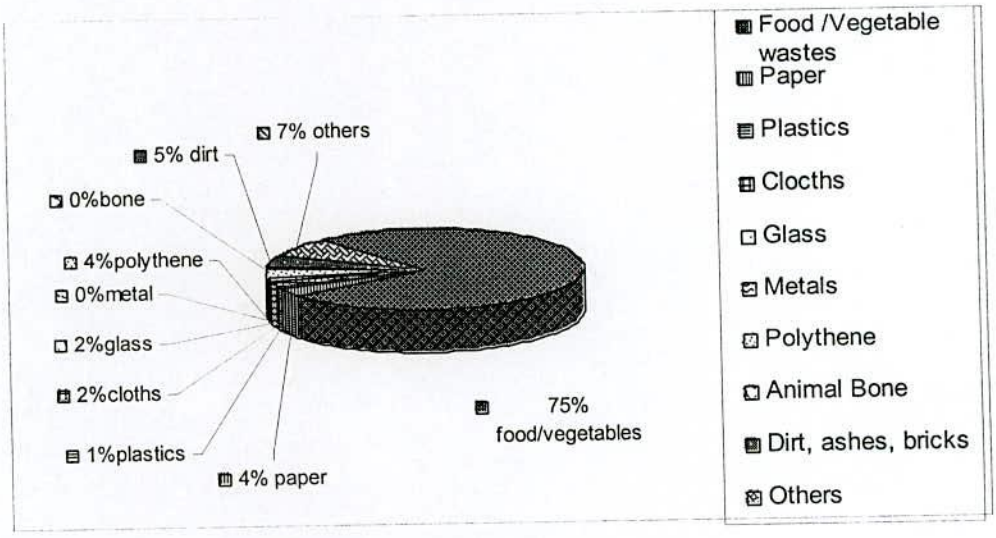


Figure 4.2 Percentage of physical composition of solid wastes found in a SDS

However, the composition is different for the case of SDS, where the food and vegetables waste forms 75%, paper 4%, cloths 2%, glass 2%, metal 0 %, polythene 4 %, dust 5% and others 7%. (Figure 4.2)

4.3 Estimation of Recyclable and Readily Recyclable Solid Waste

During the field survey the different components of wastes were measured by the waste collectors themselves. The waste collectors generally collect paper, metal, tin, plastics, broken glass, bottles, clothes for sell to recycle or reuse. However the waste collectors did not collect all of the recyclables found in the dustbin and secondary disposal site. They collected only those readily recyclable solid wastes, which have some selling value. Among the recyclables there are some slowly biodegradable wastes such as paper, plastic and bone. In absence of proper separation at the source these materials tend to decompose and lose their selling value as well as opportunity for recycling. From the composition of solid waste (Table 4.2) it can be calculated that the percentage of these recyclable solid wastes such as paper, metal, glass, plastic, bone vary between 12% to 15% according to different studies. Therefore the quantity of recyclable solid waste can be estimated from total waste generation

(520 tons/day as described in article 4.2) as (0.135×520) 70 tons/day. Therefore the readily recyclable solid waste can be estimated as 8.5% (average of collection as shown in Table 4.3) of total solid waste that is equal to 44 tons/day.

4.4 Roll of Khulna City Corporation

The developing cities like Khulna have now begun to acknowledge the environmental and public health risks associated with uncontrolled dumping of wastes. That has occurred mainly due to the active participation of private sector in solid waste management. The present scenario of Khulna city is given to highlight the management and technical issues. The management issues encompass waste generation, composition and characterization; collection, transport, processing and disposal while the technical aspects comprise implementation of legal provisions, economic and financial issues. There is a wide range of individuals, groups and organizations involved and concerned with solid waste management as service providers, intermediaries and regulators in KCC. In Khulna city, a significant portion of population does not have access to waste collection services and only a fraction of the generated waste is actually collected. Collections of waste from sources are dealing mainly by private organizations in KCC. Some private organizations (NGOs and CBOs) are working in different wards of KCC for waste management. Every organization has some non-motorized van and collects solid wastes from sources in house-to-house collection system. Householders have to pay a small amount for collection services. The conservancy department of KCC is responsible for waste management. They have some limited non-motorized vans and hand trolley (Table 4.6). In Table 4.5 a list of NGOs with their working areas and status are shown. Table 4.4 describes some demographic information of KCC related with waste management.

Table 4.4 Demographic information of KCC related with waste management

Sl. no.	Demographic Information	Type	Number
1	Total population	-	15 lacks
2	Total House holds	-	52,997
3	Estimated number of slums	-	745
4	Estimated number of slum population	-	2,27,500
5	Solid waste management officer	Conservancy Officer	1
		Assistant Conservancy Officer	1
6	Regular solid waste field staff	Conservancy Inspector	1
		Conservancy Supervisor	23
		Asst. Conservancy Supervisor	2
		MLSS	3
		Beet Sweeper (mathor)	28
		Truck driver, helper& labor	55
		Drain cleaner& spray man	62
7	Master role solid waste field staff	Street sweeper	33
		Van &wheel barrow driver	266
		Kota vehicle, dog catching and other labors	71
8	Estimated quantity of waste generated	-	300 tons/day
9	Estimated quantity collected by city corporation	-	270 tons/day
10	Land owned by city corporation for dumping solid waste	-	2 (25 acre)
11	Number of dustbins	-	1200

(KCC, 2007)

Table 4.5 Private organizations and KCC involvement in house-to-house waste collection at Khulna

Private organizations/local authority name	Working Area (Ward No.)	Status
PRODIPAN	6, 12, 24, 27,28	National Organization
PRISM Bangladesh	3, 31(part)	National Organization
RUSTIC	17 & 18 (Part)	Local Organization & Member of NGO Forum
MUKTIR ALO	21(part) & 23	Do
SPS	9, 14, & 15	Do
BRIC	4, 5, & 7	Do
RUPAYAN	19 & 20	Do
AOSED	25 & 26 (part)	Do
NABARUN SANGSAD	24 & 27 (Part)	Do
CHD	16 (part)	Do
PROTISRUTI	22 (part)	Do
PROSHANTI	30 (part)	Do
GOTI	20, 25 (Part)	Do
WORLD VISION	18 (Part)	Local Organization
SHABOLOMBI	10	Local Organization & Member of NGO Forum
SAMADAN	13	Do
CLANSHIP	17 (Part)	Do
GINNA PARA COMMUNITY	30, 31 (Part)	Local Organization
COMMITMENT	11(part)	Local Organization
ASHO GORI	11 (Part)	Local Organization & Member of NGO Forum
KCC	22, 29	The Local Authority

(KCC, 2007)

These vans collect solid wastes from community bin (roadside, home side, besides market) and carry this waste to secondary disposal sites (SDS). In KCC area there are more than sixty Secondary Disposal Sites (SDS) are available. KCC authority places some demountable containers and permanent concrete/masonry bin in the secondary sites. Masonry bin are also placed some sites and other sites are open spaces for dumping near roadside. All secondary sites in KCC area are unhygienic. In maximum SDS, solid wastes are thrown outside of container or masonry bin. Animal scavenging in those sites and odor nuisance is a common/major problem.

There are many NGOs and CBOs working in different wards of KCC for Solid waste management. The City authority doesn't collect solid wastes from houses except two wards (Table 4.5). Therefore, the NGOs limited their activities mainly to house to house collection and small scale composting activities. Table 4.6 describes the capacity of waste collection vehicles of KCC with type.

Table 4.6 Capacity with types of vehicle of KCC involved in waste transportation

Sl No.	Types of Vehicle	Number	Capacity/Vehicle
1	Heno truck (covered)	3	7 tons
2	Dump truck	8	7 tons
3	Normal truck (small)	2	3 tons
4	Dump truck (small)	8	5 tons
5	Tripping truck (container carrier)	5	7 tons
6	Tractor with trolley (big)	2	7tons
7	Tractor with trolley (small)	1	1.5 tons
8	Vacuum tanker with tractor	2	4 tons
9	Power tiller with trolley	2	0.5 tons
10	Side tipping truck double container	1	4 tons
11	Demountable container	65	7 tons
12	Rickshaw vans	260	60 kg
13	Wheel Barrow	76	30 kg

(KCC, 2007)

Some NGOs cannot collect the total waste of a ward. Therefore they collect from a part of the ward (table 4.3) City Corporation authorities collect the wastes from SDSs and transport by trucks to ultimate disposal site at Rajbandha, about 7 Km away from the main city hub. KCC vehicles (table 4.4) collect, transfer and dump every day wastes regularly. However, solid wastes are seen some places due to some constraints and lack of proper maintenance/management system. However, lack of funding, enforcement actions and sometimes lack of community involvement or participation appears to be the major barrier in improving the waste management services.

The cities like Khulna, where final dumping sites are nearby, the hauling of the wastes is not a serious problem. But adequate budgeting, cost accounting, financial monitoring and evaluations are essential for the effective management of solid waste systems. The KCC cannot collect all the wastes generated in Khulna. The amount of waste collection by KCC is shown in Table 4.7.

Table 4.7 Actual collected waste per day for disposal by KCC conservancy department

Type of truck	Capacity	Trip	Actual collected waste
Heno Truck	7 tons	6	42 tons/day
Tipping Truck	7 tons	16	112 tons/day
Dump Truck (big)	7 tons	8	56 tons/day
Dump Truck (small)	5 tons	8	40 tons/day
Normal Truck	3 tons	2	6 tons/day
Tractor with trailers	7 tons	2	14 tons/day
Total =			270 tons/day

(KCC, 2007)

KCC authorities proposed a budget of Tk. 265,98,37,325.19 for 2004–2005 financial years. Total solid waste management budget are Tk. 8,14,433,462.00, which is 3.06 % of total budget (Chowdhury, 2006). It contains salary, daily operation cost, development conservancy section cost and development project cost etc. Salary/daily operation costs of conservancy sections are 44% of total budget.

CHAPTER FIVE

RESULTS AND DISCUSSION

5.1 General

The chapter aims to present and analyze the results of questionnaire survey among waste collectors, recyclable dealers, and industries. The type and quantity of waste recycled and number of persons involved were estimated. The measures of recycling performance were calculated and the pattern of waste recycling was determined also.

5.2 Interview Results on Different Groups Involved in Recycling

Different groups of people were interviewed in this research. The interviews were conducted from April 2003 to February 2007.

5.2.1 Waste Collectors

The waste collectors are the first link in the long chain of recycling. This group comprises of men, women and children.

The waste collection was observed under two broad categories:

1. According to the mode of waste collection: House to house waste collectors (usually men and women; local name feriwala) and Waste bin collectors (usually children; both sexes, age below 14 years; local name tokai) and
2. According to the mode of waste transportation: manual, or using a tricycle.

The role of the waste collector is to collect and classify various materials that have a recycling value and can be sold to a recyclable dealer. Most of the feriwalas carry a busket, while a few own tricycles as well (figure 5.1). Tokais are working at sites of garbage dumps. At the end of the day, all of them perform some broad sorting of their collection and sell them to small recyclable dealers.

Most waste collectors come from the poorer community near Khulna district. Most of the migrants from the villages of Satkhira, Koira and Dumuria are working as waste collectors. These are the people who move out from the rural areas and come to the urban centers like Khulna looking for an employment and finding it difficult, resort to recycling activity. Overall, around 80% of the waste collectors are illiterate and the rest 20% have had primary education up to some stage (Table B.6 in Annexure). Women constitute only a small percentage of the recycling class and mostly resort to recycling as a part-time activity or as a helping hand to their husbands.

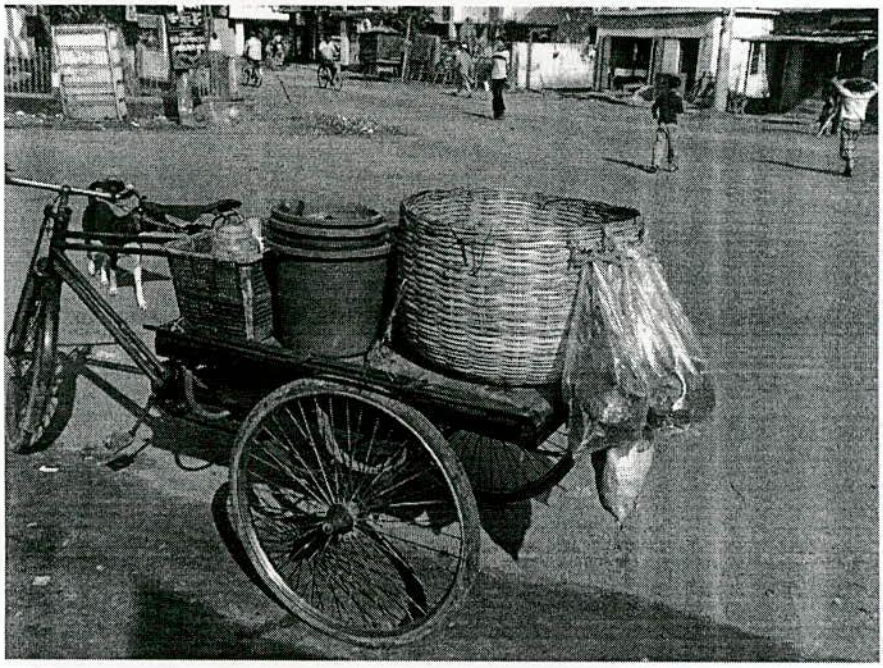


Figure 5.1 The photograph of a tricycle used by the feriwala for collecting RSW

5.2.1.1. Residential Status: Waste collectors stay in huts or tin sheds in slums, which are owned by them or rented or provided to them by the recyclable dealers. Four to five waste collectors often share the same hut, since it is not possible for anyone of them to pay the monthly rent of around Tk. 300-400 per hut (Table B.6).

5.2.1.2. Life-Style: Most of the waste collectors had incomes just sufficient enough to avail them food and accommodation on a day-to-day basis. During times of financial distress, they often approach their recyclable dealers for help. The ordinary moneylenders do not help the waste collectors because of their low economic status. The workplace relations between the waste collectors and dealers reflect in social relations and the help from small dealers is usually imminent.

5.2.1.3. Working Conditions: The tokais pick up waste from streets, drains, municipal bins, open dumping sites and landfill sites (Figure 5.2). None of these is hygienic enough, and yet the waste collectors do not use any kind of protective gears, like gumboots or gloves, and are exposed to frequent injuries like cuts from glass pieces, metals, etc. The work is unpleasant, and frequently the areas in which waste is found and assorted are used for defecation by public. The health and safety problems associated with the work are numerous and quite obvious.

The waste collectors' tangible resource (i.e., waste) is not liable to damage, theft, and supply problems or due to unexpected changes in markets. Waste collectors mostly work alone, are solely responsible for the success of their work and each day is critical for them in the sense that each day's earnings are used to provide basic necessities for that day. Average income of the waste collectors was found to be range between Tk. 25 to 130 per day in Khulna (Table B.6). This compares well with the corresponding figures of incomes of waste collectors in Dhaka whose earnings range between Tk40 to Tk200 per day (Rouse and Ali, 2001).

Figure 5.2 Collection of recyclable waste from roadside by tokai

5.2.1.4 Estimation of Number of Waste Collectors

The number of waste collectors in Khulna was estimated by conducting surveys on waste collectors, recyclable dealers, and some slum areas in Khulna. Assuming a similar distribution of waste collectors amongst the recyclable dealers in Shekpara, the survey results

were projected for the total waste collectors'. This yielded the presence of more than 2000 waste collectors in Khulna as shown in column (A+B+C) in Table 5.1.

