An Approach for the Selection and Evaluation of Integrated Municipal Solid Waste Management in Bangladesh

by

Md. Khaled Hassan Chowdhury

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering at the Department of Civil Engineering

Khulna University of Engineering & Technology
Khulna 920300, Bangladesh

November 2006

Declaration

This is to certify that the thesis work entitled "An Approach for the Selection and Evaluation of Integrated Municipal Solid Waste Management in Bangladesh" has been carried out by Md. Khaled Hassan Chowdhury 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.

Dr. Muhammed Alamgir
Professor

Md. Khaled Hassan Chowdhury
Roll No. 0101506

Approval

This is to certify that the thesis work submitted by Md. Khaled Hassan Chowdhury entitled as "An Approach for the Selection and Evaluation of Integrated Municipal Solid Waste Management in Bangladesh" has been approved by the board of examiners for the partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering, Khulna University of Engineering & Technology, Khulna, Bangladesh in November 2006.

BOARD OF EXAMINERS

1. ______________ 30.11.2006 Chairman (Supervisor)

   Dr. Muhammed Alamgir
   Professor
   Department of Civil Engineering
   Khulna University of Engineering & Technology, Khulna

2. ______________ Member

   Dr. Quazi Hamidul Bari
   Professor and Head
   Department of Civil Engineering
   Khulna University of Engineering & Technology, Khulna

3. ______________ Member

   Dr. Md. Rezaul Karim
   Professor
   Department of Civil Engineering
   Khulna University of Engineering & Technology, Khulna

4. ______________ Member (External)

   Dr. Md. Mujibur Rahman
   Professor
   Department of Civil Engineering
   Bangladesh University of Engineering & Technology
   Dhaka, Bangladesh

To

My beloved parents for their love

and

my dearest wife, for her continuous support and encouragement

ABSTRACT

Bangladesh, one of the Least Developed Asian Countries is facing very complicated situations for the management of vast quantities of municipal solid waste (MSW) generated by urban communities. Due to the absence of an integrated system there are many loop holes and constraints in the existing waste management practice, which ultimately fails to improve the overall system.

This study provides information about the present situation of MSW and its characteristics, management practices and limitations in the six city corporations of Bangladesh, namely Dhaka, Chittagong, Khulna, Rajshahi, Barisal and Sylhet. The key issues needs to be addressed for an efficient waste management system and the limitations of the present system are also identified and illustrated here explicitly. For an integrated management of MSW, the study discuss several options such as cost benefit analysis, life cycle analysis and multicriteria decision analysis (MCDA) and propose a spreadsheet tool for an integrated management system based on the MCDA. The tool is suggested for the verification of suitability and sustainability of the adopted approach. The proposed approach is based on series of spread sheets of waste system components such as contain & collect, sort & recovery, transfer & treat and dispose & make safe, and aspects of evaluation such as source & streams, cost & return, health & environment and community & structures. The spreadsheet can be used in two ways 'WasteCheck'—where the body of the table is used to highlight the most significant questions and 'WasteCase'—where the body of the table is used to highlight the most pertinent answers relating to the 'business and sustainability' justification. The selection and evaluation tools is then adopted theoretically for a case study city, Khulna, the third largest city of Bangladesh, to check its sustainability based on local needs and associated aspects. New terminology WastePoint for on-site disposal facility, WasteNode for waste transfer facility, StrategicSite for ultimate disposal facility is adopted in the study for better understanding and clarity. As the six study cities show a remarkable degree of similarity with respect to financial aspects, technical aspects and human resources development, the selection and evaluation approach can be easily extendable for other city corporations of Bangladesh as well.

CONTENTS

List of Tables

List of Figures

List of Boxes

List of Photographs

Abbreviations

ADB	:	Asian Development Bank
BBS	:	Bangladesh Bureau of Statistics
BCAS	:	Bangladesh Centre for Advanced Studies
BCC	:	Barisal City Corporation
BCSIR	:	Bangladesh Council of Scientific and Industrial Research
BUET	:	Bangladesh University of Engineering and Technology
CBO	:	Community Based Organization
CCC	:	Chittagong City Corporation
CDA	:	Chittagong Development Authority
CDS	:	Central Development Society
C/N	:	Carbon Nitrogen Ratio
DCC	:	Dhaka City Corporation
DMDP	:	Dhaka Metropolitan Development Program
DOE	:	Department of Environment
EPA	:	Environmental Protection Agency
EPI	:	Extensive Programme for Immunization
EPZ	:	Export Processing Zone

GOB	:	Government of Bangladesh
HII	:	Hospital Improvement Initiative
ISWM	:	Integrated Solid Wastes Management
IWT	:	Indonesian Windrow Technique
JICA	:	Japan International Cooperation Agency
KCC	:	Khulna City Corporation
KDA	:	Khulna Development Authority
KUET	:	Khulna University of Engineering & Technology
LDCs	:	Least Developed Countries
LDACs	:	Least Developed Asian Countries
MSW	:	Municipal Solid Waste
NGO	:	Non Governmental Organization
PRISM	:	Project in Agriculture, Rural Industry, Science and Medicine
RAJUK	:	Rajdhani Unnayan Kartipakkha
RCC	:	Rajshahi City Corporation
RDA	:	Rajshahi Development Authority
RUSTIC	:	Rural Unfortunates Safety Talisman Illumination Cottage
SDS	:	Secondary Disposal Site
SRDI	:	Soil Resource Development Institute
SWM	:	Solid Waste Management
Tk.	:	Taka (BDT)
UDS	:	Ultimate Disposal Site
UNEP	:	United Nations Environmental Programme
UNDP	:	United Nations Development Programme
WHO	:	World Health Organization

Units of Measurement

Btu	:	British Thermal Unit
gm	:	Gram
kg	:	Kilogram
km	:	Kilometer
km^2	:	Square Kilometer
Kg/m^3	:	Kilogram per Cubic Meter
KJ/kg	:	Kilojoule per Kilogram
kg/day	:	Kilogram per Day
kg/cap/day	:	Kilogram per Capita per Day
l/day	:	Liter per Day
mm	:	Millimeter
m	:	Meter
m^3	:	Cubic Meter
ml	:	Milliliter
mg	:	Milligram
mg/l	:	Milligram per liter
nm	:	Nanometer
ppm	:	Parts per million

CHAPTER ONE

INTRODUCTION

1.1 General

Solid wastes comprise all the wastes arising from human and animal activities that are normally solid and discarded as useless or unwanted. 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). Solid waste can be classified into different types according to sources such as municipal solid waste (MSW), industrial waste, agricultural waste, municipal sludges and others waste. MSW is normally assumed to include all the community wastes with the exception of industrial process wastes, agricultural solid wastes and sewage sludges.

The problem of municipal solid waste management (MSWM) has acquired an alarming dimension in the developing countries during the last few decades. The quantity of solid waste generated has increased significantly and its characteristics have changed as a result of the changes in the peoples' lifestyles due to swift industrialization and urbanization. Rapid population growth and increase of economic activities combined with a lack of training in modern solid waste management practices complicate the efforts to improve the solid waste service (ISWA & UNEP, 2002). Improvement of MSWM practices is a subject of concern for public health and environmental protection agencies in most developing countries. Compared to high income countries, the urban residents of developing countries produce less per-capita solid waste, but the capacity of the developing countries to collect, process, dispose or reuse it in a cost effective way is limited. The wastes generated by human settlements and the associated problems are similar in the developing nations with variances between regions and locations based on geographic, socio-cultural, industrial, infrastructure, legal and environmental factors.

The major issues in MSW are increasing waste quantities, unmanaged wastes, lack of quality data, lack of reliable theory, absence of implementable legislation and standards. In developing countries waste management sector does not get much attention, so inadequate budget in this sector is also a big problem. In these countries involvement of non-governmental sectors are noticeable. They usually practice door-to-door collection, transfer, recycling, composting and peoples' awareness and motivation program. But due to the absence of an integrated system there are many loop holes and short comings in the present systems, which ultimately fail to improve the overall system.

Planning of an integrated waste management needs a structural dialogue between all the stakeholders. Such a dialogue should be structured around an open evaluation of intervention options. It can be achieved by selecting proper mix of alternatives and technologies to meet changing local waste management needs (Tchobanoglous et. al. 1993).

Bangladesh, one of the Least Developed Asian Countries (LDACs), is facing very complicated situations for the management of vast quantities of MSW generated by urban communities. Due to severe rapid urbanization, rapid population growth, financial constraints, lack of motivation and absence of proper technology and effective legislation to protect the environment and to handle the waste, the whole system is becoming a threat for city dwellers, planners and other concerned stakeholders. The rapidly increasing unmanaged solid wastes have been severely degrading the urban environment and creating serious strains on natural resources and consequently, undermining equitable and sustainable development. Inadequate or unavailable solid waste collection and disposal services result indiscriminate dumping of solid wastes on streets and public areas, clogging of urban drainage systems, contamination of water resources and proliferation of insects and other rodent vectors. Solid waste generation in urban areas of Bangladesh is increasing proportionately with the growth of its population, which is around 5.6 percent per annum (JICA, 2004), while solid waste management capacity in cities and towns is lagging far behind and the gap is widening every day. All these are making the environmental scenarios of our urban life quite gloomy and dismal for the 21st century.

Solid waste management at Bangladesh is in the primitive stage and needs modernization through innovative and appropriate approach for its proper management. Biological and other treatment offers a cost effective sustainable solution for MSW. The viable options of treatment are composting, biomass briquette (fire wood) manufacturing and power generation. In practice, the main biological process applied in Bangladesh for solid wastes is composting. Any cost effective sustainable solution and/or proper management of MSW; it is essential to know the generation rate, amount, composition, physical and chemical characteristics.

In this study, as background information, the solid waste generation, in terms of rate and total quantity, composition and basic characteristics data are taken from different studies for the six major cities of Bangladesh, namely, Dhaka, Chittagong, Khulna, Rajshahi, Barisal and Sylhet. The present study mainly concentrated about the identification and evaluation of existing MSWM systems, constraints of the present practices, people's requirements and possible sustainable solutions. This study also illustrates the key issues need to be addressed for the practice of an integrated MSW management for Bangladesh and considerations of all the aspects relevant to the proposed possible options of integrated management of MSW suitable for the situation of Bangladesh are suggested.

1.2 Background of the Study

For a clean, healthier environment, appropriate and sustainable method of solid waste management is essential, especially in densely populated urban areas. In Bangladesh, one of the densely populated countries of the world, the situations are even worsening. Due to economical and technological drawbacks, absence of an integrated and sustainable management system and lack of giving proper importance in this field, the management of solid waste in Bangladesh is in very primitive's stage yet. Without some exception, the solid waste management in municipal areas is just collecting the waste from some secondary disposal point and then dumped into a low-lying area (Alamgir, 2003a and Alamgir et. al., 2005).

In Bangladesh, specifically in the urban areas, indiscriminate throwing of solid waste by the generators at the waste collection stations and improper collection system have resulted in scattered garbage, offensive odor, polluted water and breeding place for mosquitoes and flies. The sanitary environment in the urban areas has deteriorated causing adverse impacts on the health of the residents. Furthermore, partially collected wastes are disposed unscientifically at the final disposal site in an open low-lying areas or abandoned land, even along the roads, causing serious adverse environmental impacts, which threat to human and nature (Alamgir et. al. 2005a and Ali, 2001).

Accepting these serious issues, many researchers in different institutes and organizations are presently conducting many studies to address the situation better and try to make some improvement for the city dwellers specially. The details research work can be found in Ahsan 2005, Alamgir et. al. 2005a, 2005b, 2005c, Alamgir et al. 2003, Ali 2000, 2001, 2004, BUET 2000, CDM 2004, Enayetullah 1995, Enayetullah at. al. 2003, Mohiuddin et. al. 2005, Rahman 1993a, 1993b, WasteSafe 2005 etc. In all these studies generally the collection of wastes, recycling, composting, management of clinical wastes, ultimate disposal etc. were studied and most of the studies concentrated about the present situation and its possible improvement without thinking of the other tiers of the waste management system.

This study provides the information and data about the present situation of MSW and its characteristics, management practices in the urban areas and their limitations. The studies also highlight the several options of integrated management of MSW and propose a method for selection and an evaluation tools for the verification of suitability and sustainability of the adopted methods. All of these findings will help to select a method of MSW management, to cope with the present situations with better environmental considerations, to help the planners, environmentalists and engineers to choose an economically, technically as well as socially sound alternatives for better solid waste management in Bangladesh.

Effective management of solid wastes requires sound planning and setting of human resources, technical and infrastructural support. This study will provide an approach for the selection of an appropriate management of MSW from all the available alternatives. The evaluation tools will help to build a sustainable solid wastes management system for Bangladesh through sustainability check based on local needs and associated aspects.

1.3 Objectives of the Study

The main objective of this research is to develop an evaluation tool and a process for using them for the selection of an integrated municipal solid waste management in Bangladesh. However, the main objectives of this research work can be outlined as:

1. To find out the limitations and drawbacks of the present MSW management

practiced in major cities of Bangladesh through field survey, visit and direct communication.

2. To conduct the questionnaire survey regarding waste management issues, peoples perceptions and awareness, and also to identify the city dweller's requirements.

3. To select the key issues need to be addressed for an integrated MSW management.

4. Identify the possible options of integrated management of MSW suitable for the situation of Bangladesh.

5. To develop a technique for the selection of appropriate method for the selection of an integrated municipal solid waste management in Bangladesh and evaluation tool to asses the system and check its sustainability and reality, which would be technically and economically suitable for a developing country like Bangladesh

1.4 Scope and Limitation of the Study

At present no effective MSW management is being practiced even in major cities of Bangladesh. MSW generation, composition, physical and chemical characteristics, existing facilities and problems, options for improvements in six major cities of Bangladesh are analyzed through this study for economically and technologically feasible and sustainable waste management. The reliable informations are collected and the relevant parameters are determined based on the data of primary and secondary sources. This study will provide an approach for the selection of an appropriate management of MSW from all the available alternatives. The approach is compared with available MSW management approaches.

The limitations faced in this research are mainly reliable data and length of study period. The study period is allowed to collect the required data and relevant information for a specified period which is not sufficient to handle such a complex natured problem. There are the problems of acquiring all relevant data due to time constraints and confidential nature of data. Seasonal variation of MSW generation, composition, and characteristics are not identified in the study.

1.5 Organization of the Thesis

The thesis presents literature review, data analysis and findings of the study in seven chapters and three annexure. Chapter one includes general introduction, background, objectives, scope and limitations of the study. Chapter two include literature review covering details about waste characterization, integrated waste management, hierarchy of MSW management, typical integrated management system and details of multicriteria decision analysis system are described here. In chapter three overview of study areas and general information are presents. Chapter four presents the existing MSWM practices in the study cites, including quantity, characteristics, management system; waste processing, field survey, management tiers and problems of the existing MSWM. Chapter five aims to propose an integrated approach to the evaluation, selection and improvement of solid waste management system in the study areas. Chapter six presents an illustration of the implementation of the approach in Khulna city and the assessment and reality check of the implemented approach. Chapter seven includes a precise list of conclusions of the findings as an outcome of this study and provides a number of recommendations for future research.

CHAPTER TWO

LITERATURE REVIEW

2.1 General

The purpose of this chapter is to provide necessary information regarding the different aspects of ISWM, importance of ISWM, implementation options and tools, elements of ISWM etc. are described briefly in this chapter. Characteristics of MSW also described here.

2.2 Sources of Municipal Solid Waste

Generally the sources of solid wastes are related to land use and economical zoning. Although a great many source classifications can be developed, the following categories have been found useful (Tchobanoglous et al., 1993):

a) Residential
b) Commercial
c) Institutional
d) Construction & demolition
e) Municipal services
f) Treatment plans sites
g) Industrial, and
h) Agricultural.

Typical waste generation facilities, activities or locations associated with each of these sources are presented in Table 2.1.

2.3 Characteristics of Municipal Solid Waste

The composition of MSW 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 selection of the most appropriate technology for treatment, taking essential health precautions and space needed for treatment facilities.

Table 2.1 Typical solid waste generating facilities, activities and locations associated with various source classifications

Source	Typical Facilities, activities or locations where wastes are generated	Types of solid wastes
Residential	Single family and multifamily detached 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, street leaves, special items (including bulky items, consumer electronics, yard wastes, batteries), household hazardous wastes
Commercial	Stores, restaurants, markets, office buildings, hotels, motels, print shops, service stations, auto repair shops etc.	Paper, cardboard, plastics, wood, food waste, glass, metals, special waste, hazardous wastes etc.
Institutional	Schools, hospitals, prisons, government centers	As above in commercial
Construction & demolition	New construction sites, road repair/renovation 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 & tree trimmings, general wastes from parks and recreational areas
Treatment plants sites	Water, wastewater and industrial treatment processed etc.	Treatment plant wastes, residual sludge
Municipal Solid Wastes (MSW)	All of the above	All of the above
Industrial	Construction, fabrication, light & heavy manufacturing, refineries, chemical plants, power plants etc.	Industrial process wastes, scrap materials, special wastes, hazardous wastes, non-industrial general wastes
Agricultural	Field & row crops, orchards, vineyards, feedlots, farms etc.	Spoiled food wastes, agricultural wastes, rubbish, hazardous wastes

2.3.1 Composition of MSW

Composition is the term used to describe the individual components that make up a solid waste stream and their relative distribution. Information on the composition of solid waste is important in evaluating equipment needs, systems and management programs and plans.

The total municipal solid wastes from a community are composed of the waste materials identified in Table 2.1. Typical data on the distribution of MSW are presented in Table 2.2.

As noted in Table 2.2, the residential portion and commercial portion makes up about 50 to 75% of the total MSW generated in a community. The actual percentage depends on (a) the socio-economical factor, (b) the extent of the construction and demolition activities, (c) the extent of the municipal services provided, and (d) the types of water and wastewater treatment processes that are used. The wide variation in the special wastes category (3 to 12 percent) is due to the fact that in many communities yard wastes are collected separately. The percentage of construction and demolition wastes varies widely depending on the part of the country and the general health of the local, state and national economy. The percentage of treatment plant sludges will also vary widely depending on the extent and type of wastes and wastewater treatment provided.

Table 2.2 Estimated distributions of all components of MSW generated in a typical community (after Tchobanoglous et al., 1993).

Waste Category	Percent by weight	
	Range	Typical
Residential & Commercial excluding special & hazardous wastes	50-75	62.0
Special waste	3-12	5.0
Hazardous waste	0.01-1.0	0.1
Institutional waste	3-5	3.4
Construction & demolition	8-20	14.0
Municipal services	6-13	9.5
Treatment plant sludge	3-8	6.0
Total		100

Table 2.3 shows the typical distribution of components in residential MSW for low, middle and upper-income countries. This table excludes the recycled materials.

Table 2.3 Typical distributions of components in residential MSW for low-, middle and upper-income countries (after Tchobanoglous et al., 1993).

Component	Low-income countries	Middle-income countries	Upper-income countries
Organic			
Food wastes	40-85	20-65	6-30
Paper	1-10	8-30	20-45
Cardboard	-	-	5-15
Plastics	1-5	2-6	2-8
Textiles	1-5	2-10	2-6
Rubber	1-5	1-4	0-2
Leather	-	-	0-2
Yard Wastes	1-5	1-10	10-20
Wood	-	-	1-4
Misc. organic	-	-	-
Inorganic			
Glass	1-10	1-10	4-12
Tin cans	-	-	2-8
Aluminum	1-5	1-5	0-1
Other metal	-	-	1-4
Dirt, ash, etc.	1-40	1-30	0-10

2.3.2 Physical Properties of MSW

Important physical characteristics of MSW include pH, moisture content, volatile solid content and ash residue, Bulk density and particle size distribution.

a) pH

In 1909, a Danish scientist first uses the term pH (Povoire hydrogene i.e. power of hydrogen). pH is the numerical expression of the concentration of hydrogen ions in a solution. Organic materials with a wide range of pH values from 3 to 11 can be composted, but the more desirable pH range for composting is between 5.5 and 8.5 (Tchobanoglous et al., 1993).

b) Moisture Content

The important physical characteristics of solid waste are moisture content. Moisture content is a property of particular importance to incinerator design and operation because of its effect on the calorific value and the ignition characteristics of the refuse. Moisture content is also important in composting of MSW. Moisture content varies widely which influenced by local climate conditions, refuse-storage practices, method of refuse collection and refuse composition. Moisture content is usually expressed as the percentage weight of moisture per unit weight of wet or dry material. For the wet-weight moisture content it can be expressed as (Chan, 1993):

$$\text{Moisture content (\%)} = \frac{(a-b)\times 100}{a}$$

Where, a= initial weight of sample

b= weight of sample after drying at 110^0C for 1 hour

c) Volatile solid content and ash residue

The portion of organic material that can be released as a gas when organic material is burned in a muffle furnace at the temperature of 550°C (Tchobanoglous et al., 2002). Volatile solids are a particularly useful parameter in gas production. Gas production in terms of volatile solids introduced is a most functional parameter, because it is a measure of the efficiency of the utilization of volatile solids by the culture (Diaz et al., 1996). Ash residue is nothing but the residue amount rest in a muffle furnace after burnt at 550°C when the volatile matter totally removed.

d) Bulk density

Bulk density is the important physical characteristics of solid waste for final sample size reduction operation. Density data is often required to obtain the mass and volume of waste that must be managed. Knowledge of this property is also important in designing the collection equipment and treatment plant capacity. Bulk density is defined as the weight of a material per unit volume, i.e. lb/ft^3 or kg/m^3. The Bulk density can be measured as *loose, as found in container, uncompacted* and *compacted* conditions (Diaz et al., 1996).. These data are often needed to assess the total mass and volume of waste that must be managed.

e) Particle size distribution

The size of the particles in the MSW is a nutrient-related factor, because the waste is the substrate in composting and the substrate is the source of nutrients. The relation to nutrition is the effect of size of the individual particles. Particle size also determines the ratio of mass-to-surface and hence amount of a particle's mass that is exposed to microbial attack (Diaz et al., 1996). For a basic understanding of the nature of the wastes that are generally encountered, the type of distribution of particle sizes are must to be known. The particle - size distribution of waste is usually determined by sieve analysis.

2.3.3 Chemical Properties of MSW

Information on chemical characteristics of solid waste is important on evaluating alternative processing and recovery processes. The important characteristics are:

a) Proximate analysis

Proximate analysis for the determination of the properties of combustible components present in MSW includes the following tests:

i. Moisture content (loss of moisture when heated to 105°C for 1 h)

ii. Volatile combustible matter (additional loss of weight on ignition at 950°C in a covered crucible)

iii. Fixed carbon (combustible residue left after volatile matter is removed)

iv. Ash (weight of residue after combustion in an open crucible)Fusing point of ash

b) Fusing point of ash

The fusing point of ash is defined as the temperature at which the ash resulting from the burning of waste will form a solid (clinker) by fusion and agglomeration. Typical fusing temperatures for the formation of clinker from solid waste range from 2000 to 2200°F (1100 to 1200°C).

c) Ultimate analysis of solid waste components

The ultimate analysis of waste component typically involves the determination of the percent of C (carbon), H (hydrogen), O (oxygen), N (nitrogen), S (sulfur) and ash. Because of the concern over the emission of chlorinated compounds during combustion; the determination of halogens is often included in an ultimate analysis. The results of the ultimate analysis are used to characterize the chemical composition of the organic matter in MSW. They are also used to define the proper mix of waste materials to achieve suitable C/N ratios for biological conversion processes (Tchobanoglous et al., 1993).

d) Calorific value

Calorific value of organic components of MSW is determined in laboratory by using a bomb calorimeter. Two types of energy values are usually ascertained; one is Higher Calorific Value (HCV) and another is Lower Calorific value (LCV). Any substance that can be burnt or modified by some chemical or nuclear process to produce heat energy is called fuel. The term calorific value of waste is the quantitative estimate of heat energy released by burning (or modifying) a unit amount of the waste in a specified process.

e) Chemical analysis

Chemical characteristics of MSW are known by chemical analysis. Chemical analysis is the most important method of investigation and is widely used in all branches of science, which are related to chemistry. Chemical methods are used in the study of sciences like mineralogy, geology, physiology, microbiology, medicine, agriculture and other technical sciences. In practice, the analyst's problem is usually simplified considerably, because the chemical composition of most of the investigated substances is well known (Alam et al., 1991). The important chemical characteristics of MSW that are measured by different method of chemical analysis are Carbon, Nitrogen, Hydrogen, Oxygen, Potassium, Phosphorous, Sulfur and Boron.

2.3.4 Biological properties of MSW

Almost all organic components can be converted biologically to gases and relatively inert organic & inorganic solids. The controlled biological decomposition process of organic wastes into humus, which can be used as a good soil conditioner, is known as composting. The MSW of Bangladesh is suitable for composting due to its high moisture and organic content. Excluding plastic, rubber and leather components, the organic fraction of most MSW can be classified as follows:

(i) Water-soluble constituents, such as sugars, starches, amino acids and various organic acids

(ii) Hemicellulose, a condensation product of five- and six-carbon sugars

(iii) Cellulose, a condensation product of the six-carbon sugar glucose

(iv) Fats, oils and waxes, which are esters of alcohols and long-chain fatty acids

(v) Lignin, a polymeric material containing aromatic rings with methoxyl group ($-OCH_3$), the exact chemical nature of which is still not known (present in some paper products such as newsprint and fiberboard)

(vi) Lignocellulose, a combination of lignin and cellulose

(vii) Proteins, which are composed of chains of amino acids

2.3.5 Mechanical properties

Despite the fact that the proper design of processing plants as well as final disposal facilities should include a thorough understanding of the properties of refuse and its components which are until have been ignored. Perhaps this can be explained by the absence of reliable information readily available in the literature. This problem is particularly more pronounced in economically developing countries. Mechanical properties are especially important in the design of sanitary landfills and ancillary systems (Diaz et al., 1996). Major mechanical characteristics of MSW are stated below:

a. Stress-strain behaviour
b. Absorptive and field capacities
c. Permeability of compacted waste

2.4 Solid Waste Generation Rates

A reliable estimate of the quantity of solid waste generated in the city is very important for proper solid waste management. While there is a consensus among common people regarding the adverse environmental impact of solid waste, experts seem to differ widely on the estimates of waste generated in the city. MSW generation rates vary in different countries and cities because of different influencing factors. The most important factors are:

(i) Population density
(ii) Socio economic condition and standard of living
(iii) Frequency of collection and service coverage
(iv) Habits and custom of living
(v) Geographic location
(vi) Season of the year
(vii) Characteristics of service area
(viii) Source reduction and recycling activates
(ix) Public attitude and legislation

The quantities of MSW generated can be estimated in many ways:

1. Load-count analysis (Tchobanoglous et al., 1977)

In this method the number of individual loads, the corresponding vehicle load volume and the sources of waste have been collected and the weights are noted over a specified period. The unit generation rates are determined by using the field data or published data.

2. Secondary data method (Vesilind and Rimer, 1981)

This method uses secondary information such as income, product sold in stores and so on, and by means of stepwise linear regression analysis, calculates MSW production as

$$y = a + bX_1 + cX_2 + \dots\dots\dots\dots\dots + nX_n$$

Where, y= the independent variable of solid waste generation

$X_1, X_2 \dots\dots\dots X_n$ = the independent variables of each influencing parameters
a, b, c............n = constant

In most countries, the population and economic situation are often affecting the waste generation, thus the background data of population and economic indices such as GNP and GDP are required. They should be forecast in order to estimate the future solid waste generation. However, other parameters such as housing projects, land use planning and solid waste service coverage may affect the solid waste generation in the future and they can be used in this forecasting task too.

2.5 Definition of Integrated Solid Waste Management

According to Oxford Dictionary definitions of 'waste' invariably refer to lack of use or value, or 'useless remains'. Waste is a by-product of human activity. Physically, it contains the same materials as are found in useful products; it only differs from useful production by its lack of value. Pfeffer (1992) defined the solid waste is any solid material in the material flow pattern that is rejected by society. Management can be defined as the judicious use of a means to achieve an end. 'And end' is the removal of the rejected material from the material flow pattern.

It is generally accepted that the 'cost' of solid waste management is the number of 'dollars' required to eliminate the rejected material from contact with human populations. If this could be accomplished by dumping it in a used gravel pit, hauling it to sea, volatilizing it in to the atmosphere, or whatever, that is the minimum cost.

Tchobanoglous et al. (1993) stated that the solid waste management may be defined as the discipline associated with the control of generation, storage, collection, transfer and transport, processing, and disposal of solid wastes in a manner that is in accord with the best principles of public health, economics, engineering, conservation, aesthetics, and other environmental considerations, and that is also responsive to public attitudes.

Tchobanoglous et al. (1993) also defined integrated solid waste management (ISWM) as the selection and application of suitable techniques, technologies and management programs to achieve specific waste management objectives and goals.

2.6 Basic requirements

The basic requirements of ISWM are to produce less amount of wastes, by applying different approaches and managing them efficiently. In the following articles these two elements describes briefly.

2.6.1 Less waste

The Brundtland report of the United Nations 'Our Common Future' (WCED, 1987) depicts that sustainable development would only be achieved if society in general, and industry in particular, learned to produce 'more with less'; more goods and services with less use of the world's resources (including energy) and less pollution and waste. 'Waste minimization', 'waste reduction' or 'source reduction' are usually placed at the top of the conventional waste management hierarchy. In reality, however, source reduction is a necessary precursor to effective waste management, rather than part of it. Source reduction will affect the volume, and to some extent, the nature of the waste, but there will still be waste for disposal. What is needed, beyond source reduction, is an effective system to manage this waste.

2.6.2 Effective solid waste management

Solid waste management systems need to ensure human health and safety. They must be safe for workers and safeguard public health by preventing the spread of disease. In addition to these prerequisites, an effective system for solid waste management must be both environmentally and economically sustainable.

- *Environmentally sustainable:* It must reduce as much as possible the environmental impacts of waste management, including energy consumption, pollution of land, air and water, and loss of amenity.

- *Economically sustainable:* It must operate at a cost acceptable to the community, which includes private citizens, businesses and government. The costs of operating an effective solid waste system will depend on existing local infrastructure, but ideally should be little or no more than existing waste management cost.

It is difficult to minimize two variables, cost and environmental Impact, simultaneously. There will always be a trade-off. The balance that needs to be struck is to reduce the overall environmental impacts of the waste management system as far as possible, within an acceptable level of cost. Deciding the point of balance between environmental impact and cost will always generate debate. Better decisions will be made if data on impacts and costs are available; such data will often prompt ideas for further improvements.

2.7 Waste Management Systems

A management system is the framework of processes and procedures used to ensure that an organization can fulfill all tasks required to achieve its objectives (The Free Dictionary, 2006). An environmental management system enables organizations to improve their environmental performance through a process of continuous improvement. An oversimplification is "Plan, Do, Check, Act." A more complete system would include accountability (an assignment of personal responsibility) and a schedule for activities to be completed, as well as auditing tools to implement corrective actions in addition to scheduled activities, creating an upward spiral of continuous improvement.

2.7.1 Characteristics of an effective system

An economically and environmentally sustainable solid waste management system is likely to be integrated, market-oriented and flexible. The execution of these principles will vary on a regional basis.

An integrated system:

An integrated system would include waste collection and sorting, followed by one or more of the following options (Tchobanoglous et al. 1993):

- Recovery of secondary materials (recycling): this will require adequate sorting and access to reprocessing facilities.
- Biological treatment of organic materials: this will produce marketable, compost or reduce volume for disposal. Anaerobic digestion produces methane that can be burned to release energy.
- Thermal treatment: this will reduce volume, render residues inert and may recover energy.
- Landfill: this can increase amenity via land reclamation but will at least minimize pollution and loss of amenity.

To handle all waste in an environmentally safe and sustainable way requires a range of the above treatment options. Landfill is the only method that can handle all waste alone, since recycling, composting and incineration all leave some residual material that needs to be landfilled. Landfill, however, does not valorize any part of the waste. It can be used to reclaim land, but it can also cause methane emissions and groundwater pollution and consume space. Use of the other options prior to landfilling can both valorize significant parts of the waste stream, reduce the volume and improve the physical and chemical stability of the residue. This will reduce both the pace requirement and the potential environmental impacts of the landfill.

Market-oriented:

Any scheme that incorporates recycling, composting or waste-to-energy technologies must recognize that effective recycling of materials and production of compost and energy depends on markets for these outputs. These markets are likely to be sensitive to price and to consistency in quality and quantity of supply. Managers of such schemes will need to play their part in building markets for their outputs, working with secondary material processors, and helping to set material quality standards. They must also recognize that such markets and needs will change over time, so such standards should not be rigid and based on legislation, but be set as part of a total quality customer-supplier relationship.

Flexibility:

An effective scheme will need the flexibility to design, adapt and operate its systems in ways which best meet current social, economic and environmental conditions. These will likely change over time and vary by geography. Using a range of waste management options in an integrated system gives the flexibility to channel waste via different treatments as economic or environmental conditions change. For example, paper can be recycled, composted or incinerated with energy recovery. The option used can be varied according to the economics of paper recycling, compost production or energy supply pertaining at the time.

Scale:

The need for consistency in quality and quantity of recycled materials, compost or energy, the need to support a range of disposal options, and the benefit of economies of scale, all suggest that integrated waste management should be organized on a large-scale, regional basis. The optimal size for such a scheme should be in an area containing upwards of 5,000,00 households (White, 1993). Therefore, implementation of such schemes will require local authorities to work together.

2.7.2 The importance of a holistic approach

The operations within any waste management system are clearly interconnected. The collection and sorting method employed, for example, will affect the ability to recover materials or produce marketable compost. Similarly, recovery of materials from the waste stream may affect the viability of energy recovery schemes. It is necessary, therefore, to consider the whole waste management system in an holistic way. What is required is an overall system that is both economically and environmentally sustainable. A lot of recent effort has been put into schemes concentrating on individual technologies, e.g. recycling, or on materials from one source only. From the perspective of the whole waste management system, such schemes may well involve duplication of efforts or other inefficiencies, making them both environmentally and economically ineffective.

The relevance of looking at the whole system could be challenged, since waste management is split up into so many different compartments. Collection is the duty of local authorities, although it may be contracted out to waste management companies. Different operators may contribute to recycling activities. Similarly, incineration, composting and landfill operations may all be under the different operators.

Considering these the holistic approach has the following advantages:

1. It gives an overall picture of the waste management process. Such a view is essential for strategic planning. Handling of each waste stream separately is inefficient.
2. Environmentally, all waste management systems are part of the same system, the global ecosystem. Looking at the overall environmental burden of the system is the only rational approach; otherwise reductions in the environmental impacts of one part of the process may result in greater environmental impacts elsewhere.
3. Economically, each individual unit in the waste management chain should run at a profit, or at least break-even. Therefore, within the boundaries controlled by each operator, the financial incomes must at least match the outgoings. By looking at the wider boundaries of the whole system, however, it is possible to determine whether the whole system operates efficiently and whether it could run at breakeven, or even at a profit. Only then can all the constituent parts be viable, provided that income is divided up appropriately in relation to costs.