Table 5.1 Estimation of number of people involved in recycling process

Location	Waste Collectors			Dealers	Employee of Industries (E)	Total (F)
	Feriwala		Tokai			
	Men (A)	Women (B)	Children (C)	No. of Employee (D)		
Shiromoni	5	0	15	6	50	76
Fulbarigate	25	0	60	24	0	109
Dowlotpur	44	0	95	220	0	359
Khalishpur	65	10	120	120	20	335
Sheikhpara	450	20	850	600	200	2120
Sonadanga	11	0	35	50	45	141
Gollamari	10	3	50	60	45	168
Dakbangla	15	0	40	40	0	95
Munshipara	10	2	20	12	0	44
Lobon chora	8	2	15	8	350	383
Other places	15	0	12	110	40	177
Total	658	37	1312	1250	750	4007

Note: More than 500 brokers are also involved in different areas of Khulna (Table B.7)

5.2.1.5. Estimation of Waste Quantity Recycled

Estimation for quantity of waste recycled was done by using method I as described in chapter two. The average weight picked by children, man, and woman was calculated by arithmetic mean of the survey collected in each category. The total quantities of recyclable solid waste (RSW) collected daily are divided into different categories (Table 5.2) depending on the quantity collected by men, women, and children through each of the transportation mode. The detail data are shown in Annexure in Table B.4 and Table B.5. Table 5.2 shows that of all RSW in the city, paper is recycled most by the waste collectors, while animal bones are recycled least. This can be explained by the fact that after food & vegetables (78.9%), paper materials are second highest by the weight (9.5%) of the total solid waste components

generated in the city (article 4.2). Therefore, paper can be easily accessible by many waste collectors.

Table 5.2 Average daily collection of waste in weight by various categories of collectors

Category	Mode of transportation of recyclables	Average quantity (kg/day)					Total (kg/day)
		Glass	Paper	Plastic	Metal	Animal bone	
Tokai (Children)	Manual	0.5	6	1.5	1	1	10
Feriwala (Men)	Manual	1	7	3	2	2	15
	Tricycle	4	11	8	10	2	35
Feriwala (Women)	Manual	2	6	3	1	0	12

Also the numbers of men, women, and children (in terms of percentages) (Table 5.3) was evaluated by field surveys(Table B.4 and Table B.5). From the data shown in Tables 5.2 and 5.3, the average weight collected by an average waste collector was evaluated as below:

Table 5.3 Percentage of children, men and women employing different modes of transportation

Category	Mode of transportation of recyclables	
	Manual (%)	Tricycle (%)
Children	65	None
Men	8	25
Women	2	None

Average daily weight picked up by an average waste collector

= (number of children ×recycle load carried by each child

+ number of men × recycle load carried by each man

+ number of women × recycle load carried by each woman)/ total number of waste collectors

= [(65/100) (number fraction for children-manual mode) ×10(kg/child-manual mode)

+ (8/100) (number fraction for man-manual mode) × 15(kg/man-manual mode)

+ (25/100) (number fraction for man-tricycle mode) × 35(kg/man-tricycle mode)

+ (2/100) (number fraction for woman-manual mode) × l2 (kg/woman-manual mode)] = 16.69 Kg ≈ 17 Kg

Hence, total quantity of waste collected daily by the waste collectors

= Number of waste collectors x average weight picked by each waste collector

= 2000 waste collectors x 17 kg = 34,000 Kg =34 tones

Total waste generated in Khulna = 520 tones/day as described in article 4.2

Hence, the percentage of waste recycled =34/520x 100 = 6.42% of total generated waste

Hence, the percentage of waste recycled =34/70x 100 = 49% of RSW

Thus, around 2000 waste collectors in Khulna recycle 6.42% of total generated solid waste or 49% of RSW.

5.2.2 Recyclable Dealers

Recyclable dealers are the second link in the chain of recycling. They are reported under three broad categories according to mode and quantity of collection and type of waste. Figure 5.3 shows the photograph of a typical recycling dealer. The quantity of Recyclable Solid Waste (RSW) collection with different types of dealers and location are summarized in Table 5.4

1. Small Recyclable Dealers (SRD): Each SRD purchase all types of wastes from the collectors and their collection of RSW is below 250 kg/day on an average.
2. Medium Recyclable Dealers (MRD): Usually they deal in two or three kinds of specific RSW. They purchase RSW from all the SRDs and occasionally from brokers and the amount collected range between 250 kg/day to 600 kg/day.
3. Large Recyclable Dealers (LRD): The LRDs essentially specialize in specific wastes. They collect the waste from MRDs in Khulna and from outside of Khulna. On an average the amount of RSW collection by each LRD is greater than 600 kg/day.

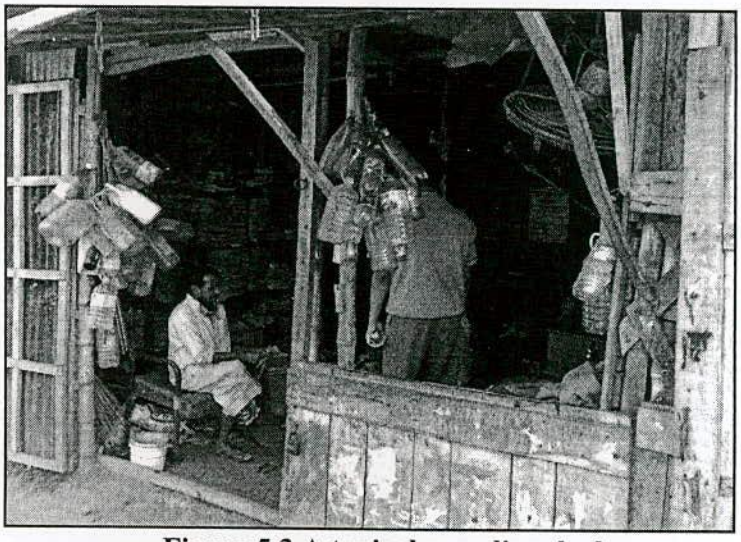


Figure 5.3 A typical recycling dealer

Table 5.4 Quantity of RSW collection on the basis of location and types of dealers

Location	Number of dealers with type			Total no. of dealers	Amount of RSW (kg/day)			Quantity of RSW (kg/day)
	SRD	MRD	LRD		SRD	MRD	LRD	
Fulbarigate	12	0	0	12	780	0	0	780
Dowlotpur	21	4	0	25	1575	1012	0	2587
Khalishpur	30	8	2	40	3300	2080	2300	7180
Shekpara	141	114	24	279	20445	30210	36000	86655
Sonadanga	7	0	0	7	420	0	0	420
Gollamari	10	3	0	13	750	780	0	1530
Dakbangla	6	1	2	9	744	310	2656	3110
Shiromoni	3	0	0	3	186	0	0	186
Munshipara	6	0	0	6	654	0	0	654
Labonchara	4	0	0	4	460	0	0	460
Other places	37	10	5	52	3145	2834	4760	10739
Total	277	140	33	450	32459	37226	45716	-

5.2.2.1 Small Recyclable Dealers (SRDs)

From the field survey it is found that there are 277 SRDs all over Khulna city (Table 5.4). The daily quantities of RSW collected by SRDs are shown in Table 5.5. Each and every SRD is dependent on tokais and feriwalas to supply them with RSW. Tokais and feriwalas sell their mixed RSW (Figure 5.4) to SRD on cash delivery basis. It is important for them to have as large a number of suppliers as possible, in order to be assured of a good turnover to support them. Providing loans is the most important means of SRDs to tie the tokais and feriwalas to them. On an average they have 5 to 6 number of tokais and feriwalas attached to them.

Figure 5.4 Mixed RSW collected by a SRD in Khulna

Table 5.5 Quantity of RSW collected by SRD at different locations

Location	Quantity collected (kg/day)					Total
	Glass	Paper	Plastic	Metal	Animal bone	
Fulbarigate	72	324	144	240	0	780
Sheikhpara	2397	8883	2820	6345	0	20445
Dakhbangla	120	240	132	216	36	744
Munshipara	72	180	102	300	0	654
Dawlotpur	210	525	210	630	0	1575
Khalishpur	510	1050	600	1140	0	3300
Gollamari	140	200	90	300	20	750
Sonadanga	63	147	42	168	0	420
Labonchara	60	140	60	100	100	460
Shiromoni	24	75	21	66	0	186
Other places	555	962	629	925	74	3145
Total	4223	12726	4850	10430	230	32459

5.2.2.2 Medium Recyclable Dealer (MRD)

There are 140 MRDs in Khulna city (Table 5.4). Average quantity of RSW collected by each MRD is shown in Table 5.6. They employ 5 to 7 people to segregate the waste. Figure 5.5 shows two specific type of waste collected by a MRD.

Figure 5.5 Metal and tin waste collected by a MRD in Khulna

Table 5.6 Daily quantity of RSW collected by MRD at different locations

Location	Average quantity collected (kg/day)					Total
	Glass	Paper	Plastic	Metal	Animal bone	
Sheikhpara	3648	3990	9690	12882	0	30210
Dakhbangla	55	74	86	85	10	310
Dawlotpur	135	276	245	356	0	1012
Khalishpur	277	416	485	846	56	2080
Gollamari	133	243	135	227	42	780
Other places	410	644	474	982	324	2834
Total	4658	5643	11115	15378	432	37226

5.2.2.3 Large Recyclable Dealer (LRD)

It was found that there are 33 LRDs in Khulna city. The average quantities of recyclable solid waste (RSW) collected by each LRD are shown in table 5.7. Most of the LRDs employ 6 to 10 people to sort, clean the wastes. They sell the recovered materials to industries both in the formal and the private sectors. Figure 5.6 shows plastic waste collection of a LRD.

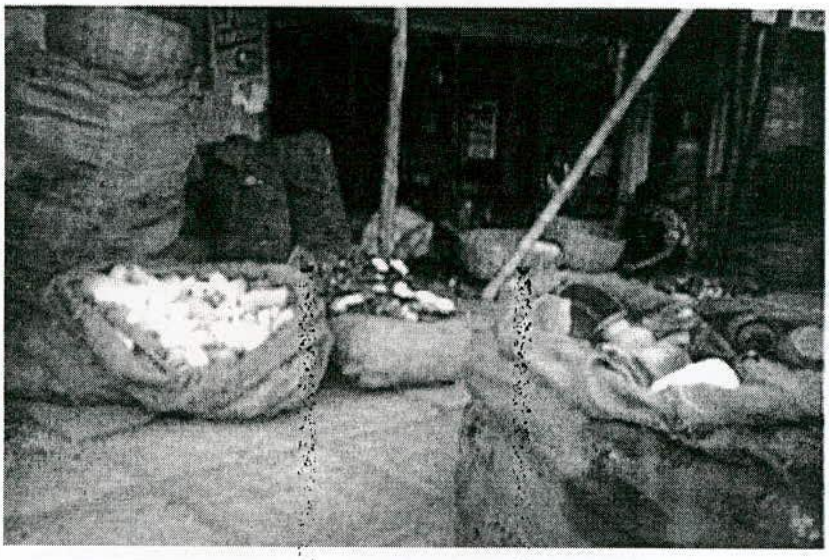


Figure 5.6 Plastic waste collected by a LRD in Khulna

Table 5.7 Daily Quantity of RSW collected by LRD at different locations

Location	Average quantity collected (Kg/day)						Total (Kg/day)
	Glass	Paper	Plastic	Metal	Animal bone	Rubber (Old Tyre)	
Sheikhpara	720	1440	4160	29680	0	0	36000
Dakhbangla	452	801	493	310	0	0	2056
Khalishpur	432	234	342	720	72	500	2300
Other places	997	720	856	1997	190	600	5360
Total	2601	3195	5851	32707	262	1100	45716

5.2.3 Recycling Industries (RI)

From the field survey it was found that there are 31 recycling industries in Khulna. Almost half of them were interviewed. The major recycled items and the corresponding end user industries are shown in Table 5.8. The purpose of having face- to- face interview is to have a more in depth conversation with the final recyclers, and to draw their opinion on the development of the industry. Apart from bone, plastic paper, iron and tyre all recycling industries are located outside Khulna district.

Table 5.8 Major recycled items and the corresponding RIs in Khulna city

Type of Waste	Total number of RI	Recyclable amount collected (Kg/ Day)	Products	Name of Industries
Plastic	11	7513	Wheel of toy rickshaw, Cork, Electric switch, Plastic bottle, Dropper,	Al Amin Plastic Industry, A. Rahman &Sons Plastic Industry, M/S Tofazzal Honda Parts, Gani Plastic, M/S Commilla Plastic, Soudia Plastic, Panna Plastic, Nazimuddin Plastic, Sorwar Plastic, Bhai Bhai Plastic Cutting, Delwar Plastic.
Iron (Cast Iron)	5	3000	MeasuringWeight, Tawa, Fry Pan, Hamandista,	Universal Steel Foundation, ,M/S Zaman Foundation, VIP Foundation, Kashem Foundation, AVF Foundation
Iron (Mild Steel)	6	25805	Machine Parts, Knives etc	Bismilla Iron, M/S Kamal Enterprise, M/S Touhid Iron, M/S Jamal Foundation, M/S Tareq Enterprise,Tamiz Uddin Iron
Bone	4	19333	Cap of capsule, Comb, Fertilizer, Tiles, Stick Etc.	Sattar Bone Mill, New Khulna Mill,. Talukdar Bone Mill, Pearl Bone Mill
Paper	1	2334	Hard paper used for book binding and packets of sweet, shoe	Sattar Paper Mill
Tyre	4	2200	New Tyre	Mitali Tyre Industry, Sonadanga tyre, Jalal Tyre Resouling, AbdurRahman Tyre
Total	31	60185		

Estimation of Waste Recycling Quantity by using method II

Using method II(article 2.10) the total quantity of waste recycling by the SRD 32.46 tons/day (Table 5.5), by MRD 37.23 tons /day (Table 5.6), by LRD 45.72 tons/day (Table 5.7) and by industries at end of recycling chain is estimated 60 tons/day as shown in Table 5.8. The recycling quantity by industries is equal to (60/520*100) 11.54% of total generated waste and (60/70*100) 86 % of RSW (article 4.3).

5.2.3.1 Paper Recycling Industry

There is one paper-recycling industry in Khulna. They consume scrap paper to reprocess the paper product. The paper materials are second highest by the weight (9.5%) of the total waste components generated in the city. Including corrugated cardboard, high grade paper and mixed paper typically represents 39 percent of the total recyclable waste collected by SRDs. This amount is increasing day by day.

Grocer reuses one portion of discarded paper by making packets. Paper mills have always recycled damaged product and scrap from converters. Paper mills purchase additional post consumer waste paper based on fiber strength, fiber yield and brightness according to the type of product produced. Waste paper is collected by Tokais, Fariwala, from waste bin, house hold, road sides and dumping site. Industries purchase waste paper from LRDs directly or through brokers.

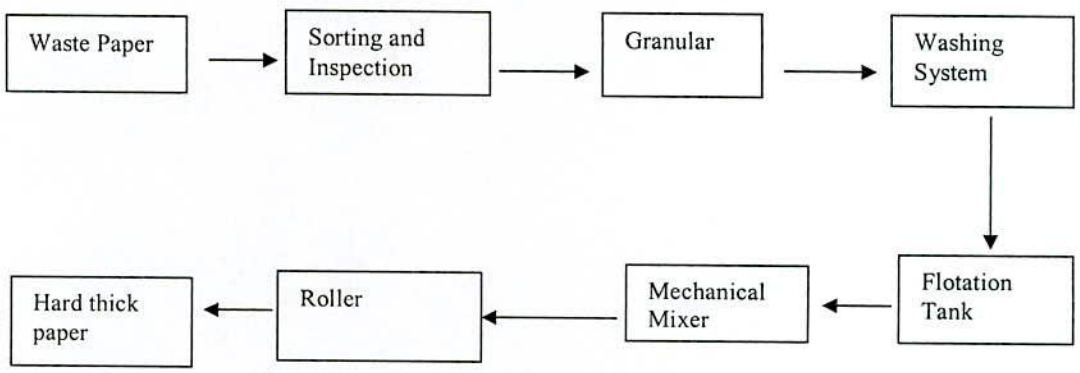
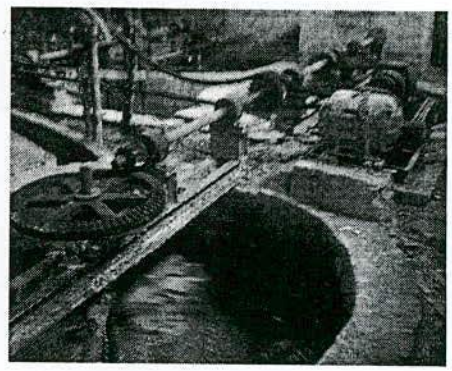


Figure 5.7 Typical flow diagram for the paper recycling industry

In this way recycled papers are produced. From these recycled papers we get products such as packet of sweets, hardboard, and bookbinder covers, cartons, shopping bags etc.

(a)



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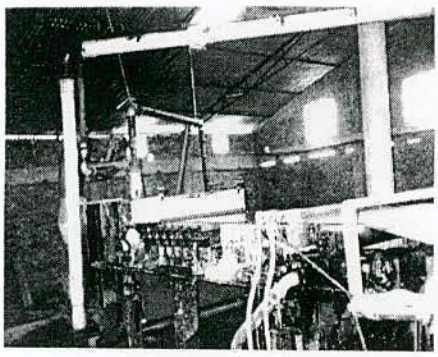

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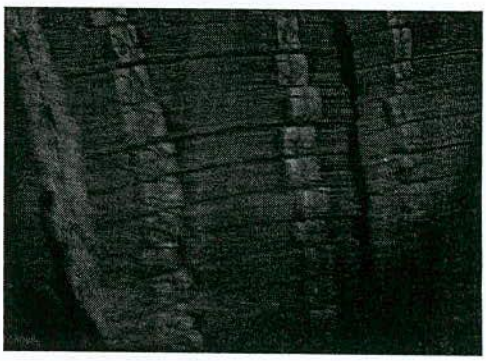


(d)

Figure 5.8 Paper recycling in Sattar Paper Mill (a) Waste Paper (b) Mixing (c) Rolling (d) Product

5.2.3.2 Plastic Recycling Industry

There are 11 plastic recycling industries in Khulna. The growth in use of plastics in consumer products has occurred because plastics have largely replaced metals. Plastics have several advantages. They are light and thus reduce shipping costs. They can be formed in variety of shapes and can be formulated to be flexible or rigid. The principal types of plastics now recycled are polyethylene terephthalate (PETE) and high density polyethylene (HDPE),

polyvinyl chloride (PVC), low density polyethylene (LDPE), polypropylene (PP), polystyrene (PS), mixed and multilayer plastics. They comprise a somewhat larger percentage on a volume basis.

The processes of plastic recycling in steps are explained below:

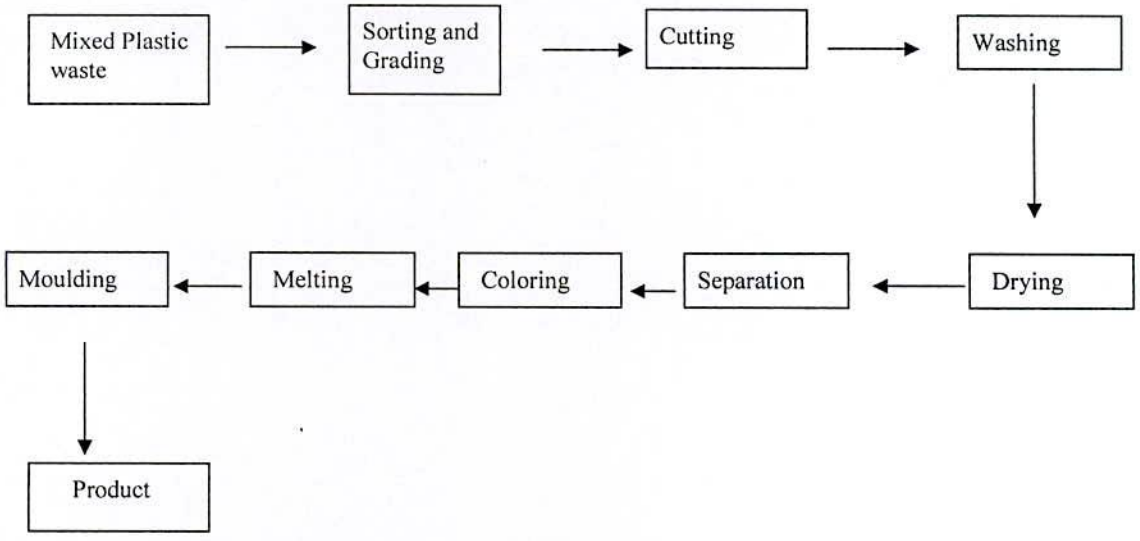


Figure 5.9 Typical flow diagram for the plastic recycling industry

Sorting: Collected plastics are sorted according to their physical properties such as color, thickness, and hardness.

Washing: Sorted or broken materials are washed. The chips are washed using hot water, detergents to remove labels, adhesives and dirt and a centrifugal separator is used to separate the flakes from the dirty water, paper and debris.

Separation: After they are washed, if the mixture does not separate readily a series of hydro cyclones may be required for both light and heavy streams, with the processes tailored to mix of bottles.

Drying: after separation, a spin dryer is used to remove free water and the flakes are then dried with hot air to reduce moisture content to about 0.5 percent.

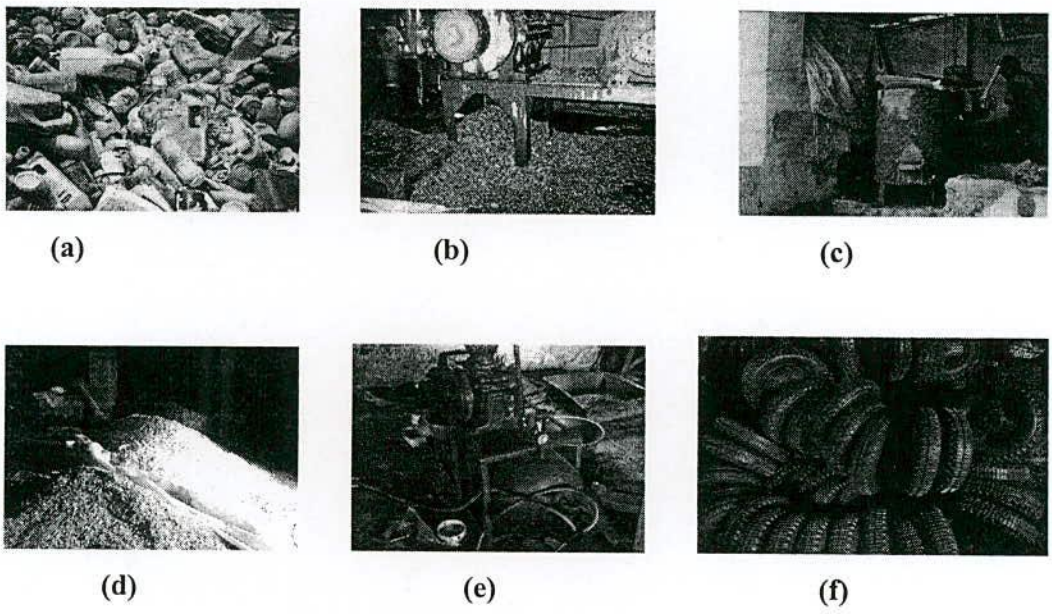


Figure 5.10 Plastic recycling in Al- Amin Plastic Industry (a) Mixed plastic waste (b) Cutting/Breaking (c) Washing (d) Drying (e) Moulding (f) Product (wheel of toy)

Coloring: After drying, the chips are mixed with colors.

Melting: The flakes are fed into the extruder at large diameter end of the screw and compressed as they are carried toward the extrusion die. The combined heat from flow friction and supplemental heating bands causes the resin to melt and volatile contaminants are vented from the mixture. Immediately before the die the melted passes through a fine screen that removes remaining solid impurities; this step is known as melt filtration.

Moulding: Molding of plastics comprises of forming an article to the designed shape by application of heat. After melt filtration, varieties of necessary products are produced such as toy rickshaw wheel, water pot etc by molding.

5.2.3.3 Iron Recycling Industry

From field survey it is found that there are 11 iron recycling industries in Khulna. Solid waste contains 1.1 percent metal (iron and aluminum) and tins in Khulna city. The sources of metal are old and cut pieces of pipe, discarded building materials, industrial scrap and machine

shop cuttings, construction debris, aluminum can, tin can etc. But most of the scrap iron comes from Chittagong. The processes of metal recycling in steps are noted below:

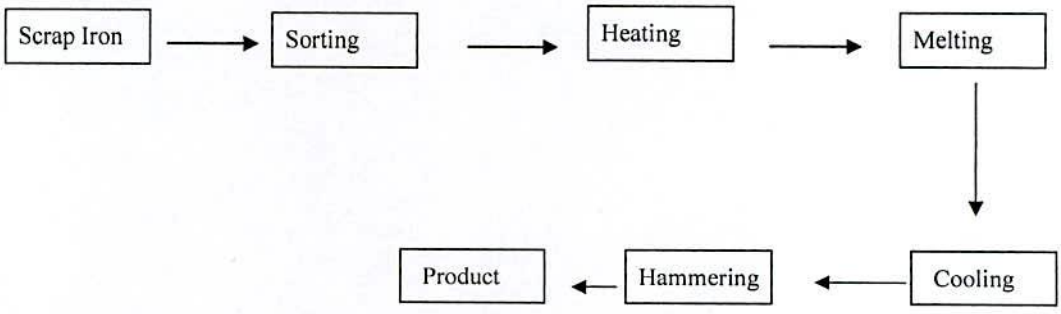


Figure 5.11 Typical flow diagram of the iron (mild steel) recycling industry

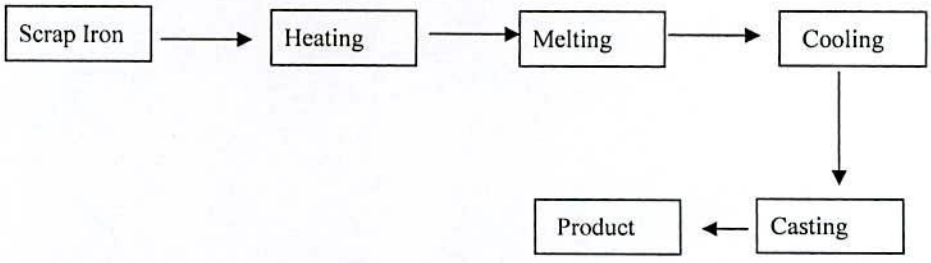
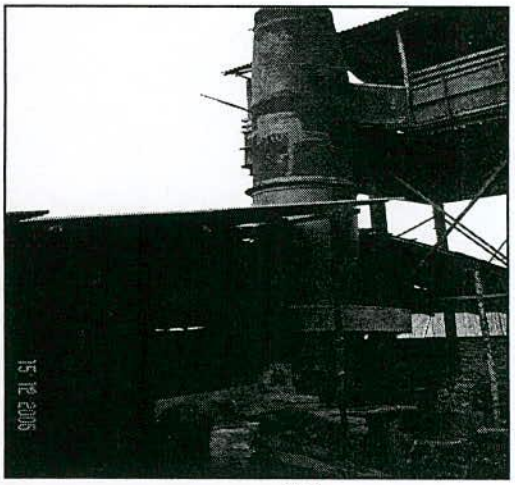


Figure 5.12 Typical flow diagram of iron (Cast Iron) recycling industry

Machine Parts, Knives etc are the products from scrap mild steel. Recycling of scrap cast iron by industry produces many products such as head of tube well, haman dista (durmush), frying pan, measuring weight, nut and bolt etc.

(a)



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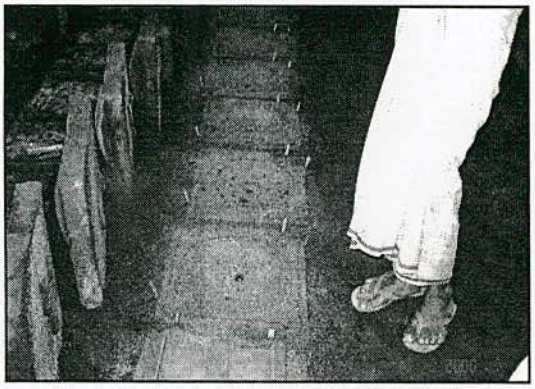

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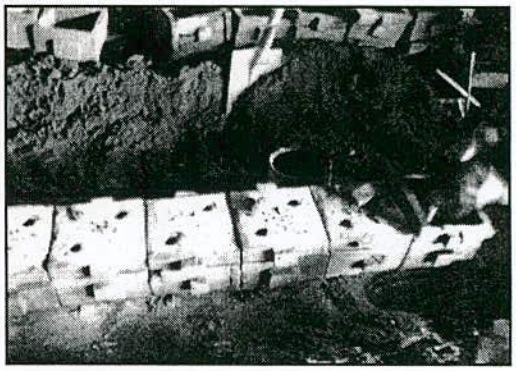


(d)

(e)

(f)

Figure 5.13 Iron Recycling in Universal Steel Foundation (a) Scrap Iron (b) Furnace (c)Die (d) Die casting (e) Finishing (f) Product (Frying Pan)

5.2.3.4 Animal Bone Recycling Industry

Animal bone contains horns, teeth, bone, hoop etc. All these types of bones are collected not only from Khulna but also Jessore, Kushtia, Chuadanga, Jhinaidah etc. The amount of bone varies from season to season. Highest quantity of bone is collected in winter season and lowest amount is collected in rainy season due to foul odor. The various steps of bone recycling are shown in Figure 5.14