2.7.3 A total quality system

To achieve fully integrated waste management will require major system changes from the present situation. The objective of an integrated system is to be both environmentally and economically sustainable. This is a total quality objective (Oakland, 1989); it can never be reached, since it will always be possible to reduce environmental impacts further, but it will lead to continual improvements.

Application of total quality thinking can be of further use in waste management. To reach a total quality objective one builds a system to achieve this objective. To deliver environmentally and economically sustainable waste management requires putting together a system designed for this purpose. This is a key point. Trying to improve present systems by using recycling or composting as 'bolt-on extras' is unlikely to work. Different components of the system are inter-connected so it is necessary to design a whole new system rather than tinker with the old one. Radical system changes may also allow previous economic inefficiencies to come to light, which can be used to offset any increased costs.

2.8 Planning for Integrated Waste Management

Developing and implementing an ISWM plan is essentially a local activity that involves the selection of the proper mix of alternatives and technologies to meet changing local waste management needs while meeting legislative mandates. Three important aspects are the proper mix of technologies, flexibility in meeting future changes and the need for monitoring and evaluation are considered briefly in the following discussion.

2.8.1 Proper Mix of Alternatives and Technologies

A wide variety of alternative programs and technologies are now available for the management of solid wastes. Several questions arise from this variety: What is the proper mix between (1) the amount of waste separated for reuse and recycling, (2) the amount of waste that is composted, (3) the amount of waste that is combusted, and (4) the amount of waste to be disposed of in landfills? What technology should be used for collecting wastes separated at the source, for separating waste components at Materials Recovery/Transfer Facilities (MRFs), for composting the organic fraction of MSW, and for compacting wastes at a landfill? What is the proper timing for the application of various technologies in an ISWM system and how should decisions be made?

Because of the wide range of participants in the decision-making process for the implementation of solid waste management systems, the selection of the proper mix of alternatives and technologies for the effective management of wastes has become a difficult, if not impossible, task. The development of effective ISWM systems will depend on the availability of reliable data on the characteristics of the waste stream, performance specifications for alternative technologies, and adequate cost information.

2.8.2 Flexibility in Meeting Future Changes

The ability to adapt waste management practices to changing conditions is of critical importance in the development of an ISWM system. Some important factors to consider include,

(i) Changes in the quantities and composition of the waste stream,
(ii) Changes in the specifications and markets for recyclable materials, and
(iii) Rapid developments in technology.

If the ISWM system is planned and designed on the basis of a detailed analysis of the range of possible outcomes related to these factors, the local community will be protected from unexpended changes in local, regional, and larger-scale conditions.

2.8.3 Monitoring and Evaluation

ISWM is an ongoing activity that requires continual monitoring and evaluation to determine if program objectives and goals (e.g., waste diversion goals) are being met. By developing and implementing monitoring and evaluation programs required changes can be made to the ISWM system. It depends on wastes characteristics, changing specifications and markets for recovered materials and development of new and improved waste management technologies etc .

2.9 Hierarchy of Integrated Solid Waste Management

A hierarchy (arrangement in order of rank) in waste management can be used to rank actions to implement programs within the community. ISWM programs and systems should be developed in which the elements of the hierarchy are interrelated and are selected to complement each other. The ISWM hierarchy is composed of the following elements: source reduction, recycling, waste transformation, and landfilling. In Figure 2.1 (Tchobanoglous et al. 1993) typical hierarchy of MSW management is present. For the broadest interpretation of the ISWM hierarchy, it can be expanded to waste management tiers as source reduction and segregation, Waste collection, Waste transfer and transportation, Waste transformation, Recycling of waste by various approaches and ultimate disposal. The schematic diagrams of these tiers are shown in Figure 2.2. In the following sections these are discussed briefly.

2.9.1 Source reduction

The highest rank of the ISWM hierarchy, source reduction, involves reducing the amount and/or toxicity of the wastes that are generated. The term source reduction is used to describe those activities that decrease the amount (weight or volume) or toxicity of waste entering the solid waste stream. It also encompasses those activities that increase product durability, reusability and reparability.

Source reduction is first in the hierarchy because it is the most effective way to reduce the quantity of waste, the cost associated with its handling and its environmental impacts. Waste reduction may occur through the design, manufacture and packaging of products with minimum toxic content, minimum volume of material, or a longer useful life. Waste reduction may also occur at the household, commercial or industrial facility through selective buying patterns and the reuse of products and materials.

2.9.2 Storage at source and segregation

In 1757 in USA the dwellers of the New York City begin digging refuse pits instead of throwing garbage out of windows and doors (EPA, 2006) which are the first reported ancient on-site source storage. On-site storage facilities of wastes and proper segregation before that are two most important elements of ISWM. Storage of MSW at the source is influenced by the following factors:

a) *The effect of storage on the waste components:* important considerations in the onsite storage of wastes are the effect of storage itself on the characteristics of wastes being stored. These effect of storing wastes includes (i) biological decomposition, (ii) the absorption of fluids, and (iii) the contamination of waste components
b) *The type of containers to be used:* The types and capacities of the containers used depend on the characteristics and types of solid wastes to be collected, the type of collection system in use, the collection frequency and the space available for the placement of containers.

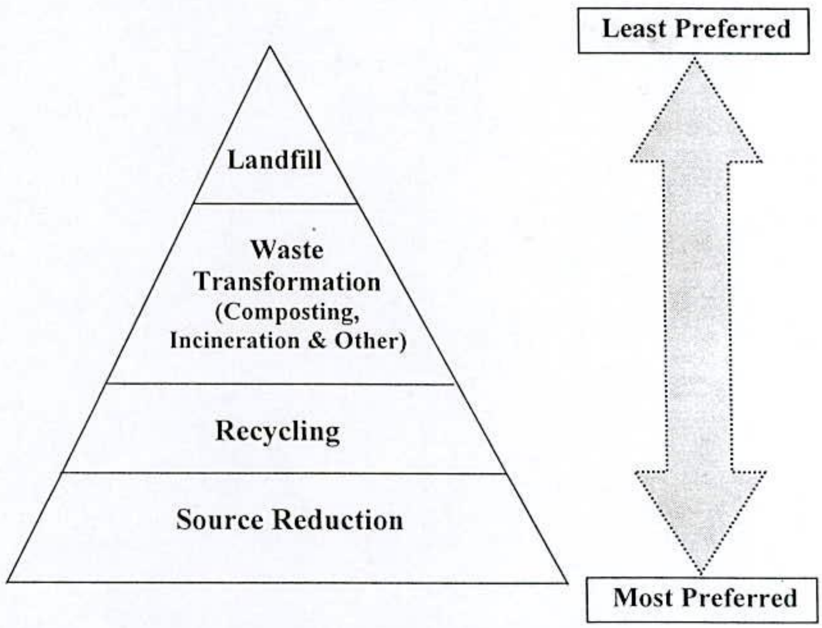


Figure 2.1: Typical hierarchy of integrated solid waste management.

c) *The container location:* The container locations depend on the type of dwelling or commercial and industrial facilities, the available spaces and access to collection services.
d) *Public health and aesthetics:* In developing countries most of the generated MSW are from residential sources, which are generated in areas with limited storage space. As a result, they can have significant public health and aesthetics impacts. Public health concerns are related primarily to the invasion of areas used for the storage of solid wastes with vermin and insects that often serve as potential disease vectors. Aesthetic

considerations are related to the production of odors and the unsightly conditions that can develop when adequate attentions are not given to the maintenance of sanitary conditions.

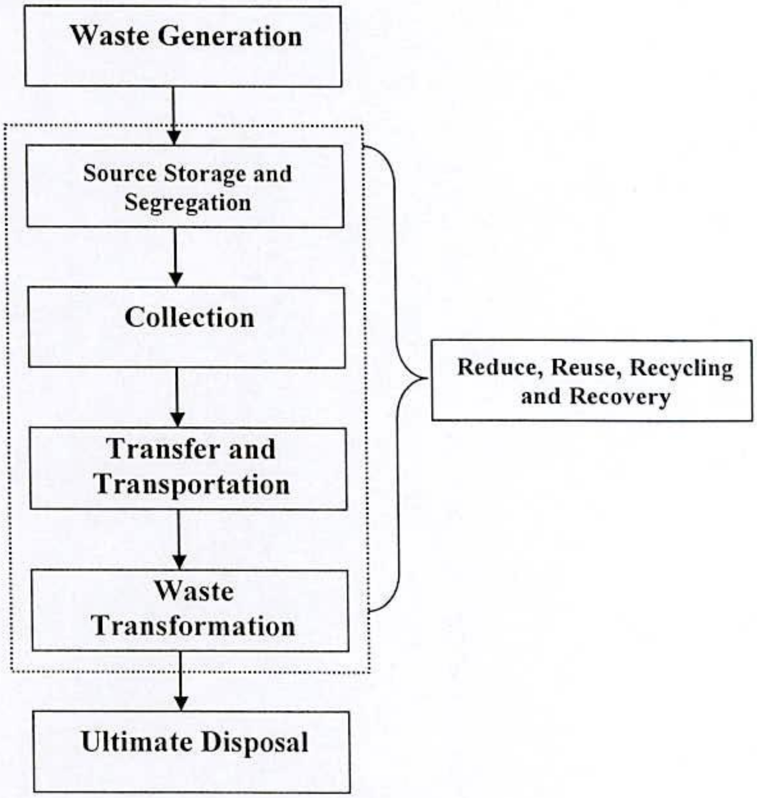


Figure 2.2 Extended tiers for ISWM hierarchy

Dry waste should be separated from wet biodegradable waste. Recyclable waste should be given to agencies, which buy the waste from the generator and re-route it to the recycling process units. Non-recyclable waste (inorganic) such as PET mineral bottles, nitrogen sealed packaging chips, tetra packs, thermo-coal, carbon paper, plastic coated visiting cards and sachets should be collected in separate containers.

Biodegradable wet waste can be treated with common methods like yard composting, home composting or vermin-composting. As per the Municipal Solid Waste Rules 2000, the segregation of waste is to be undertaken as follows:

i) Organic waste;

ii) Recyclable waste;

iii) Others – inorganic waste.

2.9.3 Collection of wastes

Systematic approach of waste collection evolved in the early nineteen century. Horse-drawn cart is usually used to collect the waste from different sources. The term collection includes not only the gathering or picking up of solid wastes from various sources, but also the hauling of these wastes to the location where the contents of the collection vehicles are emptied. Collection of un-separated and separated solid waste in an urban area is difficult and complex because the generations of residential and commercial-industrial solid waste take place in every home, every building and every commercial and institutional facility as well as in the streets, parks and vacant areas. While the activities associated with hauling and unloading are similar for most collection systems, the gathering or picking up of solid waste will vary with the characteristics of the facilities, activities, or locations where wastes are generated. Collection process usually required 40-60% of the total solid waste management cost. Typically, collection is provided under various management arrangements, ranging from municipal services to franchised private services conducted under various forms of contracts.

2.9.4 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.

2.9.5 Waste transformation

Waste transformation, involves the physical, chemical, or biological alteration of wastes. Typically, the physical, chemical, and biological transformations that can be applied to MSW are used

(i) To improve the efficiency of solid waste management operations and systems,
(ii) To recover reusable and recyclable materials, and
(iii) To recover conversion products (e.g., compost) and energy in the form of heat and combustible biogas.

The transformation of waste materials usually results in the reduced use of landfill capacity. Waste transformation involves the physical, chemical or biological alteration of wastes. Typically the physical, chemical and biological transformations that can be applied to MSW are used, (i) to improve the efficiency of SWM operations and systems, (ii) to recover reusable and recyclable materials, and (iii) to recover conversion products (like compost) and energy in the form of heat and combustible biogas. The transformation of waste materials usually results in the reduced use of landfill capacity. For developing countries with high percentage of biodegradable wastes, the process of composting is an attractive waste transformation technique. Aerobic and anaerobic waste transformation processes are the two major choices for waste transformation. Generally the operation of anaerobic process is more complex than that of aerobic processes. But anaerobic processes offer the benefit of energy recovery in the form of methane gas and thus are net energy producers. Aerobic processes are net energy users because oxygen must be supplied for waste conversion, but they offer the advantage of relatively simple operation and can significantly reduce the volume of the organic portion of MSW.

2.9.6 Recycling

Recycling is an important factor in helping to reduce the demand on resources and the amount of waste requiring disposal by landfilling. Reduce, Reuse, Recycling and Recovery (generally known as 4R's) and treatment of MSW are one of the most promising ways of waste reduction and make economical output from waste. The main objective of 4R policies and treatment of wastes are:

(i) To recover useable material

(ii) The preparation of these materials for reuse, reprocessing, and remanufacture

(iii) To recover conversion products and energy

(iv) To improve the efficiency of solid waste management systems

Empirical evidence suggests that by practicing waste prevention, reusing products, recycling, and making environmentally conscious purchases, businesses can cut costs and increase profits. Cost savings take the form of:

- Lower waste disposal costs
- Lower waste treatment costs
- Lower energy costs
- Savings on materials and supplies
- A reduction in regulatory compliance costs
- Lower storage costs
- Cost recovery through the sale of recyclable materials
- Cost recovery through sales of 4Rs technologies.

Treatment of MSW industry covers the four components, these are recycling, composting, land filling and waste-to-energy via incineration Treatment is the chemical conversion from hazardous to non-hazardous by incineration or some other means. Another form of recycling is composting. Controlled biological decomposition process of organic wastes into humus, a soil-like material is known as composting. Composting is nature's way of recycling organic wastes into new soil used in vegetable and flower gardens, landscaping and many other applications. It is important to view compost feedstock as a usable product, not as waste requiring disposal. When developing and promoting a composting program and when marketing the resulting compost, program planners and managers should stress that the composting process is an environmentally sound and beneficial means of recycling organic materials, not a means of waste disposal.

Reduce

Waste reduction means avoiding the generation of waste. It is defined as the prevention of waste at source or as eliminating waste before it is created. The term is now often interchanged with 'waste minimization', 'waste avoidance' or 'waste prevention'. Source reduction means any procedure to reduce wastes at the point of generation, in contrast to sorting out recyclable components after they have been mixed together for collection. This in the first place save the financial and environmental burden of disposal costs and also reduces the amount of raw materials (oil, minerals etc.), which are needed for the manufacture of goods. Reduction places the responsibility on designers and producers of goods to reduce the quantity of material used in the manufacture of their products. It needs national policy, legislation, people's motivation and effective program for successful waste reduction. In Box 2.1 some slogans to motivate the people's to reduce the wastes are presented.

Box 2.1 Community motivation slogan for Reduce (After EPA, 2005)

- Do not use excessive water during bathing, washing etc.
- Save power, gas, fuel
- Buy goods with no packaging, such as bread, fruit and vegetables
- Turn off unwanted lights, computers, televisions and DVD players when not in use
- Photocopy and print on both sides
- Store data electronically to avoid printing off
- Review documents on-screen before printing to avoid waste
- Purchase durable equipment.
- Use rechargeable batteries and refillable ink cartridges

Reuse

Reuse means the reusing of a product in its original or a different purpose. In recent years, due to modernization the society became "throw away", which has led to a decline in the re-use of materials. Reuse help to reduce waste and minimize the depletion of natural resources.

Recycling

Recycling is the reprocessing of wastes, either into the same material (closed loop recycling) or a different material (open loop recycling). The recycling of waste materials plays a vital part in any waste management strategy. This involves the reprocessing of waste into a useable raw material or product, and enables items to have an extended life, reducing the burden of disposal and the depletion of natural resources. It is the key mechanism to recover useful products and reduction in waste quantity. Separating a given waste material from the waste stream and processing it so that it may be used again as a useful material for products that may or may not be similar to the original. This has obvious advantages although we need to consider the associated costs involved in transport and collection, which quite often result in higher market prices for some recycled products.

Recovery

Recovery refers to materials removed from the waste stream for the purpose of recycling and/or composting. However recovery does not automatically equal recycling and composting. Source separation is the best process to recover different categories of recyclables items at source, i.e. at the point of generation, to facilitate reuse, recycling and composting.

Treatment is the chemical conversion of wastes from hazardous to non-hazardous wastes by incineration or through some other else. Incineration is the process of reducing the combustible portion of the waste by burning at high temperature. MSW incinerators can recover power and/or heat. The main emissions are carbon dioxide, water and ash residues. Through this process, MSW can generate energy while reducing the amount of waste about 80-90% in volume and 75% in weight.

2.9.7 Ultimate Disposal

After everything done in the above processes, ultimately, something must be done with

(i) The solid wastes that cannot be recycled and are of no further use
(ii) The residual matter remaining after solid wastes have been separated at a materials recovery facility; and
(iii) The residual matter remaining after the recovery of conversion products or energy.

There are only two alternatives available for the long-term handling of solid wastes and residual matter: disposal on or in the earth's mantle, and disposal at the bottom of the ocean. Landfilling, the last rank of the ISWM hierarchy, involves the controlled disposal of wastes on or in the earth's mantle, and it is by far the most common method of ultimate disposal for waste residuals. It is the lowest rank in the ISWM hierarchy because it represents the least desirable means of dealing with society's wastes.

Although source reduction, materials recovery, reuse, recycling, and composting should gradually divert large parts of MSW, a significant portion of residual waste must still be placed in an ultimate disposal facility. Since the turn of the last century, the use of landfills, in one form or another, has been the most economical and environmentally acceptable method for the disposal of solid wastes throughout the world. Landfills, in various forms, have been used for many years. The first recorded regulations to control municipal waste were implemented during the Minoan Civilization, which flourished in Crete (Greece) from 3000 to 1000 B.C.E. Solid wastes from the capital, Knossos, were placed in large pits and covered with layers of earth at intervals (Tammemagi, 1999). This basic method of land filling has remained relatively unchanged right up to the present day. Such a facility has two basic requirements: (i) safe encapsulation of the waste and its reaction products, while it is decomposing or being stabilized; and (ii) control of the reaction processes, so as to improve the rate or products of stabilization, render emissions harmless, and recover value.

Such requirements are achieved in modern sanitary landfill reactors. These are well-engineered facilities located, designed, resourced, operated, monitored, closed and restored, and cared for after closure, to ensure compliance with specified detailed regulations. The regulations are established to protect human health and the environment. In addition, such engineered landfills can collect potentially harmful landfill gas emissions and convert the gas into energy. Equipment is also installed to re-circulate the generated leachate (which can accelerate the waste stabilization processes) and also clean up excess leachate before its discharge into water bodies.

2.10 Necessity of Integrated Solid Waste Management

Integrated solid waste management is a way of handling MSW through a variety of interrelated activities. It may include source reduction, recycling, composting, combustion and land filling. Integrated solid waste management involves three key steps:

i) Deciding how best to handle each portion of the municipal solid waste stream;

ii) Implementing a system of interrelated handling methods; and

iii) Maintaining and updating the system.

Integrated solid waste management is an approach that considers all MSW handling methods, from source reduction to land filling, and implements the activities which best meet the needs of the community. An integrated system also incorporates technical and political issues, including human health, safety and welfare, environmental protection, public acceptance, and efficient and economical management.

There are a number of reasons that communities are moving towards integrated systems to address MSW challenges (SSEB, 2000):

Multiple Needs - New goals and mandates have created many different demands on MSW management systems. All these demands cannot be met with a single management method. For example, a community cannot meet reduction goals or, in many cases, assure certain years of capacity by simply disposing of all MSW in a landfill.

Efficiency and Flexibility - Having an integrated MSW system allows a community to identify the most efficient method for handling each portion of its waste stream. Also, using more than one MSW management method allows a community to shift from one method to another as conditions change. For example, evolving legislation and court decisions on local government control over the flow of MSW could impact methods of managing it.

Cost-Effectiveness - An integrated approach considers long-term costs and thus helps a community to choose the MSW management system that will cost the least over the long-term. For example, a community may choose to recycle a material, even if its disposal is less costly, to conserve landfill space and delay the need for a new disposal facility.

Environmental Integrity - Developing an integrated MSW system increases the community's opportunity to recognize and address the environmental benefits and risks associated with each management option.

Wider Scope - Developing an integrated system goes beyond the technical aspects of designing facilities and programs. An integrated approach also deals with management issues, such as how to pay for and administer the MSW management system.

Local Control - Developing an integrated system allows a community to consider and select the options that best meet its long-term needs. When the community takes the time to make well-thought-out decisions, rather than reacting under pressure, it maintains more control over how MSW will be managed.

2.11 Typical Integrated Management System

Integrated Solid Waste Management (ISWM) is defined by researchers and academics as the selection and application of appropriate techniques, technologies and management programs to achieve specific waste management objectives and goals (UNEP, 2001b). Understanding the inter-relationships among various waste activities makes it possible to create a plan in which individual components complement one another.

A system is the representation of an object, model or idea in some form, other than that of reality itself (Qureshi et al., 1999). Many of the system identified are decision support models, using a variety of methods and tools, such as risk assessment, environmental impact assessment, cost benefit analysis, multicriteria decision making and life cycle analysis, as part of the decision making process. Most systems identified assume that all options and decision criteria have already been identified and that the most important stage of the process is the actual evaluation of the alternatives using one of these tools or methods. The type of tool selected also depends on the decision being made and on the decision-makers (Guitouni and Martel, 1998; EEA, 2003). In some cases, the goal of the system is simple (to optimize waste collection routes for vehicles), while in others, it is more complex (to evaluate alternative waste management strategies). Rogers (2001) categorizes systems or models into two categories: (a) those that use optimizing methods and (b) those that use compromising methods. While Rogers's categorization is centered on engineering project appraisal, it can be applied to waste management systems as well.

Optimizing models assume that the different objectives of the proposal can be expressed in a common denominator or scale of measurement, whereby the loss in one objective can be directly evaluated against a gain in another. Optimization models include cost benefit analysis and present worth evaluation with the common scale of measurement usually expressed in monetary terms. In contrast, compromising methods assume that the decision-maker may have limited knowledge regarding the decision situation and are based on Simon's (1976) concept of 'bounded rationality'. Guitouni (1998) also makes the point that the "idea of the optimal solution is abandoned for the notion of the "satisfaction of the decision maker and that this is the beginning of the development of many Multicriterion Decision Analysis (MCDA) methods." These methods are based on the principle that any viable solution has to reflect a compromise between the various priorities, while the discrepancies between the actual outcomes and objective levels are traded off against each other by means of preference weights. Each alternative is judged in relation to multiple priorities, so that the desired alternative is one that performs comparatively well according to these priorities.

In case of ISWM, three main categories of systems or models have been identified: cost benefit analysis, life cycle inventory and multicriteria system. Nevertheless, the systems described have limitations and none have considered the complete waste management cycle, from the prevention of waste through to final disposal. Most are only concerned with refining the actual multicriteria technique itself or of comparing the environmental aspects of waste management options (recycling, incineration, and disposal). In addition, while many systems recognize that for a waste management system or strategy to be sustainable, it must consider environmental, economic and social aspect. The involvement of the people who generate the waste, (i.e. the general public) in a meaningful way in the decision making process is very important for a sustainable management which generally does not address in these systems.

Cost Benefit Analysis

This tool enables decision-makers to assess the positive and negative effects of a set of scenarios by translating all impacts into a common measurement, usually monetary. This means that impacts, which do not have a monetary value, such as environmental impacts, must be estimated in monetary terms. There are several ways to do this, such as estimating the costs of avoiding a negative effect (e.g. the cost of pollution control on an incinerator) or to establish how much individuals are willing to pay for an environmental improvement. Social impacts can also be evaluated in the same way. On completion of the analysis, the scenario with the greatest benefit and least cost, is the preferred scenario.

Benefits and limitations of Cost Benefit Analysis

Cost benefit is a relatively analysis where everything measures in terms of monetary unit. During the calculation of environmental or social impact, several assumptions are made to calculate the impact. In brief the benefits and drawbacks of are as follows:

(i) The results are presented in a clear manner, with all impacts summed up into one monetary figure.

(ii) It enables decision-makers to see what scenarios are efficient in their use of resources.

(iii) There is uncertainty involved in estimating the monetary value of several environmental and/or social impacts in monetary terms. This also raises ethical issues.

(iv) The assumptions about prices may change during the lifetime of the waste programme, changing the preferred outcome (e.g. changes in landfill costs may impact on how much waste is recycled).

Life Cycle Analysis

Life cycle analysis/assessment (LCA) is a tool that studies the environmental aspects and potential impacts throughout a product's life from raw material acquisition through production, use and final disposal (i.e. from cradle to grave). While most life cycle studies have been comparative assessments of substitutable products delivering similar functions (e.g. glass versus plastic for beverage containers), there has been a recent trend towards the use of life cycle approaches in comparing alternative production processes and this includes the use of LCA in comparing waste management strategies. It also provides a general overview of the product system, which can then be combined with other assessment. tools, such as risk assessment to evaluate the product or service over the entire lifecycle.

According to McDougall et al. (2001), LCA offers a system map, that sets the stage for a holistic approach and then by comparing such system maps for different options, whether for different products or waste management systems, environmental improvements can be made. McDougall et al. (2001) link the concepts of Integrated Waste Management with that of Life Cycle Analysis.

Benefits and limitations of Life Cycle Analysis

LCA considered the first numerical approach to SWM. Here the whole management system is considered in one system boundary considering the waste as a product from generation to ultimate disposal. In brief the benefits and drawbacks of are as follows:

(i) Use of LCA techniques will not necessarily guarantee that one can choose which option is "environmentally superior" because it is not able to assess the actual environmental effects of the product, package or service system. The actual environmental effects of emissions and wastes will depend on when, where and how they are released into the environment. LCA allows the trade-offs associated with each option to be assessed and comparisons made.

(ii) LCA is but one tool in the "environmental management toolbox" and should not be used in isolation to decide such issues as which waste management treatment option is to be preferred.

(iii) A difficulty associated with LCA is establishing where the boundary is and the definition of the functional unit.

(iv) The results produced by variations of LCAs (e.g. investigating the same product) differ in practice.

(v) LCAs are restricted to looking at environmental impacts only usually.

2.12 Multicriteria Decision Analysis System

2.12.1 General

MCDA is a multi-disciplinary approach amenable to capturing the complexity of natural systems, the plurality of values associated with environmental goods and varying perceptions of sustainable development. The stakeholders participating in a MCDA procedure have the possibility and the responsibility to take into account perspectives and information that may go beyond those considered in their own discipline. Multicriteria decision making has some inherent flexibility and better stakeholder involvement. Despite an early insight by Benjamin Franklin into multicriteria formulation of decision problems in 1772, when Franklin used structuring and evaluation to solve problems with conflicting criteria and uncertainty, it was not until 1972 that the term multiple criteria decision making (MCDM) was introduced into management science. Now-a-days the terms multicriteria decision analysis (MCDA) are more common for the same thing.

Over the past two decades, MCDA has developed into a discipline in its own right. A common characteristic of all MCDA approaches is that taking several individual and often conflicting criteria into account in a multidimensional way leads to more robust decision making rather than optimizing a single dimensional objective function (such as cost benefit analysis). In addition, the multicriteria approach assists decision makers to learn about the problem and the alternative courses of action from several points of view. The normal approach is to identify several alternatives, (such as different waste management scenarios) which are then evaluated in terms of criteria that are important for the system or circumstances of the system being developed. The result is a ranking of the alternatives. The type of criteria chosen in these model types depends on the objectives of the system, and therefore could include risk assessment or environmental impact assessment.

MCDA has undergone an impressive development during the last 30 years, in part because it is amenable to handling today's complex problems, in which the level of conflict between multiple evaluation axes is such that intuitive solutions are not satisfactory. MCDA is not a tool providing the 'right' solution in a decision problem, since no such solution exists. The solution provided might be considered best only for the stakeholders who provided their values in the form of weighting factors, while other stakeholders' values may indicate another alternative solution. Instead, it is an aid to decision-making that helps stakeholders organize available information, think on the consequences, explore their own wishes and tolerances and minimize the possibility for a post-decision disappointment [Belton and Stewart, 2002]. Multiple MCDA methods are available, suitable for a wide variety of decision situations. Furthermore, several weighting techniques have been developed to help stakeholders involved in a MCDA procedure become aware and articulate their preferences. However, certain structural elements are common to all decision situations, independent of the MCDA method used These structural elements are briefly described in the following paragraphs.

2.12.2 Structural Elements

The core elements in a MCDA problem are certainly the set of alternative actions and the set of criteria along which these actions have to be evaluated. However, there are a number of structural and external characteristics that go beyond an arithmetic definition of these basic elements. Several approaches are available to help approach these characteristics in a consistent and systematic way. One of the most convenient and comprehensive is the **CAUSE** checklist (Criteria, Alternatives, Stakeholders, Uncertainty, Environment) [Belton and Stewart, 2002].

Criteria represent the decision maker(s) or other stakeholders' points of view along which it seems adequate to establish comparisons [Bouyssou, 1986]. There are two main approaches to determining the set of criteria, reflecting the two ways of building a MCDA problem. A top-down approach is compatible with 'value focused thinking' where criteria are built in a hierarchical structure, known as 'value tree', leading from primary goals to main (fundamental) objectives, which in turn are further broken down to specific criteria [Keeney and Raiffa, 1976, Keeney, 1992]. The bottom-up approach supports 'alternative-focused thinking', where criteria are identified through a systematic elicitation process, and may subsequently grouped in broader categories. In both cases, a coherent set of criteria presents the following properties:

Value relevance: Criteria are linked to fundamental goals of the stakeholders enabling them to specify preferences.

Understandability: The concept behind each criterion is clear and there is a common view about the preferred direction of the alternatives' performances.

Measurability: The performance of alternatives can be expressed on either a quantitative or a qualitative measurement scale.

Completeness: The set of criteria strives to cover all important aspects of the problem considered while still being concise and operational.

Non-redundancy: No criteria reflects the same concept as another, thus avoiding double-counting and over-attributing importance of a single aspect.

Alternatives are usually thought of as 'given', in the sense that they are *a priori* and strictly defined. However, alternatives may result from the systematic exploration of the objectives pursued in the decision situation considered. Especially in problems of strategic nature, the challenge is to detect interesting alternatives not obvious or apparent at first sight- on the basis of the main concerns expressed during problem identification. In his work on "value-focused thinking" Keeney [1992] emphasizes the importance of generating alternatives through creative thinking focused on the values of the people concerned. In other occasions, where decision makers face a large number of *a priori* defined alternatives, a first crucial step is to identify a manageable set of 'good' or 'interesting' or 'representative' alternatives. Screening or sorting techniques can facilitate the search for preferred alternatives. Finally, the alternatives may be implicitly defined as combinations of discrete actions. In such cases, decision makers seek to determine the most attractive combination (portfolio) of the available actions.

Decision maker(s) or other **stakeholders** involved in the decision situation are those identifying the nature of the problem and driving the solution procedure towards the preferred direction. Although the two terms are sometimes used interchangeably, for our purposes, decision makers are those assigned with the responsibility to take the final decision, whereas stakeholders is a much broader notion encompassing any single individual or group of people with an interest or concern in the examined problem. The decision makers are thus expected to take into account the stakeholders' point of view depending on their overall managerial behavior, the type of the problem considered and the ability of stakeholders to assist or to hamper the solution's implementation. However, the involvement of stakeholders in the MCDA procedure is useful in capturing several aspects of the problem and getting a better insight to its potential consequences. Acknowledging **uncertainty** is another crucial element of MCDA problems. The main cause of uncertainty is limited knowledge about external parameters that may influence the performances of the considered actions. This type of uncertainty can be handled by constructing scenarios for various possible values of these uncertain parameters, as well as by the exploitation of probabilities in the treatment of stochastic events. In addition, decision makers have to handle internal uncertainty stemming from hesitations during the problem structuring process (which alternatives, how important are the criteria, etc.). The problem's solution depends greatly upon the way both external and internal uncertainties are taken into account and the techniques used to incorporate them into the analysis.

Environment refers to all those parameters defining the decision context. They may include fiscal, legislative or cultural aspects, which may broaden or restrict the scope of the analysis and impose constraints in the decision making procedure. Even if all other elements are the same, the problem's solution might differ if the decision is taken in another location or time period.

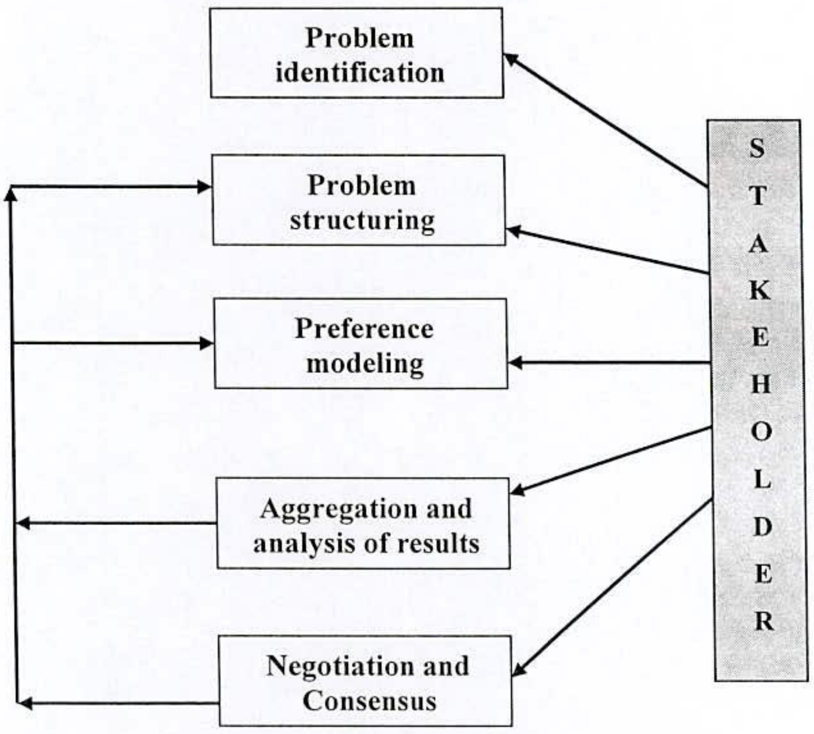


Figure 2.3 Simplified flow diagram of MCDA

2.12.3 Advantages and Disadvantages of MCDA

The main advantages of MCDA are as follows,

(i) Allows a systematic approach to evaluate policy options and helps understanding of the problem.

(ii) Directly involves the stakeholders facing a particular decision problem in order to detect their preferences and values regarding the decision criteria.