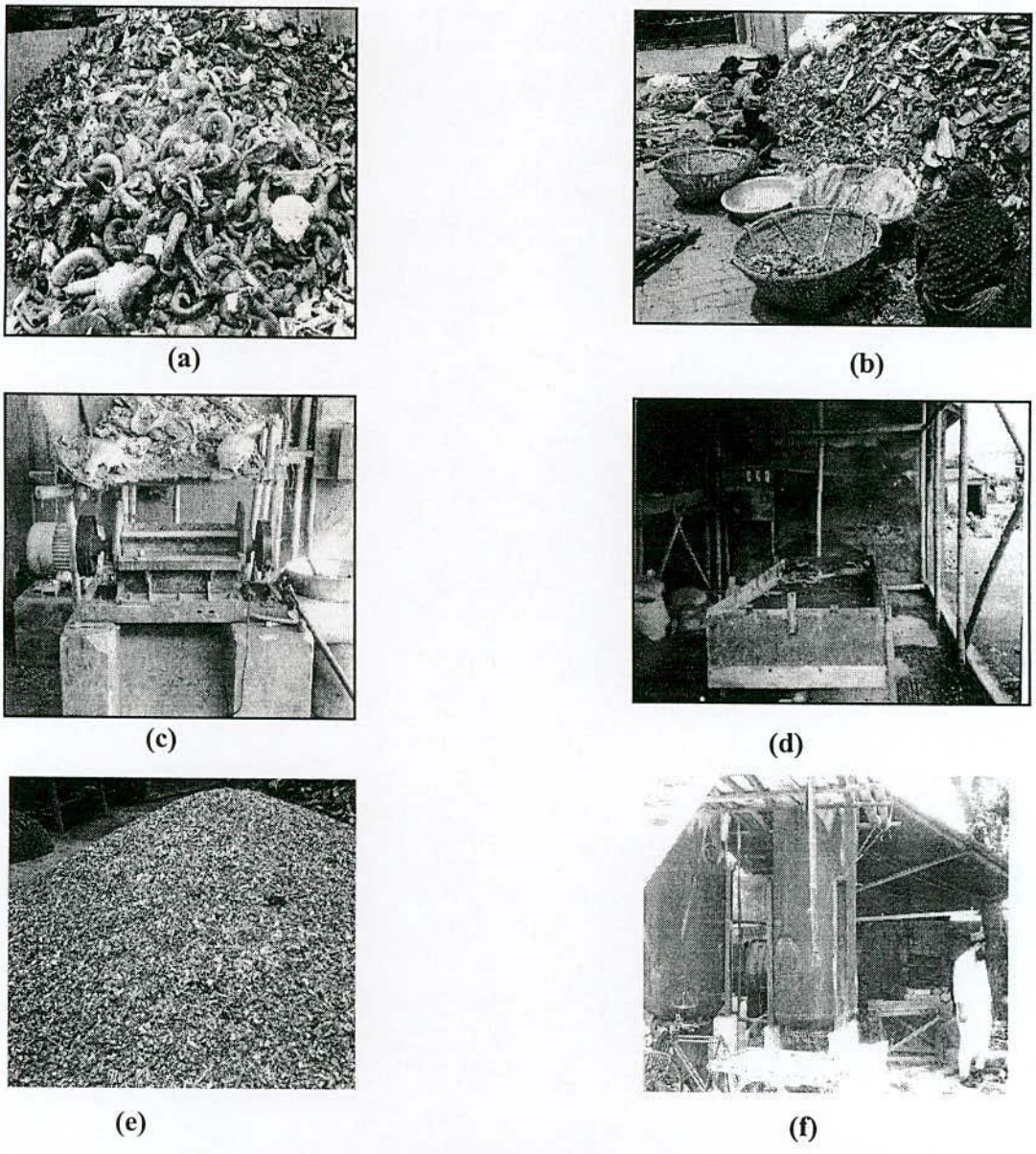


Figure 5.14 Animal Bone Recycling in Sattar Bone Mill (a) Animal Bone (b) Sorting (c) Grinding (d) Straining (e) Bone powder after straining (f) Heating Chamber

The collected animal bones are sorted on the basis of items such as horns and heads, bones of legs etc. Then the sorted bones are grinded by machine. After grinding powder is produced through straining and sent to other industries to Dhaka and European countries as raw material. Some portions of grinded bone are used to produce gelatin by heating in a closed chamber. This gelatin is sent to Medicine Company in Dhaka to make cap of capsule, babies' food etc. From animal bone varieties of products are produced such as button, comb, organic fertilizer etc. The various steps of bone recycling are shown in Figure 5.15.

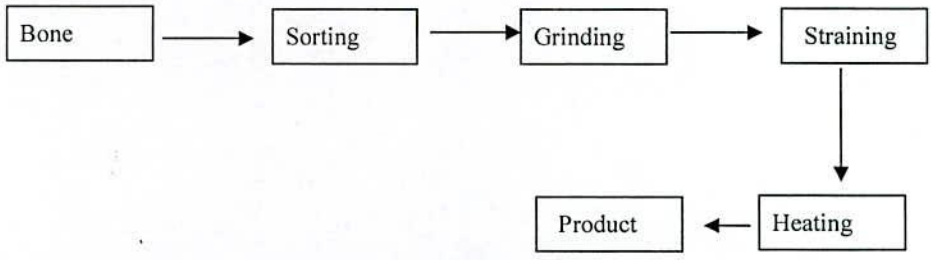


Figure 5.15 Typical flow diagram for the animal bone recycling industry

5.2.3.5 Tyre (Rubber) Recycling Industry

All types of tyre such as track, bus, and motor cycle tyre are recycled by tyre recycling industries in Khalishpur. Owners give these old tyres to recycling industry to convert into new recycled tyres. Recycling is done by several steps (Figure 5.16). These steps are as follows:

Cutting: Old tyres are cut into regular shapes by mechanical cutter

Levelling: After cutting the old tyre is pasted by rubber manually with help of glue.

Heating: There is a heating chamber (boiler) to heat the old tyre pasted with rubber.

Moulding: Now applying heat and pressure mechanically new tyre is produced by molding

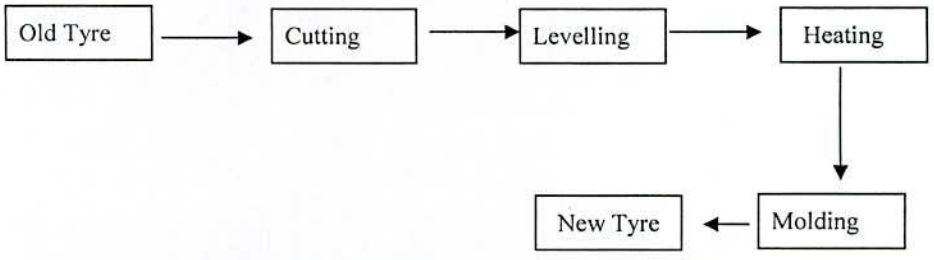
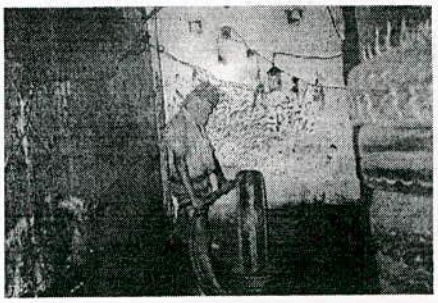
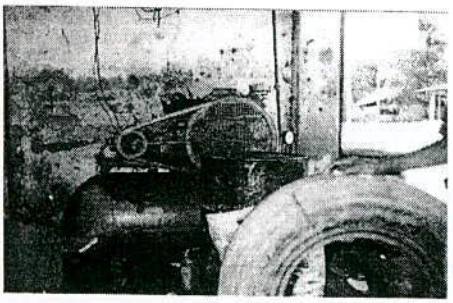


Figure 5.16 Typical flow diagram for the tyre recycling industry



(a)



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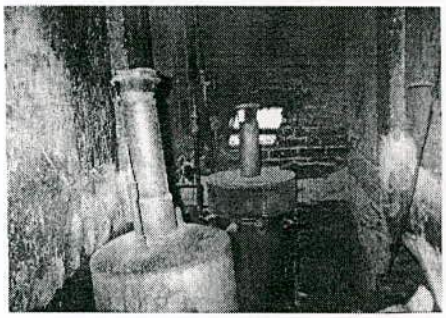

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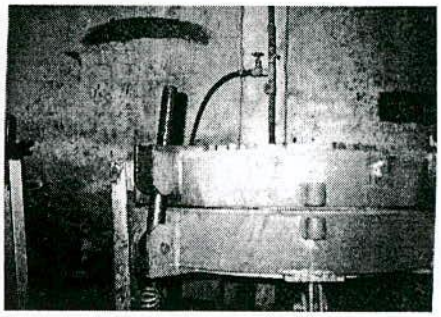


(d)

Figure 5.17 Tyre Recycling in Mitali Tyre Industry (a) Cutting (b) Levelling(c)Heating chamber (d) Moulding

5.3 Measures of Recycling Performance

Various measures of recycling performance are calculated and described below

5.3.1 Capture Rate

The term capture rate (also referred to as the source recovery factor) denotes the weight percent of an eligible material in the total solid waste stream actually separated for recycling as described in article 2.9.1. The capture rates for various RSW shown in Table 5.9.

Table 5.9 Capture rate of different RSW

RSW	Capture rate
Glass	0.81
Paper	2.45
Plastic	0.93
Metal	2.0
Bone	0.04

Capture rates are calculated by dividing the weight of each RSW separated at SRD by the weight of total solid waste. It is expressed in percent.

5.3.2 Participation Rate

The participation rate denotes the percent of households that regularly separate recyclables as described in article 2.9.2. From the household survey (Table B.9) results can be shown in percentage in Figure 5.18

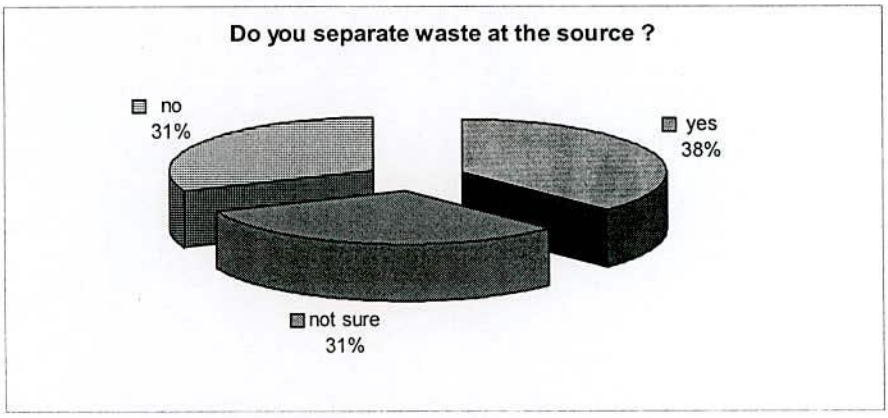


Figure 5.18 House hold survey on separation of recyclable at source

From the figure 5.18 it is seen that 38% household answered with yes option to separate RSW at the source. Therefore the participation rate is 38%.

5.3.3 Recycling Rate

The term recycling rate is sometimes used to denote the quantity of recyclables collected per household per unit of time as described in article 2.9.3. From household survey (Table B.8) it is found that the RSW collected per household of 5 members is 190 gm/day. Therefore the recycling rate is 38 gm/residence. day.

5.3.4 Diversion Rate

The diversion rate is calculated by dividing the weight of solid waste that is recycled (37.23 tons/day as shown in Table 5.6) and composted (According to KCC , 2005 composting in

Khulna is 5 tones/day) by the weight of total solid waste (520 tones/day) and expressed in percent. The diversion rate for solid waste of Khulna is 12.3%

5.4 Recycling Pattern

From the survey it is clear that it is the private sector that is responsible in recycling of solid waste in Khulna. The waste collectors groups from private sector are playing a prominent role in collection of recyclables as a main source of income. All of the buyers of RSW are from private sector and only a few formal manufacturers are involved in using RSW as raw material. There are several stages of waste recycling in Khulna city that are described below:

5.4.1 Stage One

The primary source (households, industries etc) generates wastes. Some portion of the wastes has economic value such as paper, glass, tin cans, iron and old aluminum utensils. These are separated for the purpose of sale to the feriwalas (house-to-house waste collector). Other portion then goes to waste bins, drains, roadsides and finally to ditches and dumping site.

5.4.2 Stage Two

At the lowest stratum of the recycling chain are the waste bin collectors (tokai). They are visible in every community of the city and come from nearby slums and squatter settlements. It is estimated that at present 1312 tokais are working in KCC area (Table 5.1)

5.4.3 Stage Three

Feriwalas are playing a very important role in the recycling process. They are the buyers of separated recyclable items stored for selling at the primary source (Figure 5.19). This study reveals that there are 695 feriwalas involved in the chain of recycling network of Khulna (Table 5.1). This estimate has been based on the information provided to by the small dealers, feriwalas and brokers. A feriwala carries a cane basket of round shape or a van. The type of

goods he deals totally depends on the market situation. The products he trade are normally separated at source and not contaminated by mixing with garbage contrary to the tokais.

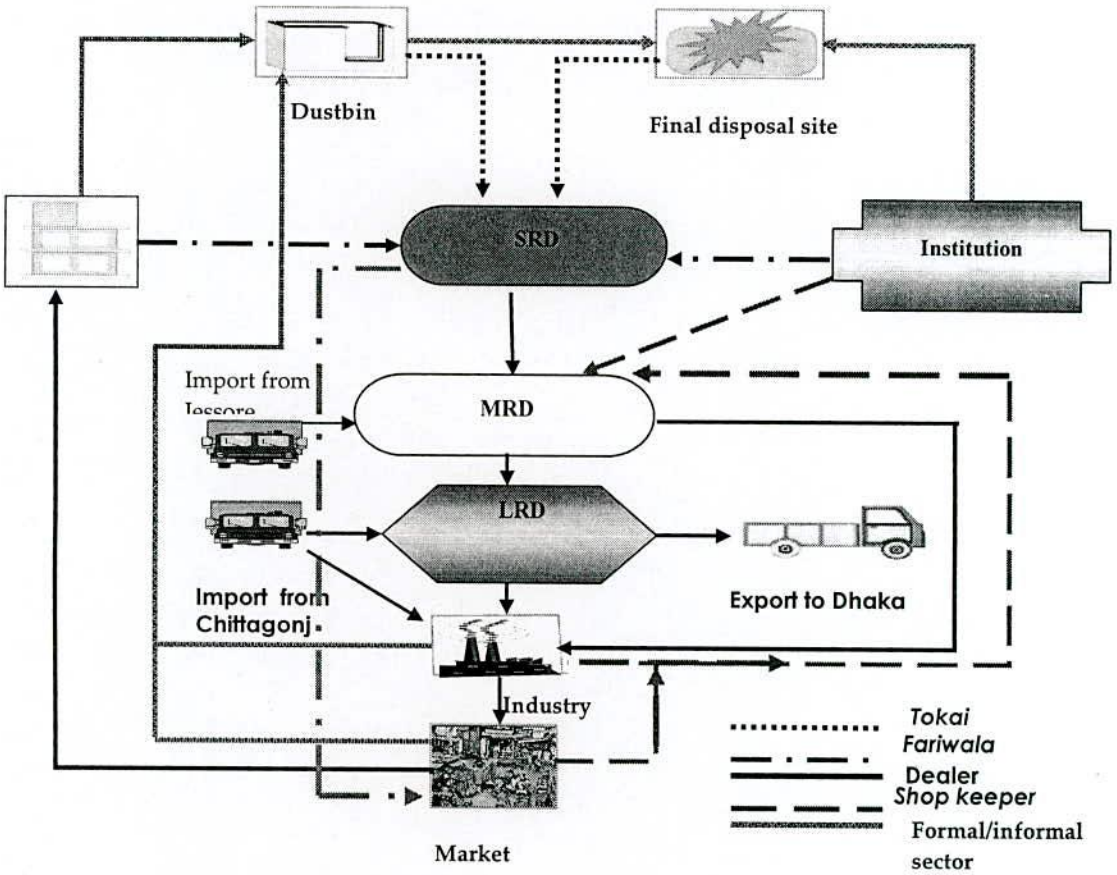


Figure 5.19 Recyclable Solid Waste (RSW) trade chain in Khulna

They purchase materials include bottles, broken glasses, tin cans, containers, newspaper, magazines, aluminum utensils, construction waste (construction rod, sanitary fittings etc.) in exchange of money, daily necessaries (vegetables, new plastic bottles etc) or sweets.

5.4.4 Stage Four

The small recyclable dealer (SRD) purchase waste materials from tokais and feriwalas in exchange of money. Most of the SRDs sort, clean and sell the recovered materials to medium recyclable dealers (MRDs). There are more than 277 SRDs in Khulna according to survey as presented in Table 5.4. They accept all types of waste from tokais and feriwalas and pay them accordingly. On average, they have 5 to 6 members of tokais and feriwalas attached to them.

5.4.5 Stage Five

The medium recyclable dealers (MRDs) then purchase particular kinds of waste from SRDs. The medium dealers usually deals in more than two kinds of specific wastes and passes these recyclables to the large recyclable dealers that essentially specialize in specific wastes. There are about 140 medium recyclable dealers in Khulna as shown in Table 5.4. They employ 5 to 7 people to segregate the waste.

5.4.6 Stage Six

Most of the Large Recycling Dealers (LRDs) buy their raw materials from the MRD and the brokers. In KCC area there are about 33 LRDs (Table 5.4). They receive their supply from all over Khulna and also from Chittagong. Most of the LRDs employ 6 to 10 people to sort, clean and sell the recovered materials to industries both in the formal and the private sectors. They do not buy directly from the waste collectors. One of the important reasons for this is the variable quality and small quantity.

5.4.7 Stage Seven

Final destination of the materials collected by different actors starting from from feriwalas, tokais comes to recycling industries (RI) through a chain of dealers like SRD, MRD, LRD and brokers. Trade between LRDs and RIs is more formal than the existing relationship among the SRDs and tokais. Some time LRDs use their own transport. It may be a tricycle (rickshaw van) or open truck. The price of these materials varies with the supply and demand of the market.

This private sector as described above comprises a chain constituted by waste collectors (Feriwala and Tokai), recyclable dealers (small, medium and large recyclable dealers) and industries at the top. At the lowest stratum of the recycling chain are the tokais and feriwalas as shown in Figure 5.20.

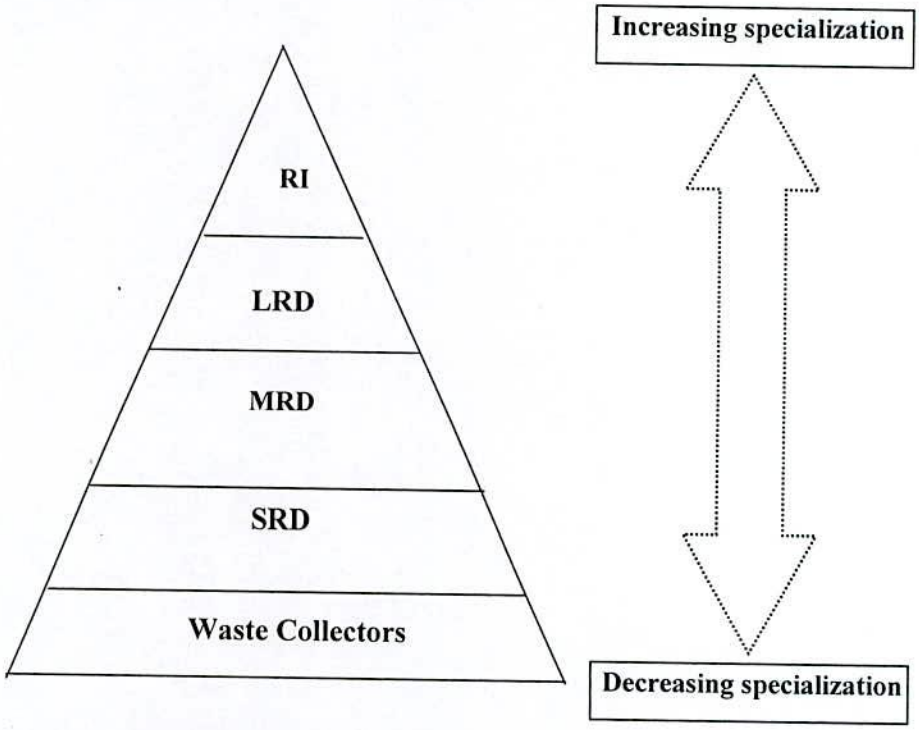


Figure 5.20 Hierarchy of solid waste recycling varies according to numbers

It has a hierarchical structure, with increasing specialization and decreasing numbers as we move upwards (Figure 5.20). At every stage waste is stored more specifically and in bulk, to assort the most valuable component

5.5 Discussion

5.5.1 Variation in Percentages of Recycling

The estimated quantities of RSW recycled by waste collectors in Khulna are 34 tones/day (Article 5.2.1.5). The amounts of RSW collected by SRDs are 32.46 tones per day (Table 5.5.) The amount of RSW collected by MRDs are 37.23 tones / day (Table 5.6). The amounts of RSW collected by LRDs are 45.72 tones/day (Table 5.7). Finally the amounts of RSW recycled by the RIs are 60.19 tones/day (table 5.8). This can be explained by the fact that the

SRDs collect waste only from Khulna and through waste collectors. The MRDs purchase RSW from all SRDs and occasionally from feriwalas and brokers of Khulna and nearby district like Jessore. So the amounts collection of MRDs are higher than that of SRDs. However, the LRDs collected the RSW from MRDs of all over the Khulna city and outside (mainly Chittagonj) of Khulna by trucks. Therefore, their quantity is much higher than that of any other group. They also sell some sort of processed RSW (such as glass, iron) to industries and markets outside Khulna. They do so because all types of recycling industries are not available in Khulna. For example, the collected glass contains broken glass and bottle. Almost all collected glass can be used to produce new glass containers and bottles. As there is no glass recycling industry in Khulna city the total portion of collected glass are sent to Dhaka. Another reason for sending waste outside Khulna is for getting more benefit. The RIs on the other hand purchase RSW from LRDs sometimes through brokers and sometimes through the shopkeepers by using trucks. The mass balance for present recycling pattern is shown in figure 5.21.

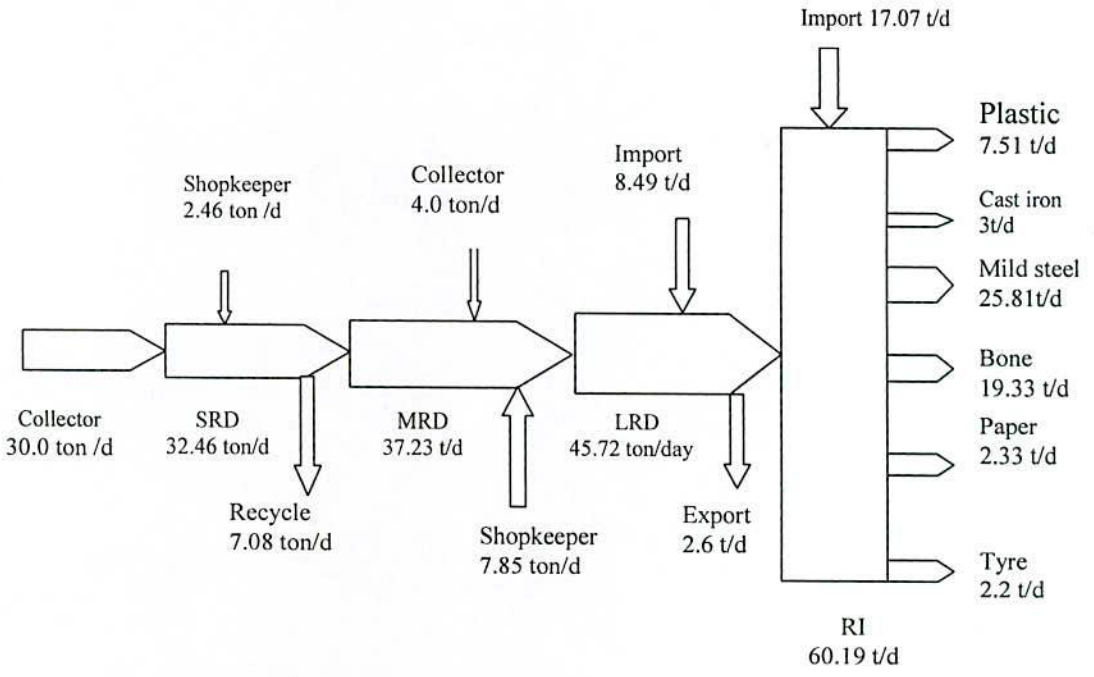


Figure 5.21 Mass balance for present recycling activities in Khulna

From the mass balance it can be seen that at MRD almost all of the RSW are come from different sources of Khulna. Therefore it is reasonable to estimate the quantity (37.23 tons/day) of MRD as the total recycling of RSW of Khulna. This is equal to 7.2% of generated waste (520 tons/day as shown in article 4.2); 53.2% of RSW (70 tons/day, as

shown in article 4.3) and 84.6 % of readily RSW (44 tons/day, as shown in article 4.3). However, the RIs are recycling 60.19 tones/ day which shows that if all the recyclables (70 tones/day) of Khulna are transported to RIs they can recycle (60.19/70*100) =86% of the RSW. But there is a lack of organizing this private activity. So the RIs often fall in short of RSW supply from local LRDs. That is why they import RSW as raw material from outside Khulna. From the interview with industry workers it is found that the capacity of production is more than present data. They are often face problems by lack of raw material supply and shortage of money.

The study shows that (Figure 5.22) among the recyclable dealers paper (39%), iron (32%) and plastic (15%) are recycled most by the SRDs whereas Glass (13%) and bone (1%) are recycled least. This can be explained by the fact that paper and plastic materials are mostly found at the collection points (house hold, waste bin, dumping site, road sides etc) of waste collectors (tokai). So the waste collectors (feriwala) easily collect these light materials and sell to the SRDs. Iron is also separated at the household and industries for sell and can be easily collected by SRDs.

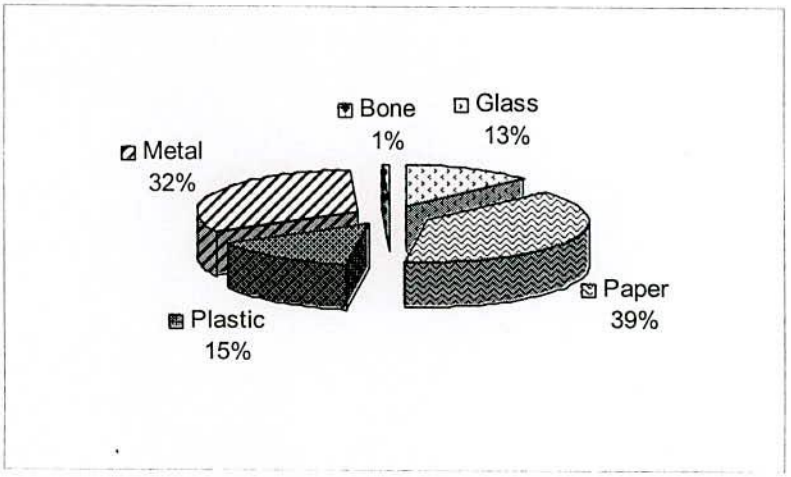


Figure 5.22 Recycling percentage by SRDs

However the case is different for MRDs who collect 41% of metal, the highest percentage of their collection. This can be explained by the fact that among the RSW metal especially iron is relatively costly material. Generally people do not through it to the waste bin. Besides that the main sources of metal (scrap iron) are industries, construction and maintenance projects etc. The MRDs generally contact directly or through brokers with the owner of scrap iron and

collect it by using trucks. So the waste collectors do not find much iron to supply iron to the SRDs. On the other hand paper reduces to only 15% in MRDs (Fig 5.23) This can be explained by the fact that a large amount of paper is recycled by the SRDs by making packets for the grocers. So all the paper collected by the SRDs do not come to MRDs. Plastic (30%), glass (13%), bone (1%) remain almost same like SRDs.

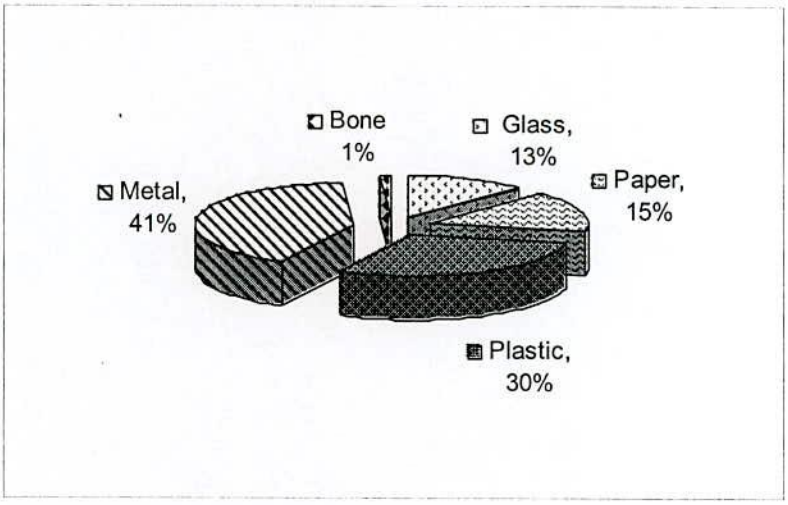


Figure 5.23 Recycling percentage by MRDs

In the case of LRD a new RSW (such as scrap tyre) appears by jumping the waste collector, SRDs and MRDs in the chain of recycling. The fact is that tyre is another valuable material. The owner of car normally carries the tyre to the LRDs for resoling by paying money. Sometimes the LRDs purchase scrap tyres from garages of cars all over the city. In the case of LRDs the percentage of metal increases to 71% (figure 5.24). This can be explained by the fact that LRDs import metal (mainly iron) from the MRDs of Khulna as well as from outside Khulna. On the other hand the percentage of paper (7%), plastic(13%) and glass (6%) reduces because the LRDs sell these materials to Dhaka as raw material. So the percentages of bone collection of LRDs remain almost same like MRDs because LRDs buy directly from MRDs.

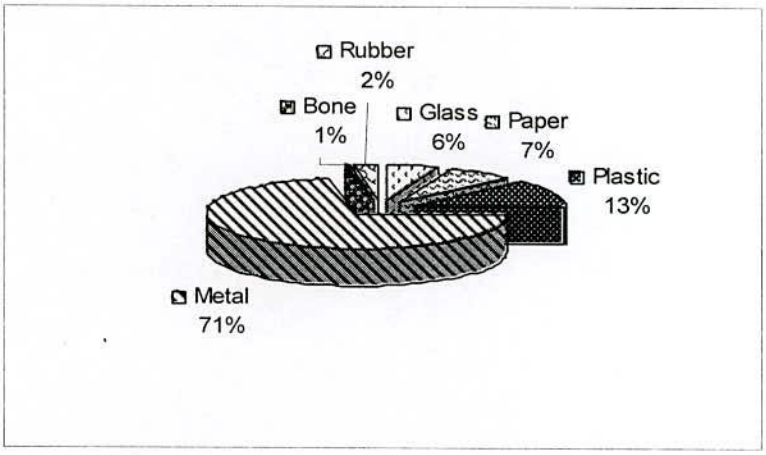


Figure 5.24 Recycling percentage by LRDs

In the case of RIs the percentage of bone (32%) and metal (48%) are higher than those of LRDs (figure 5.25). Because the bone recycling industries purchase bone from not only from all the LRDs of Khulna but also from different meat markets of Khulna, Jessore and Kustia. Among the metals only iron is recycled in Khulna. Aluminium, tin etc are transported to Dhaka by LRDs. The iron recycling industries purchase iron from LRDs of Khulna and from industries of Chittagong. Glass is transported to Dhaka by LRDs. Tyre Recycling Industries collect scrap tyre from LRDs and also directly from the owner of cars. Sometimes they purchase scrap tyre and sell new tyre. Sometimes the owner of cars comes to the industry and recycle scrap tyre to new tyre by paying money to the industry. In the market the price of a new tyre (Chinese tyre) of a bus or truck is 3,500 taka. However, the price of the recycled tyre of same size is 3,000 taka. So there is a competition between new tyre and recycled tyre.