(iii) A mixture of quantitative and qualitative information can be incorporated. MCDA goes beyond the evaluation of purely economic consequences and allows non-economic criteria to be assessed on, an equal basis.

(iv) Can consider a large variety of criteria, whether quantitative or qualitative, independent of the measurement scale. Hence, it allows for a more comprehensive analysis for sustainability, since it can include all aspects of sustainability rather than being restricted to marketed goods or monetized costs and benefits [Oman, 2000].

(v) Account can be taken of the preferences of the various stakeholder groups with conflicting objectives.

(vi) Multicriteria techniques offer a level of flexibility and inclusiveness that purely economic based models tend to lack.

(vii) These methods do not produce the "best" solution, but a set of preferred solutions or a general ranking of all solutions. Solving such a multicriteria problem is therefore, a compromise and depends on the circumstances in which the decision aiding process is taking place.

However, it also posses the following limitations,

(i) There is a need for personal judgment and experience in making the decisions.

(ii) Some of the multicriteria techniques are very cumbersome and unwieldy.

(iii) The allocation of weights to each criterion is subjective. Changing the weights could lead to a different result.

A details description of the various MCDA techniques can be found in Guitouni and Martel (1998), Rogers (2001), Roy (1991) and Salminen et al. (1998).

No single solution completely answers the question of what to do with our waste. Every community or region has its own unique profile of solid waste. The composition of the waste varies, depending on such diverse variables as urbanization, commercial enterprises, manufacturing, and service sector activities. Similarly, the attitudes of people in different regions of the country vary regarding waste management practices. Community and waste diversity are two reasons why no single approach to waste management has been accepted as the best method. Since there is no preferred method, every community must create its own best approach to dealing with its waste. In MCDA, due to its flexible decision approach one can made its own approach to handle the waste management issues. Considering these, in this study the MCDA approach is adopted to develop an integrated municipal solid waste management system for Bangladesh.

CHAPTER THREE

OVERVIEW OF THE STUDY AREAS

3.1 General

French traveler *Francois Bernier* (1676) said about the amazing beauties of Bangladesh, 'It has a hundred gates open for entrance but not one for departure'. It is a land of enormous beauty, hundreds of serpentine rivers, crystal clear water lakes surrounded by ever green hills, luxuriant tropical rain forests, beautiful cascades of green tea gardens, world's largest mangrove forest etc.

This chapter describes the historical background and general information such as location, city layout, population, socio-economic and environmental condition of the study areas, six major cities of Bangladesh, namely, Dhaka, Chittagong, Khulna, Rajshahi, Barisal and Sylhet. Overview of MSW management such as source storage and separation; primary collection, on-site storage, secondary collection and transportation; reuse, recycling and treatment; composting, ultimate disposal site and problems of existing management practices of MSW in four major cities of Bangladesh are described here.

3.2 Historical Background of the Study Areas

The city corporation areas of six major cities of Bangladesh, namely, Dhaka, Chittagong, Khulna, Rajshahi, Barisal and Sylhet are considered in this study. The administration of all these six cities is headed by a Mayor, elected directly voted by the city dwellers of the respective city corporation. Brief accounts of historical development of these cities are described here. However, details references can be found in DCC (2005), CCC (2005), KCC (2005), RCC (2005), BCC (2005) and SCC (2005).

Dhaka, the capital city of Bangladesh is one of the densely populated cities of the world. The literal meaning of the Bengali word 'Dhaka' is "concealed". The short-lived partition of Bengal into two provinces in 1905, which established Dhaka as the capital of East Bengal, triggered a nationalist uprising that largely incubated the broader Indian independence movement. In the 1950s and 1960s, increasing political and cultural friction between East and West Pakistan gave birth to a secularist Bengali nationalist movement in the East, and later erupted in the nine-month long Bangladesh Liberation War in of 1971, which established an independent Bangladesh with Dhaka as its capital.

In 7^{th} century A.D. The Chinese traveler poet, Huen Tsang, described Chittagong as the city as "a sleeping beauty emerging from mists and water". It first gained prominence with the arrival of the Portuguese for whom it was an important harbor city. In the 18^{th} century, the East India Company took control of it. Chittagong used to be a possession of the Kingdom of Arakan. Later it was claimed by the king of Burma and this led to a conflict between the Burma and the United Kingdom in 1824. From there, it was roundly under control of the British. With the withdrawal of the British from the Indian subcontinent in 1947, Chittagong became part of East Pakistan. In 1971 it became part of Bangladesh after it won its independence from Pakistan.

Khulna city, the third biggest 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 headquarters, which serves as a gateway to the seaport of Mongla, the second largest seaport of the country. Rajshahi city, the fourth largest city in Bangladesh, is the headquarters of the Rajshahi division comprising the northwestern districts lying west of the Jamuna river and north of the mighty Padma river. It is famous for archeological and historical places like Mohastnangor, Paharpur Buddhist Monastery, Kantajee's Temple, Ramshagar Dighi, Choto Sona Masjid, Shopnopuri and Rajshahi University.

Barisal city, the fifth largest city and located south west part of Bangladesh. It is a revering area. It is also famous for gardens of coconut trees. There is a well-known proverb in the Barisal region "paddy, river and canal the combination of these three things make the name Barisal".

Sylhet region is in the northeastern part of Bangladesh. The geopolitical situation of Greater Sylhet was as such that it was bounded to look with interest in all periods of history- ancient, medieval and modern. Bordered by Khasia-Jayantia hills in the north and Cachar in the East. The river passes through Sylhet in Surma. According to old legends, in the 12^{th} century, King

Khetrapal dug up a canal from the river 'Barak' and named it as per the name of his beautiful queen 'Surma'. The Ancient name of Greater Sylhet was Srihatta, which in Sanskrit means - a prosperous center of trading.

Table 3.1 shows the year of establishment of six major city corporations of Bangladesh with the year of establishment as municipal committee.

Table 3.1 Establishment of six city corporations of Bangladesh

City corporation	Establishment as municipal committee	Establishment as city corporation
Dhaka city corporation	1864	1990
Chittagong city corporation	1863	1990
Khulna city corporation	1884	1990
Rajshahi city corporation	1876	1991
Barisal city corporation	1869	1998
Sylhet city corporation	1878	2002

3.3 General Information

3.3.1 Location and Layout

The city of Dhaka is located in the southern portion of the district of Dhaka and almost in the middle portion of the country. The city is surrounded by the main river Buriganga in the south; the Balu and the Shitalakhya rivers in the east; Tongi Khal in the north and the Turag river in the west. Chittagong is situated within 22°-14′ and 22°-24′-30′′ N Latitude and between 91°-46′ and 91°-53′ E Longitude and on the Right Bank of the river Karnafully. It is surrounded by Potia thana in the south-west site, Bay of Bengal in the southern site and other hilltrack area is adjacent to the District .Khulna city is situated on a natural levee of the Rupsha and Bhairab rivers and characterized by ganges tidal floodplains with low relief, criss-crossed by rivers and water channels and surrounded by tidal marshes and swamps. Surrounding districts are Satkhira, Bagerhat, Norial and Jessore. Rajshahi city is located in the northern region of the country. The city is bounded on the north by Paba Thana, on the east by Charghat Thana, on the south by the Padma river and on the west by Godagari Thana. Barisal city is situated in southwest region of the country. Sylhet city is bounded by Asham and Meghalaya stats of India, on the south Moulovibazar district, on the east Asham state of India and on the west the district Sunamgonj and Habigonj.

Table 3.2 shows the location of six city corporations of Bangladesh with latitude and longitude.

Table 3.2 Location of six city corporations of Bangladesh

Name of city	Latitude	Longitude	Location in map
Dhaka[1]	24° 40' N to 24° 54' N	90° 20' E to 90° 30' E	Middle region
Chittagong[2]	22°-14′ N to 22°-24′-30′′	91°-46′ E to 91°-53′ E	South east region
Khulna[3]	22° 30' N	89° 20' E	South west region
Rajshahi[4]	24° 21' N to 24^0 23' N	88° 28' E to 88° 38' E	North west region
Barisal[5]	22° 20' N	90° 15' E	South west region
Sylhet[6]	$25^0$54' N	$91^0$52' E	North east region

Source: [1]DCC (2005), [2]CCC (2005) [3]KCC (2005), [4]RCC (2005), [5]BCC (2005) & [6]SCC (2005)

The layout of six major cities of Bangladesh, namely, Dhaka, Chittagong, Khulna, Rajshahi Barisal and Sylhet are shown in Figure 3.1.

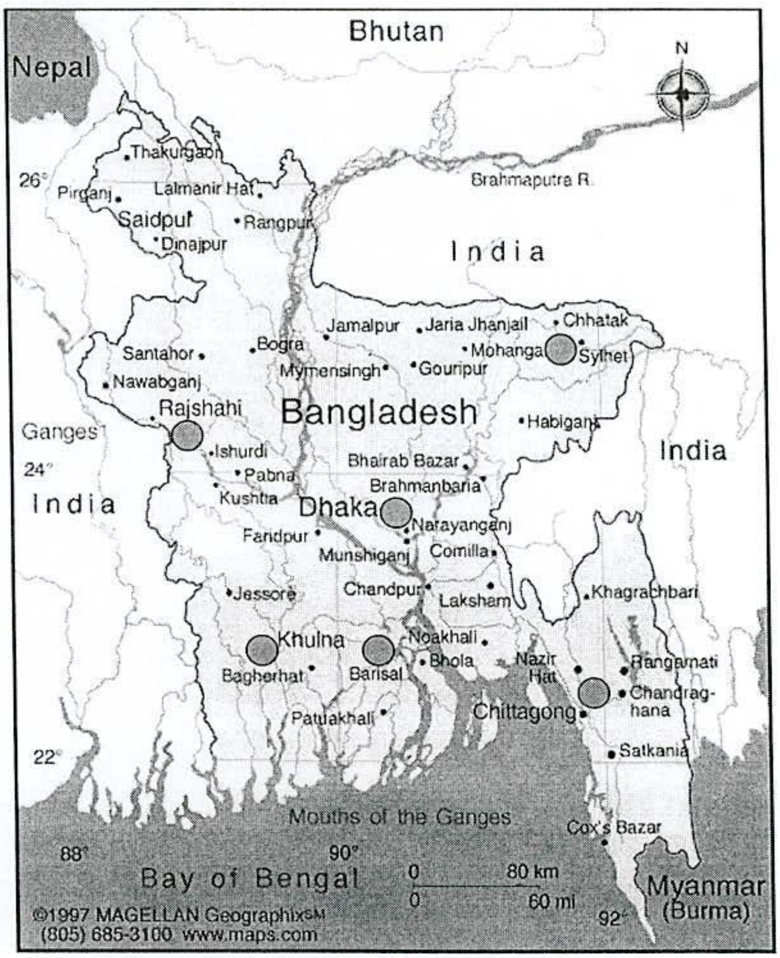


Figure 3.1 Location of study areas in Bangladesh

3.3.2 Population

Dhaka, the capital city of Bangladesh, with a population of about 11 million in 2005 as claimed by different mass media, is one of the densely populated cities of the world. The total population in Dhaka city grew from only 3.4 million in 1991 (BCAS, 1991) to 7.0 million in 1999 (DCC, 1999). The rapid rise in population of Dhaka city has been caused mainly by a large number of people migrating from rural areas. CCC conducted a survey in 2002 to focus about the total population in the city corporation with a growth rate of 1.8%. The city corporation authority calculated the total population in 2004 as about 3.7 million among them male 54.37% and female 45.63%; population density per sq km 23700. Muslim 83.92%, Hindu 13.76%; Buddhist 2.01%, Christian 0.11% and others 0.2%. Khulna city is also a densely populated area with 18,424 populations per square kilometer (KDA, 2004). According to BBS in 2001 census, total population in Khulna city area is 0.77 million. The total population in Khulna city area was 0.66 million in 1990, 0.85 million in 1998 (BBS, 2001) and estimated to 1.5 million in 2005 (KCC, 2005). The rapid rise in population in this city due to large number of migrating people from rural areas of neighboring districts such as Satkhira, Bagerhat, Norial and Jessore. Rajshahi city covering an area of 9.15 sq. km (3.53 sq. miles) and consisting of 8 municipal wards recorded with population of 39,993 in 1951; 56,885 in 1961; 96,645 in 1974 and 1,43,493 in 1981. In census 1991, total population was 2,94,056 over an area 48.00 sq. km consisting of 30 municipal wards. The decadal population growth rate is 15.6% and annual compound growth rate is 1.46%. In census 2001, the population of Rajshahi city was around 0.4 million and the total populations are about 0.45 million in the year 2005 as claimed by city authority. In Barisal city, total population was about 0.40 million as claimed by city authority in the year of 2005. Among the total population, adults are about 1,64,433, which is 41.39% of total population. The rate of literacy is nearly about 80%. According to Bureau of Statistics, considering 3% growth rate over 2003 Census the total population in the 2004 Census is taken to be 3,51,724 in the Sylhet city corporation area. According to city corporation the estimated population in 2005 was about 0.5 million.

Table 3.3 shows total population and area of six major cities of Bangladesh.

Table 3.3 Total population, city area and number of wards in four major cities of Bangladesh			
City corporation	**City area (sq. km)**	**Population (million)**	**No. of wards**
Dhaka[1]	360	11.00	90
Chittagong[2]	156	3.70	41
Khulna[3]	47	1.50	31
Rajshahi[4]	48	0.45	30
Barisal[5]	45	0.40	30
Sylhet[6]	27	0.50	27

Source: [1]DCC (2005), [2]CCC (2005) [3]KCC (2005), [4]RCC (2005), [5]BCC (2005) & [6]SCC (2005)

3.3.3 Socio-economic condition

Bangladesh is one overpopulated and economically vulnerable country. The country's economy is based on agriculture. Rice, jute, tea, sugarcane, tobacco, and wheat are the chief crops. Economic indicators show that average per capita income of the people of Bangladesh is nearly US$ 450 and GDP is US$ 14.89 million (MOHFW, 2004). In Dhaka city, around 55 percent of people live below the poverty line. Half of this figure lives in slums and squatter settlements. Within a decade, the slum population has risen to about 3 million. Access to water supply, sanitation, solid waste management and other municipal services is extremely limited.

Almost 40% of the country's heavy industrial activities includes Dry-dock, Dock yard, Still mills, Cement and Clinker factory, Cable manufacturing, Oil refinery etc are situated in the city. Moreover the city accommodates huge numbers of light and medium scale industrial activities along with the Chittagong Export Processing Zone (CEPZ). The inhabitants are divided into four broad socio-economic categories based primarily on their own perception of their socio-economic status, living standard and stated incomes and expenditures. This average income ranges from 5000 to 50,000 Tk. But. the distinction between the middle and upper income categories is quite sharp. Similarly, the poor category is very distinct and lies entirely below the 5,000 Tk mark.

Khulna city is strategically located in an important hub as far as its development potentialities are concerned. The average household income per month is Taka 5,543 (US$ 90). 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). In Rajshahi city, industrial activities are comparatively poor. Inadequate development of infrastructure facilities, shortage of capital and its low productivity regionally acted as a brake on the development of economy like industry, trade and commerce. According to BBS in 1991 census, 6.61% of the dwelling households depend on agricultural as the main source of household income. In Barisal city, the economic condition of the people of this city is neither so high nor so low as most of the city dwellers are living in middle class status. The region is apparently more affluent in terms of economic indicators, mainly because of a large number of expatriates living abroad, but the relative inequality in resource distribution is rather pronounced than in many other parts of the country. The Sylhet region lags behind the national average in almost all sectors of human development.

3.3.4 Environmental condition

In Dhaka city, environmental pollutions are increases day by day. The city is suffering with its expanding population bringing three major issues of environmental concern: air pollution, water pollution and municipal solid wastes. The city also suffers from unexpected local flooding due to drainage congestion during heavy rainfall. There is no proper drainage system to relief from excess water during rainfall, which is responsible for sudden floods within the city areas.

Chittagong is a hilly area and it is surrounded by green tress .It is also famous for it numbers of historical ponds. But due to rapid urbanization bare land, ponds and tree areas are being covered by different infrastructures. The city contains almost fresh air coming from sea. There is a lot of natural and artificial canals spreading all over the city. These canals might be a good navigation route for internal communication. But due to careless activities of the city dwellers and lack of proper maintenance from the authority these canals are now become dumping sites of wastes. Six seasons are predominantly strong here. Summer is not very hot here and winter is also not severe cool. As it is a sea shore area, water of here contains a sort of salinity. But water supply authority tries to supply fresh water to the city dwellers.

In Khulna, 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. Rajshahi has a sub- tropical monsoon climate region. The mean relative humidity is found to low in March (60.2%) and it is high in August - September (88.4%). Ground water contamination is high due to high content of iron is 0.4 - 3.5 mg/l and manganese is 0.1-1.52 mg/l. Barisal, as a small city, usually neat and clean comparatively to other cities. But it is obvious that the rapid urbanization brings the pollution along with the development.

Table 3.4 shows the annual average rainfall and temperatures in six major cities of Bangladesh.

Table 3.4 Annual average rainfall and temperatures in six major cities of Bangladesh

City corporation	Annual avg. rainfall (mm)	Temperature (summer)	Temperature (winter)
Dhaka	1824	30 to 37°C	10 to 20°C
Chittagong	2687	32.5^0C (max.)	13.5^0C (min.)
Khulna	1715	30°C (avg.)	15°C (avg.)
Rajshahi	1625	43.3°C (max.)	8.8°C to 25.9°C
Barisal	1526	32°C (avg.)	12°C (avg.)
Sylhet	3500	33^0C (max.)	13^0C (avg.)

Source: DOE (2005)

Transformation of Municipality to City Corporation, present Sylhet is now flourishing by the concept of rapid urbanization. This concept enhancing the local people's investment in the field of constructing large superstructures, which are totally business oriented. In spite of this, the environmental condition including air water and soil are much better than any other part of Bangladesh. Till now there is no report of exceeding the permissible limit of pollution in the physical environment. But it is obvious that, this rapid urbanization will bring the pollution along with the development.

3.4 Remarks

Summarize the above information and date we can conclude that there are no huge difference in the study cities. Except some geographical difference almost everywhere the population density, socio-economical pattern, temperature, rainfall etc. are almost same. Some of the new city corporations have not yet build their full functional capabilities as city corporation, mainly due to financial, manpower problem and inadequate presence of expert. The city corporation authority usually involves in the following functions:

- Construction and maintenance of roads, bridges and culverts;
- Removal, collection and disposal of refuse;
- Provision and maintenance of street lighting;
- Provision of water supply;
- Establishment and maintenance of public markets;
- Provision, maintenance and regulation of graveyards and burning places;
- Registrations of birth, deaths and marriages;
- Maintenance of slaughter houses;
- Control over private markets;
- Provision and maintenance of parks and gardens;
- Naming of roads and numbering of houses;
- Provision of nominal stipends to primary education institutions; and
- Slum improvement.

But by laws they are not responsible to collect the wastes from the household level. For most of their activities, they need fund from the central government, as due to loose the popularity the city mayor never goes for tax expansion.

CHAPTER FOUR

EXISTING MUNICIPAL SOLID WASTE MANAGEMENT AND ITS CONSTRAINTS IN BANGLADESH

4.1 General

The problem of waste is primarily an urban phenomenon. Rapid urbanization and indiscriminate setting up of industries within cities, as is the case in Bangladesh, worsens the problem. About a fourth of Bangladesh's population is currently live in urban areas. The local government authorities of a city have historically been responsible for managing the solid waste generated within the city. In most of the city corporations, there is no separate department for solid waste management. Solid waste management system is organized and run by the conservancy section of city corporation, whose prime responsibility is to provide services to the city dwellers in street lighting, drain cleaning, street sweeping, sanitation, waste management, and other facilities related to the benefits of city inhabitants.

4.2 Quantity of Solid Waste

Bangladesh, like most of the developing countries, is facing a serious environmental problem due to huge amount of MSW generation and its mismanagement. The study reveals that generation rate is nearly similar to each major city. Overall, the per capita generation varies from house to house depending on the economic status, food habit, age and gender of household members, seasons. Even it varies in different days of a week. Table 4.1 shows the income level based MSW generation rate at household source in six major cities of Bangladesh. Total generations of MSW in the six major cities of Bangladesh are given in Table 4.2. Contribution of different sources in total generation of MSW in the six major cities of Bangladesh are given in Table 4.3 and Table 4.4 shows the generation of MSW in six major cities of Bangladesh. All these waste data (Table 4.1 to 4.4) are present here are based on a feasibility study (WasteSafe 2005) recently conducted in the Department of Civil Engineering, Khulna University of Engineering & Technology.

Table 4.1 Income level based MSW generation rate at Household source in six major cities of Bangladesh

Income Level	Generation rate (kg/capita/day)					
	Dhaka	**Chittagong**	**Khulna**	**Rajshahi**	**Barisal**	**Sylhet**
A	0.504	0.378	0.368	0.343	0.327	0.429
B	0.389	0.343	0.333	0.320	0.278	0.395
C	0.371	0.350	0.319	0.242	0.247	0.340
D	0.305	0.253	0.264	0.309	0.269	0.248
E	0.270	0.189	0.203	0.239	0.172	0.260
Average	**0.368**	**0.302**	**0.297**	**0.291**	**0.258**	**0.335**
SD	**0.137**	**0.128**	**0.070**	**0.071**	**0.085**	**0.138**

Note: SD-Standard Deviation

Table 4.2 Total generation of MSW in the six major cities of Bangladesh

Sources	Daily Generation of MSW (tons/day)					
	Dhaka	**Chittagong**	**Khulna**	**Rajshahi**	**Barisal**	**Sylhet**
Residential	4048.00	1102.30	455.50	130.95	103.20	167.50
Commercial	1177.61	183.07	60.143	31.54	20.14	39.66
Institutional	62.45	14.91	5.26	2.06	1.89	2.76
Municipal Services	28.30	6.67	2.86	2.11	1.49	1.72
Others	20.00	8.00	5.00	3.00	3.00	3.00
Total	**5340**	**1315**	**520**	**170**	**130**	**215**

Table 4.3 Contribution of different sources in total generation of MSW in the six major cities of Bangladesh

Sources	MSW generated daily from different sources (%)					
	Dhaka	**Chittagong**	**Khulna**	**Rajshahi**	**Barisal**	**Sylhet**
Residential	75.86	83.83	85.87	77.18	79.55	78.04
Commercial	22.07	13.92	11.60	18.59	15.52	18.48
Institutional	1.17	1.14	1.02	1.22	1.46	1.29
Municipal Services	0.53	0.51	0.55	1.24	1.15	0.80
Others	0.37	0.60	0.96	1.77	2.32	1.40
Total	**100**	**100**	**100**	**100**	**100**	**100**

Table 4.4 Generation of MSW in six major cities of Bangladesh						
MSW Generation	**Dhaka**	**Chittagong**	**Khulna**	**Rajshahi**	**Barisal**	**Sylhet**
Population (Millions)	11	3.65	1.5	0.45	0.40	0.50
MSW generation (tons/day)	5340	1315	520	170	130	215
MSW generation rate (kg/capita/day)	0.485	0.360	0.346	0.378	0.325	0.430

.It should be noted that in a tropical country like Bangladesh, waste generation varies depending on the season of the year. During the wet season and the fruit season (jackfruit and mango season), waste generation is higher than dry winter season, and the variation may be as high as 20% (SCAS, 1998). Table 4.4 indicates the total MSW generation and per capita waste generation in six major cities of Bangladesh from this project study. Dhaka city has the largest generation of 5,328 tons/day, whereas 2,355 tons generated daily from rest of the five major cities. Figure 4.1 shows the percentage of MSW generations in six major cities of Bangladesh. Per capita waste generation in major cities is ranged from 0.325 to 0.484 kg/day. High per capita waste generation is 0.484 kg/day in Dhaka city whereas low generation rate is 0.325 kg/day in Barisal city. Figure 4.2 indicates the MSW generations according to sources in six major cities of Bangladesh.

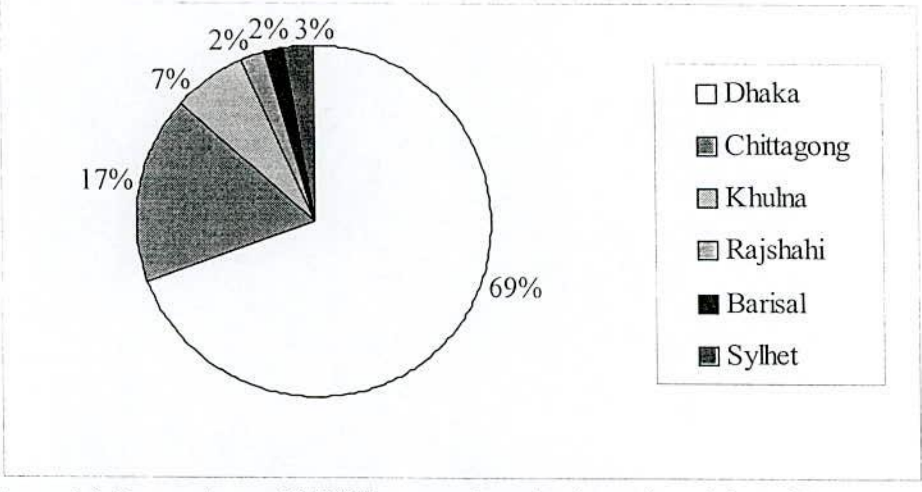


Figure 4.1 Percentage of MSW generations in six major cities of Bangladesh

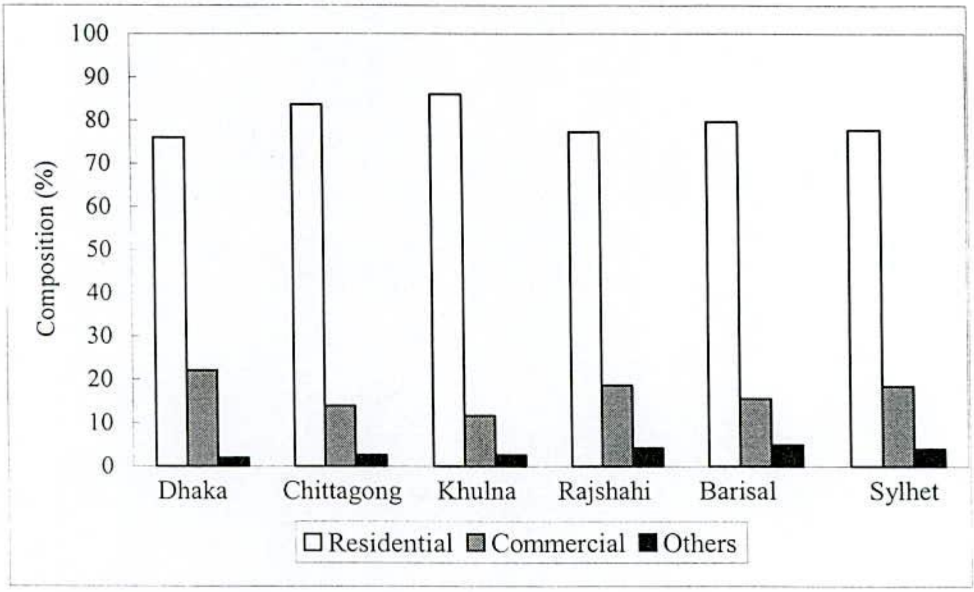


Figure 4.2 MSW generations according to major sources in the six cities of Bangladesh

4.3 Characteristics of Municipal Solid Waste in Bangladesh

There is a little variation in the MSW composition at major cities of Bangladesh. The biodegradable fraction is normally very high as compared to other fractions, essentially due to the use of fresh vegetables. Table 4.5 indicates MSW composition in six major cities of Bangladesh where food and vegetable waste ranges between 68 to 81% whereas paper and plastic waste constitute 7.2 to 10.7% and 2.9 to 4.3%, respectively. The remaining portions of waste are rubber, cloth, metal, tin, glass, dust and others. The average composition of MSW in six cities of Bangladesh according to source and SDS are also given in Table 4.5 for comparison.

Since solid waste from different sources is typically dumped into the same container/truck and obviously get mixed. The composition presented in Table 4.5 represents the average composition of solid waste from different sources. A number of studies have been conducted [e.g. Rahman, (1993), IFRD & BCSIR (1998)] to determine the composition of solid waste generated in different cities of Bangladesh. From previous studies it can be seen that in Dhaka city, food wastes are varied over a wide margin ranging from 58.72 to 88% where as paper and plastics are 1 to 9.59% and 1 to 6.76%, respectively. The remaining portions of waste are rubber, cloth, metal, tin, glass, dust and others. The composition represent here from this study are very close to the values of previous studies.

Table 4.5 Physical composition of MSW in the six major cities of Bangladesh (In wet weight %)

MSW Composition	DCC	CCC	KCC	RCC	BCC	SCC	AVG.	SDS
Food & Vegetables	68.3	73.4	78.9	71.1	81.1	73.5	74.4	69.5
Paper & Paper Products	10.7	10.0	9.5	8.9	7.2	8.6	9.1	6.2
Polythene & Plastics	4.3	2.9	3.1	4.0	3.5	3.5	3.5	5.0
Textile & Woods	2.2	2.1	1.3	1.9	1.9	2.1	1.9	6.3
Rubber & Leathers	1.4	1.0	0.5	1.1	0.1	0.6	0.8	2.2
Metal & Tins	2.0	2.2	1.1	1.1	1.2	1.1	1.4	1.2
Glass & Ceramics	0.7	1.0	0.5	1.1	0.5	0.7	0.7	1.5
Brick, Concrete & Stone	1.8	1.1	0.1	2.9	0.1	1.8	1.3	2.2
Dust, Ash & Mud Products	6.7	5.2	3.7	6.5	3.1	5.4	5.1	2.0
Others (bone, rope etc.)	1.9	1.2	1.2	1.3	1.3	2.8	1.6	4.0
Total	100	100	100	100	100	100	100	100

Note: DCC- Dhaka City Corporation, CCC- Chittagong City Corporation, KCC- Khulna City Corporation, RCC- Rajshahi City Corporation, BCC- Barisal City Corporation, SCC- Sylhet City Corporation; Avg.-Average; SDS-Secondary Disposal Site

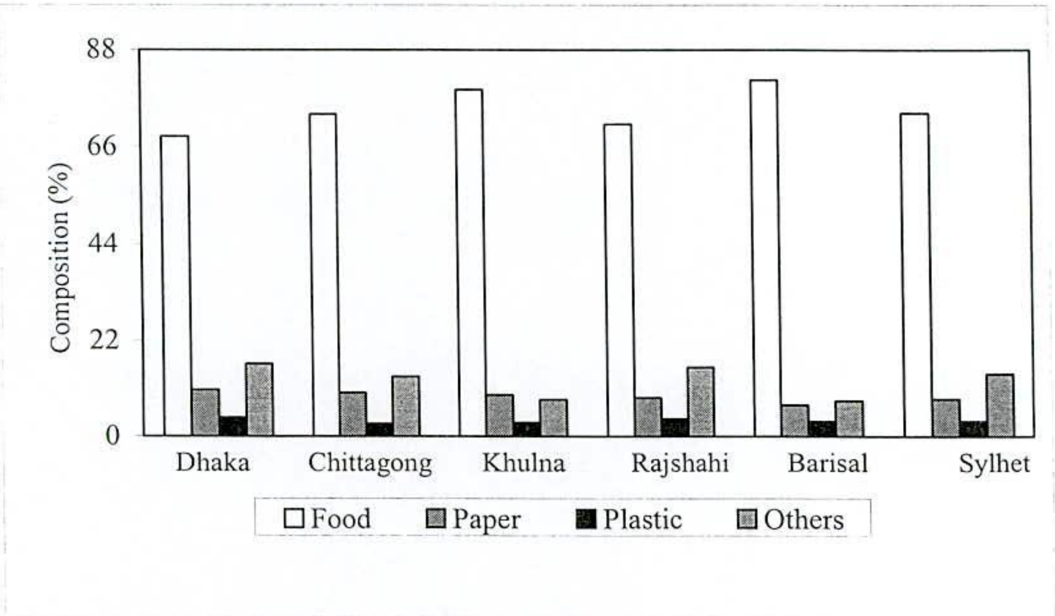


Figure 4.3 The average composition of MSW in six major cities of Bangladesh

The MSW composition at SDS is established by collecting 10 samples from different secondary sites of each city. The average physical composition of MSW at SDS in six major cities of Bangladesh is shown in Table 4.6. The average food & vegetable waste are 69.5%

whereas paper with a portion of 6.2%, which is largely lower than food waste in secondary sites. Plastics are 5.0%, which indicates the packaging materials are not densely related to the daily life. Metal component is only 1.2%, which is very low quantity, and its major portion comes from soft drink cans while the dust & ashes are 2.0% resulting from the daily street, house and yard sweepings.

Table 4.6 Physical composition of MSW in the six major cities of Bangladesh

Cities	Year	Composition (% by wet wt.)							
		Food	Paper	Plastic	Textile, Wood	Rubber, Leather	Metal	Glass	Others
Dhaka[1]	1993	65-88	1-7	1-2	1-2	-			7-15*
Dhaka[2]	1998	70.00	4.00	5.00	0.16	-	0.13	0.25	16.00
Dhaka[3]	1998	65.81	4.13	6.76	6.38	-	6.01^		16.92
Dhaka[3]	1998	62.25	4.68	5.44	7.40	-	1.16^		20.23
Dhaka[3]	1998	58.72	5.68	5.96	5.75	-	7.17^		23.89
Dhaka[3]	1998	67.17	9.59	5.08	4.65	-	2.93^		13.51
Dhaka[3]	1998	81.18	1.77	3.53	1.15	-	1.15^		12.37
Dhaka[3]	1998	73.68	3.40	3.49	3.58	-	6.79^		15.85
Dhaka[3]	1998	82.05	1.02	2.68	3.11	-	7.45^		11.14
Dhaka[5]	2005	68.30	10.70	4.30	2.20	1.40	2.00	0.70	10.40
Chittagong[5]	2005	73.40	10.00	2.90	2.10	1.00	2.20	1.00	7.40
Khulna[5]	2005	78.90	9.50	3.10	1.30	0.50	1.10	0.50	5.10
Rajshahi[5]	2005	71.10	8.90	4.00	1.90	1.10	1.10	1.10	10.80
Barisal[5]	2005	81.10	7.20	3.50	1.90	0.10	1.20	0.50	4.50
Sylhet[5]	2005	73.50	8.60	3.50	2.10	0.60	1.10	0.70	9.90

Note: *Includes glass, metal & others; ^ Includes metal, glass & woods
Source: *[1]Rahman, 1993a; [2]IFRD & BCSIR, 1998; [3]BCSIR, 1998; [4]Moqsud, 2003; [5]WasteSafe, 2005*

4.4 Physical and Chemical Characteristics of MSW

4.4.1 Physical characteristics of MSW

The important physical characteristics of MSW evaluated in this study are pH, percent of moisture content, volatile solid content and ash residue; bulk density and particle size distribution. Table 4.7 represents the physical characteristics of MSW in six major cities of Bangladesh as evaluated through the study of WasteSafe (2005).