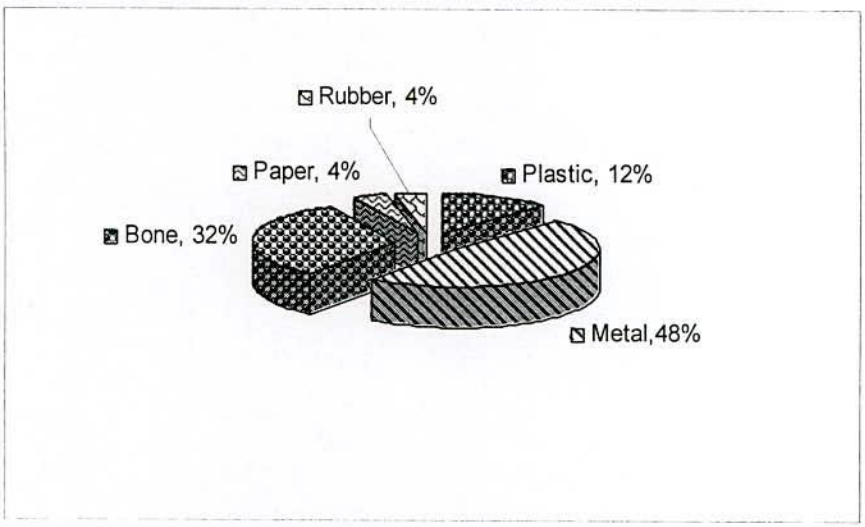


Figure 5.25 Recycling percentage by RIs

5.5.2 Clinical Waste Recycling

Recently a NGO named Prodipon collect clinical wastes from different hospitals and clinics of Khulna. They use the process incineration for management of sharp needle, syringe etc. They recycle the plastic bags etc.

5.5.3 Difficulties Encountered During Field Survey

The difficulties faced in this research are mainly acquiring all relevant data due to confidential nature of data. Repeated attempts were made to gather information from different recycling industries and dealers. Some of them contacted, however, were not prepared to reply to interview questions. Some of the recyclable dealers who initially accepted an interview subsequently failed to keep their promise. Recycling dealers did not like to give actual selling price and buying price and the actual amount of recycled product to avoid income tax.

CHAPTER SIX

INCOME GENERATION FROM RECYCLABLE SOLID WASTE

6.1 Market Price Mechanism

The price of a particular item of RSW is governed by the way the recycle market operates. The deciding factor is usually the current demand for the material and the inflow of collected material into the market.

- If the material is in excess, then the RIs decide the price.
- If the material is scarce, then the dealers dictate the price.
- In a neutral situation, market fixes the price depending on demand and supply.
- In some cases (for example tyre), the price of the new material affects the pricing of the recycled material. If the new material and waste material have same or nearly the same prices, then the face value of that particular recycled material is bound to fall in comparison to the new material. In contrast, if the new material witnesses a price rise, then often the recycled material prices also rise. This price rise of a recycled product however, may not be proportional to the price rise of new material.
- Periodic fluctuation in the prices is also observed. Some of the LRDs, who have surplus holding and storage capacities to store the waste, wait till the demand rises and hedge market prices.

6.2 Value Addition to the RSW

The item- wise waste prices and their appreciation in the waste market is presented in Table 6.1. The value added in the waste trade chain from the SRD level to RI level varies from 23 % to 100 % depending on the recycling potential of the material, its ease of availability and the demand in the market. From Table 6.1, it is evident that the highest value addition occurs for PET bottles, which have a long life and are readily recyclable and reusable. On the other hand iron obtains the highest revenues to the dealers because of their low prevalence in the waste (Metal and tins 1.1% as shown in Table 4.1 A) and due to the high market cost of iron.

Table 6.1 Prices of RSW at different recycling levels

RSW		Price at SRD (Tk/Kg)	Price at MRD (Tk/Kg)	Price at LRD (Tk/Kg)	Price at RI (Tk/Kg)	Value added in the process
Paper	white	10.00	12.00	14.00	-	-
	mixed shredded paper	6.00	8.00	9.00	10.00	67%
	cartons and brown packing papers	5.00	6.50	8.00	9.00	80%
Glass	Broken glass	0.50	0.75	1.00	-	-
	Bottles	1.00	1.25	1.50	-	-
Plastic	Hard plastic(shampoo bottles etc)	22.00	23.00	25.00	27.00	23%
	PET bottles (mineral water bottles)	5.00	8.00	9.50	10.00	100%
Iron		23.00	24.00	26.00	30.00	30%
Bone		3.00	3.50	4.00	5.00	67%

6.3 Organizing The Sector

Currently the waste collectors often take of the task recycling in the absence of alternative employment. The working conditions are unhygienic and security equipment such as boots and gloves are never worn. The chances of transmission of infections are therefore high. Once the waste collectors are sick, they suffer from the risk of loosing the meager earnings in the absence of medical facilities. Besides, the work has associated insecurities: for example, in the rainy season nothing can be collected for days, and this means economic hardships.

Presently, the recycling activity is completely private. By organizing and formalizing the activity the work can be recognized as an employment (hence is subject to labor laws and entitlement to medical facilities). Therefore organized recycling may be a way out for the alleviation of the living conditions of the waste collectors. It was with this view that three approaches are proposed and are evaluated for the feasibility of formalization of the private recycling sector by the authority or KCC.

6.3.1 Recycling Approach-A: Regularize the services of all waste collectors. Approach A is based upon the basic concept of rehabilitation of existing waste collectors in Khulna and organizing the waste collector by transforming the waste collectors into a scientific sorting and recycling of the waste. Following are the major assumptions of the approach:

1. All the waste collectors would be rehabilitated. The KCC would take over the unorganized trade and provides employment to the poor waste collectors.
2. The recyclable dealers are likely to find alternative employment at their own, due to greater specialized skills and better financial status.
3. Existing all the waste collectors would participate in the organized activity
4. The wage to be paid to an employee is Tk. 120 per day. This minimum wages is primarily applicable to workers in the unorganized sector.
5. Gross profits earned from the waste are based upon the value of the waste recovered (34 tones) by the waste collectors. To estimate the gross profit earned from the above material, an analysis is done as exhibited in Table 6.2. The calculations have been performed using the prices of the various materials at the level of SRD. This is justified as LRDs often hoard the waste creating artificial scarcity in the market and cause the waste prices to fluctuate. The total number of SRDs in Khulna is 277.
6. The other overheads, interviews with KCC officials revealed it, such as office charges, supervising charges, storage and transportation of waste, and miscellaneous overheads, would account for additional charges to the tune of 30% of the wages.

Net profit = total value of the recycled waste - expenditure incurred by the KCC

= (gross profit earned per day x number of SRDs) - (number of waste collector x average daily wages +overhead charges)

= [282.50(Tk./day/dealer) x 277(number of SRDs)] – [2000(number of waste collectors) x 120(Tk. /day) +2000(number of waste collectors) x 120 Tk/day) x 0.30(percent fraction)]

=78,252.50 Tk. per day – Tk. 3, 12,000 per day = (-) Tk. 2, 33,747.50 per day

Net loss = Tk. 8, 09, 37,837.50 per year

This obviously would be unacceptable to the KCC as it would result in a loss-making proposition for the KCC.

Table 6.2 Gross profits earned at the small recycling dealer level

Recyclable material	Mean profit at small shop (Tk./kg)	Amount traded per day (kg)	Profit earned per dealer Tk/day
Paper	2	32	64.00
Plastic (hard)	6	20	120.00
Plastic (soft)	3	10	30.00
Glass	0.5	13	6.50
Animal Bone	2	3	6.00
Metal	4	14	56.00
Gross profit earned per day (Tk)			282.50

6.3.2 Recycling Approach B: Regularize a few waste collectors and equip them with tricycles. In this approach, a few waste collectors from the private sector could be employed and provided with tricycles to enhance their productivity. Following are the major assumption of this approach:

1. The waste collectors may be provided with tricycles to increase their efficiencies.
2. Each tricycle costs TK. 9,500
3. The maximum collection capacity of tricycle driven by men is as found from field surveys is 65 kg/day. This implies that 523 tricycles will have to be brought and an equal number of waste collectors can be employed.
4. Assume 30% overheads over the salary component and accounting for a depreciation period of 15 years (considering the life time of a tricycle is 15 years)

Net profit/loss = total value of the recycled waste- expenditure incurred by the KCC

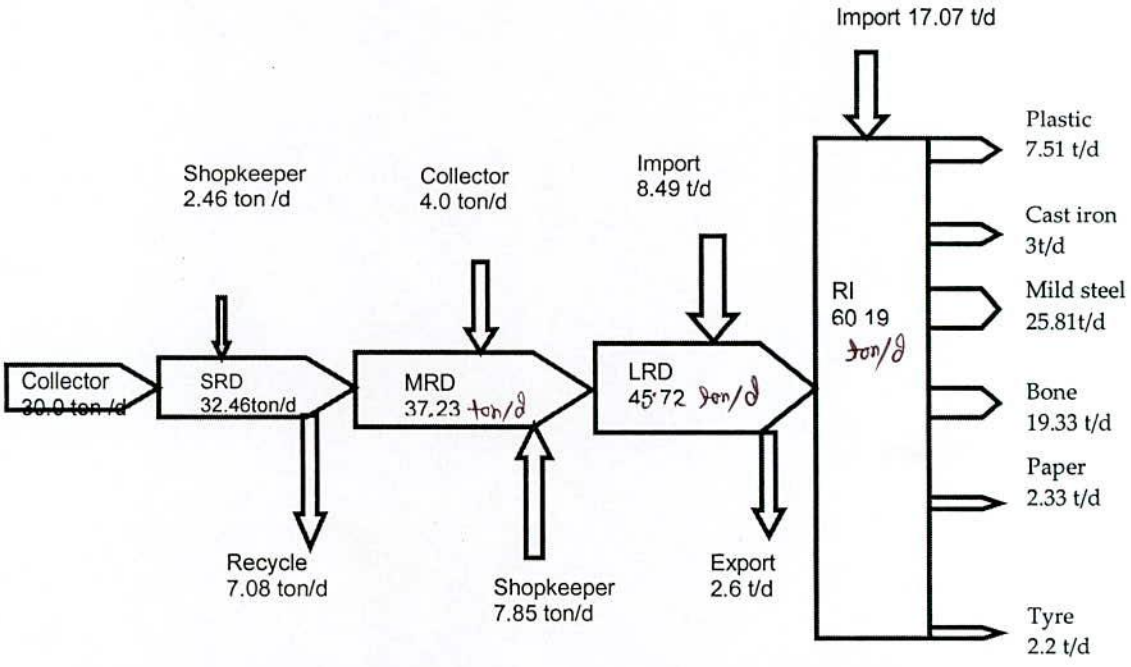
= (gross profits earned x number of small recycling shops) - (wages + one time investment to buy tricycles/15 + 30% overheads over salary component)

= 282.50(Tk/day) x 277(number of SRD) x 365(days/year) - [523(number of waste collectors) x 120(Tk/day) x 365(days/year) + 523(number of tricycles) x 9,500(Tk/tricycle)/15(years) + 0.30(percent fraction) x 523(number of waste collectors) x 120(Tk/day)]

= Tk 53, 04,701.17 per year

This proposal seems economically sustainable, as recovered costs of the recycled waste would far exceed expenses. However, this proposal has the obvious shortcoming of seeing 1477 waste collectors loose their daily employment. Finding alternative employment for

these left-outs would be an unenviable task. Also, this proposal would imply loss of job for children and women, since they do not use tricycles. The mass balance for the approach is shown in Figure 6.1.



`Figure 6.1 Schematic mass balance of recycling activities for the approach B

6.3.3 Recycling Approach C: Considering 50 tones/day collection of RSW (71% of total RSW) and regularize more waste collectors than that of approach B and equip them with tricycles. In this approach, more collectors from the private sector could be employed and provided with tricycles to enhance their productivity and the rest of the collectors could be employed in SRDs or MRDs to sort much waste. Following are the major assumption of this approach:

1. The waste collectors may be provided with tricycles to increase their efficiencies.
2. Each tricycle costs TK. 9,500
3. The collection capacity of tricycle for waste collector as found from the field surveys is 60 kg/day. This implies that 834 tricycles will have to be brought and an equal number of waste collectors can be employed.
4. The waste collectors could supply RSW to both the SRDs and MRDs at same price. The MRDs would not import RSW from outside Khulna.

5. Assume 30% overheads over the salary component and accounting for a depreciation period of 15 years (considering the life time of a tricycle is 15 years)

Net profit/loss = total value of the recycled waste- expenditure incurred by the KCC

= (gross profits earned x number of SRDs and MRDs) - (wages + one time investment to buy tricycles/15 + 30% overheads over salary component)

= 282.50(Tk/day) x 417(number of SRDs and MRDs) x 365(days/year) - [834(number of waste collectors) x 120(Tk/day) x 365(days/year) + 834(number of tricycles) x 9,500(Tk/tricycle)/15(years) + 0.30(percent fraction) x 834(number of waste collectors) x 120(Tk/day)]

= Tk 59, 10,488.50 per year

This proposal seems economically sustainable, as recovered costs of the recycled waste would far exceed expenses. The rest 1166 waste collectors will find alternative employment in the SRDs and MRDs to sort and process much waste. Therefore, this proposal would imply no loss of job for children and women, since they can easily sort RSW. The mass balance for the approach C is shown in Figure 6.2.

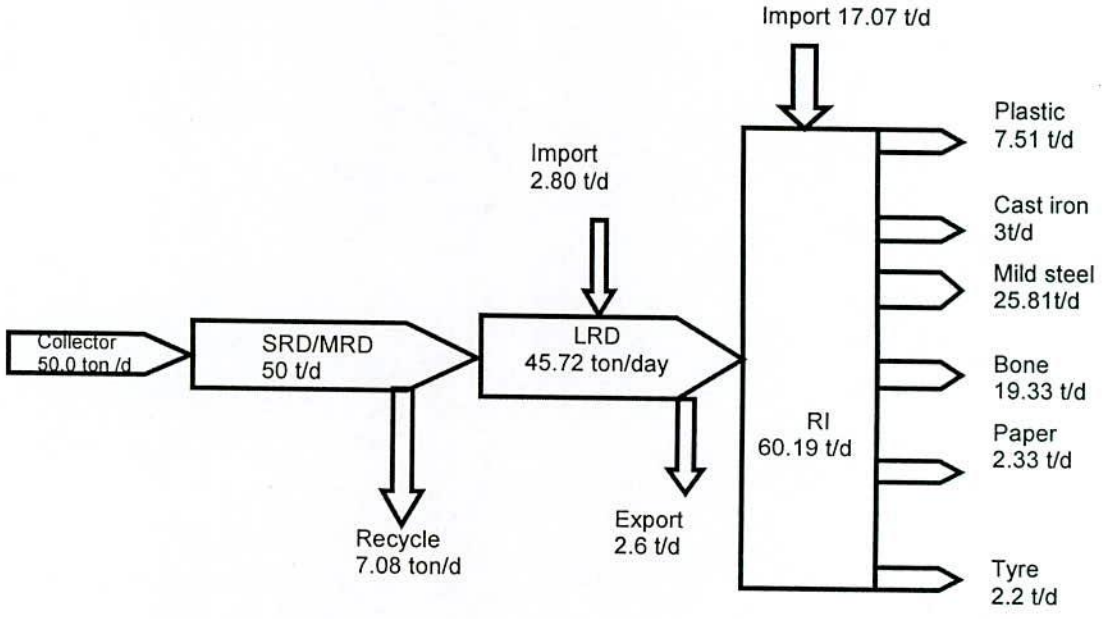


Figure 6.2 Schematic Mass balance of recycling activities for the approach C

6.4 Expenditure Savings by The Private Sector

Khulna City Corporation spent taka 2, 88, 03,000 during 1998-99 financial year for solid waste management and collects only 80 ton/day. Thus per ton expenditure per day for solid waste management in Khulna is Tk.986.40 (Enayetullah & Maqsood, 2000).

It may be seen from the article 5.5 that the private sector is responsible for removing 37.23 tons/day of solid waste per day in Khulna. So, it can be estimated that private sector is saving national revenue Tk. 1, 34, 04,140.28 per year.

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

6.1 General

The results obtained from this study the present waste recycling pattern, the percentage of recycling, involved people, impact of recycling and approaches for efficient recycling in Khulna city are summarized in this chapter.

6.2 Conclusions

During the study and formation of the approaches some consideration has been revealed. Following are the important conclusions that are drawn from the present study.

1. In Khulna, the recycling of solid waste is currently carried out by a private sector comprising waste collectors at the lowest end and a succession of dealers and industries. The process creates a market of recyclable solid waste, and value addition occurs for the various recyclables in the recycle stream. The existence of waste, mainly non-bio degradable and slowly biodegradable has opened quite an extensive possibility for various groups of the community to utilize it. All the buyers of the recyclable items are the private sector and only a few formal manufacturers are involved in using recyclable substance as raw material. Although recycling of solid waste is not included in the waste management policy of local authority, yet it has become a main source of income for several groups of the private sector. Private sector is saving revenue of Tk 1, 34, 04,140.28 per year by collecting solid waste 37.23 tons/day.

2. About 7.2% (37.23 tons/day) of total generated waste of Khulna are recycled by the private sector in the city. That is 53.2% of recyclable solid waste (70 tons/day) or 84.6 % of readily recyclable solid waste (44 tons/day) are recycled daily in Khulna. There are 450 recyclable dealers (277 SRD, 140 MRD and 33 LRD) and

most of the recycling dealers are situated in Shekhpara. More than 4,500 people are involved in the recycling chain of the city. Among the RSW paper, plastic, iron, animal bone, tyre/rubber, glass, aluminum, tin are processed or recycled by the dealers. They deal with 45.72 tons/day of RSW that come from all over Khulna city as well as from nearby districts of Khulna.

3. There are 31 recycling industries in Khulna and their quantity of recycling is 60.19 tones/day which include wastes from all over Khulna city and also outside from Khulna. Most of the recycling industries are located in Labachara and shiromoni areas. Paper, plastic, iron, animal bone, tyre/rubber recycling industries are in Khulna. They use locally available technology for recycling such as manual sorting and cleaning and mechanical heating/cooling, die casting or molding. The flow diagrams for various recycling industries are developed after extensive field survey. The recycling industries recycle 60.19 tons/day, which is equal to 86% of recyclable waste. However these include RSW from outside Khulna. There are no glass, aluminum, and tin recycling industries in Khulna. Therefore these RSW are transported to the industries outside the city mainly in Dhaka.

4. Among the RSW paper (39%), metal (32%) and plastic (15%) are recycled most whereas Glass (13%) and bone (1%) are recycled least by the SRDs. The case is different for MRDs who collect metal 41%, the highest percentage of their collection. On the other hand paper reduces to only 15% in MRDs . Plastic (30%), glass (13%), bone (1%) remain almost same like SRDs. In the case of LRD a new RSW (such as tyre) appears by jumping the waste collector, SRDs and MRDs in the chain of recycling. In the case of LRDs the percentage of metal increases to 71%. This can be explained by the fact that LRDs import metal (mainly iron) from the MRDs of Khulna as well as from outside Khulna. On the other hand the percentage of paper (7%), plastic (13%) and glass (6%) reduces. In the case of RIs the percentage of bone (36%) and metal (53%) are higher than those of LRDs. Among the metals only iron is recycled in Khulna. Aluminium, tin etc are transported to Dhaka by LRDs. The iron recycling industries purchase iron from LRDs of Khulna and from industries of Chittagong. Glass is transported to Dhaka by LRDs. Tyre Recycling Industries collect scrap tyre from LRDs and also directly from the owner of cars.

5. At present it is estimated that there are 2000 waste collectors (feriwala & tokai) are involved in recycling activities. They collect and sometimes process 34 tons/day that is equal to 49% of RSW. Currently, the waste collectors often take up the task in the absence of alternative employment. The working conditions are unhygienic and security equipment such as boots and gloves are never worn. The chances of transmission of infections are therefore high, and once sick, the waste collectors suffer from the risk of loosing the meager earnings in the absence of medical insurance and facilities. Besides, the work has associated insecurities: for example, in the rainy season nothing can be collected for days, and this means economic hardships.

6. Presently, the recycling activity is completely private. Organizing and formalizing the activity so that the work is recognized as an employment (and hence is subject to labor laws and entitlement to medical facilities) may be a way out for the alleviation of the living conditions of the waste collectors. It was with this view that three approaches are proposed and are evaluated for the feasibility of formalization of the private recycling sector. It is possible to organize the recycling activity, so that the waste collectors lead a secured and better life. Approach A is not financially viable. Approach B is financially viable with loss of jobs for women and children that have socio-economic impacts on the life of these waste collectors. Approach C is financially and socially viable and the private sector may also be encouraged to enter into the waste business by employing the waste collectors. In turn, the government may grant assured waste supplies to the private parties and can structure the waste markets so that the profits reach in a more sustained and assured manner to the waste collectors.

6.3 Recommendations

The following recommendations are suggested to improve the present condition and for future study:

1. The study on solid waste recycling provides insights into the profit of recyclables, but also reveals details on the plight of waste collectors. The waste collectors might ultimately need to be formally incorporated in waste management systems, both at local level systems, as well as in the larger urban framework. For this, there should be an accent on training them. Training would also be required on personal hygiene as most waste collectors are presently unaware of the consequences of garbage sorting without adopting safety guidelines. Measures need to be taken to protect livelihoods while working to improve both the efficiency and the living and working conditions of those involved.

2. Proper storage and source separation are the key factors for recovering useable and recyclable materials, and realizing reductions in the amounts of waste for disposal. Furthermore, the waste collectors may organize doorstep waste collection and this may provide them an opportunity to improve their working conditions, safety levels and incomes. The local bodies can further give incentives to NGOs in their effort of organizing waste collectors in primary collection of recyclable material and/or organic waste, and provide financial and logistic support to the extent possible. Future study may be conducted to develop models for efficient recycling by practicing source separation.

3. Future study may be conducted to arrange the positions of dealers/industries to optimize the traveling distances of RSW. In conducting efficient recycling distances of recycling dealers or industries from sources is a key factor that is not considered in this study.

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ANNEXURE A

A Sample Structured Question

Questionnaire Survey on Solid Waste Recycling Dealer

Name of Shop:..... Date: .....

Location:.....

Type of RSW		Amount of RSW collection (kg/day)	Price (Tk/kg)		Source and Destination of RSW	No. of Employee
			Buying	Selling		
Paper	Fresh					
	Scrap					
Glass	Bottle					
	Broken					
Plastic	Soft					
	Hard					
	Rubber/ Shoe					
Metal	Iron					
	Tin					
	Aluminum					
Bone						
Battery	Dry cell					
	Daniel cell					
Others						
Total						

Questionnaire Survey on Feriwala

Name of Fariwala:..... Date: .....

Working place:..... Mode of Transport.....

Living condition:.....

Type of RSW		Amount (kg/day)	Price (Tk/kg)		Source and Destination of RSW
			Buying	Selling	
Paper	Fresh				
	Scrap				
Glass	Bottle				
	Broken				
Plastic	Soft				
	Hard				
	Rubber				
Metal	Iron				
	Tin				
	Aluminum				
Bone					
Battery	Dry cell				
	Daniel cell				
Others					
Total					

Questionnaire Survey on Tokai

Name of Tokai:..... Date: .....

Location:.....

Item		Amount (kg/day)	Selling price (Kg/day)	Selling place	Living Condition
Paper	Scrap				
Glass	Bottle				
	Broken				
Plastic	Soft				
	Hard				
	Rubber/Shoe				
Metal	Iron				
	Tin				
Bone					
Battery					
Others					
Total					

Questionnaire Survey on Solid Waste Recycling Industry

Name of Industry:.....

Address:.....

---

1. What are the raw materials?
   Ans:
2. From where raw materials are collected?
   Ans:
3. How much raw materials are collected?
   Ans:
4. What are the buying prices of these materials?
   Ans:
5. After how many days these raw materials are being collected?
   Ans:
6. What products are being produced?
   Ans:
7. How many products are produced?
   Ans:
8. Where these products are being supplied?
   Ans:
9. What is the selling price of these products?
   Ans:
10. Where these products are being sold?
    Ans:
11. How many workers are involved with the production?
    Ans:
12. Are these raw materials being collected from Khulna?
    Ans:
13. If not, then why it is not being collected from Khulna?
    Ans:
14. What is the effectiveness of these products in general use?
    Ans:
15. What is the demand of these products in the market?
    Ans:
16. What amounts of raw materials are lost during the production?
    Ans:
17. How can the production be incre4ased?
    Ans:
18. What is the process of recycling of raw materials?
    Ans:

ANNEXURE B

TABLE B.1 DETAIL DATA OF SMALL RECYCLABLE DEALER

No. of SRD	Paper (kg/day)	Glass (kg/day)	Plastic (kg/day)	Metal (kg/day)	A. Bone (kg/day)	Others (kg/day)	Total (kg/day)	Location
1		89		57			146	Sheikhpara
2		87		50			137	"
3		90		30			120	"
4		98		80			178	"
5		110		23			133	"
6		90		25			115	"
7		56		60			116	"
8		78		50			128	"
9				67			67	"
10				87			87	"
11				34			34	"
12				54			54	"
13				67			67	"
14		90		85			175	"
15		100		25			125	"
16		65	73	34			172	"
17				55			55	"
18				67			67	"
19		98		83			181	"
20		87	40	67			194	"
21		76	30	55			161	"
22		95	20	90			205	"
23			10	34			44	"
24		78	34	35			147	"
25		98	65	34			197	"
26	150		34	54			238	"
27		98	24	34			156	"
28	100	78		45			223	"
29		98	24	70			192	"
30			10	57			67	"
31		100	56	55			211	"
32		67	67	45			179	"
33		98	45	45			188	"
34	29	56	56	90			231	"
35		15		35			50	"
36		89	68	0			157	"
37	70		60	40			170	"
38		38		56			94	"
39				40			40	"
40	22	90	23	25			160	"
41		0		30			30	"
42	20	60	40	34			154	"
43	25	67	10	60			162	"
44	35	80	50	25			190	"
45	30	110	22	40			202	"

No. of SRD	Paper (kg/day)	Glass (kg/day)	Plastic (kg/day)	Metal (kg/day)	A. Bone (kg/day)	Others (kg/day)	Total (kg/day)	Location
46	15	20	10	65			110	"
47	15	78	10	90			193	"
48		100	60	26			186	"
49	25	58	42	85			210	"
50	40	38	28	0			106	"
51		68		45			113	"
52		90		60			150	"
53	30	98	40	70			238	"
54		78		70			148	"
55	50	87		30			167	"
56				40			40	"
57	30	97	50	0			177	"
58		70	80				150	"
59	61	80					141	"
60	60	100					160	"
61	50	78					128	"
62	55	60		58			173	"
63	73	110	49	30			262	"
64	65	100	40	28			233	"
65	55	56	30				141	"
66	10	29	12	40			91	Fulbarigate
67	0	18	11	15			44	"
68	6	20	14	10			50	"
69	12	15	16	20			63	"
70	5	45	12	20			82	"
71	3	35	7	15		0	60	"
72	5		11	25			41	Dawlotpur
73	10	14	8	30	0		62	"
74	16	34	10	25	0		85	"
75	14	28	8	30	0	0	80	"
76	11	32	12	33	0		88	"
77	9	45	9	32	0		95	"
78	5	25	12	35	0	0	77	"
79		24	15	37			76	Moylapota
80	20	40	10	2			72	"
81	36	37	11	5			89	"
82	40	40	62	60			202	"
83	28	65	88	58			239	"
84	12	21	77	45		7	162	"
85	10	17	47	45			119	"
86	12	17	5	23			57	Sonadanga
87	6	20	5	20		3	54	"
88	11	25	4	22			62	"
89	8	23	9	24			64	"
90	8	21	7	30	0		66	"
91	9	20	6	25		3	63	"
92	18	20	10	30	0	10	88	Gollahmari
93	15	12	8	35			70	"
94	7	33	10	35	8		93	"

No. of SRD	Paper (kg/day)	Glass (kg/day)	Plastic (kg/day)	Metal (kg/day)	A. Bone (kg/day)	Others (kg/day)	Total (kg/day)	Location
95	16	15	8	20	0		59	Gollahmari
96	25	30	25	20			100	Dakbangla
97	35	45	25	45		7	157	"
98	12	55	26	36	8	4	141	"
99	8	15	18	25	8	5	79	"
100	15	30	25	55		6	131	"
101	25	65	13	35	20	5	163	"
102	41	8	10	17			76	2no. Castom
103	40	6	9	11			66	"
104	116	14	5	20			155	Fatema Sshool
105	140	15	12	20		4	191	"
106	165	4	5	15		4	193	"
107	176		5	15			196	"
108	120	8	10	20			158	"
109		5	1	5			11	Notunbazar
110	25	21	16	20			82	Nirala
111	3	8		2			13	"
112	25	20	18	20			83	"
113	22	20	20	56			118	Khalishpur
114	27	25	24	75	0		151	"
115	12	32	20	24	0	2	90	"
116	10	40	32	98		5	185	"
117	15	46	35	20			116	"
118	21	45	25	19		1	111	"
119	20	28	16	38			102	"
120	15	50	7	21		3	96	"
121	10	45	16	17		4	92	"
122	15	32	15	30			92	"
123	20	22	10	20			72	"
124	10	4	21	19			54	Farazipara
125	27	28	25	60			140	"
126	20	15	18	50	0	0		"

TABLE B.2 DETAIL DATA OF MEDIUM RECYCLABLE DEALER

No. of MRD	Glass (kg/day)	Paper (kg/day)	Plastic (kg/day)	Metal (kg/day)	A. Bone (kg/day)	Total (kg/day)	Location
1			135	195		330	Shekhpara
2	36	45		222		303	"
3		55	118	123		296	"
4	63	67	122			252	"
5	57		100	120		277	"
6		55	112	145		312	"
7		45		150		195	"
8	52		75	136		263	"
9		35		135		170	"
10	45		73	134		252	"
11		56		200		256	"
12	55		55	135		245	"
13		85	175			260	"
14	90		180			270	"
15	82	82	130			294	"
16	31	45	90	86		252	Khalishpur
17	41	52		158		251	"
18	31.5	56	34.5	149	15	286	"
19	35	55	118	30	13	251	"
20	55	74	86	85	10	310	Dakbangla
21	33	66	65	86		250	Dowlatpur
22	34.5	72	57.5	92		256	"
23	34	78	48	66	28	254	Gollamari
24	54.5	84	42	85		265.5	"
25	54	64	63	90.5	30	301.5	Nirala
26	28	65	32	106	35	266	kastom ghat