The pH values of MSW are measured as ranging in between 7.70 to 8.69. So it can be clearly observed that the MSW of six major cities are in acidic form. Organic materials with a wide range of pH values from 3 to 11 can be composted, but the more desirable pH for composting ranges from 5.5 to 8.5 (Tchobanoglous et al., 1993).

The moisture contents of MSW measured lies between 52 to 70%. Due to this high moisture content, wastes in these areas shows rapid biodegradability. For aerobic composting process, moisture content should be in the range between 50 to 60% during the composting process (Tchobanoglous et al., 1993).

Table 4.7 Physical characteristics of MSW in the six major cities of Bangladesh

Characteristics	Dhaka	Chittagong	Khulna	Rajshahi	Barisal	Sylhet	Average
pH	8.69	8.23	7.76	7.72	7.70	7.71	8.0
Moisture content (%)	70	62	68	56	57	69	63
Volatile solid (%)	71	54	56	48	43	65	55
Ash residue (%)	29	46	44	52	57	35	46
B. Density[a] (loose)* kg/m^3	578	605	610	588	621	609	599
B. Density[b] (loose)* kg/m^3	621	549	566	568	577	669	583
B. Density[b] (medium)* kg/m^3	951	865	764	921	926	899	891
B. Density[b] (compact)* kg/m^3	1127	994	875	1052	1048	1037	1026

*Note: [a]By field test; [b]By laboratory test; *in wet weight basis; Loose: Just fill up the mold without any compaction or input energy; Medium: Compacted in 3 layers providing 12 blows/layer by a hammer of 5.5 pounds in 12" free fall; Compact: Compacted in 3 layers providing 25 blows/layer by a hammer of 5.5 pounds in 12" free fall.*

The volatile solid contents are measured is between 48 to 71%, while the ash residues are obtained lies 29 to 57%. Bulk densities of MSW in six major cities of Bangladesh are measured by both field and laboratory testing. In field testing the loose density lies in between 578 to 621 kg/m^3. In laboratory testing the bulk densities are categorized into three groups such as loose, medium and compact. The bulk densities ranges in loose state 549 to 621 kg/m^3, medium state 764 to 951 kg/m^3 and in compacted state 875 to 1127 kg/m^3.

Table 4.8 represents the particle size distribution of MSW in six major cities of Bangladesh, which are established by sieve analysis of 10 samples from each city.

Table 4.8 Particle size distribution of MSW in the six major cities of Bangladesh

City	Percent finer								
	Sieve opening (mm)								
	200	**100**	**76.2**	**38.2**	**19.1**	**9.52**	**4.76**	**2.38**	**Pan**
Dhaka	100	78	62	42	23	12	8	3	0
Chittagong	100	80	74	53	32	22	18	13	0
Khulna	100	92	82	64	41	28	24	13	0
Rajshahi	100	85	75	61	46	35	27	19	0
Barisal	100	80	69	50	29	19	14	9	0
Sylhet	100	82	67	49	28	16	12	6	0
Average	**100**	**83**	**72**	**53**	**33**	**22**	**17**	**11**	**0**

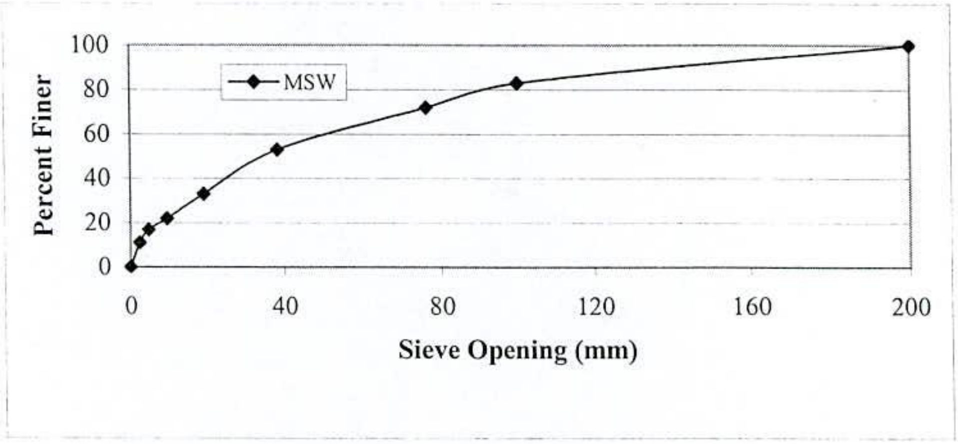


Figure 4.4 Average particle size distribution of MSW in the six major cities of Bangladesh

4.4.2 Chemical Characteristics of MSW

Chemical characteristics of MSW are especially important to determine its possible environmental impacts and in some cases its reuse values. The important chemical characteristics of MSW are carbon, nitrogen, carbon nitrogen ratio, phosphorous, potassium is presented in Table 4.9 and the calorific value is given in Table 4.10.

The percentages of carbon as measured are ranged from 2.67 to 24.93. These wide variations of results caused due to different composition of waste from different sources. The percentages of nitrogen are ranged from 0.17 to 1.62. The ratios of C/N are obtained as 10.17 to 17.22. The percentages of potassium are measured in between 0.38 to 1.37. The percentages of phosphorous as measured are ranged from 0.23 to 0.41.

Table 4.9 Chemical characteristics of MSW in the six major cities of Bangladesh					
City	**C**	**N**	**C/N**	**K**	**P**
	(%)	(%)	-	(%)	(%)
Dhaka	9.02	0.89	10.17	0.62	0.31
Chittagong	2.67	0.17	17.22	0.57	0.23
Khulna	24.93	1.62	16.08	1.37	0.41
Rajshahi	6.53	0.56	12.15	0.38	0.31
Barisal	15.15	1.23	12.44	1.18	0.40
Sylhet	10.70	0.90	11.96	0.42	0.32
Average	**11.50**	**0.89**	**13.34**	**0.76**	**0.33**

Note: C-Carbon, N-Nitrogen, C/N- Carbon nitrogen ratio, P-Phosphorous, K-Potassium; % P as P_2O_5= % P × 2.29; % K as K_2O = % K × 1.20

The calorific values for major components of MSW are shown in Table 4.10. The highest calorific value is 20,467 kJ/kg for rubber. In Bangladesh, the composition of food wastes is very high, while paper, plastic, rubber and wood are comparatively very low in MSW.

Table 4.10 Calorific values for major components of MSW	
Components of MSW	**Energy [a] (kJ/kg)**
Food wastes	5907
Paper	12994
Plastics	20077
Wood	14578
Rubber	20467
MSW=	**7349**

[a] as oven dry basis; Btu/Ib × 2.326 = kJ/kg

4.5 Existing Management Practices of MSW in Bangladesh

Solid waste management has so far been ignored and least studied environmental issues in Bangladesh, like in most developing countries, but recently the concerned stakeholders have begun to consider this area to be an inseparable component to protect human and nature. In Bangladesh, urban population have been increasing at a very steep rate, about 6% and concentrated mostly in six major cities, where nearly 13% of total population and 55 to 60% of total urban population are living. In the cities, the city authority generally manages MSW, however, recently, some NGOs, CBOs and Private organization are working with city authority's initiatives in collaboration or independently. But the situation remains unchanged. It becomes evident that an integrated solid wastes management (ISWM) is required considering the relevant socio-economic settings and technological aspects of the country. To explore the possibility of adopting an ISWM, the limitations, constraints and relevant experiences of existing management system are required to examine explicitly. The strengths and drawbacks at all levels of the existing wastes management systems starting from generation source to ultimate disposal are identified.

Data and related information were collected through field survey, physical interview, literature and other appropriate means. Source storage and separation are done in an informal and uncontrolled means; hardly 30 to 40% of city dwellers practiced it (WasteSafe 2005). Wastes are collected from generation sources by NGOs, CBOs and city authority by door-to-door collection systems. Door-to-door collection systems are introduced recently for wastes collection from generation sources, mainly households, and then dispose major portion of it to the nearest SDS. City authorities collect these wastes and transfer to the (Ultimate Disposal Site) UDS. There is no engineering/sanitary landfill in Bangladesh. All the UDS of Bangladesh are uncontrolled crude open dumping site where even minimum environmental protections are not provided. Recycling, reuse and reduce are not getting support from formal authority, even the composting, a great potential sector of waste treatment and minimization considering the nature of MSW in Bangladesh, fails to reach desired target due to improper planning (Ali et al. 2004, Sinha & Enayetullah 2000 and Enayetullah & Sinha 2003).

However, major portions of wastes remain unmanaged - throwing them in the adjacent spaces, roadsides and drains. A portion of medical wastes is managed by NGOs (Alamgir et al. 2003) and the remaining follows in the same path of MSW. However, in Dhaka city two private companies have been collecting wastes from SDS and transferred to the UDS for the last 2 years in 6 wards, only out of 90 through a contract. In Khulna city, authority handed over one ward (Ward No. 29) out of 31, in private sector. In these wards total management including door-to-door collections, drain sludge's collection and ultimate disposal of MSW, has been running by a private sector for the last 10 years. A typical waste flow diagram from source to ultimate disposal of Bangladesh is presented in Figure 4.5 (WasteSafe 2005).

As a result, city authorities are facing very complicated situations for the management of vast quantities of MSW. Due to severe financial constraints, lack of motivation, absence of effective legislation to protect the environment, lack of commitment of authority, the MSW has becoming a threat for city dwellers, planners and other concerned stakeholders. There are approximately 17.50 million people living in these six city corporations (after BBS, 2001), generating about 7,800 tons of MSW daily (WasteSafe 2005). Table 4.11 provides the basic information of six-city corporation of Bangladesh.

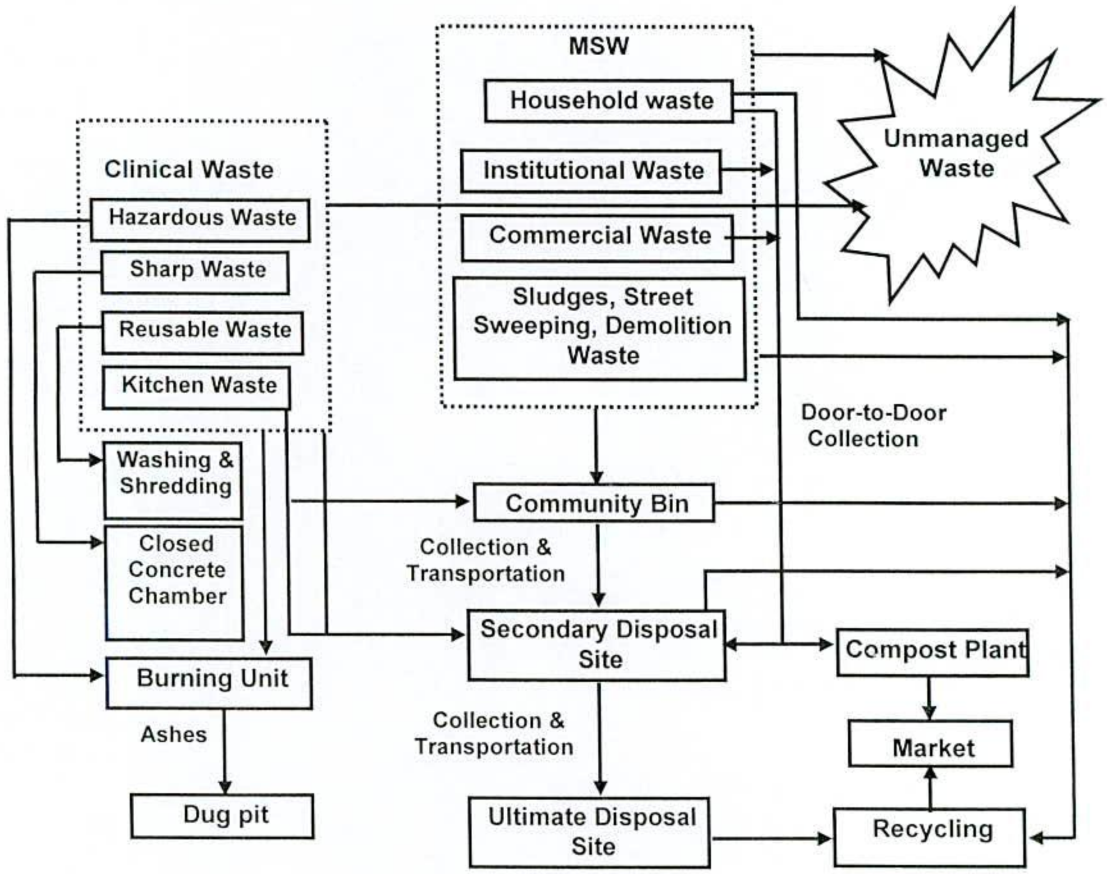


Figure 4.5 Flow path of MSW from source to ultimate disposal in Bangladesh

Table 4.11 Basic information of six city corporations of Bangladesh

City Corporation	City area (sq km)	Population (million)	No. of wards	Wastes generation rate (kg/cap/day)	Total generation (tons/day)	UDS
Dhaka	360	11.00	90	0.485	5340	2
Chittagong	156	3.65	45	0.360	1315	2
Khulna	47	1.50	31	0.346	520	1
Rajshahi	48	0.45	30	0.378	170	1
Barisal	45	0.40	30	0.325	130	1
Sylhet	26.5	0.50	27	0.430	215	1

Note: UDS-Ultimate Disposal Site

4.5.1 Source Storage & Segregation

It has been realized that segregation of waste at source level is the best option to reduce the waste flow to the following stages and ultimately to the final disposal site. Household waste should be separated into different containers/bags for the different categories of waste such as biodegradable and non- biodegradable wastes, which should be collected/dispose separately. Biodegradable waste, which consists of leftover foodstuff, vegetable peels, etc., should be taken to compost facility. Non- biodegradable waste consisting of cans, aluminum foils, plastics, metal, glass, and paper could be recycled. Door-to-door collection of waste is a good method of segregation, but it is not a common practice yet in Bangladesh except in some major cities where some NGOs/CBOs/private organizations are doing such work.

Residential area is the main source of MSW in Bangladesh. The other important sources are commercial place including markets, hotels, restaurants and others. Institutional category include wastes from schools, colleges, universities and government offices, medical facilities and municipal services include street sweeping, drain cleaning but excluding treatment facilities, etc. In Bangladesh, significant portion of population does not have access to waste collection services and only a small fraction of the generated wastes are actually stored for collection and management. A little fraction are also recycled and reused from stored wastes at households. Moreover, due to lack of motivation, awareness and commitment, a considerable portion of wastes, 40 to 60%, are not properly stored, collected or disposed in the designated places for ultimate disposal. As a result, the unmanageable increasing quantity of MSW creates alarming environmental problems.

Householders those cooperating existing management system, store wastes in a plastic or metal container of different size and shape and keep it inside the house or premises, mostly in kitchen and/or corridor. Places where door-to-door collection system prevail, the waste collector collect the container at a particular time and after empty it in their vehicle return it to the homeowner. In other cases, the dwellers dispose these wastes to the nearest community/secondary bin. Generally, single bin is practiced and the collection van also has single compartment, so the waste becomes mixed. Study reveals that source storage and separation of organic, inorganic and hazards are highly neglected by the city dwellers. Figure 4.6 shows the different types of bin uses at household in residential areas.

Table 4.12 shows the possible segregation of wastes depending of their biodegradability. Several organic materials with high lignin contents (such as newsprint, paper etc.) are significantly less biodegradable and in this study they are considered as non-biodegradable.

Table 4.12 Typical segregation of household waste of Bangladesh

Biodegradable Wastes	Non-Biodegradable Wastes
Food waste	Paper and paper products
Vegetables wastes	Plastic/polythene
Yard wastes	Pet Bottles/Oil Containers
Animal Bone	Textile/Clothes/Rags
Misc. biodegradable	Rubber/Leather/Wood
	Rope/Straw/Coconut
	Glass Bottles/Metal/ Tin Can
	Ceramic/Crockery
	Bricks/Concrete/Demolition
	Battery/Aerosol Bottles
	Shampoo/Shaving/Nail polish/
	Shoe polish
	Paint Items

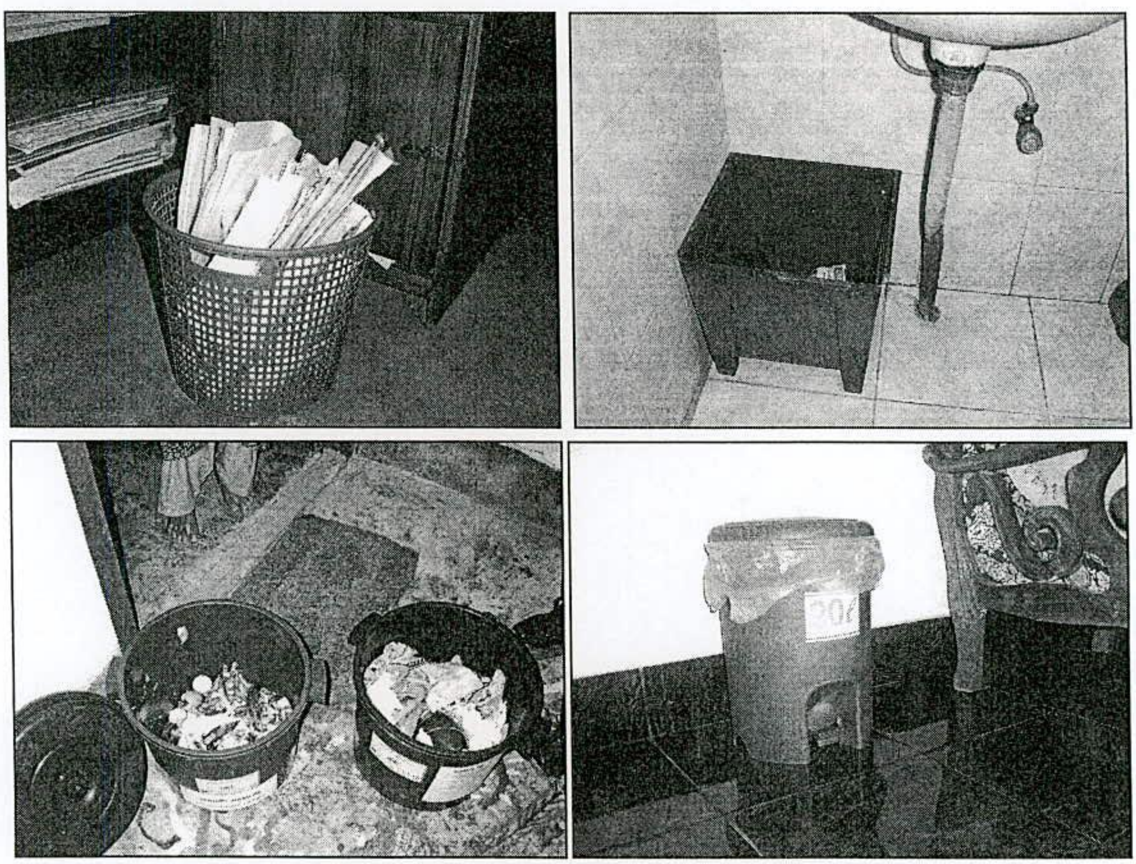


Figure 4.6 Different types of bin uses at household in residential areas

4.5.2 Primary collection

In Bangladesh, a significant portion of population does not have access to waste collection services and only a fraction of the generated wastes are collected by door-to-door collection systems introduced by NGOs and CBOs. Solid wastes are collected from generation sources by NGOs, CBOs and city authority by door-to-door collection systems, and most of the cases owner by himself disposes it to the nearest community bins/SDS/open land/road sides/drains. City authorities collect these wastes and transfer to the UDS. City corporation's motorized vehicles collect the wastes from SDS and transfer to the UDS. Some NGOs transfer their collected organic wastes to composting plant. Whilst city authority has some limited numbers of non-motorized Rickshaw vans and Hand trolley those are mainly used for the collection of MSW from community bins located at roadside, home side, near market, and transfer to SDS. Besides this drain sludge's are also collected by these vans.

In the areas where door-to-door collection systems are not available, house dwellers or servant carry wastes to nearby community bins/secondary sites. Waste collection trucks visit these locations at regular interval and collect wastes for ultimate disposal. Households store the wastes at their own responsibility; however, in an experimental attempt, some NGOs and CBOs supply the bins to motivate people for cooperating waste management system. Experiences reveal that proper storage and dispose in proper hand/place are first steps to achieve desired goal. Motivation to households and door-to-door collection are proved very useful. But the city authority does not have the resources to provide door-to-door collection system because it requires more human resources, physical facility, more responsibility to collect the waste daily directly from generation sources and require proper planning and tight schedule (Ahsan et al. 2005). However, Chittagong and Rajshahi city authorities are directly involved in door-to-door collection system (Chowdhury et al. 2005). In other cities, door-to-door collections are done by mainly NGOs and CBOs. Figure 4.7 and 4.8 shows the wastes collection system from generation sources and disposal.

Non-motorized rickshaw vans are generally uses to operate the collection system. One driver and one helper are assigned for each van and the collection generally occurs daily for 8 to 9 hours (7 am to 5 pm) from residential sources as well as some offices. Non-motorized rickshaw vans are almost similar 3-wheeler type, which are uses in different cities of Bangladesh. The capacity is nearly 270 kg/van/trip.

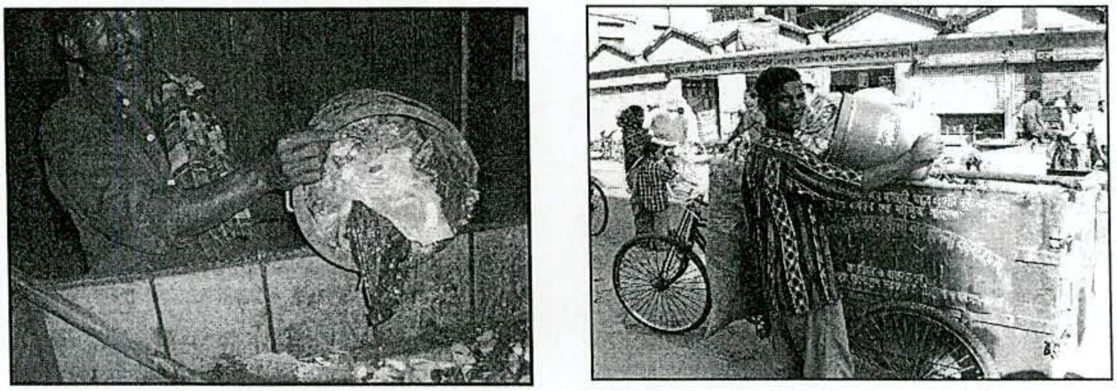


Figure 4.7 Collections of waste from generation sources

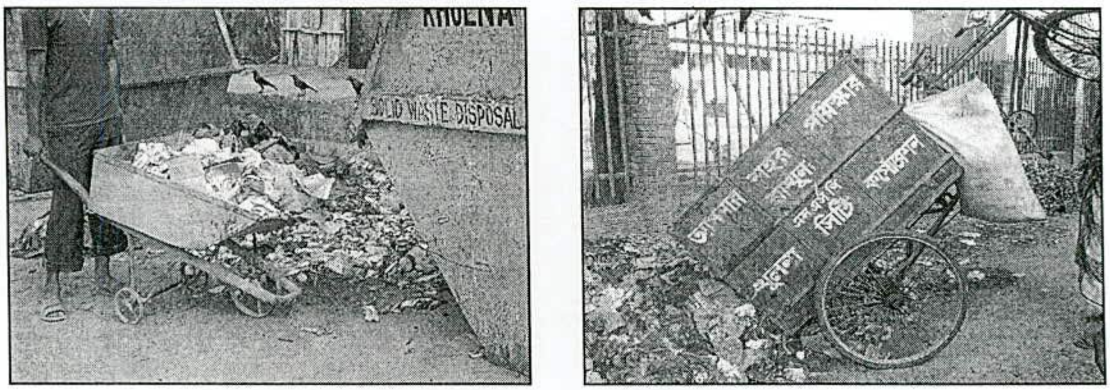


Figure 4.8 Deposition of wastes at on-site storage

4.5.3 On-site storage

On-site storage can be classified as the secondary disposal site (SDS), transfer station and handover point, which receives wastes from primary source and transfers to the designated location for processing/recycling/treatment and mostly for ultimate disposal. There is no transfer station and handover point in Bangladesh in true sense. SDS is considered as the facilities where large amount of wastes are accumulated and finally transferred to the desired sites by large vehicles such an open or closed Trucks, Demountable haul container truck, etc. SDS may be an open space or roadside accumulation of solid wastes. They are brick masonry bins, concrete bins, demountable large steel haul container, roadside spaces and unused open low-lying areas. In Bangladesh, city authority is solely responsible for providing SDS; collect wastes from SDS and transfer for final disposal as per existing City Corporation Act. These sites are located in the selected places based on population, space availability, accessibility and other unseen factors. Wastes are deposited in SDS directly by the generators, NGOs, CBOs and city authorities. In some cases, especially for the residential areas along narrow streets where SDS is not suitable, community bins are provided from where wastes are transferred to SDS. The wide variety of types and shapes of community bins are built by the civic bodies and/or city authority, which are located on the roadsides at frequent intervals. Community bins are mostly made of the concrete but masonry and steel container are also available. The concrete and masonry bins are in variable sizes but normally rectangular in shape of one meter wide, one meter high and one/two meter long. Generally there is a door at one side and no cover on the top of the community bins. Wastes from community bins are transferred to SDS mostly by city authorities through non-motorized Rickshaw van and hand trolley.

In DCC areas, there are more than 846 SDS, 640 community bins and 206 waste containers. For the last 2 years, in 6 wards two private organizations are involved to dispose the wastes from SDS to UDS. They built their own SDS of large size and practiced better management. In CCC areas, the total numbers of SDS and community bins are 1506 in which 849-masonry bins, 66 concrete bins, 32 steel containers and 558 open spaces. Beside this, there are huge numbers of unauthorized small dumping sites spreading through out CCC. In KCC, there are more than 60 SDS, around 1200 community bins and 28 Haul Containers, located on roadsides throughout the city. In RCC areas, there are 44 open space types SDS and about 190 Community bins spreading over the whole city. Presently there is no dustbin in RCC areas because in a recent attempt all the dustbins were removed from SDS. Rickshaw van pullers collect wastes from different sources and dump it to the open spaces randomly at SDS. There are 150 SDS in BCC randomly over the whole city; as a result, in some wards of BCC, there is no SDS. In SCC areas, there are about 74 SDS out of which only 30 to 35 sites are in uses now. Concrete/masonry bins are placed in most SDS. Recently, three large sized SDS with better facilities are constructed with the assistance of a NGO.

In the MSW management tier, SDS plays a very pivotal role. But the situations of SDS in each city are very much unpleasant, alarming and it reveals as an ineffective step causing most nuisances and deteriorating city environment at large scale as shown in Figure 4.9. Since SDS situated mostly at busy roadsides, so to receive and deliver wastes, proper management with very strict timing for collection and transfer is required which can not be addressed by the city authority with existing management system, so, alternative options of

SDS should be considered. In the meantime, BCC already demolished all the permanent structures in SDS, while SCC is not using some points of SDS and already removed roadsides Littering Boxes. DCC is preparing master plan and KCC is considering building a transfer station as experimental basis. In such situation options should be keep open to solve this problems either by transfer station or handover points and the suitability of such options needs to be explored. Figure 4.9 shows the different types of secondary disposal sites of MSW.

Figure 4.9 Secondary disposal sites of MSW in major cities of Bangladesh

As the location and design of the dustbins are not suitable, peoples don't prefer to use dustbin usually. They through the wastes around the dustbins. Where haul container is located, its opening is so high that people just through their waste towards it. All the dustbins are usually open, so birds; dogs and scavengers search for foods and valuable items. Also during rainfall, the wastes spread in the surrounding areas. This creates very unhealthy environmental condition. Also, usually the dustbins located in the city center and some posh areas are getting more attention from the city corporation than the dustbins located in the outskirt or less important areas of the city. As a result, those uncollected wastes are creating public nuisance. Due to this, in some community the local people demolished the dustbins, which again spread the wastes in wider areas.

Most of the dustbins are very old and already out of order due to lack of maintenance/repairing. In most cases the community bins located on the roadside are of inadequate capacity resulting in spillage of wastes. This coupled with less frequent collection results in scattering of wastes by winds and animals which become extremely unsightly and a pubic nuisance.

4.5.4 Secondary collection and transportation

Generally the city authority collects wastes from SDS and transfers it to the UDS. Motorized vehicles are used for collection of MSW from SDS and non-motorized vehicles are used for transfer wastes from community bins to SDS usually. The functional element of collection includes not only the gathering of solid wastes and recyclable materials but also the transportation of these materials after collection, to the location where the collection vehicle is emptied. Respective city authority collect the wastes from secondary points and transported it by motorized vehicles/trucks and finally disposed in the designated ultimate disposal site of the city. Although NGOs and CBOs collect wastes from households/generation points and dump it to the secondary disposal sites, they do not take responsibility for the collection & transportation of wastes from secondary disposal sites.

Conservancy department of the city corporation setup the time-schedule and types of vehicle for collection and transportation. Generally collection vehicles such as covered waste truck, normal truck, open truck, waste truck with compactor, tractor with trolley, haul container truck, power tiller with trolley are used for waste collection and transportation. Staffs are assigned with each vehicle for collection and disposal. Demountable containers are only hauled by tipping truck and no workers are required for collection and disposal but its numbers are also limited. Usually collection and transportation are done at day times which obstruct the movement of pedestrians and traffics and creates nuisance and pollution due to spillage of wastes and leakage of liquid from the wastes. Figure 4.10 to 4.12 shows the typical waste collection and transportation in the major cities of Bangladesh.

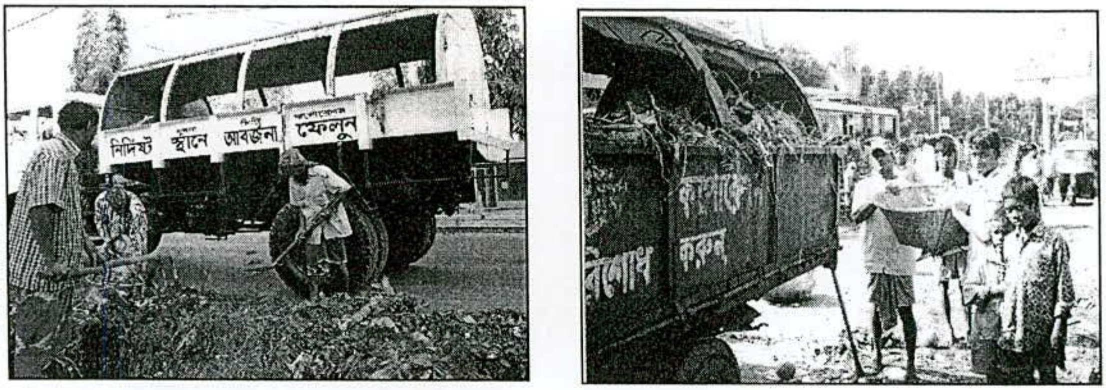


Figure 4.10 Typical wastes collection process

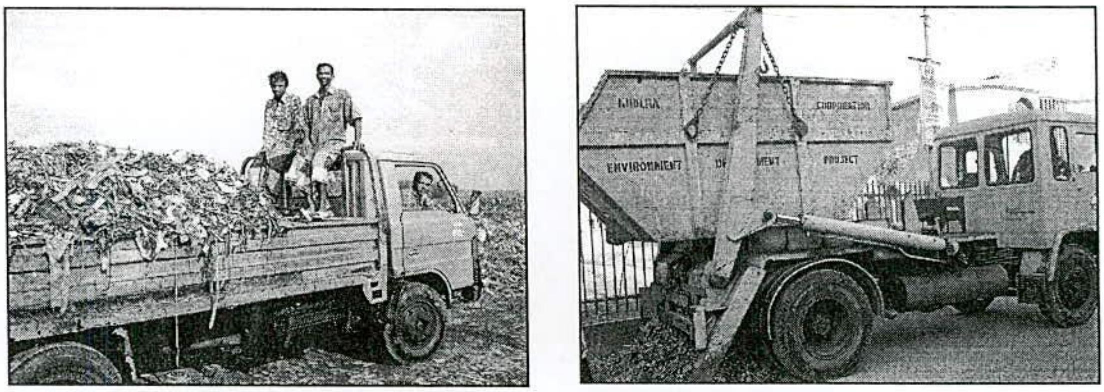


Figure 4.11 Typical wastes transportation process

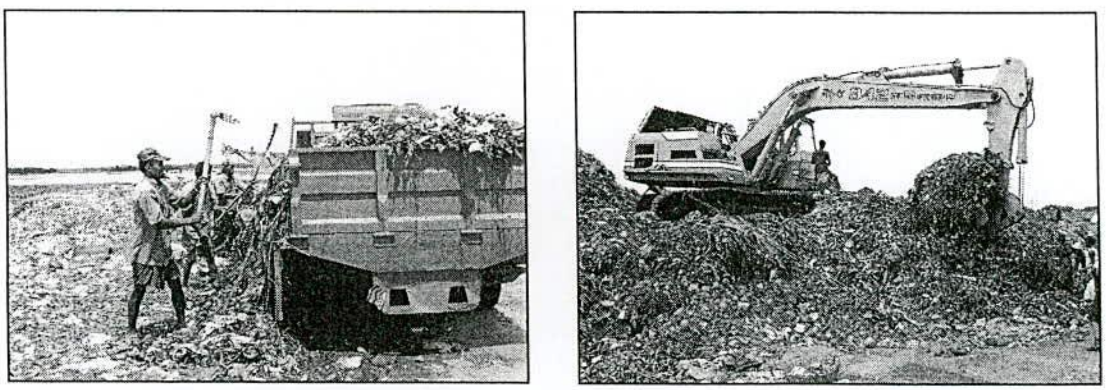


Figure 4.12 Typical ultimate disposal process

City authority does not have proper and required number of vehicles and staffs to perform this operation successfully, even; the present management system is not capable to utilize the existing resources properly. As a result, the collection of wastes from SDS is very much disappointing and creating lot of hazards, as wastes remain there for longtime. Table 4.13

shows the total number of motorized vehicles and amount of wastes daily collected, transported and dumped in the studied sites.