TABLE B.3 DETAIL DATA OF LARGE RECYCLABLE DEALER

No. of Whole sale Shop	Paper (kg/day)	Glass (kg/day)	Plastic (kg/day)	Metal (kg/day)	A. Bone (kg/day)	Others (kg/day)	Total (kg/day)	Location
1				6520			6520	Sheikhpara
2	1630						1630	"
3				2050			2050	"
4				3333			3333	"
5				6666			6666	"
6				500			500	"
7		800					800	"
8		2000					2000	"
9				600			600	"
10				410			410	"
11				550			550	"
12		15	100	1022			1137	Shere bangla
13	34	34	66	670			804	"
14	667						667	Gollahmari
15	500	120	190	45	45	6	906	Dakbangla
16	700	150	200	50	50	5	1155	"
17		215	105	270	5	2	597	Khalishpur

TABLE B.4 DETAIL DATA OF FARIWALA

No. of Fariwala	Glass (kg/day)	Paper (kg/day)	Plastic (kg/day)	Metal (kg/day)	A. Bone (kg/day)	Total	mode of transport
1(man)	1	6	4	1	0	12	manual
2(man)	0.5	8	2	2	3	15.5	manual
3(man)	0.5	9	3	3	4	19.5	manual
4(man)	2	5	3	2	1	13	manual
5(man)	3	12	9	7	2	33	Tricycle
6(man)	4	0	12	14	3	33	Tricycle
7(man)	0	14	14	8	0	36	Tricycle
8(man)	3	6	15	10	0	34	Tricycle
9(man)	5	0	14	12	3	34	Tricycle
10(man)	3	12	8	16	0	39	Tricycle
11(man)	5	6	7	15	5	38	Tricycle
12(man)	0	10	6	10	4	30	Tricycle
13(man)	6	10	10	5	3	34	Tricycle
14(man)	5	15	6	0	4	30	Tricycle
15(man)	4	16	6	15	0	41	Tricycle
16(man)	7	18	0	11	3	39	Tricycle
17(man)	6	16	3	8	0	33	Tricycle
18(man)	5	19	2	9	1	36	Tricycle
19(woman)	2	6	3	1	0	12	manual

TABLE B.5 DETAIL DATA OF TOKAI

Mode of transportation : Manual

No. of Tokai	Glass (kg/day)	Paper (kg/day)	Plastic (kg/day)	Metal (kg/day)	A. Bone (kg/day)	Total (kg/day)
1	1	4	3.5	0.5	1	10
2	1	5	1	1	1	9
3	0.5	6	2.5	0	0.5	9.5
4	1	7	1	1	1	11
5	0.5	5	2	1	1	9.5
6	0.5	5	1	0	1	7.5
7	0	6	1	1	2	10
8	0.5	7	1.5	0.5	1	10.5
9	1	6	1	0.5	2	10.5
10	0.5	4	3	0.5	0	8
11	0	5	2	1	1	9
12	0	6	1.5	1	1	9.5
13	1	4	2	2	2	11
14	1	0	2	1	2	6
15	0.5	0	2	3	1	6.5
16	1	5	0	1	0	7
17	0	6	1	2	0	9
18	1	5	0	2	1	9
19	1	7	0	2	2	12
20	1	6	1.5	1	2	11.5
21	0.5	8	0.5	1	1	11
22	1	6	1	0.5	1	9.5
23	0	5	2	1.5	0.5	9
24	0	8	1	1	1	11
25	0	6	1	2.5	1	10.5
26	0.5	7	0.5	2	0.5	10.5
27	1	8	1.5	1	1	12.5
28	1	9	2	0	1	13
29	0.5	5	2	2	1.5	11
30	0	6	2	0	1	9
31	0	9	3	0.5	1	13.5
32	0.5	6	2	0.5	0.5	9.5
33	0	6	1	0.5	0.5	8
34	0	7	2	1	1	11
35	0	10	1	0	1	12
36	0	11	2	0	0	13

TABLE B.6 EDUCATION, LIVING CONDITION , DAILY INCOME OF COLLECTORS

Sl no. of collectors	Education level	Living condition	No. of people sharing living	Rent (taka)/hut	Daily Income (taka)
1	Primary	Hut	4	300	25
2	Primary	Tin shed	5	325	30
3	illiterate	Hut	4	350	50
4	illiterate	Hut	4	350	45
5	illiterate	Tin shed	5	300	90
6	Primary	Hut	4	300	50
7	illiterate	Hut	4	350	120
8	illiterate	Tin shed	5	350	100
9	illiterate	Hut	4	400	40
10	Primary	Hut	4	350	80
11	illiterate	Hut	5	400	70
12	illiterate	Tin shed	4	350	130
13	illiterate	Tin shed	4	400	55
14	illiterate	Hut	5	350	67
15	illiterate	Hut	4	400	90
16	illiterate	Tin shed	4	350	95
17	illiterate	Hut	5	400	125
18	illiterate	Hut	4	350	25
19	illiterate	Tin shed	4	300	90
20	illiterate	Hut	5	300	120

TABLE B.7 BROKERS INVOLVED IN RECYCLING PROCESS

Areas in Khulna	Number of brokers
Shekhpara	200
Khalishpur	80
Labanchara	180
Daulatpur	45
Total	505

TABLE B.8 AVERAGE GENERATED WASTE OF A STANDARD FAMILY CONSISTING OF FIVE MEMBERS

Types of waste generated	Average quantity (gm/day)
Food & vegetables	1200
Plastic	50
Glass	35
Paper	80
Metal	25
Others	10

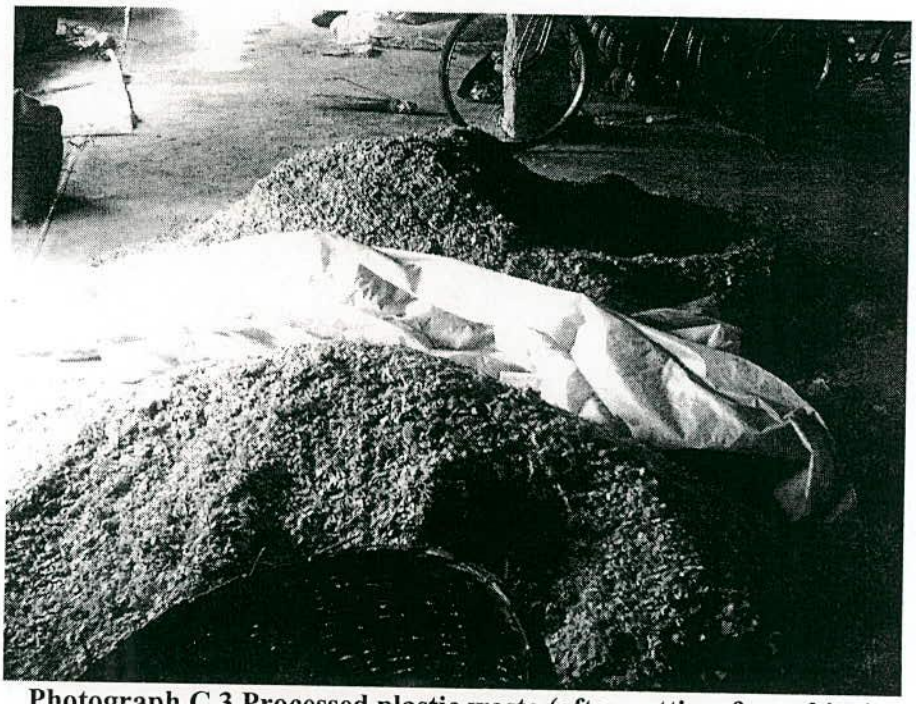
TABLE B.9 PEOPLE WILLINGNESS ABOUT RECYCLING

Question	Response among 16 families		
	Yes	No	Not Sure
Are you willing to use recycled products?	11	3	2
Do you practice source separation of RSW?	6	5	5
Do you see recycling is environmentally sound?	13	1	2
What type of waste do you separate?	paper, plastic bottles, broken glass, metal, tin etc.		

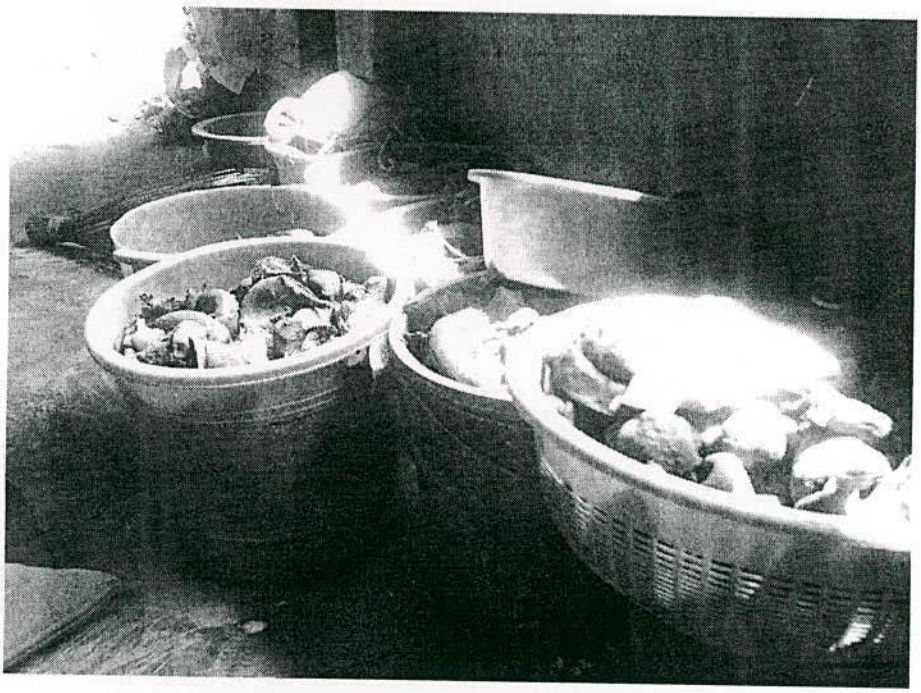
ANNEXURE C

Photograph C.1 Mixed plastic waste

Photograph C.2 Separated plastic waste



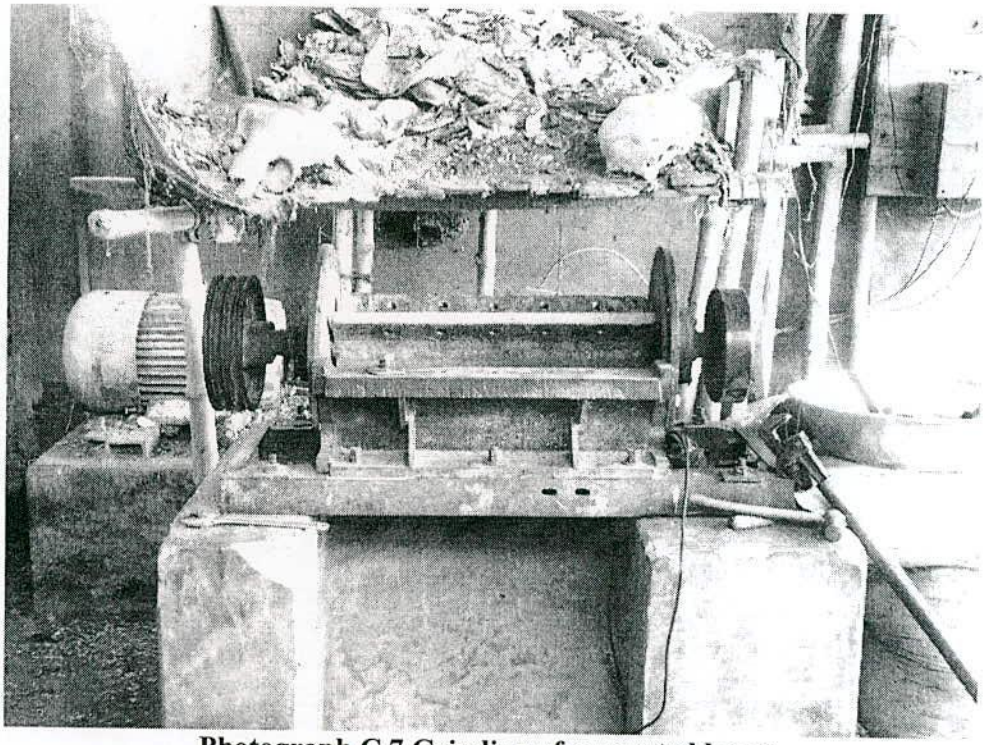
Photograph C.3 Processed plastic waste (after cutting & washing)



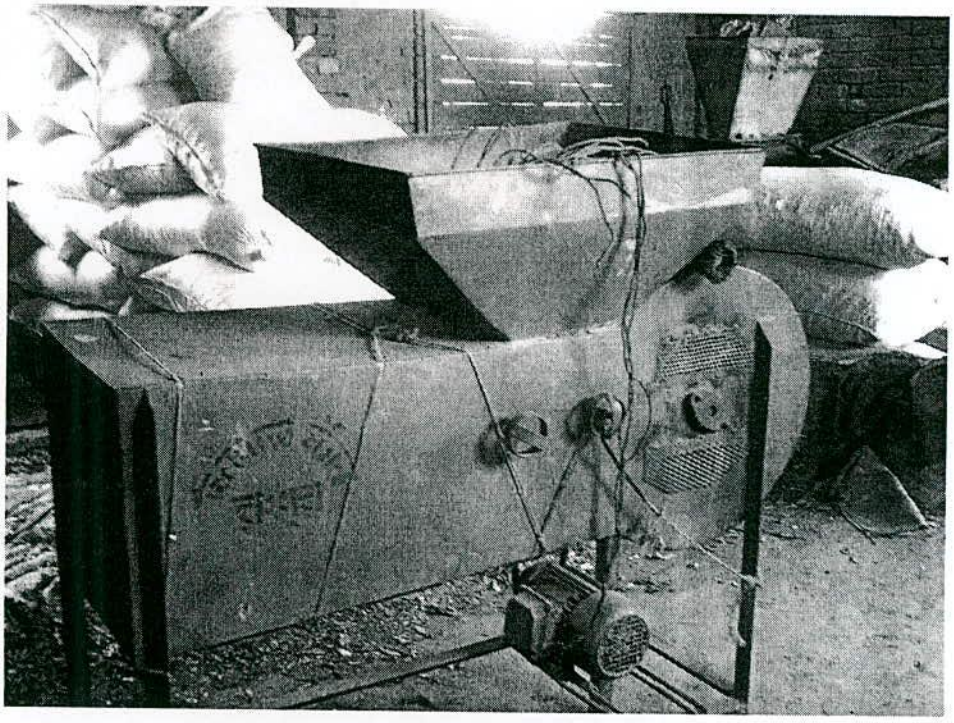
Photograph C.4 Processed plastic waste (after melting)

Photograph C.5 Recycled plastic product (water pot)

Photograph C.6 Separated bones (horns)



Photograph C.7 Grinding of separated bones



Photograph C.8 Processed bone (powder)