Table 4.13 Number of motorized vehicles for wastes collection, transportation and disposal

City	Number of motorized vehicles	Amount collect, transport and dispose (Tons/day)
Dhaka	373	2000-2400
Chittagong	49	500-550
Khulna	32	240-260
Rajshahi	15	60-80
Barisal	7	30-40
Sylhet	17	60-80

Table: 4.13a Number of collection and transportation vehicles in DCC

Type of collection and transportation Vehicle	Number of units
Open truck	
Open truck 1.5 ton	101
Open truck 3 ton	105
Open truck 5 ton	36
Open truck total	**242**
Container carrier	
Container carrier 3 ton (container volume 6 m^3)	118
Container carrier 5 ton (container volume 12m^3)	10
Container carrier total	**128**
Trailer truck 30 ton	3
Total of collection and transportation Vehicles	**373**

Table: 4.13b Capacity of collection vehicle for CCC

Vehicle category	Vehicle no.	Vehicle capacity(each)	Vehicle type
Truck	49	4 m^3 to 8 m^3	Motorized
3 wheeler van	63	1 m^3	Non-motorized
Wheel Baro	600	0.1m^3	Non-motorized

Table: 4.13c Types of vehicles are used for solid waste collection from SDS in KCC		
Types of Vehicles	**Number**	**Capacity** (Ton/trip/vehicle)
Motorized:		
Hino Truck	3	7
Dump Truck (Big)	9	7
Dump Truck (small)	5	7
Normal Truck (small)	2	7
Tractor with Trolley (big)	2	7
Tipping Truck (Container Carrier)	7	3
Tractor with Trolley (small)	1	1.5
De-sledging Vacuum Tanker with tractor	2	4
Power tiller with trolley	1	0.5
Sub total	**32**	
		Capacity (Kg/trip/van or barrow)
Non - Motorized		
Rickshaw Vans	190	60
Wheel barrow	76	25
Sub total	**266**	
Total No. of Vehicles	**298**	

Table: 4.13d Capacity of collection vehicle for RCC			
Vehicle category	Vehicle no.	Vehicle capacity	Vehicle type
Truck	8	3 ton	Motorized
Truck	2	5 ton	Motorized
Tractor	4	5 ton	Motorized
3 wheeler van	120	0.60 m^3	Non-motorized
Wheel Barrow	45	0.1m^3	Non-motorized

Table: 4.13e Capacity of collection vehicle for BCC and SCC			
City Corporation	Vehicle category	Vehicle no.	Vehicle capacity
BCC	Truck	7	3 ton
CCC	Truck	17	5 ton

Source: This study

4.5.5 Ultimate Disposal

The safe and reliable long-term disposal of solid wastes is an important component of integrated waste management. Although source reduction, reuse, recycling, and composting can divert significant portions of MSW, large amount of wastes still needs to be placed in landfills. There are no controlled/engineered/sanitary landfills in Bangladesh. The sites are situated in and around the city areas of low-lying open spaces, unclaimed lands, riverbanks and roadsides. DCC and CCC, each operates two sites, namely, Matuail & Gabtali and Raufabad & Halishahar, respectively, while other city corporation, operates one site each, namely, Rajbandha, Shishu Park, North Kawnia and Lalmati by KCC, RCC and BCC respectively. All types of MSW are disposed including some portions of medical wastes. Crude open dumping sites are always incompatible with the surroundings. The exposed waste spreads all over the site are unsightly as no proper system maintained for filling the area. Wind blown litters and indiscriminate dumping of waste outside the site and on the surrounding ponds and adjacent surface water.

Environmental pollution at open dumping site includes air pollution, water and soil contamination due to generation of leachate, gas, odour, dust and potential fire hazard etc. The uncontrolled burning of solid waste creates smoke and other air pollution. Garbage nuisance conditions are also pose higher risk for human beings. As major parts of disposed wastes are biodegradable organic wastes, landfill gases generates continuously. But there is no provision for the escape of gases in existing sites, causing risk of explosions and fire hazard. In ultimate dumping site, leachate percolates and contaminates surface and ground water. The sources of groundwater are sometimes very near to ultimate disposal site. Peoples use this water in different purposes like bathing, washing, drinking and farming. Surface water is also contaminated because solid wastes are dumped near/at the marshy land, ponds, rivers and canals. Contaminated water is harmful for fish and aquatic lives by reducing the amount of oxygen in the water. Chemical and oil spills, which are mixed with MSW, can also cause severe water contamination that kills water birds, shellfish and other wildlife. Figure 4.13 shows the final disposal sites of Dhaka, Chittagong, Khulna, Rajshahi, Barisal, and Sylhet city.

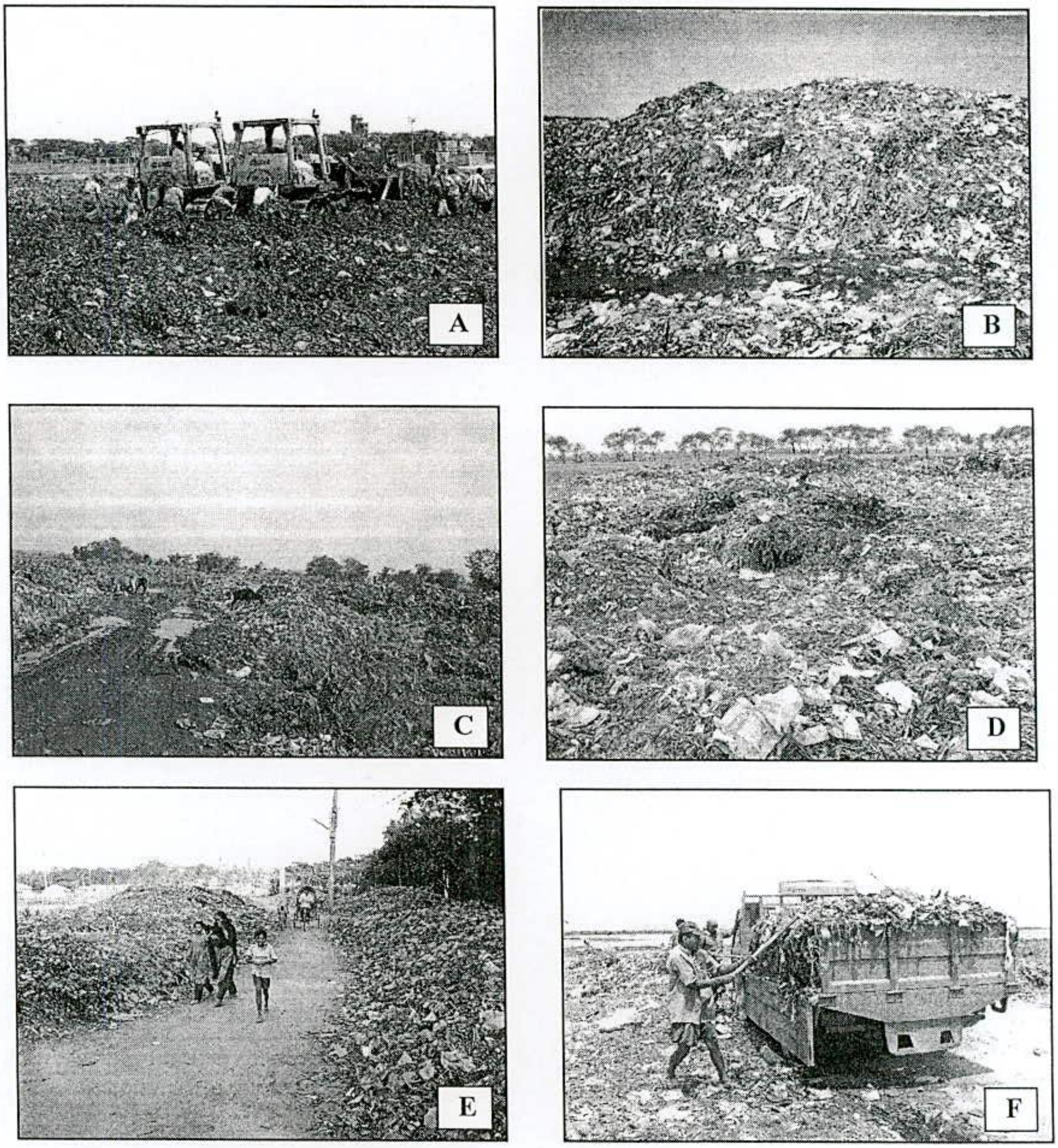


Figure 4.13 Final disposal sites at (A) Dhaka (B) Chittagong (C) Khulna (D) Rajshahi (E) Barisal and (F) Sylhet city

As one of the most densely populated countries and heavy pressure of new inhabitants in the six major cities, city authorities are facing severe problems to get new sites for ultimate disposal. Due to non-engineered situation, the existing sites are also going to early closure. Peoples are also protested to close the existing sites because of their hazards nature. Even the authority tries to buy some land for this purpose hiding real information to adjacent inhabitants. So, the existing open dumping method for ultimate disposal will not get the support from concerned stakeholders in future. The city authority might think about the up-gradation of existing sites to control present situation and proposed full environmental friendly future disposal sites in accordance with local conditions and technological capabilities.

4.6 Processing of MSW

Processing techniques are used in SWM systems to improve the efficiency of SWM systems, to recover resources and to prepare materials for the recovery of conversion products and energy.

4.6.1 Recycling

Informal sectors by various groups of community are playing an important role in recycling of solid waste in Bangladesh. All the buyers of the recyclable items belong to the informal sector and only a few formal manufacturers are involved in using recyclable substance as raw material. However in study areas, it is not practiced widely and effectively except for certain urban areas.

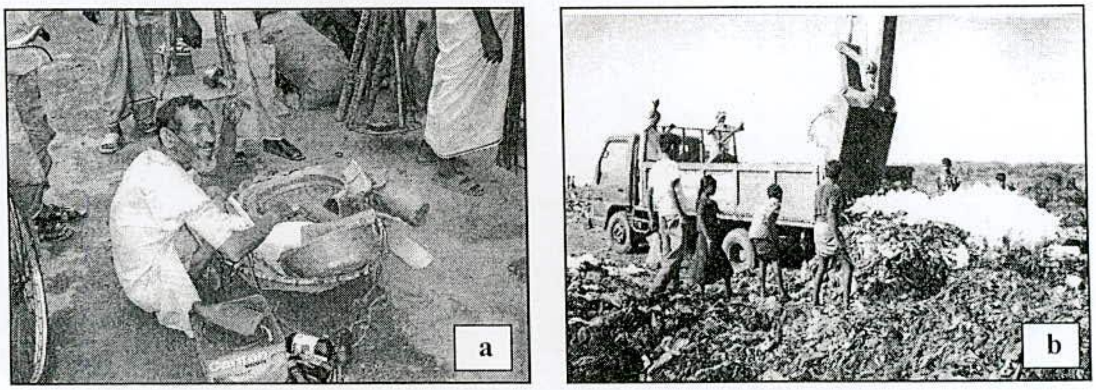


Figure 4.14 Recyclable items collection by (a) Vendor, (b) Scavengers

Many households dispose reusable/recyclable materials with their daily kitchen waste, which should be reused or recycled. Some people also sale these materials to local vendors/hawkers (locally known as 'Ferrywala', Figure 4.14a). Various types of recycling materials are collected/reclaimed by this hawkers and/or scavengers (street children, locally known as 'Tokai', Figure 4.14b). The collected/ reclaimed materials are paper & paper products such as magazine, white paper, newspaper, paper cartoon, book etc; Plastic materials such as plastic, container, basket, gallon, pet bottle etc; Iron or metal (steel) such as oil tin container, tin, tin can, oil drum, metal wire etc. and others such as wood, leather, slipper and shoes, bronze, auto batteries, rubbers, bones, broken glass bottle, ferrous metal, aluminum, brass, silver etc. Figure 4.15 shows the typical recyclable items of solid wastes available in Bangladesh.

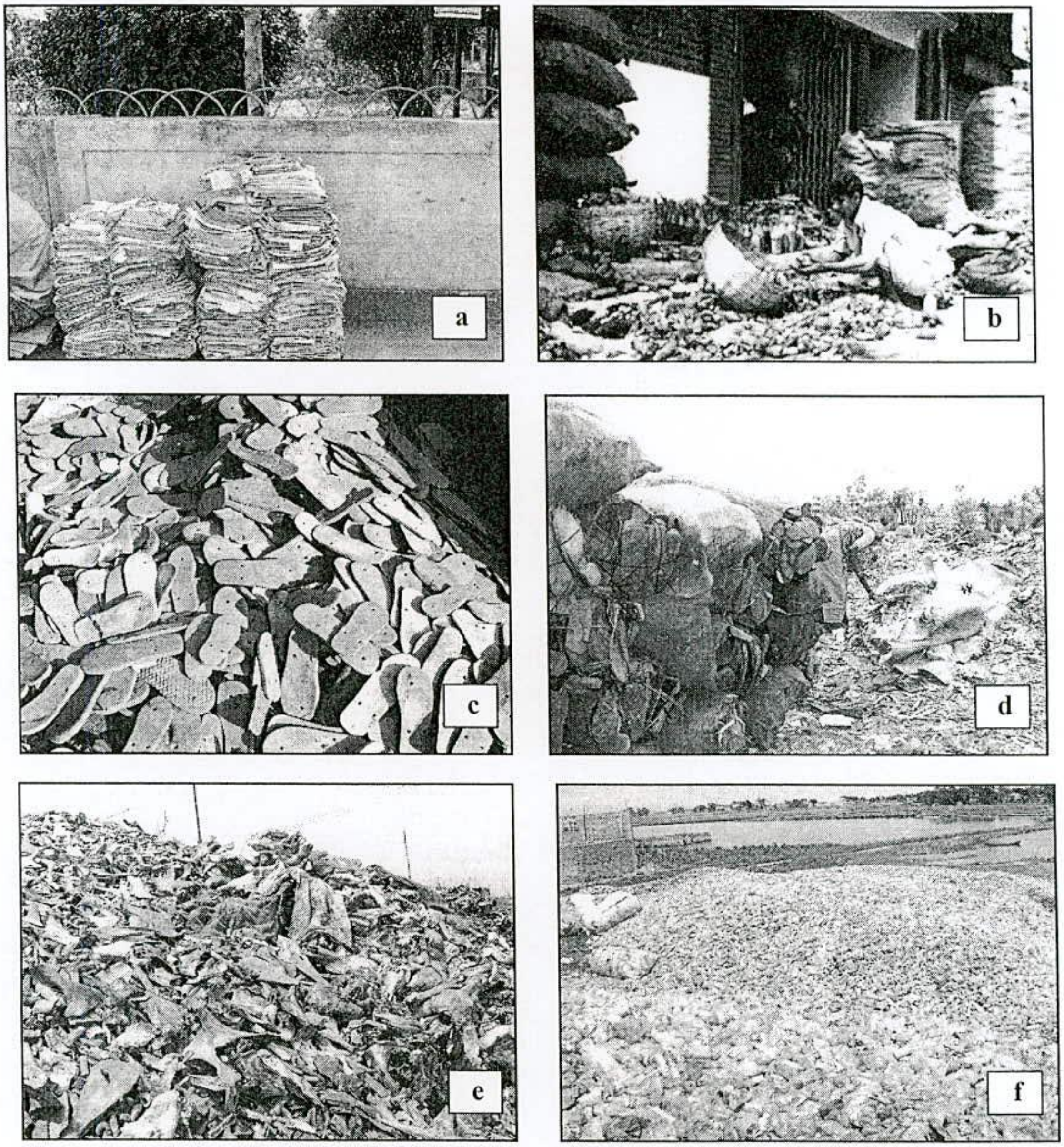


Figure 4.15 Recyclable items in solid wastes (a) Paper (b) Glass (c) Rubber (d) Leather (e) Bone and (f) Plastic/PET bottle

Recycling of post consumer materials found in MSW has four stages in Bangladesh:

a) Recovery of materials from sources and waste stream

In Bangladesh, generally recovery/recycling is carried out in three phases. Phase one is the source separation, where the generators separate refuse having resale value such as papers & paper products, bottles, fresh containers, plastic materials, tin, glass, metal, old clothes, shoes etc. and sell these recycling goods to street hawkers. Hawkers are collected reusable and recyclable materials from house to house and sell them to nearer recycling shops which are locally known as 'Vangari Dokans'.

In second phase, the poor children of slum dwellers known as "Tokai" are collecting different items of low market value from on-site storage bins/containers and open storage spaces. The items include broken glass, cans, cardboard, waste papers, polythene, rags, pet bottles, coconut shells, metals and miscellaneous commercial waste discarded by householders.

The final phase is the recovering of reusable and recyclable materials from UDS. Scavengers/Tokai are salvage recyclable wastes mainly when collection vehicles are being immediate unloaded at dumping site. Figure 4.16 shows the scavenging for recycling materials in SDS & UDS of Bangladesh.

b) Intermediate processing such as sorting and compaction

Local businessman, whole seller and/or merchant done sorting and compaction of reusable and recyclable materials. Hawkers and scavenger sold their collected materials to local businessman. Businessmen separate every items and stakes individually. Then they sell the collected recycled goods to merchant. The reclaimed materials are reaches recycling shops through these scavengers where intermediate processing like washing, drying and sorting are carried out in traditional way and sell them to whole seller/ merchant. Plastic materials, in small scale, are also exporting after shredding and cleaning.

Figure 4.16a Scavenging for recycling materials in SDS in Bangladesh

Figure 4.16b Scavenging for recycling materials in UDS in Bangladesh

c) Transportation of recyclable materials

Merchants are send compacted and sorted reusable/recyclable wastes to factories. In Bangladesh, all industries and/or factories are capital based. So finally all reusable/recyclable materials are sending to Dhaka from different cities of Bangladesh for manufacturing.

d) Final processing to provide a raw material for manufactures or an end product

Ultimately all reclaimed materials are supplied to factories/industries for reuse as raw materials, recycling and/or appropriate processing. Some materials like soft drinks bottles, oil containers/drums are going to initial producer for reuse. Producer uses others materials as raw material for new production.

Recycling and composting are mainly practiced at six major cities of Bangladesh, namely, Dhaka, Chittagong, Khulna, Rajshahi, Barisal and Sylhet. Table 4.14 shows the amount of daily recyclable wastes in major cities of Bangladesh. Waste-to-energy combustion and landfill gas, the byproducts of MSW are not practiced in Bangladesh.

In Dhaka, recycling and resource recovery forms practically one of the important industries. It plays an important role in waste minimization and creating earning opportunity for slum dwellers, scavengers and vendors. According to profile of Dhaka city, it is estimated that the total labor force is approximately 1.17 million. Also it is estimated that more than 0.1 million people are dependent on and involved in the recycling activities at present. This means that approximately 10% of the total labor forces in Dhaka city gathers around recycling sector. Among those people, approximately 74,000 peoples are engaged with recovering materials out of various points of the stream of MSW, where 12% are Tokai's. Tokai's separates most of the recyclable items at the secondary sites before the waste are conveyed to the dumping site. Main recycling markets are situated at Matuail, Anondobazar, Nimtoli and other places.

Although recyclable wastes in Dhaka city are of variety from paper to bone, main recyclable materials widely collected from MSW are plastic, paper, glass, metal and others. There are approximately 200 shops for plastic shoes recycling and 300 shops for other plastic items recycling in Dhaka city. Plastic, paper, glass, metal (steel) recycled daily are estimated as 103, 168, 24, and 41 tons/day, respectively. The volume of other recyclable items is estimated as 94 tons/day. So total estimated recyclable materials are 430 tons/day and in ranges from 420 to 450 tons/day, which is 8 to 9% of total generation.

In Chittagong, more than 1200 recycling shops are scattered in different places and approximately 14000 to 15000 people are involved with this occupation. The main markets are at Debar-par, Nimtola, Vutaua colony, Kalurgar etc. Little portion of reclaimed materials is reuse/recycling in Chittagong and major portion are supplied to Dhaka for appropriate processing. Daily estimated recyclable materials are approximately 90 to 100 tons, which is 7 to 9% of total generation.

In Khulna, the recycling shops are located in mainly Fulbari gate, Rail gate, Khalispur, Shekpara, Sher-e-bangla market, Goalkhali more and other places. More than 400 recycling shops and 8 to 10 are wholesale recycling shops are located in city areas, in which approximately 1500 to 1700 people are involved with this occupation. It is estimated that at present 600 scavengers are working for collection of recyclable materials from secondary sites as well as dumping sites in Khulna city. Mostly all the buyers of the recyclable items belong to the informal sector and approximately 25% of total recyclable wastes are collected from UDS. Daily estimated recyclable materials recovered are approximately 25 to 30 tons, which is 5 to 7% of total generation and almost all reclaimed materials are supplied to Dhaka for further processing.

Table 4.14 Daily recyclable wastes in the six major cities of Bangladesh

City	Recyclable wastes (tons/day)	% of total generation
Dhaka	420 – 450	8 - 9
Chittagong	90 - 100	7 - 9
Khulna	25 - 30	5 - 7
Rajshahi	15 - 18	9 - 11
Barisal	3 - 5	3 - 5
Sylhet	5 - 8	3 - 4

In Rajshahi, main markets of old material shops are situated at Raninagar, Bhadra and Stadium market. There are many people known as 'Street Hawker' and 'Tokai' collect recyclable materials from different places such as households, dustbins, disposal sites, etc. in the city. Street hawkers mainly collect recyclable materials from households. About 650 man and woman are engaged as street hawker in city areas. A street hawker can collect about 15 to 30 kg recyclable materials and earn Tk. 80 to 100 per day. About 350 Tokai's are engaged in this sector and can earn Tk. 30 to 60 per day. Shopkeepers do some intermediate processing like washing, drying, and sorting. Afterward they sell recyclable materials to consumers as well as supply them to the different shops or factories in Dhaka. Daily estimated recyclable materials recovered are approximately 15 to 18 tons, which is 9 to 11% of total generation.

In Barisal, more than 250 recycling shops are established and approximately 800 to 1000 people are involved with this occupation. Most of these shops, 3 to 5 employees are working and buying different types of recyclable materials. Recyclable materials come from either within the city areas or outside the city areas. Daily estimated recyclable materials are approximately 3 to 5 tons, which is 3 to 5% of total generation. In Sylhet, more than 300 recycling shops are established and approximately 1000 to 1200 people are involved with this occupation. Large amount of wastes are diverting here from open ultimate dumping due to recycling and composting. Daily estimated recyclable materials are approximately 5 to 8 tons, which is 3 to 4% of total generation. However the ultimate success of waste minimization might depend on the establishment of good market price of these recovered materials. Local small industries in some cases strongly dependent on the availability of reclaimed material for reprocessing. Commonly non-hazardous wastes are recycled in Bangladesh; however there is a strong need for recycling of hazardous or special wastes like solvents.

4.6.2 Composting

The MSW of Bangladesh is suitable for composting due to its high moisture and organic contents. In Bangladesh, mainly NGOs are involved in composting. They are involved in composting of organic wastes in five city corporations, namely, Dhaka, Chittagong, Khulna, Rajshahi and Sylhet. During the study period no composting plant is found in Barisal city. Besides the city corporation areas, composting plants are also set-up in some municipalities with technical assistants from experienced NGOs, financial support from donor agencies with the collaboration of local city authorities. Recently, private sectors are also come forward to invest in this sector. However, this sector is also facing several problems such as finance, appropriate technology, required land, proper location and continuous supply and quality of wastes, quality of compost and marketing facilities. Recently, one composting plant in Sylhet was forced to stop its operation due to the objection from adjacent inhabitants. The situation of the surveyed composting plants also are not encouraging (WasteSafe 2005), some of them are in a stage to stop the operation for the inherent reasons. In general, health and hygienic aspects are absent in all the composting plant. The staffs are not accustomed and even don't care of using safety articles. Most of them have been suffering from persistent diseases such as cough, allergy, skin diseases etc.

Small scale composting of night soils and other organic wastes is common in some parts of Bangladesh (Ahmed and Rahman 2000). It is found that the composting activities have been initiated as organized base (pilot-scale type) in different cities of Bangladesh by different organizations including city corporation, NGOs and CBOs. Different plants in different cities are shown in Table 4.15. Mostly the processes adopted in these cities are windrow or active pile system. The barrel or small container composting methods is also getting popularity particularly in urban slums, colonies, etc. Typical composting process in Bangladesh is presented in Figure 4.17.

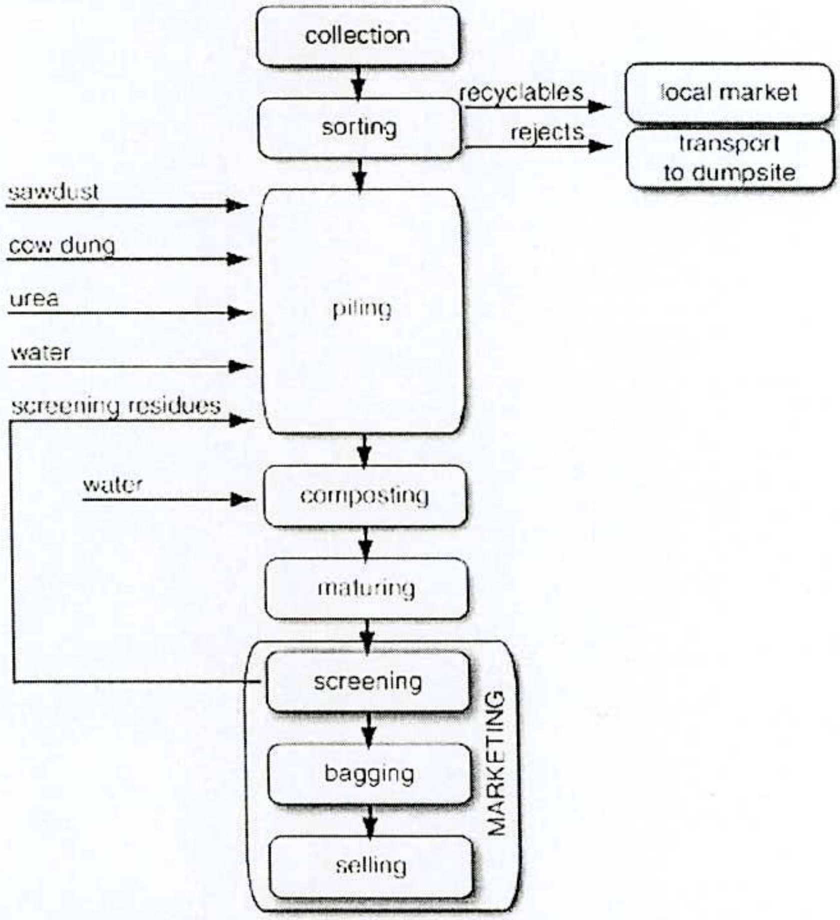


Figure 4.17 Typical flow chart of composting process (After Enayetullah at.al, 2003)

Table 4.15 Different compost plants in the six major cities of Bangladesh

City	Name of Organizer	Plant Nos.	Plant Type	Capacity per plant (tons/day)	Compost Production (tons/day)	Retail Price Tk./kg	Status
DCC	Waste Concern	5	Windrow & Box	1.00	0.18-0.20	2.5-5.0	R
	Prodipon	1	Windrow	1.00			R
CCC	NOUJUYAN	1	-	-	-	5.0	R
KCC	Prodipon	1	Windrow	1.00	0.2-0.3		R
	Prism	3	Windrow	1.00			R
	RUSTIC	1	Windrow	1.00			R
RCC	LOFS	1	Windrow	0.40	0.13	4.0-5.0	R
BCC	-	-	-	-	-		-
SCC	SP	1	Box	2.50	0.60		S
	EPCT	1	Box	0.03	0.01		R

R- Running; S- Shutdown; SP- Sylhet Partnership- ; RUSTIC- Rural Unfortunates Safety Talisman Illumination Cottage ; Prism- Project in Agriculture, Rural Industry, Science and Medicine.

Figure 4.18 Typical composting process (a) Sorting of organic waste (b) Piling of waste using windrow method (c) Turning of waste at regular interval (d) Screening after maturation

The small windrows or piles of about 3 tons pre-sorted waste mixture are manually formed on a bamboo frame. The bamboo frame is used to increase the passive aeration. Usually the piles are dismantled in every week for remixing and moisture adjustment. After six weeks the raw composts are again piled up on other place for final maturation. Figure 4.18 shows the sequence of decomposing process of organic waste by Prodipan.

4.6.3 Other Treatments

There is no incineration plant in Bangladesh for combustion of MSW. Some small scale limited burning units are situated in some cities of Bangladesh. Burning of hazardous clinical wastes, generates from different clinics/hospitals is done at high temperatures in the presence of sufficient air to achieve complete combustion to reduce its toxicity (in the case of organic solvents and Polychlorinated biphenyls - PCBs). Generally dry wood and kerosene oil are used to assist burning. At present, different shapes and sizes of burning units present in Bangladesh, although mechanisms are almost same as shown in Figure 4.19. Usually materials like cotton, syringe, saline bag, dressing, gauge, bandage etc are burned in the burning unit.

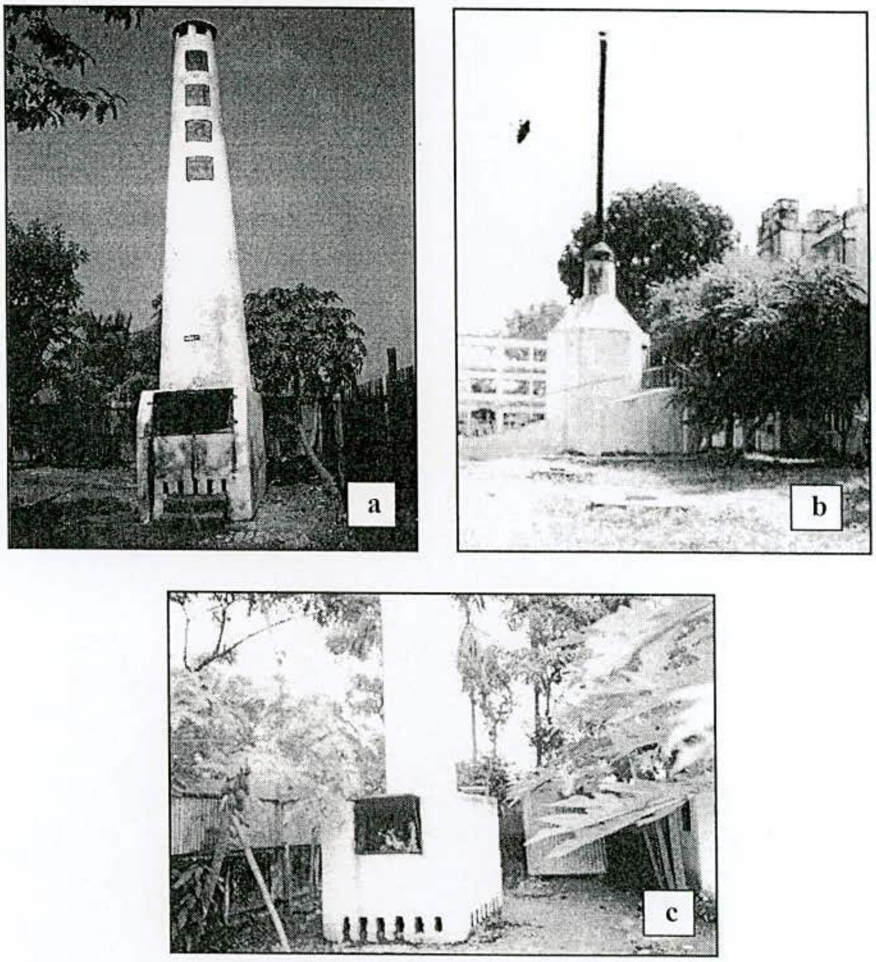


Figure 4.19 Different burning units in Bangladesh (a) at Khulna city (b) at Rajshahi city and (c) at Barisal city

The burning unit is divided into three basic parts such as ash chamber, burning chamber and chimney. Ash chamber is considered as lower portion of the unit i.e. below the burning chamber and above the final ground level. It is a rectangular or circular in shape. It is a chamber with slopping floor and a door at the wall to facilitate entrance for cleaning. Burning chamber is considered as the middle portion of the unit i.e. below the chimney and above the ash chamber. A hole at the roof to emit the heat energy and a door for storage of wastes into the unit. Chimney is the upper portion of the unit through which heat passes into the atmosphere.

In Dhaka city, only active burning unit is situated at "Shanir Akhra". Dhaka medical college has also a one burning unit, but it is not working at present. "Waste concern" a national NGO, planned to set up an auto clave incinerator for the treatment of medical waste, which is under prime consideration. In Chittagong city, only "Eye Hospital" has one burning unit to reduce hazardous effect of clinical wastes, established in 2004. Maximum burning capacity of this unit is 10 kg/day. At Present average 2 to 3 kg combustible hazardous waste are burnt in evening, once in a day. In Khulna city, at first Prodipan, a national NGO takes the initiative for safe management of clinical wastes by establishing a burning unit in the year of 2000. It is situated at Rajbandha (far about 7 km from city) near UDS of MSW. There is no system to monitor the quality of the emission of gases into the air and ashes produced due to the burning of the general hospital wastes. About 8 to 10 tons clinical wastes comes from 47 public health care centers such as hospitals, clinics and other pathological laboratories are burnt here within a month.

In Rajshahi city, the burning unit was established in the year of 2000 under a project financed by Government of Bangladesh (GOB). The hazardous wastes generated from hospital and clinics are burnt in incinerator by using dry wood and kerosene oil. About 5 to 6 tons clinical wastes are burnt within a month. About 25 hospitals and clinics are engaged under this operation. In Sylhet city, only burning unit situated at "Osmani Medical College" is not working now. In Barisal city, Prodipan also established and running a burning unit similar to Khulna city.

The study reveals that a proper segregation scheme for separating hospital waste into hazardous and non- hazardous categories is desired for Bangladesh. This should be coupled with proper separation of hazardous waste and dedicated treatment facilities so that co-disposal of hazardous waste with municipal waste can be avoided.

4.7 Field Survey

A detail questionnaire survey was done focused on the impressions and opinions of the residents of different cities on the existing storage, segregation, disposal practices, present primary collection system, options and choices, types and location of secondary disposal site, reuse and recycle practices, opinion on present management system etc.

For this in each city corporation 500 questionnaire sheets were supplied provided with 36 questions and multiple answer options. Among them in each city 250 people were interviewed directly and the rest 250 people were filled up the questionnaire form by them and later returned it to the surveyors. During supplying the sheets, the different socio-economic conditions of the people were considered, so that the results reflect the views from all level of society. A sample questionnaire sheet is given in Annex A.

The questionnaire sheets are divided into three sections, a) Household Solid Waste Segregation, Storage and Disposal (10 questions), b) On-site Storage and Disposal (7 questions) and c) Waste Management (19 questions).

Among the surveyed people, 65 to 75% were male and 25 to 35% were female respondents. More than 60% of the respondents are adults, followed by teens, senior citizens and juniors. The education status of the respondents can be grouped into four categories-able to read and write as literate category, appeared or passed SLC (secondary and lower secondary) as SLC category, passed SLC and below University level education as College category, and above that category is the University category. More than 60% of the respondents were of college category, followed by University, literate and SLC. The profession of the respondents were grouped into students, business, service, housewives and others in these five categories. Monthly income level of the respondents were grouped into five categories—less than BDT 5,000, BDT 5,000 to 10,000, BDT 10,000 to 20,000, BDT 20,000 to 30,000 and above BDT 30,000 per month.

There is a clear need to inform and motivate the city dwellers and the associated people about the various aspects of municipal solid wastes and its management. Most of the people living in the urban areas of Bangladesh have little knowledge about how much solid waste is generated, what are the types and characteristics, how it has been collected and where these increasingly generated wastes go for ultimate disposal in futures. The city dwellers often ignorant about the existing MSW management in the cities. They do not want to participate financially in improving MSW management. They believe that they already pay taxes to the city corporation and city corporation has to take this responsibility and do not want to pay any extra fees for such services.

Recently, however, the city corporation's and various NGOs have begun to focus and started to work partly on solid waste, to improve the management system. Due to their activities and campaign the public is gradually given attention to solid waste issues and become conscious and aware. Public media such as radio, TV, processions, meetings are helping to create awareness and motivate more responsible behavior about MSW management. There is a strong needs to campaign mass awareness programmes to the children and school students in school levels, staring from elementary level, which is yet to be started. Campaign and some sorts of regulation in the offices of government, semi-government and private sectors including NGOs might confer fruitful contribution in MSW management both in the institutional and household levels. Dustbins are placed in a community in the belief that that dwellers will dispose of their wastes to the bins. But some people's attitudes and habits are so ingrained that they feel comfortable about dumping their waste any open field or drain, which is very near to their home. Many housewives leave their maidservants to take care of it, and do not mind whether she disposes of the wastes in designated place or not. Their attitude is as if "waste out of house is out of danger". Related to the proper management they often suffer from NIMBY (not in my back yard) syndromes.

For a house-to-house collection system, the collector needs to follow a tight collection schedule in order to cover the area due to shortage of manpower. So the householders of each area are given a certain time to handover all their wastes to the collector. But some householders don't make their wastes available to the collector at the scheduled time, on the excuse that their wastes are still being produced. Later they dispose those wastes to the bin, when no collection is in operation. For a proper and efficient management system, the people of the community should be included as part of the system. With those objectives, many meetings have been conducted with the people by some ward supervisors but little response is sometimes forthcoming from the city dwellers. Neither authority nor city dwellers perform their duties properly to contribute in an effective and sustainable MSW management. In case of city dwellers their contribution in managing MSW management look very insignificant as expected from the points of responsibility and obligation. Householders do not deposit wastes properly. Even though they store wastes at home, during dumping of wastes either they dump wastes nearest drain, vacant plot etc. or throw wastes outside the dustbins instead of getting facility. It has also been seen that few people who live fourth, fifth or above floor of a building do not dump wastes just through wastes nearest drain or vacant plot. A questionnaire survey was carried out to know the public awareness to the solid wastes and its management, and public opinion of the existing services provided by the city corporation. People comments about MSW management in the major cities of Bangladesh are shown in Figure 4.20 to 4.22.

4.7.1 Household solid waste segregation, storage and disposal

The survey result reveals (Figure 4.20a) that 56% of people use some form of dustbin or container to contain the wastes, 20% use some form of polyethylene bags. The rest 24% usually do not store the wastes in the household premises.

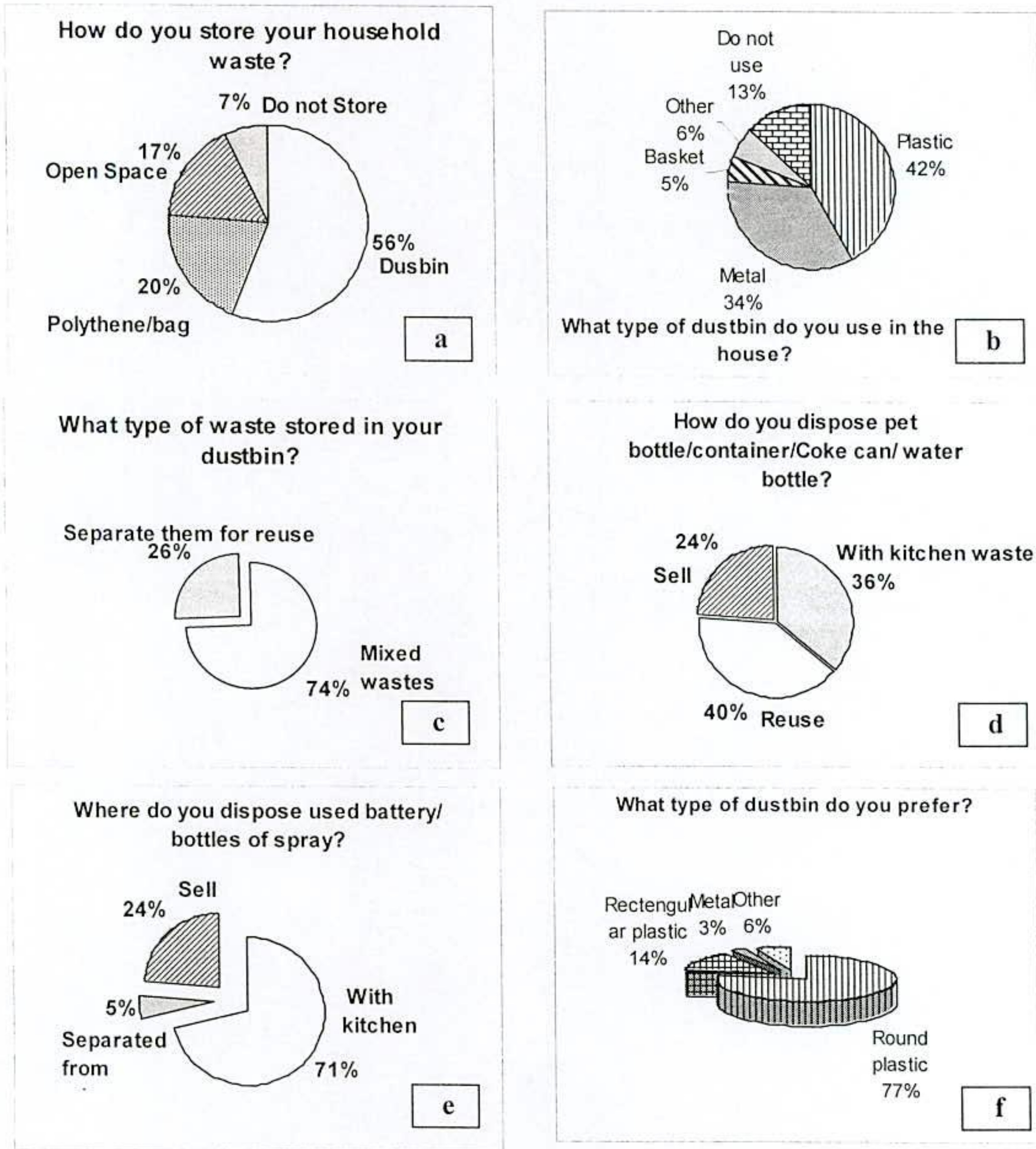


Fig 4.20 People comments about household solid waste segregation, storage and disposal

Figure 4.20b shows that 74% of household dwellers do not segregate the wastes before storage in the dustbin. 71% of people stored the household hazardous materials (like batteries, empty cosmetics container, cleaner container etc.) with the kitchen wastes as shown in Figure 4.20c. 24% of people sell these items to the recycling vendors. Figure 4.20d indicates that 77% people prefer round plastic type container for waste contain, while 14% prefer rectangular type. 40% of dwellers reuse the PET bottle and 24% sell them (Figure 4.20e). Figure 4.19f shows that 42% use plastic bin while 34% use metal bin in their house.

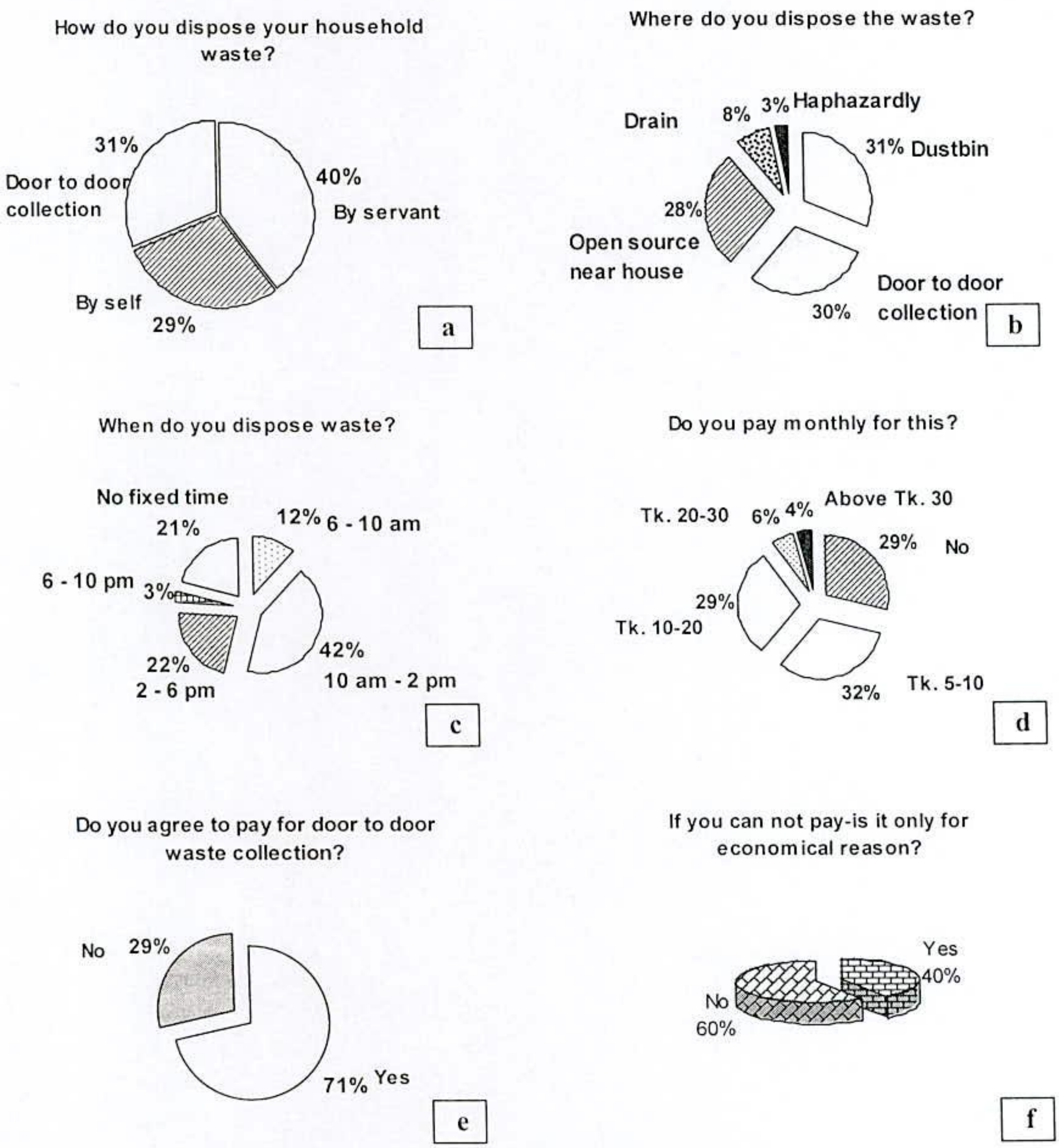


Fig 4.21 People comments about on-site storage and disposal

4.7.2 On-site storage and disposal

The survey result shows (Figure 4.21a to 4.21f) the people's comments about the on-site waste management and disposal. Figure 4.21a shows that 69% of dwellers either by themselves or by servant dispose the daily wastes, while door-to-door collection system prevailed in the rest 31%. A considerable fraction of city dwellers disposed their wastes in the available open spaces against 31% in the dustbins and 30% to the door-to-door collection, while still a considerable fraction in the drain (Figure 4.21b). 54% people like to dispose their waste before noon (from Figure 4.21c). Figure 4.21d shows that 71% of people pay some amount of money for the collection system. Figure 4.21e and 4.20f shows that 29% of people are not willing to pay for collection and out of them 40% mentioned their economical problem.

4.7.3 Waste Management

Figure 4.22 (a to l) shows the peoples comments and suggestions regarding the present management system. It reveals that though 27% people prefer communal dustbin in there areas, but there is no such bin in 45% dwellers areas (Figure a and c). More then 50% people prefer short walking distance of bin to dispose the waste (Figure b). 58% dweller prefers noon is there best waste collection time from home, while 28% prefer afternoon (Figure 4.22d). Figure (e) shows that only 53% dwellers reported regularity of waste collection. From Figure (f) we can see that 77% of people shows negative stand about the open dumping of wastes in the UDS and 97% of people aware of its environmental pollution (Figure g). Paper, plastic and metal are the major recyclable items that the dwellers sell/reuse (Figure h). 93% people know about the compost manure and its production source (Figure i). For source separation 67% of people suggest that use of multiple bins will be a good idea though 33% oppose this idea (Figure j). Majority of the dwellers are not satisfied with the present management system (Figure l)

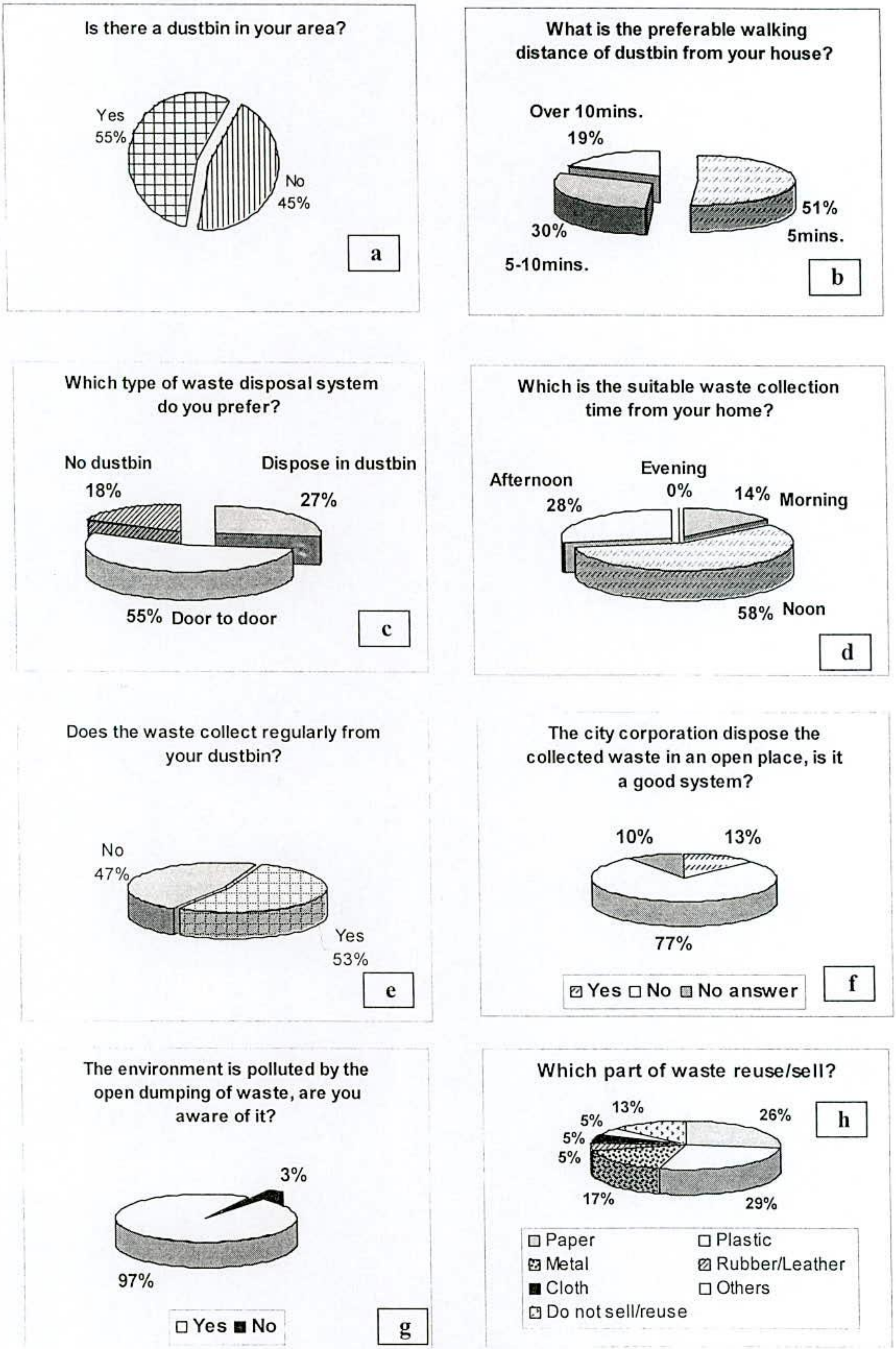


Fig 4.22 People comments about waste management system

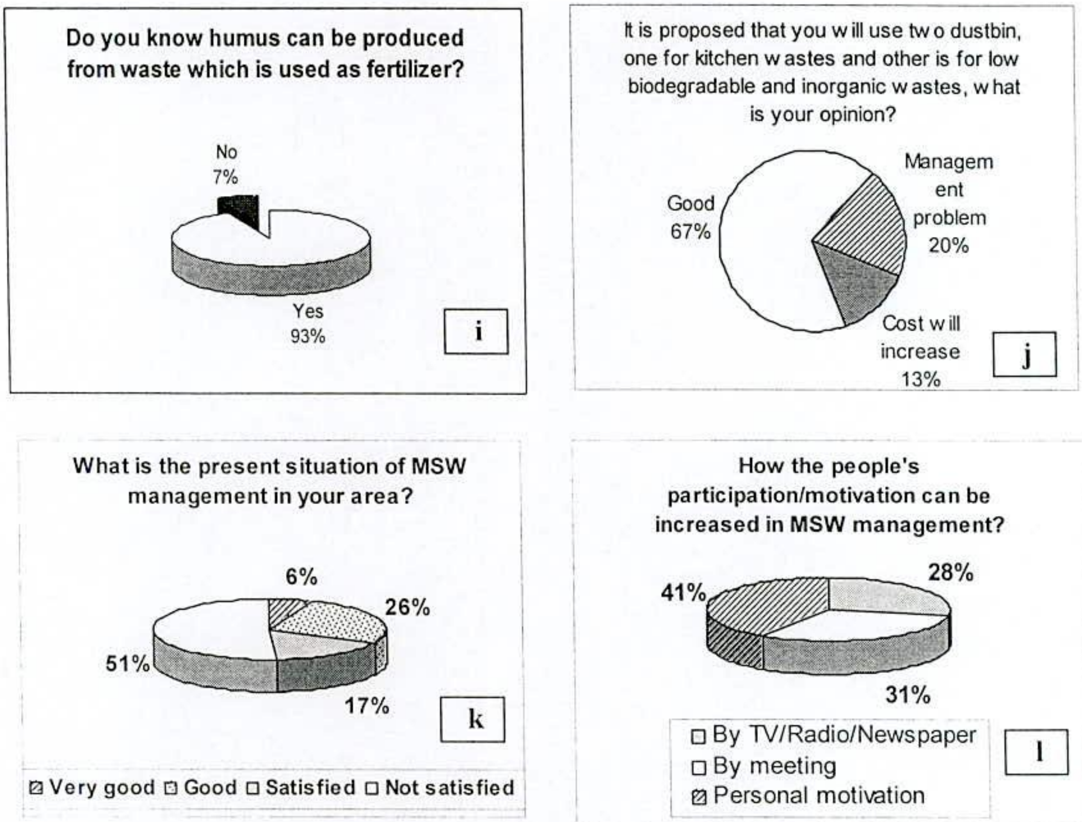


Fig 4.22 Continued

4.7.4 Findings from the Field Survey

By summarize the survey results; a clear idea can be obtained about the present waste management system, its limitations and improvement choices. From the survey results as described in the previous section, the following considerations can be made:

In household level 74% people mixed wastes are stored and 56% people store it some sort of container. 77% respondents prefer round plastic type container, while 14% choose rectangular plastic type container. 64% people reuse or sell household recyclable items, while 71% people dispose household hazardous items with the kitchen items. 40% of people just through their wastes in open spaces and drains, while 30% dispose by door to door system. 42% people dispose waste before the noon and 71% of them agree to pay for the collection service. 18% people want to get door to door collection facility while 55% people do not want dustbin in their areas. 40% respondents do not want to pay charge for door to door collection system due to financial problem. 47% people reports that the waste collection from the SDS is not regular. Paper and plastic are the major parts (55%) of reusable/recyclable items. 51% people are not satisfied on the SWM services from city authority. 72% respondent's gives emphasis on the community involvement programs to improve the public awareness.

4.8 MSW Management Tiers

The management tiers in the study areas reveal that the different options, factors and loop-holes exist in the existing MSW management. The observations are described in the following sections.

4.8.1 Source storage

Different types of container used for source storage in the household level is presented in Figure 4.23. Mainly plastic made basket/bucket are used but metal container as well as container made with local materials are also available. There are several socio-economical and geological factors which influence this tire. Among these factors the socio-economic conditions, habits and living standard are related to the economical condition of the dwellers. Family size and availability of space and geographical locations are also influence the source storage practice. Proper legislations and its implementation and attitude of the respondent are also play very important role in this tier.

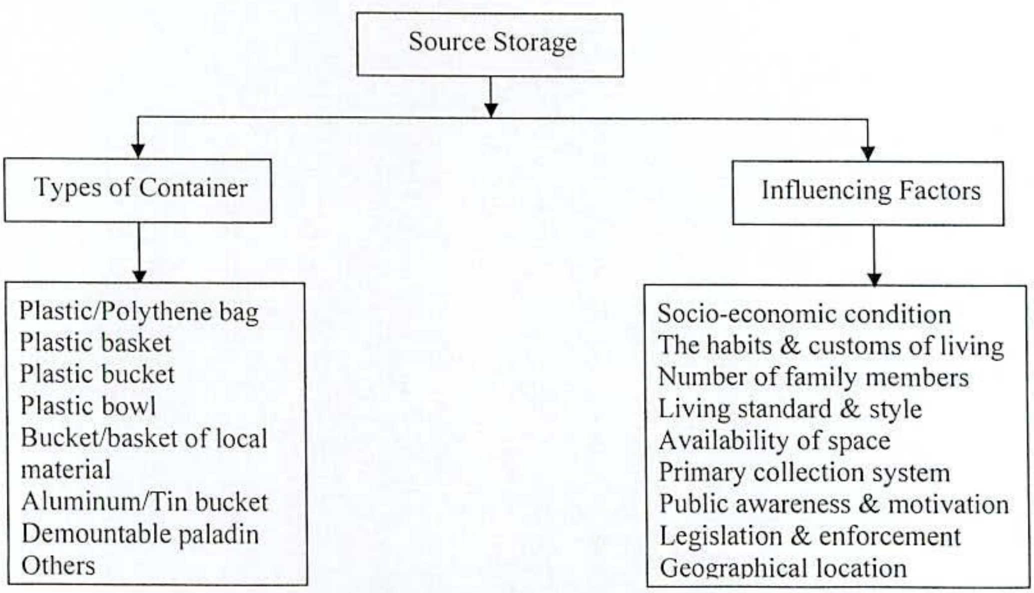


Figure 4.23 Typical flow diagram of storage at source and its parameter

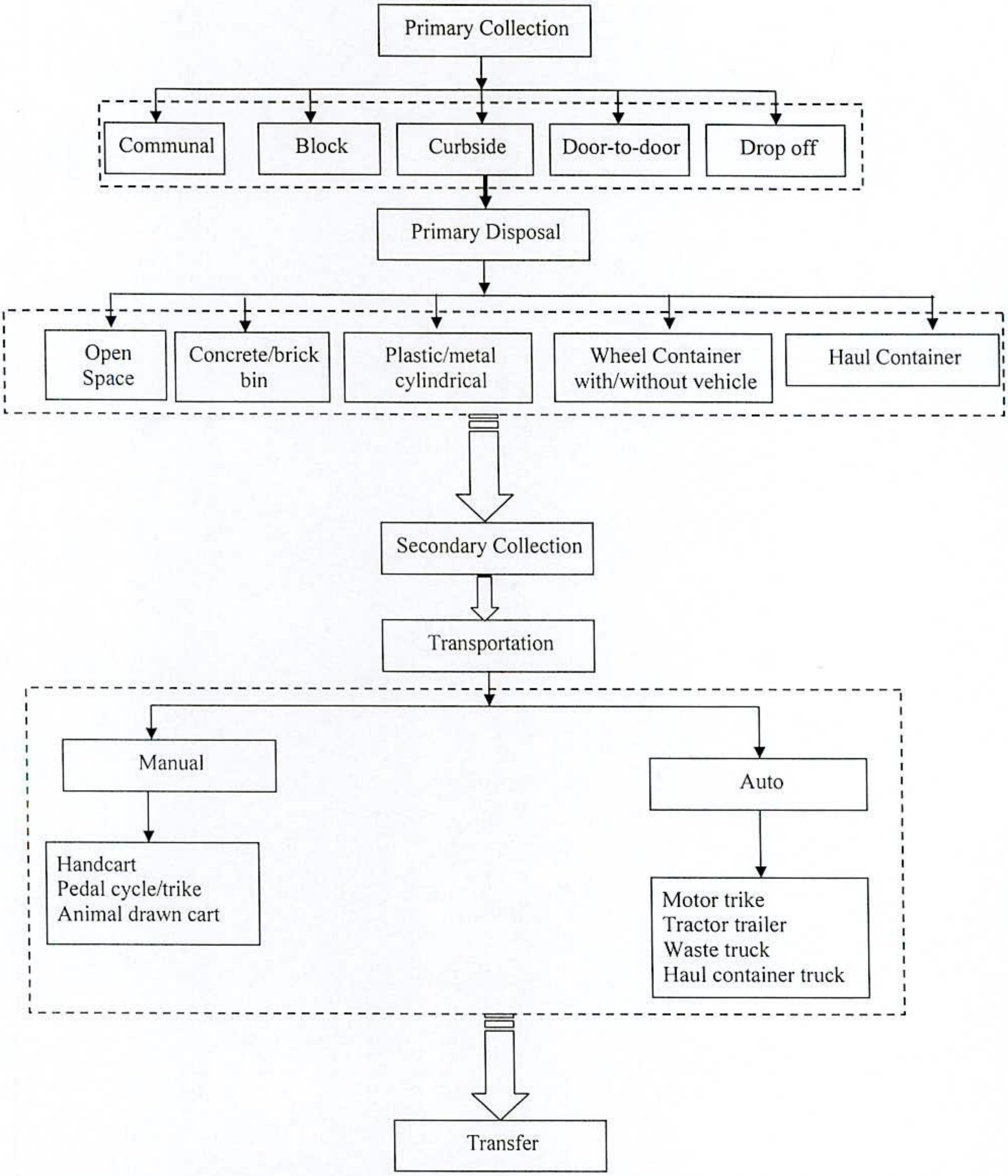


Figure 4.24 Typical flow diagram shows waste collection and transfer options from secondary disposal site

4.8.2 Waste collection and transfer

Different waste collection and transfer options from secondary disposal sites are shown in Figure 4.24. It reveals the different types of container options at secondary sites. The availability of haul container is seen only in Dhaka, Chittagong and Khulna cities. Wheel container and concrete/brick bins are present in all city corporations. During the collection process different methods are applied. The transportation stage consists of both manual and automatic options. Manual transportation mainly consists of handcart and pedal trike van. In the automatic transferring options there are different types of vehicles. But normal truck and haul container are predominant here.

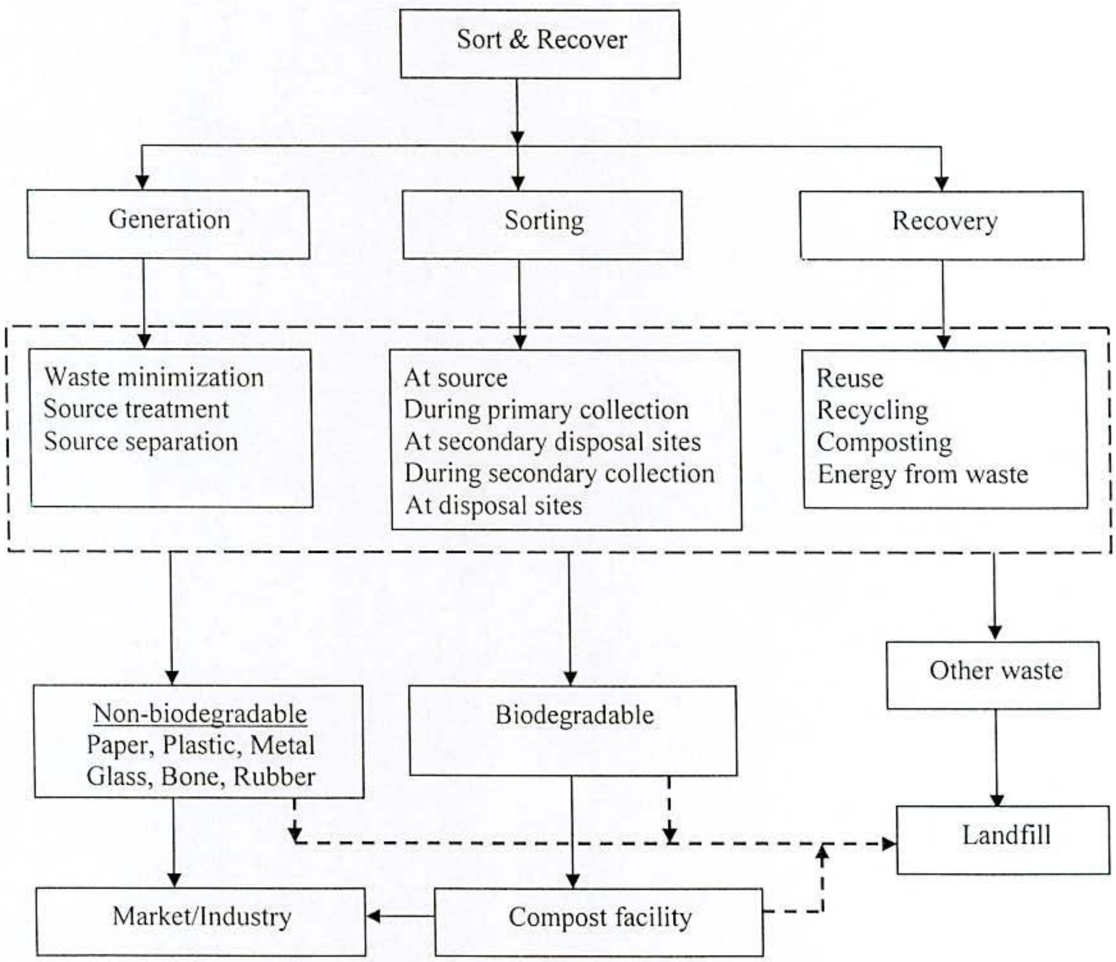


Figure 4.25 Typical flow diagram shows waste sorting options

4.8.3 Waste sorting and recover

Typical waste sorting activities in the study areas are summarized in Figure 4.25. It shows the sort and recovery options and practices in different waste flow path. Sorting and recovering from the wastes can be done at the generation source, during primary and secondary collection, at SDS and UDS and in the transfer station or recovery process plant. During sorting wastes are sorted in biodegradable and non-biodegradable portions mainly. Biodegradable portions consists mainly organic kitchen wastes. Non-biodegradable portions consists mainly paper, plastic, metal, glass, leather, rubber, clothes, animal bones etc. which can be used in different industries as raw material. A small part of the biodegradable wastes go to the composting facilities. After sorting, treatment and processing there are still a large amount of unusable residue which then goes to the ultimate disposal facility.

4.9 Problems of Existing Management of MSW

Deficiency and lack of relevant facilities prevail in every stages of solid waste management in the study areas. The problems exist in the areas of organizational, human resource and capabilities; technological capabilities, public awareness and motivation; economic and finances and ineffective legislation and enforcement, etc. as discussed briefly in the following articles.

4.9.1 Organizational

It is important to recognize that the pre-conditions for the success in any MSW management are strong, far-sighted and sustained political leadership and cooperation. Ultimately no organizational solution will succeed without such backing. Organizational arrangements of MSW management often face many difficulties, and are sometimes also made inefficient by corruptions. The organizations should be staffed by technical and experienced persons, whereas they are only too often operated by inexperienced non-technical persons. In this respect, it is a common observation that overalls conservancy services are inadequate and unsatisfactory in managing solid wastes in almost all the cities of Bangladesh. During this study it is realized that a credible solution cannot be achieved without being an overall change in the attitudes, commitment and administrative set-up to handle MSW problems. A typical organizational structure for the MSW in Bangladesh in the major cities is presented in

Figure 4.26. Though the conservancy department is entrusted for the management of solid waste, but they rely highly on the engineering section for the transportation and dumping site management. Also in the conservancy section usually non-professional persons are involved which causes less effectiveness. As the mayor is elected person and CEO is a government nominated person work above this two section, and there may arise the conflict of interest between these, the whole system sometimes proved inefficient for the SWM.

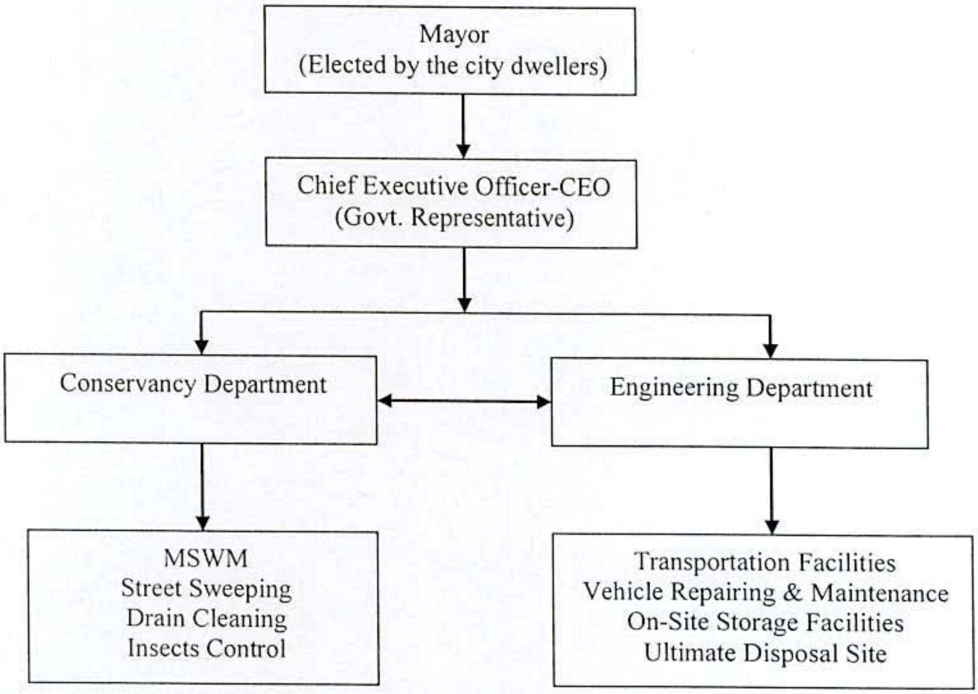


Figure 4.26 Typical organizational set-up for MSWM in the major cities of Bangladesh

The study depicts that there is a strong need to focus on the overall planning and management functions, and work to develop certain well-defined operational tasks within its overall waste management system. The existing organizational layout in terms of administration and function is far beyond the requirements to develop an effective and integrated management for municipal solid wastes. There is no independent body or cell exclusively for MSW management within the administrative set-up of City Corporation. Solid wastes management is generally take care by the Conservancy sections along with other municipality services with the interaction of Engineering Section. Often conservancy section gives preference to other function to proof their credibility since waste management is complex in nature and it is difficult to achieve success from it in the present circumstances.

The key aspects and the tiers that make the management transparent, efficient and liable to all concerned stakeholders are absent in the present organizational layout. It looks very much general in nature rather comprehensive and integrated. Waste management activities not only dependent with other municipality services within the conservancy section but also depends with another section, mainly engineering section. As a result quick decision and prompt actions could not be implemented resulting inefficiency of the services. Moreover, in the present organizational layout there is no scope to make direct agreement with NGOs/ CBOs/Private sector within the own initiatives of Conservancy Section.

Limitations:

- Conservancy inspector is a non-technical person in some city corporation of Bangladesh, so the appropriate decision taking may be difficult since now-a-days waste management is very much a technical approach.
- Coordination between Engineering and Conservancy Department is not well coherent and effective, resulting less structural development to management system.

Associated problems of the NGOs and CBOs

Despite achieving noticeable success in waste collection by door-to-door collection system from generation sources, NGOs & CBOs are facing many multi dimensional problems, which can be summarized as:

- As the van puller and helper get tinny salary, there is lack of encouragement to perform the duty properly.
- Service charge collection is a common problem for all NGOs and CBOs. On average 20% of households are not paying or delaying the payment of collection fees as per the agreement.
- In the secondary disposal point due to technical problems such as size, shape, location and design aspects of bin, the spreading waste creates serious pollution.
- Marketing of compost product is a great concern of NGOs, as the market of compost yet to be established.
- Non-motorized rickshaw vans require frequent repairing and needs to be changed after 4-5 years. So continuous financial support is required for its operation and maintenance

- Some times irregular and weak participation of city/ward authority with NGOs and CBOs create unwanted situation.
- Due to lack of awareness, motivation and commitment, people does not cooperate as desired. Even the cooperation from some ward commissioners are not encouraging.

NGOs and CBOs are only involved in a part of MSW management, so its involvement does not yet able to change the overall scenario as desired by the city dwellers.

4.9.2 Human resources and capabilities

In general, the city corporation authorities in the cities of Bangladesh have very less number of staffs required for effective activities of MSW management. Moreover, no technical or logical ratios are maintained among the various types of staffs as per the category and technical capabilities. Again chief conservancy officer in most cases does not have required academic, technical and administrative qualification. So, proper administrative and technical steps related to MSW could not be expected from the responsible person. Therefore from the study it is realized that the in-depth, appropriate administrative and technical persons should be posted in the right position, so that the problem could be comprehended easily and able to take right decision as per the requirements. Table 4.16 presents the typical manpower in the conservancy section of major cities of Bangladesh.

Table 4.16 Typical manpower involved in conservancy department of major cities of Bangladesh

Designation	Category
Conservancy Officer	Officer
Asst. Conservancy Officer	Officer
Conservancy Inspector	Field Officer
Conservancy Supervisor	Field Officer
Asst. Conservancy Supervisor	Field Officer
Sweeper	Labour
Truck Driver	Driver
Truck Helper	Worker
Truck Labours	Labour
Drain Cleaner	Labour
Spray Man	Labour
Street Sweeper	Labour
Dog Catching Labours	Labour
Van/Wheel Barrow Driver	Labour
Temporary Appointed Labours	Labour

MSW generated due to different activities in the various places of the city such as individual homes, multi-storied apartment buildings, slums, commercial and industrial facilities, as well as streets, parks, public places and even the vacant areas of every community. Limited numbers of workers randomly collect the wastes from different sources. Since the door-to-door collection system is followed or tried to follow by the corporation authority, it is essential to employ lot of waste collection workers, truck crews etc in the office than the existing condition. As an example, in a region of a major city of Bangladesh for the door-to-door collection system of solid wastes in the city are engaged 120 rickshaw van puller and 45 Wheelbarrow puller, whereas in total 300 rickshaw van puller is essential to continue the system efficiently. It is reported that one rickshaw van puller can collect wastes from 200 households within the working time in a day. However, it is well known that the door-to-door collection system is aesthetically and environmentally more satisfactory but comparatively more expensive than the other types of collection. For market wastes collection especially for fruit and vegetable waste, markets-authority generally provides waste collection worker partially and also transfer the waste collected from other sections. So it is impossible for them to collect wastes from households in that ward. Communal fixed dustbins are used beside the door-to-door collection system and required more time to collect wastes resulting in shortage of transportation crews. However, it is estimated that the collection and disposal rates of wastes by the authority through the existing manpower from various sources to the ultimate disposal site is able to collect 40 to 50% of total generated MSW.

As city corporation has short of financial support; their only resource is their manpower. If manpower has proper skill then the other shortcomings can be minimized easily. There should be some provision to give necessary training on the requirement of management. But it is unfortunate that the employees are not trained, they are experienced by confronting problems. One thing to be noticed that the maximum employee are not permanent, most of them are worked for daily wage basis as a result the job security is absent there. Also capabilities of employee are hampered by the lack of basic training. So if the city corporation wants a smooth running of the system they should try for proper training to increase the capabilities of employees. In such instance city authorities can look for cooperation and financial support from donor agencies for set-up training institute because required trainings for the staffs are the prime requirements for the effective implantation of the decision of MSW management programs.

Limitations

- Manpower in respect of existing management system is enough, but in a whole it is considerably less to meet the requirements of total management of solid waste.
- Most of the labors are involved in temporary basis. This uncertainty lets them less response to their duties or responsibilities, affecting decreased efficiency.
- Due to lack of skilled municipal workers, sometimes it is difficult to achieve the desired goals.
- Absence of evaluation to the employees creates less accountability to their responsible authority.
- Mismanagement of labors often creates disorder in collection, transportation and also in managing ultimate disposal site.
- Data for different categories of waste generation, quantity collected and disposed etc. do not exist.
- Further data on waste composition is also not available at micro and macro levels, which could give an indication of the potential for composting and recycling.

4.9.3 Technological capabilities

It means the technique and technology practices/available for collection, transportation, disposal and treatment facility. Efficiency is the first priority in any system. Most of the transportation vehicle are old enough or collected from different donor authority in second hand condition and most of the time this vehicles stay out from the services for repairing, which drop off efficiency. Another is that in SDS due to technical problems such as size, shape, location and design aspects of bin, the spreading waste creates serious pollution.

4.9.4 Financial aspects

The poor situation of MSW management in the major cities of Bangladesh is primarily due to limited financial provision by the Government, but also lagging in potential financial participation by the householder. The broadest categories of householder in the city are now middle class and lower middle class. Their economic condition is very bad. For this reason they do not want to spend money on things they consider non-essential. In some areas of the cities there appear to be no conservancy services although a budget is allocated for managing solid waste. So the unwanted and unpleasant situation in MSW management is sometimes not only due to financial situation but also due to commitment and proper utilization of the allocated money.

The total expense on the MSW management in the city corporation areas is about 3 to 5% of the total expense of the authority. Most of the amount is spent on the salary, collection and transportation of wastes from different sources to the ultimate disposal of wastes. There is no specific amount for further development of MSW management practices by the authority in the city areas. The primary concern is the amount of money that is required for proper management and safe disposal of MSW (Figure 4.27). It is also revealed during the study that the economic condition of the seven case study sites is not same because city corporation's authority collect few revenue from the city dwellers compared with the services provided to them in terms of MSW management. However, authority is trying to follow the door-to-door collection system. This practice is very good in aesthetic condition but expensive than any other types of collection systems. Adequate budgeting, cost accounting, financial monitoring and evaluations are essential for the effective management of solid waste systems. In the developing cities in general and the study city in particular, most official responsible for MSW management do not have accurate information concerning the real costs of operations, which are often as a result of unfamiliarity and lack of capacity to use available financial tools and methods.

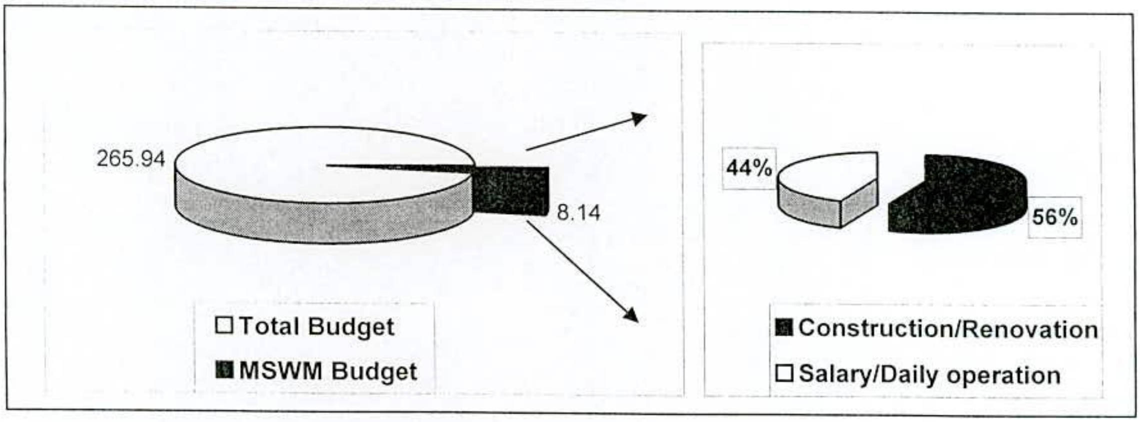


Figure 4.27 Total budget allocations for a city corporation of Bangladesh (amount in crore)

Adequate budgeting, cost accounting, financial monitoring and evaluations are essential for the effective management of solid waste systems. In the developing cities in general and the study city in particular, most official responsible for MSWM do not have accurate information concerning the real costs of operations, which are often as a result of unfamiliarity and lack of capacity to use available financial tools and methods.

4.9.5 Law, legislation and enforcement

There is no effective legislation about solid waste deposition, handling and for overall management in Bangladesh. If anybody or locality do not use dust bin or dispose of waste to and fro, he is noticed by the ward conservancy officer and penalized financially as per the provision present in the conservancy rules. But it is lengthy process of law and there is no example of punishment over somebody. There are no rules and regulations on the storage, separation and dumping of solid wastes in the city. Anybody can storage and dump wastes in any places if the owners of the places do not raise any objection. All the time wastes are dumped indiscriminately at various places such as on roads, into drains etc. Even in the fringe areas authority is dumping wastes at vacant places on the request of public. Conservancy section has a rule for the collection workers to wear appropriate shoes, hand gloves and apron for health safety, but the workers hardly to be seen wearing these safety measures due to lack of motivation and awareness about the consequence health hazards.

People throw waste hither and thither, which causes enormous public health and environmental problems. With sufficient and continuous prior motivation, awareness and warning, if laws existed and penalties were enforced in phases giving proper notification, such as fine or jail for the haphazard dispose of waste, it can be expected that the people would be more careful about disposing of their generated solid waste. There are a certain laws to let the people dispose wastes into dustbin properly. Such regularities enforcement is a necessary part to achieve desired goal of any implemented MSW management.

4.9.6 Public awareness and motivation

There is a limited campaign or steps to increase the public awareness about the adverse effect of unmanaged wastes on behalf of the authority. Even most of the citizens do not know where the wastes ultimately deposited and what are the possible environmental consequences after deposition. Presently lots of NGOs are working in the sectors of MSW management. Occasionally they are conducting awareness campaign but unfortunately collective and integrated approaches are absent and there is no follow-up of the steps and the continuation of efforts. Still most of the people think that the management of solid wastes generated in the city is the responsibility of the respective city authority, only, since they pay taxes and elect local representatives to solve their problems. The main points that have the direct influence on the present condition of MSW management system in the city authority are listed below:

(i) In household, there is no on-site handling system i.e. separation of different components of solid waste before collection and storage.
(ii) Uses of one container for storage of wastes in the household.
(iii) Irregular and improper dumping of wastes into the dustbins.
(iv) Dumping of wastes on roads, vacant plots, drains and ponds etc.
(v) Dumping of wastes into the dustbins or secondary disposal sites for all day long.
(vi) Botheration during collection of wastes from households.
(vii) Lack of knowledge as to the adverse environmental effect of unmanaged solid wastes.

4.10 ISWM for Bangladesh

Rapid urbanization and population growth in the major cities of Bangladesh create huge generation of MSW, which the authority is unable to manage properly with the present management system. At present no expert is involved in the conservancy section in major cities of Bangladesh. So, there is no integrated plan to improve the existing system. By implementing small changes and adopting new options in the all SWM tires, an expert/professional can formulate an ISWM plan. The study reveals that the present organizational set-up should be changed and an independent wing with proper authority having transparency and accountability to stakeholders should be set-up to handle only MSW problems.

CHAPTER FIVE

APPROACH FOR THE EVALUATION AND SELECTION OF INTEGRATED MANAGEMENT SYSTEMS

5.1 General

This chapter aims to propose an approach for the evaluation, selection and improvement of integrated management systems to address the problems associated with municipal solid waste (MSW) in the context of Bangladesh. This approach offers a conceptual framework for identifying options for consideration in all tiers and aspects of MSW management and their systematic evaluation against a broad range of criteria and stake holder's interests.

5.2 Waste System Components

Waste components are the basic functional elements of a waste management hierarchy. Waste System Components can be categorized in the following four components:

a) Contain and Collect
b) Sort and Recover
c) Transfer and Treat
d) Dispose and Make Safe

5.2.1 Contain and Collect

By providing proper waste containment at source the total waste management systems can be improved. Proper storage and source separation is the key mechanism to recovering useable and recyclable products, and realizing reductions in the amount of waste for disposal. Although it is difficult to practice this in Bangladesh, it should be recognized as a basic goal of integrated MSW management. At least one thing should be achieved meanwhile – *"Don't throw wastes out, but store them in a designated place, by any means"*. Local authorities should consider the necessary steps for source storage, as a first measure is shown in Box 5.1.

Box 5.1: The steps should be considered for source storage by local authorities

- Introduce an intensive awareness and motivation campaign aimed at city dwellers, for storage of their generated wastes, at least in a single bin.
- Encourage NGOs to come forward for this awareness campaign and provide appropriate bins to the poor people.
- Make 'use of bin to store waste' mandatory for all commercial premises, starting from very small shops.
- Make 'use of bin to store waste' mandatory for all institutional premises within the city areas.
- Provide intensive awareness campaigns at public places, including terminals, persuading people not to litter wastes, rather put them in the nearest bin.
- Complementary awareness campaigns should be introduced in every school, college, university and also public and private offices.
- Every month the city authority to declare names of those Institutes/commercial places achieving near 100% success in waste storage inspections.

After that the primary collection of waste from its source is one of the most important connectors in building smoothly running chains among all the elements of MSW management. The success of any management system of MSW greatly depends on the efforts and success of primary collection. The frequency and reliability of waste collection also has tremendous impacts on source storage requirements.

Provisions for the primary collection of waste tend to be either kerbside or door-to-door. In a door-to-door collection system, householders/proprietors or their staff hand over their generated waste to collectors, who collect waste from door-to-door and transfer the waste to secondary disposal sites (SDS). With the kerbside system, collection has to take place as per a fixed schedule known to the public, who place their wastes at the collection points not earlier than one hour before collection is due. Collectors collect waste from those points and transfer it to SDS. Collection is typically by lifting, carrying, emptying and returning the bins to the premises or kerbside. The collection vehicles are commonly handcarts or cycle rickshaws, carrying larger containers into which the waste is emptied. The intended frequency is often daily, due to the climate and organic nature of the waste. Sufficient collection vehicles, containers, manpower and financial support are required for both type of effective collection systems.

In the absence of either kerbside or door-to-door collection, community bins are commonly used in Bangladesh. Special care should be taken over community bins, as they are one of the major sources of environment degradation. Such receptacles rely on householders and businesses, or their workers, delivering their waste themselves. As such community bins are usually open containers in the open air; they seriously pollute the environment, and cause nuisances for the surrounding areas. It becomes common place to throw waste on the streets and footpaths besides community bins; either because they are full, or since their contents are often sorted there by scavengers.

The studies show that many city dwellers in the study areas are interested in door-to-door waste collection services and are also ready to pay for them. Such services help ensure the proper delivery of wastes to the SDS, and prevent their throwing hither and thither. They also avoid the environmental detriment of numerous kerbside containers being put out and left out: a considerable impact where containers are not standardised (like wheelie bins) and daily collections are intended. Where collection is not yet feasible, the replacement of large open community bins by a limited number of smaller covered containers may be beneficial. Properly sized and conveniently sited shared containers can facilitate both collection and transportation; but it remains vital that they in turn are regularly collected or emptied by (or on behalf of) the authorities, and their waste taken to an SDS or other transfer or disposal point.

The location and design of the SDS are critical in terms of health and hygiene and environmental impact, if wastes are to be deposited properly, and transferred in a timely manner for treatment or ultimate disposal. The typical scenarios at such sites, as depicted in the study, are highly alarming. SDSs in the study areas have traditionally taken the form of (i) fixed masonry open box containers in brick or concrete, (ii) portable demountable large steel skips or containers, or (iii) plain curbside earthen areas or concrete pads. Types (i) or (ii) are sometimes called community dustbins. However, this study intends to redefine and rename the SDS. This is partly since, for clarity, it is preferred to use the term 'disposal' only in the context of 'final' disposal. But it is also because it is felt that a need to better describe the function of these SDSs sites, and to distinguish that from the quite different role of the 'transfer station', which will be dealt with in Article 5.2.3 below. It is suggested that the SDS should in future be thought of as a "local waste assembly or handover point", but called simply a **'WastePoint'**. This can cover all the traditional forms of SDS, but will also include, for instance, the smaller, more local community containers (such as plastic wheeled bins or metal paladins) which might eventually replace a single 'community dustbin' type SDS. Then the WastePoints might be coded as B_1, B_2, B_3 etc for such individual communal bins; P_1, P_2, P_3 etc for simple pads accommodating more than one such bin; E_1, E_2, E_3 etc for enclosures for a wider range of facilities as shown in Figure 5.1. The waste plan and ultimately the legislation can then more easily specify who should provide, maintain and take waste to and from each type of WastePoint.

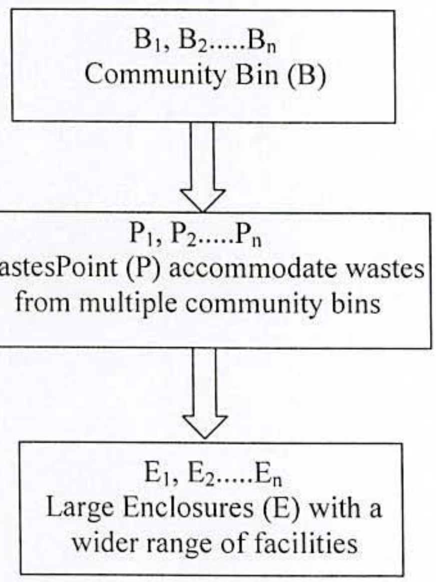


Figure 5.1 Simplified flow diagram for the concept of WastePoint

5.2.2 Sort and Recover

Waste avoidance and minimization are achieved via source reduction, reuse and recycling. The success of source reduction depends on the development and wider use of 'clean' production techniques and 'clean' technologies. These can be promoted through the regulation of industry, the formulation of economic instruments to encourage plant, process and product modification, and an increasing awareness by consumers of the benefits of eco-friendly products. Enormous potential nonetheless exists to implement source reduction programs over time. The important strategies can be pursued are shown in Box 5.2 (after EPA 1999).

Box 5.2: The strategies can be pursued for source reduction

- Redesign products or packaging to reduce material content or facilitate dismantling.
- Avoid unnecessary packaging – choose items with little or no or reusable packaging.
- Borrow, rent or share items – rent or borrow party supplies, tools, appliances and electronic equipment; share newspapers, magazines.
- Sell or donate goods instead of throwing them out – donate clothes, textiles, appliances, and furniture; offer camera items before throwing.
- Reuse bags, containers, matting, and similar items.
- Lengthen the lives of products to postpone disposal, through regular maintenance or choosing to repair or adapt an item.
- Introduce massive awareness campaigns at Government or city authority levels. NGOs/CBOs may fruitfully be involved in such activities.
- Extend waste avoidance and minimization campaigns into schools, colleges, universities and across both public and private sectors.

Alongside source reduction, plus the source storage of that waste which is produced, source separation should be introduced as soon as practicable. That involves storing waste in at least in two separate containers:

(i) The rapidly biodegradable organic fraction, which needs daily collection, and

(ii) The non-biodegradable or slowly biodegradable fraction, comprising both hazardous and non-hazardous inorganic.

Certain recoverable materials may be put aside for economic uses in that source separation process e.g. for animal feed, or to be given or sold to bottle or paper collectors or merchants. Other more specific items may usefully be separated from the residual mainstream wastes, before they are taken to the WastePoint -- not least any hazardous elements for which alternative treatment or disposal routes are offered. However, such specific provision for non-saleable wastes tends to be rare in the study areas, which struggle to deal effectively with a single bin per household.

Separation is, of course, pointless unless both collection and treatment/disposal of the separated wastes follow distinct pathways and processes. It was found in the questionnaire survey that 50% of respondents claimed to be prepared to store waste in two separate bins (one for biodegradable/compostable waste and another for non-biodegradable waste) if the city authority or some NGOs & CBOs were to provide a separate collection system. However, many people living in the slum areas are not motivated even to store their wastes in a single bin. The tend have higher priority concerns for the city authorities to address before MSW collection, such as sanitation, drain clearance and water supply.

In the absence of source separation, wastes may still be sorted further down the line, although with the penalty of cross-contamination from other wastes. At present, sorting which is not done by households or businesses themselves tends to be undertaken by the waste collectors on their handcarts or tricycles, or by scavengers at the WastePoint or at official tipping sites and unauthorized dumps. This results in unacceptable health and environmental conditions, not least for the waste pickers, but also for the community at large.

It is realized that any sorting away from the waste source should be taken place in areas of transfer stations, material recovery centers, treatment plants or disposal sites provided, equipped and supervised for that purpose. Private sector or NGO can be also involved in these actions. It follows that, primary sorting should all take place either at the source premises (i.e. strict source separation) or directly onto waste collection vehicles (at door or curbside) or straight into containers at a WastePoint. There should then be rules and regulations to the effect shown in Box 5.3.

Box 5.3: The regulation should be introduced at WastePoint

- No primary sorting is to be done on the surface of street or of other public places, including at the new WastePoints. (That should be made a firm distinction from the old SDS: in the rare cases where a location is good enough to accommodate both, the WastePoint role should be separated from the material recovery/sorting function).
- Secondary sorting is only to be undertaken in designated areas of transfer, treatment or disposal points, and only by authorized persons.

Separation and sorting can play a vital role in minimizing the cost of waste management, providing proper materials for recycling, and creating jobs. But while they can be encouraged in principle, the implications of providing them effectively must not be underestimated. Color coded bins may need to be provided, with instructions, to householders to encourage proper source separation. These must then be collected (or delivered) separately, which could involve separate containers on collection vehicles, and/or separate vehicles at different collection frequencies. Room and resources must then be found for equivalent separation and duplication at the WastePoints or SDSs. Not least, there then need to be separate bulk transfer vehicles, bays, handling equipment and/or containers to get the stuff to convenient treatment plants or disposal sites. Those in turn need adequate capacity and effective processes to convert each separate waste stream to marketable product, and/or to dispose of the residue safely.

And finally, sustainable markets are needed for the recycled products. There are, however, serious health and safety, plus job security, issues for the waste pickers. There is also a strong need to support these recycling industries, especially the small scale operators, to help create and sustain viable markets for recycled product, and ensure the proper disposal of any residues.

To obtain the required degree of success, value recovery and recycling in the study areas should not be left entirely to the 'informal sector'. The system should also be guided by "formal standards' and 'community initiatives', in order to increase efficiency and help establish sustainable recycling trade chains, the important steps should be considered are shown in Box 5.4.

Box 5.4: The steps should be considered for sustainable recycling trade chains

- Identify, in as great detail as possible, those items, which have recycling value, and the different sources at which they are generated.
- Encourage primary source separation of recyclable items from the generated wastes. Such materials should never be mixed with rapidly biodegradable organic wastes or hazardous wastes, and preferably not with any other waste.
- Undertake awareness campaigns on waste minimization, separation and recycling, through Central Government, City Authorities, NGOs, and CBOs. The targeting for these should include the middle classes, whose waste generation is otherwise likely to increase with rising incomes.
- Gradually limit, equip and regulate those sites, at which any secondary sorting is authorized, and those organizations, businesses and waste pickers registered to do such sorting. (Effective source separation should reduce its viability anyway.)
- Subject to space, environmental, etc. factors, preferably provide for secondary sorting at dedicated material recovery centers or waste transfer stations (i.e. before waste is further mixed), rather than at ultimate treatment or disposal sites.
- Wherever secondary sorting is undertaken, the site operators should provide meaningful health and safety protection to the waste pickers, including adequate isolation from vehicles or equipment involved in other activities.
- Encourage and take initiatives to help develop the recycling industry, such as financial and other support for the setup of small enterprises to buy and use recycled materials, and assistance in marketing recycled items abroad.

5.2.3 Transfer and Treat

Many of the greatest costs and environmental impacts of waste management are incurred in the transport of waste. While the primary role of the WastePoints is the assembly of waste convenient to its sources, the primary role of waste transfer stations is the bulking of waste for its economic and environmentally acceptable onward transport to treatment or disposal facilities. For ease of reference in this study the bulk transfer stations will be renamed as '**WasteNodes**'.

The principle is that relatively few WasteNodes receive waste from the many WastePoints or (by arrangement) direct from major waste generators. At a transfer station, the waste is tipped into some sort of bay or bunker, and re-loaded into bulk containers, which carry it on by road, rail or waterway for further sorting, treatment or disposal. These bulk waste movements tend to be much less costly per tonne-kilometer than moving waste all the way with the collection vehicles, and thus enable it to be taken economically to more remote treatment and disposal facilities, typically outside the urban area. Moreover, having the break-point and bulking at a transfer station gives the flexibility to deliver waste on to a changing pattern of treatment and disposal sites, as technologies evolve and landfills are completed.

The result of this is that having WasteNodes eliminates uncertainties for urban waste collection systems, by providing a stable network of reception stations against which they can be optimized. It enables the WastePoints to be cleared on a reliable schedule - which could be weekly, daily, or several times daily, depending on the type of waste and container, the accessibility of the location, and local waste generation rates. It enables that waste to be taken to, and rapidly discharged at, a fixed location within each sector of the urban area. And it enables those WastePoint to WasteNode movements to be accomplished by a variety of short-range carrier vehicles, suited to the constraints of different road patterns and congestion conditions, and to a changing pattern of container types and collection systems.

Establishing such WasteNodes also encourages the gradual investment in improved waste handling vehicles and equipment, to serve reasonably predictable waste throughputs. Such efficiencies are crucial if more sophisticated systems, involving the switching rather than the emptying of containers, or the handling of containers of separated wastes, are ever to be implemented. But establishing WasteNodes should also help tackle the need for faster, more reliable transfers of mixed waste, within given plant and space constraints, meanwhile.

The bulking at a WasteNodes is commonly (but not always) undertaken by some form of wheeled loading bucket. It may (but need not) also involve mechanical shredding and/or compaction, primarily for ease or economy of handling and movement, although with effects for subsequent waste treatment or transformations. Sometimes other elements of sorting, treatment or disposal will be co-located at the transfer station: but we then prefer to see those as facilities in their own right, serving a distinct role to that of waste bulking and transfer, and usually under different operational management. Similarly, where a transfer station happens to be located alongside a transfer station (which is often convenient), their functions should nevertheless be kept quite separate, with only the transfer station being open to public access.

One of the reasons for the early establishment of such transfer stations is the great difficulty of finding suitable locations within any urban area. Although a WasteNode does not bring all the environmental impacts of a composting plant or landfill site, they are essentially very busy depots, with a multitude of small intake movements from the WastePoints, and fewer but heavier outward vehicular movements to treatment and disposal facilities. The activities inevitably create traffic congestion, plus noise, dust, fumes etc. Clearly the WasteNodes need locating close to major transport infrastructure (be it road, rail or waterway), and within industrial or commercial, rather than residential or institutional areas. They also need enough room to provide proper vehicular access and queuing arrangements, construct effective screen walls or banks, and to allow for the development of enhanced facilities over time, such as the storage and handling of separate waste streams. Since suitable sites are not easily come by, and new sites tend to be more controversial than improving existing facilities, the farsighted planning of adequate networks of WasteNodes will prove invaluable to the future of waste management in Bangladesh.

The success of WasteNodes is one of the key issues in integrated MSW management, yet tends to be an under-addressed aspect in the study areas. This is partly due to the fact that it is not a popular angle of waste management for community attention and NGO involvement. It is also perhaps because waste transfer stations and vehicles in the waste tend to involve major equipment investments. But the same principle can be applied to waste, which arrives from WastePoints by handcart, bullock cart or motor trike, but leaves the transfer stations by open truck or tractor-trailer. Simply having a network of transfer stations locations, whose primary purpose is the efficient and environmentally responsible onward bulk movement of the waste, provides dedicated space and managerial focus for gradual service and system improvements. To ensure the proper management of this waste transfer and transport function, the city authority should be considered the important points, given in Box 5.6. The relatively modest set-up costs are one of the attractions perceived by many CBOs and NGOs in venturing into community composting initiatives, as are the employment benefits of this labor-intensive approach. But economics also enter into all subsequent decisions in the implementation of the compost option. It tends to dictate the sites available: in urban areas especially, few even of the most successful composting operations could afford to pay the full economic costs of the land they occupy. It influences the selection of a particular compost system, and of the associated structures and equipment. Most importantly, it acts as a constraint on the continuity of the operation, in that a composting undertaking can only survive for as long as its income streams (whether from waste collection fees, compost sales, or public/charitable subsidies) cover all its labor, plant and other outgoings. To encourage its development in both public and private sectors, techniques appropriate to various socio-economic settings and technological capabilities should be officially recognized and promulgated by the national and local Governments, with the aid of concerned NGOs. The most important issues to involve private sector in the MSW are given in Box 5.5.

Box 5.5: Important aspects to be considered for involvement of Private sectors

The city authority usually has overall responsibility for the transfer and transport of waste. The study suggests that, at least in most of the selected cities, where the city authorities had attempted to perform this task exclusively using in-house resources, it was rarely conducted satisfactorily. By contrast, their limited experience to date in involving the private sector in the transfer and transport function seems to have indicated potential efficiencies in terms of cost and performance. However, any such involvement should be transparent and competitive. The role should only be entrusted to private operators under detailed terms and conditions specified in a formal contract. Proper evaluation and monitoring should be conducted on their performance. And any such engagement should cover several years at least, so that the companies have sufficient incentive and security to invest in the necessary infrastructure.

Incineration with energy-from-waste is the other main treatment and value recovery route. There are no general-purpose MSW incinerators presently operating in the study cities. Open burning, mostly accidental or unauthorized, takes place to some extent at secondary disposal and ultimate disposal sites – a practice which should be banned by Government and specific environment protection laws and regulations. Some small facilities have been established in the study cities to burn infectious hospital wastes, but these are not designed to operate at the requisite temperatures for safe treatment, and not equipped with proper pollution control devices. Other small single-purpose waste incinerators are operated at various institutions. Such initiatives should be strictly controlled, so that incinerators for hazardous clinical wastes meet adequate environmental protection standards, and since incineration is rarely a viable and responsible solution for managing other wastes in the present circumstances of the study sites. That is partly due to the inherent composition and characteristics of MSW in the study areas, particularly after dry recyclables have been removed: i.e. high moisture content, high organic content and low calorific value. But it is also a result of the high capital, operating and maintenance costs of responsible incineration, and of increasingly stringent air pollution control concerns and measures. The technological prerequisites are not readily available nor the technical expertise to develop sound plant, the trained managers and operating personnel, the facilities for routine maintenance and spare parts, or the pollution control equipment and consumables. The sustainability of such systems in the study areas cannot be ensured, even with the involvement of private companies or multinational organizations, through donor agency funding or other means. So with the possible exception of strategic facilities for hazardous clinical waste streams, incineration should be accorded a low priority in the present socio-economic context. The major key issues for sustainable waster transfer and transport are given in Box 5.6.

Box 5.6: Important points for ensuring sustainable waste transfer and transport

(i) Plan and provide, in phases, a network of WasteNodes, one for each major city sector, to which waste from the WastePoints is taken for onward bulk transfer to treatment and/or disposal facilities. Explore the possibilities of alternative modes of bulk transport in planning the scale and location of both the WasteNodes and the treatment and disposal facilities.
(ii) Give careful consideration to the scale, location and design of each WasteNode, so as to minimize their environmental impacts, and allow for gradual investment in their functional and technological development.
(iii) Where there is no experience of constructing and running transfer stations, a pilot scheme should be provided first, then further WasteNodes designed based on feedback from its operation; study visits to facilities elsewhere can also be invaluable, but need to cover a variety of relevant situations and solutions, rather than simply the latest showpiece plant(s) from a single contractor.
(iv) If no suitable place can be found for the construction of a WasteNode, or until one can be provided, longer-distance hauls directly from WastePoints to treatment or disposal facilities can be practiced as an alternative.
(v) Where space permits, an option for waste sorting and picking may be provided at a WasteNode. This is particularly relevant as a transitional measure, while SDS are being converted into WastePoints, with the phasing-out of on-street scavenging. The longer-term intention might be to utilize the same space to accommodate the handling of source-separated waste, or to develop some major waste recycling or treatment center at the site. However, any interim provision for waste picking must be segregated as much as practicable from the waste transfer function, and should offer better worker health protection than is customary.
(vi) NGOs, CBOs or the private sector may be involved in the building and/or running of the WasteNodes, and financial institutions should be encouraged to provide appropriate support. Whenever there is such non-governmental involvement, there should be continuous performance monitoring and evaluation by or on behalf of the city authority.

5.2.4 Dispose and Make Safe

There were no properly engineered sanitary landfills operating in the case study cities. The open dumping presently practiced is a scenario, which poses serious threats to both human health and nature. Such dumps should be phased out as a matter of urgency. While it is no easy matter with an established site, some may lend themselves to re-engineering, in whole or part, to create an improved facility. Preventive or clean-up measures will need to be taken at others, particularly to protect potable water sources in the vicinity. But by far the best solution, the only affordable disposal solution for the foreseeable future - is to establish new fully engineered landfills.

The basic requirements for responsible landfills should not be beyond the resources of cities. Encapsulation of the waste can achieved by finding sites where the natural geology offers such containment, or by forming lining layers by compacting certain natural clays (which have been found to be plentiful in most parts of Bangladesh). The standard of encapsulation required (and indeed, affordable) is a function of the toxicity of the waste and its decomposition products, and of the exposure and risks of their reaching sensitive receptors in the locality, such as drinking water supplies.

Similarly, covering of the deposited waste is not overly demanding, provided the landfill is subdivided into manageable cells, and the working area within them at any time is minimized. Daily cover can be practiced using inert fractions of the waste, or natural materials such as Hessian. Final capping, to reduce rain penetration and gas emissions, can again use local clays and/or sub-soils. The standards may not reach those of Western practices, involving polymer membranes and the like; but the wastes concerned are not generally as hazardous as many of the industrialized wastes encountered in the West; nor is it evident that sites cannot be found with acceptable risk exposures.

5.3 Aspect of Evaluation

For a particular waste component, the different choices need to evaluated, to cope with the best economical and environmental considerations. The aspects of evaluation consists the following:

a) Sources and Streams
b) Costs and Returns
c) Health and Environment
d) Community and Structure

5.3.1 Sources and Streams

The source and streams can be expressed in terms of tonnes or cubic meters of each waste stream, per hour, day, week or year. However, it demands a more profound evaluation than the accounting exercise, which that might suggest.

Firstly, city dwellers rightly expect their central and local governments to make proper provision for the management of all waste in every waste stream, regardless of the source and quantity, of its variable and uncertain composition, of whether or not it has residual value, or of how troublesome or hazardous it is or might become. Governments and their agencies may legislate or contract for others to have responsibilities for parts of the waste for parts of the time; but the money stops with them in making and enforcing such arrangements, or dealing with wastes when others default. Government policies and programs must thus address the whole problem, not just its easiest or most fashionable parts; they must deal with both short-term crises and long-term change; and of course, they must do so with limited resources. So all waste streams should taken into the evaluation process.

Another issue is the different processing routes for different types of waste, and the quantities of waste potentially or actually following each route. There is a pure mathematical aspect to that, and it could be very complex as wastes are transformed, leaving one stream, and entering or re-entering others. For the priorities given to each waste stream, the decisions on how they are stored and moved, on the treatment technologies employed, on the feedstock and emissions of those processes, and on the final fate of the residues, reflect numerous interest trade-offs between producers and consumers, waste generators, collection and disposal authorities, waste workers, recycling merchants, investors and environmentalists.

So the Sources & Streams is a critical interface between the technical organization of an integrated MSW system and the balance of political priorities it serves. There are two important activities and capabilities this organization needs to consider.

Firstly, it requires the project management and technical skills of engineers and other specialists, to work together on the planning, design, specification and implementation of all the various aspects of the system, from the waste containers and vehicle routings at the collection end, to the cell linings and gas controls at final disposal. But in many cities of Bangladesh there is a history of overstaffing, duplication and job protection, due to political and other reasons and due to this there is inactivity, inefficiency, low spirits and absenteeism, lack of flexibility and resources to support change.

Secondly, is the need for objective information as a basis for informed decision making. Continuous records kept of all MSW operations need to feed into a practical management information system. Regular monitoring and review should be undertaken of all activities at all tiers of MSW management within the city areas, whether run by public authorities and agencies or by NGOs, CBOs and the private sector. This monitoring and review task may be undertaken by some internal city unit, or an independent technical group might be commissioned. Evaluation findings and possible solutions should be discussed immediately, and remedial measures implemented in phases. All relevant stakeholders should be involved.

Finally, it is needed to consider those waste streams occurring under exceptional circumstances: such as major events or natural calamities. Although such exceptional waste streams raise issues of resources, responsibilities and environmental, it is fitting to deal with them here, since professional capabilities of rapid response and executive action can be so crucial in such situations.

5.3.2 Costs and Returns

Costs and Returns head is in principle intended to embrace much more than straightforward costing and budgeting: indeed it can, and should where possible, cover all the features of full cost-benefit and investment analysis.

The main issues relating to the financial aspects of MSW management are commonly seen to arise solely due to the inadequate resources and/or the absence of national level policy and guidelines for the allocation of resources to handle this striking problem. In general a single digit percentage of the total budget for city authority is allotted for the whole of their conservancy services. Waste management is only a part of such services. As a result most MSW management in the Bangladesh is run within severe budget constraints. Central government should extend its direct support in this area, since city authorities are reluctant to lose votes by increasing local taxes. In addition, the financial constraints can be alleviated through community and private sector participation, if these are encouraged by a favorable climate.

Society tends to be widely divided, based on educational and economic standards. In these countries, many people cannot read or write, and they struggle hard just to maintain sufficient daily food. They still generate waste, and should ensure its proper disposal, but generally have little knowledge of the related health and environmental risks. It makes no sense to seek fees for waste services from such city dwellers; but their awareness of good practices can be gradually improved through educational campaigns. By contrast, 'middle-class' educated people, having reasonably good economic circumstances, can afford to pay for convenient and reliable waste management services. They may still need persuading of this, and many will by happier to fund the removal of waste from their neighborhood than its proper treatment and disposal. But, at the extreme, the approach which works with residents of high-class apartments needs to be different from that made to people living in the slums.

5.3.3 Health and Environment

Adverse environmental impacts and health threatening issues arising from poor solid wastes management have both immediate and longer-term affects. Under present practices in many study cities, as revealed by the study, badly managed MSW poses severe threats to human health and nature. The most immediate risks are due to direct contact with infectious materials stored, handled and disposed of within the main streams of solid wastes. Moreover, even fresh, uncontaminated wastes attract disease bearing insects and vermin, which transmit infections to nearby communities. And over the longer term such wastes generate leachates, which can pollute watercourses and drinking water sources in their various phases of biodegradation.

The short-term heath and environmental impacts are mitigated with effective collection, transport and disposal of residues, at least into some form of authorized and controlled facility. Separate and secure systems for the management of hazardous hospital and clinical wastes should be implemented as a matter of urgency; interim measures should be introduced meanwhile, to better protect waste workers and pickers from the inherent risks.

Addressing the longer-term problems in Bangladesh effectively requires disposal in properly engineered sanitary landfills, out-of-bounds to public access, with adequate precautions for monitoring and remediation of the gas emissions and generated leachates. Health protection should be improved for all waste workers, including those employed in non-governmental organizations and the private sector.

5.3.4 Community and Structure

There are various dimensions of socio-economic and organizational implications. Private sector involvement and public awareness and participation tend to be the big buzzword, and the team will certainly be supporting them. Again experiences working in and with central and local government authorities and other decision making bodies and conducting continuing dialogue between stakeholders, lead to develop some definite perspective.

The city corporations or municipal authorities have little effective local legislation exists relating to solid wastes. Few special agencies or teams have yet been established for MSW management. But the need for both regulation and capabilities is well recognized. This is a great opportunity to create dedicated divisions to tackle the collection and disposal roles. Appropriate staff should be assigned or appointed, with an emphasis on logistics and organizational skills in the collection services, and on developmental and operational skills in the disposal services. Regular training and motivational workshops should be conducted for staff, NGOs and other private organizations, with academic or professional inputs. Administrative capabilities need to be enhanced to prepare for the drawing up, letting and monitoring of internal service-level agreements, and/or contracts with NGOs/CBOs or the private sector. Where appropriate, consultancy or aid agency advice and assistance should be sought in introducing such changes, and overcoming problems of low labor productivity, poor maintenance, fragmented management, defective accounting systems or inadequate financial resources. But the city authorities themselves must use their power and credibility to drive the changes forward.

City dwellers are the primary stakeholders involved in the process of MSW management. They have to realize that it is ultimately their waste, and take responsibility for it. They will be the direct beneficiary of more appropriate and effective waste services. The civic societies, led usually by progressive citizens, can play a vital role as mediators between the city dwellers and the implementing authorities. The city dwellers should express their opinions and participate actively in improvement initiatives of Government, city authorities, NGOs/CBOs or the private sector. They should be familiarized with the complementary roles of waste collection and waste disposal services: i.e. that their responsibilities do not end with the removal of the waste, but with it being recycled and/or rendered harmless. They should also try to understand the technical constraints, and the risk and cost factors, in waste management options.

The incorporation of NGOs and the private sector at every tier of MSW management in the study areas is widely advocated. This is against a perception that city authorities have not been up to the job themselves, and that the NGOs and private companies can bring in not only additional resources, but also different skills and experiences, and greater efficiency. But in the study areas a few NGOs or private companies have the scope of capabilities and depth of experience to run an integrated MSW system. Grassroots and community level organizations are well suited to the intensive public contacts, which Contain and Collect and Sort and Recover activities require. Their contributions can not only reduce the burden of municipal administration, but enable the municipalities to meet their social obligations more effectively. By contrast, private companies tend to be better suited to the challenge of developing and running the sort of facilities and technologies required for the Transfer and Treat and Dispose and Make Safe components. They are good at delivering specific projects, or operating specific plant, to schedule and within budget.

In short, all concerned stakeholders should share common points of agreement, compromise and commitment in order to play their parts whole-heartily in the effective implementation of an appropriate MSW management strategy. Government, city authorities, academicians, NGOs/CBOs, and private contractors need to work jointly as team, with the cooperation of city dwellers and other waste generators, for the successful construction and operation of an integrated system.

5.4 Integrated MSW Management Approach

To propose an integrated approach to the selection, evaluation and improvement of solid waste management systems for municipalities in the study areas, MCDA approach is considered. The approach is based on series spreadsheets of waste system components (Contain and Collect, Sort and Recover, Transfer and Treat, and Dispose and Make Safe) and aspects of evaluation (Source and Streams, Cost and Returns, Health and Environment, and Community and Structure). The approach is to seek the improvement of waste management through,

(i) A structural dialogue between stakeholders and
(ii) About the planning and implementation of change.

The dialogue aims to promote desirable checks and balances between the focus and motivation of specific interests through the following spreadsheet tools:

(i) To promote a device to think the problems systematically and holistically and,
(ii) To help for setout more selectively a balanced 'business and sustainability' for some proposed intervention action.

The common spreadsheet format consists of:

(i) Waste system components forming the row headings of the spreadsheet i.e. contain & collect; sort & recover; transfer & treat and, dispose & make safe, and

(ii) Aspects of evaluation components forming the column headings of the spreadsheet i.e. sources & streams; costs & returns; health & environment and, community & structure.

5.4.1 Spread Sheet for Selection Approach

5.4.1.1 Options for Container and Collection

Typical elaboration of contain and collect options and sub-options for the considered approach are given in Table 5.1. In contains the elements such as container at source, collection from source, vehicle to transfer the waste to secondary disposal site and frequency of collection. All the possible option and sub-option used to contain waste at the generation source and methods to collect wastes from sources are presented in the spread sheet. They illustrate that at source plastic bag, single bin or box, demountable paladin container can be used. There are different sub options to choose a particular type of container. For a single bin container, the choice depends on its capacity, shape and dimension and construction material like plastic or metal. Depending on requirement and avail ability one can choose from these options and sub-options. Similarly for different types of container, we can choose from their different sub-options.

For collection or drop-off from source the available options are door-to-door collection, curbside collection, communal collection, drop-off in open space and block collection by vehicle either mixed or in segregated condition. For each of these options there are different sub-options like for communal collection, it can be done for a building or a group of buildings.

To choice a vehicle from collection to first drop-off the different choices are flatbed or boxed handcart, pedal cycle or trike, animal drawn (cow/horse/ass etc.), motor trike, trailer and waste truck. The sub-options for these are loading, unloading, loose waste and container carrying. One can easily choose a vehicle by combing these options and sub-options according to his demand.

For SDS or local points the available choices are container/bin on the street, container or trailer, motor vehicle or open spaces, with different choices from sub-options and disposed in a mixed or segregated condition. For example, for container on the street the sub-options for choice are place, size of the container, surface area, drainage condition, requirement of signs and availability of staffs.

Table 5.1: Typical elaboration of 'Contain & Collect' checklist

CONTAIN & COLLECT		
Element	**Options**	**Sub-options**
Containers *(at source)*	Plastic bag(s) - loose/ in-bin	Availability/ size/ grade/ fate
	Single bin/box/paladin/etc - owned	Capacity/shape-dimension/construction
	Two-or-more bin/etc - owned	Capacity/shape- dimension /construction
	Demountable paladin, skip etc	Cap/ Dimension /Construction-return/Exchange
Collection *(or drop-off, from source)*	Door-to-door/ curbside	At property/curbside-by-property
	Communal (i.e. private or restricted)	For building/ group-of-buildings
	Drop-off (i.e. at open, public facility)	Street, neighborhood, local point
	Mixed/ segregated on vehicle	Segregated as source/ further segregation
Vehicles *(collection to first drop-off)*	Handcart - flatbed/boxed	Loading/unloading, loose/containers
	Pedalcycle/trike - flatbed/boxed	Loading/unloading, loose/containers
	Animal-drawn cart - flatbed/boxed	Loading/unloading, loose/containers
	Motor trike - flatbed/boxed	Loading/unloading, loose/containers
	Tractor-trailer - flatbed/boxed	Loading/unloading, loose/containers
	Waste truck - pick-up/purpose-made	Loading/unloading, loose/containers
Local Points (Secondary Disposal Site)	On-street or loading pad - loose waste	Place, size, surface, drains, signs, staff
	Container(s)/trailer at point	Switch-w-empty/return-same-empty
	Powered vehicle at point	Times/duration/storage/loading
	None - direct to transfer or disposal	Direct to transfer station/disposal site
	Mixed/segregated at local point	Segregated as delivered/ further segregation
Frequency	Collection from source (if any)	By waste type (if segregated)
	Collection from local point	By waste type (if segregated)

5.4.1.2 Options for Sorting and Recovery

Typical sort and recovery options are shown in Table 5.2. To facilitate sorting and recovery, segregation of waste at the point of generation is considered here.

For generation point the available options are to minimize waste, possibility of source treatment and source separation, with the related sub-options for each. For example, for separation of waste at source the choices are it may collected as kitchen organic wastes, dry recyclable waste and other mixed wastes. For the other options suitable sub-options can be choose.

For sorting the choices are it can be done at source, at local point (SDS), at transfer station, and at the UDS. The available sub-options should be checked are the whole process, inputs of wastes, proportions of the wastes and the reliability of the process.

Recovery can be done by reuse, recycle and waste to energy process. But before taking any of these options the processing, inputs and proportions sub-options should be checked. For reuse and recycling marketing facility and for waste to energy its environmental effects can be checked.

Table 5.2: Typical elaboration of 'Sort & Recover' checklist

SORT & RECOVER		
Element	**Options**	**Sub-options**
Generation	Waste minimization	Re-design/re-engineer/housekeeping
	Source treatment (e.g. home compost)	Domestic/commercial/industrial
	Source separation	Kitchen-organ/dry-recycle/other
Sorting	At source (i.e. source separation)	Process/inputs/proportions/reliability
	At local (i.e. secondary) point	Process/inputs/proportions/reliability
	At transfer (i.e. bulk) station	Process/inputs/proportions/reliability
	At disposal site	Process/inputs/proportions/reliability
Recovery	For reuse	Process/inputs/proportions/markets
	For recycling	Process/inputs/proportions/markets
	Energy from waste	Process/output/utilization/emissions

5.4.1.3 Options for Transfer and Treatment

Typical options and sub-options of transfer and treatment are given in Table 5.3. Here elements are transport in from sources or WastePoints to intermediate transfer or treatment facilities and then to the final disposal sites.

The choices for transport in are direct transport by collection vehicle, by using trailer from local points, open pick up from local points and special type of truck used to collect wastes transport waste from the local points. For each of this option there are different sub-options, like for special waste transport truck the loading and unloading facility, capacity of the truck, traveled distance and required number of trips.

For transfer of waste unloading and reloading methods, facilities and rate, sorting and storage facility and rate are the options should be look at. With this there are sub-options, for example for sorting and storage facilities capacity of such facility, input process, control of the system and output process are the choices from which one has to chose the best option. Similarly, for other options there are available sub-options to choose from.

For treatment facilities the choices are compaction, shredding, composting, digestion, incineration and pyrolysis with available sub-options. Like for composting the process, input of waste, capacity of the plant and emission from the sites. For other options and sub-options choice, one can peak his transfer and treatment option.

Table 5.3: Typical elaboration of 'Transfer & Treat' checklist

TRANSFER & TREAT		
Element	**Options**	**Sub-options**
Transport In	Collection vehicle direct	Direct to transfer station/ disposal site
	Tractor-trailer from local points	Load/unload, capacity/distances/trips
	Open pick-up from local points	Load/unload, capacity/distances/trips
	Purpose-made truck from local points	Load/unload, capacity/distances/trips
Transfer	Unloading method/facility/rate	Inputs/efficiency/turnaround
	Sorting and storage - if any	Capacities/inputs/controls/outputs
	Reloading method/facility/rate	Inputs/efficiency/turnaround
Treatment	Compaction, shredding etc	Process/inputs/capacity/emissions
	Composting, digestion etc	Process/inputs/capacity/emissions
	Incineration, pyrolysis etc	Process/inputs/capacity/emissions
Transport Out	Bulk road haul	Capacity/dist/frequency, load/unload
	Waterway, rail etc	Capacity/dist/frequency, load/unload

5.4.1.4 Options for Safe Disposal

Typical safe disposal options are given in Table 5.4. Preparation of the site, cells operational facilities, operational options and environmental control, site closure and restoration of a disposal site are considered as the elements for safe disposal of wastes.

For the preparation of the site it may need preparation of the site and associated infrastructure, cell and void spaces in the site, operational facilities and monitoring facilities.

These will be backed by several sub-options like for cell and void space the formation of the cell, lining of the cell, drainage facilities for leachate are need to be considered. For other options similarly there are available sub-options to choose.

For the operation of a landfill site reception of waste and its control, handling of waste and its placement in proper space, encapsulation of the cell, leachate handling and treatment technology and gas recovery and utilization of its are the major choices. The sub-options expand the fields of implementation for each choice, as for leachate handling and treatment, extraction of leachate, recirculation of it, treatment technology and disposal of treated leachate. Sub-options are also available for other option of operation.

For the environmental monitoring, closure of landfill site and its restoration the sub-option should be looked at are environmental nuisance, groundwater pollution, emission to the atmosphere, final earth cover for closure, vegetation for reuse etc.

Table 5.4: Typical elaboration of 'Dispose & Make Safe' checklist

DISPOSE & MAKE SAFE		
Element	**Options**	**Sub-options**
Preparation	Site and infrastructure	Land, access, screening, drainage, etc
	Cells and void space	Formation, lining, leachate drainage
	Operational facilities	Weighbridge, lab, plant, staff etc
	Monitoring facilities, background data	Surveys, boreholes (on/off site)
Operation	Waste reception + control	Identification, holding, routing etc
	Waste handling + placement	Haul + tip, compaction, daily cover
	Cell capping (or interim cover)	Cover/capping, gas wells and mains
	Leachate handling + treatment	Extract, recirculate, treat, dispose
	Gas recovery + utilization	Extract, flare, heat, generate, liquefy
Control	Environmental monitoring	Nuisance, groundwater, atmospheric
	Closure + restoration	Final cover, vegetation, after use

5.4.2 Spread Sheet for Evaluation Approach

Typical aspects of evaluation are shown in the Table 5.5. They are Source & Streams, Costs & Returns, Health & environment and Community & Structure.

Table 5.5: Typical Aspects of Evaluation			
Evaluation aspects components			
SOURCES & STREAMS *tonnes, cubic meters per hour, day, week, month, year*	**COSTS & RETURNS** *unit, currency per tonne, currency per annum*	**HEALTH & ENVIRONMENT** *health + environmental impacts, indicators*	**COMMUNITY & STRUCTURE** *socio-economic + organizational implications*

The conceptual framework for spreadsheets is presented in Table 5.6 by assembling the selection approaches (row headings) and evaluation approaches (column headings).

Table 5.6: Conceptual framework for spreadsheets

Waste System Components	Evaluation aspects components			
	SOURCES & STREAMS	COSTS & RETURNS	HEALTH & ENVIRONMENT	COMMUNITY & STRUCTURE
CONTAIN & COLLECT				
SORT & RECOVER				
TRANSFER & TREAT				
DISPOSE & MAKE SAFE				

5.4.3 Full Spreadsheet Format

To get the fuller spreadsheet, one should combine all the options, sub-options of waste system components and available/probable aspects of evaluation which is present in Table 5.7. It can be titled with the necessary information of the project and organization. It should be noted here, that while it is vital to be able to consider the whole array of 'checks' (waste system components) and 'balances' (aspects of evaluation) represented in the table, the user will normally be working only with a subset of checks and balances at any time. It must also be stressed that users should adapt theses as appropriate flexible approach to best fit their problem situations. Row or column headings may be amended, added, dropped, or re-ordered to suit circumstances and perceptions. For each element, after the evaluation one can draw some summary points, at the end row of each element.

Terminology used in the spreadsheet

In the spreadsheet some new word and terminology are used. In the subsequent paragraphs they are clarified for easy of under standing.

(i) Source A, B, C

MSW are generated from different sources. Like household, commercial, clinical hazard etc. All these sources are simplified under three sources, source A, B and C respectively.

For the waste generation calculation both weight (tonnes) and volumetric (cubic meter) measurements are generally used in terms of per unit time (hour, day, week, month and year).

(ii) No Change

In every urban area, where there is a waste management system, the existing system is termed as "No Change". To propose any new system or option, always the new one should be compared with the existing one.

(iii) Scenario I and Scenario II

These are the newly proposed modified options to improve the existing system, shortly name as S-I and S-II respectively. During a decision making process, when to change an existing system, it should be always compared with at least two modifies options. Considering the all affects from these two or more modified proposal, one can then select the best possible solution.

Calculation of total cost and return is usually expressed in terms of currency per tonne or currency per year.

Table 5.7: The fuller spreadsheet framework

Integrated System Evaluation

Organization Name: …………………………………Project Name/Number: ……………………………

Aspects of Evaluation / Waste System Components		**SOURCES & STREAMS** *tonnes, cubic meters per hour, day, week, month, year*									**COSTS & RETURNS** *unit, currency per tonne, currency per annum*			**HEALTH & ENVIRONMENT** *health and environmental impacts, indicators*			**COMMUNITY & STRUCTURE** *socio-economic and organizational implications*		
Element	**Options**	Source A			Source B			Source C			NC	S-I	S-II	NC	S-I	S-II	NC	S-I	S-II
		NC	S-I	S-II	NC	S-I	S-II	NC	S-I	S-II									
CONTAIN & COLLECT		NC	S-I	S-II	NC	NC	S-II	NC	S-I	S-II	NC	S-I	S-II	NC	S-I	S-II	NC	S-I	S-II
Containers *(at source)*	Plastic bag(s) - loose/ in-bin																		
	Single bin/box/paladin/etc - owned																		
	Two-or-more bin/etc - owned																		
	Demountable paladin, skip etc																		
Collection *(or drop-off, from source)*	Door-to-door/ curbside																		
	Communal (i.e. private or restricted)																		
	Drop-off (i.e. at open, public facility)																		
	Mixed/ segregated on vehicle																		
Vehicles *(collection to first drop-off)*	Handcart - flatbed/boxed																		
	Pedalcycle/trike - flatbed/boxed																		
	Animal-drawn cart - flatbed/boxed																		
	Motor trike - flatbed/boxed																		
	Tractor-trailer - flatbed/boxed																		
	Waste truck - pick-up/purpose-made																		
Local Points (Secondary Disposal Site)	On-street or loading pad - loose waste																		
	Container(s)/trailer at point																		
	Powered vehicle at point																		
	None - direct to transfer or disposal																		
	Mixed/segregated at local point																		
Frequency	Collection from source (if any)																		
	Collection from local point																		
Container & Collection Summary																			

Table 5.7: Continued

Aspects of Evaluation / Waste System Components		**SOURCES & STREAMS** *tonnes, cubic meters per hour, day, week, month, year*									**COSTS & RETURNS** *unit, currency per tonne,, currency per annum*			**HEALTH & ENVIRONMENT** *health and environmental impacts, indicators*			**COMMUNITY & STRUCTURE** *socio-economic and organizational implications*		
Element	**Options**	Source A			Source B			Source C			NC	S-I	S-II	NC	S-I	S-II	NC	S-I	S-II
		NC	S-I	S-II	NC	S-I	S-II	NC	S-I	S-II									
SORT & RECOVER		*NC*	*S-I*	*S-II*	*NC*	*NC*	*S-II*	*NC*	*S-I*	*S-II*	*NC*	*S-I*	*S-II*	*NC*	*S-I*	*S-II*	*NC*	*S-I*	*S-II*
Generation	Waste minimization																		
	Source treatment (e.g. home compost)																		
	Source separation																		
Sorting	At source (i.e. source separation)																		
	At local (i.e. secondary) point																		
	At transfer (i.e. bulk) station																		
	At disposal site																		
Recovery	For reuse																		
	For recycling																		
	Energy from waste (see also below)																		
Sorting & Recovery Summary																			
TRANSFER & TREAT		*NC*	*S-I*	*S-II*	*NC*	*NC*	*S-II*	*NC*	*S-I*	*S-II*	*NC*	*S-I*	*S-II*	*NC*	*S-I*	*S-II*	*NC*	*S-I*	*S-II*
Transport In	Collection vehicle direct																		
	Tractor-trailer from local points																		
	Open pick-up from local points																		
	Purpose-made truck from local points																		
Transfer	Unloading method/facility /rate																		
	Sorting and storage - if any																		
	Reloading method/facility /rate																		
Treatment	Compaction, shredding etc																		
	Composting, digestion etc																		
	Incineration, pyrolysis etc																		
Transport Out	Bulk road haul																		
	Waterway, rail etc																		
Transfer & Treatment Summary																			

Table 5.7: Continued																			
Aspects of Evaluation / **Waste System Components**		**SOURCES & STREAMS** *tonnes, cubic meters per hour, day, week, month, year*									**COSTS & RETURNS** *unit, currency per tonne, currency per annum*			**HEALTH & ENVIRONMENT** *health and environmental impacts, indicators*			**COMMUNITY & STRUCTURE** *socio-economic and organizational implications*		
Element	**Options**	Source A			Source B			Source C			NC	S-I	S-II	NC	S-I	S-II	NC	S-I	S-II
		NC	S-I	S-II	NC	S-I	S-II	NC	S-I	S-II									
DISPOSE & MAKE SAFE		NC	S-I	S-II	NC	NC	S-II	NC	S-I	S-II	NC	S-I	S-II	NC	S-I	S-II	NC	S-I	S-II
Preparation	Site and infrastructure																		
	Cells and void space																		
	Operational facilities																		
	Monitoring facilities, background data																		
Operation	Waste reception + control																		
	Waste handling + placement																		
	Cell capping (or interim cover)																		
	Leachate handling + treatment																		
	Gas recovery + utilization																		
Control	Environmental monitoring																		
	Closure + restoration																		
Disposal & Safety Summary																			
OVERALL SYSTEM APPRAISAL																			

5.4.4 Use of spreadsheet

This spreadsheet can be used in two ways, the Reality Check and the Action Case.

WasteCheck (the Reality Check) is an application of the spreadsheet where the body of the table is used to highlight the most significant questions which need to be answered in a given context: for instance, about health and environmental aspects of container and collection options, as presented in Table 5.8.

Table 5.8: Use of spreadsheet in a WasteCheck application

WasteCheck		
CONTAIN & COLLECT		**HEALTH & ENVIRONMENT**
Element	**Options**	
Containers *(at source)*	Plastic bag(s) - loose/ in-bin	*Body of table used to highlight most significant questions, which need to be answered, like What can be done to ensure safe storage and handling of hazardous clinical wastes? etc.*
	Single bin/box/paladin/etc - owned	
	Two-or-more bin/etc - owned	
	Demountable paladin, skip etc	
Collection *(or drop-off, from source)*	Door-to-door/curbside	
	Communal (i.e. private or restricted)	
	Drop-off (i.e. at open, public facility)	
	Mixed/ segregated on vehicle	
Vehicles *(collection to first drop-off)*	Handcart - flatbed/boxed	
	Pedalcycle/trike - flatbed/boxed	
	Animal-drawn cart - flatbed/boxed	
	Motor trike - flatbed/boxed	
	Tractor-trailer - flatbed/boxed	
	Waste truck - pick-up/purpose-made	
Local Points (Secondary Disposal Site)	On-street or loading pad - loose waste	
	Container(s)/trailer at point	
	Powered vehicle at point	
	None - direct to transfer or disposal	
	Mixed/segregated at local point	
Frequency	Collection from source (if any)	
	Collection from local point	
Container & Collection Summary		

WasteCase (the Action Case) is an application of the spreadsheet where the body of the table is used to highlight the most pertinent answers relating to the 'business and sustainability' justification for some potential intervention action in a given context, as presented in Table 5.9.

Such applications may incorporate any number of rows for relevant checks (waste system components) or columns for relevant balances (aspects of evaluation), although they will generally need to be highly selective to be meaningful and manageable.

Table 5.9: Use of spreadsheet in a WasteCase application		
WasteCase		
CONTAIN & COLLECT		**HEALTH & ENVIRONMENT**
Element	**Options**	
Containers *(at source)*	Plastic bag(s) - loose/ in-bin	*Body of table used to set out answers relating to 'business and sustainability' assessment of potential intervention action, like How can participation be increased in fee-based collection schemes?*
	Single bin/box/paladin/etc - owned	
	Two-or-more bin/etc - owned	
	Demountable paladin, skip etc	
Collection *(or drop-off, from source)*	Door-to-door/ curbside	
	Communal (i.e. private or restricted)	
	Drop-off (i.e. at open, public facility)	
	Mixed/ segregated on vehicle	
Vehicles *(collection to first drop-off)*	Handcart - flatbed/boxed	
	Pedalcycle/trike - flatbed/boxed	
	Animal-drawn cart - flatbed/boxed	
	Motor trike - flatbed/boxed	
	Tractor-trailer - flatbed/boxed	
	Waste truck - pick-up/purpose-made	
Local Points (Secondary Disposal Site)	On-street or loading pad - loose waste	
	Container(s)/trailer at point	
	Powered vehicle at point	
	None - direct to transfer or disposal	
	Mixed/segregated at local point	
Frequency	Collection from source (if any)	
	Collection from local point	

Ordinance 1960. It was again reconstituted as Khulna Paurashava on the 20th January, 1972 according to the Bangladesh Local Councils Municipalities order, 1972. In 1991 it was upgraded to Khulna City Corporation (KCC).

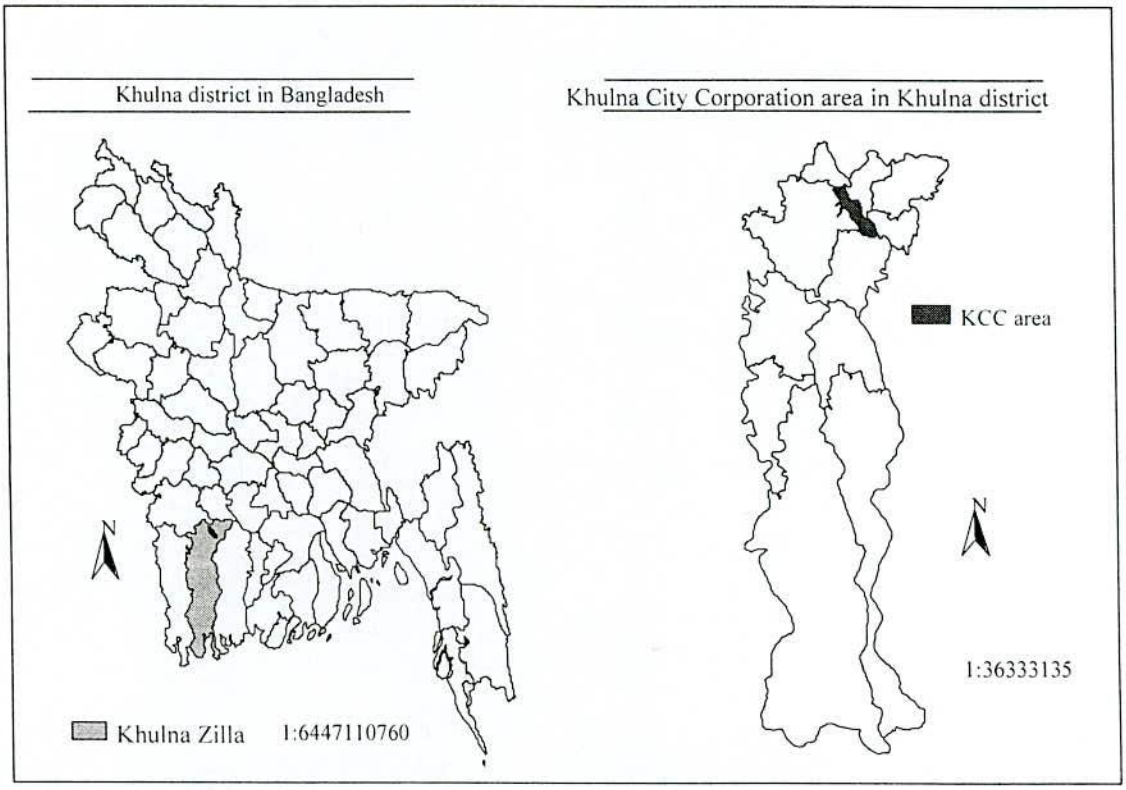


Figure 6.1 Location of Khulna city in context of Bangladesh and Khulna District (after KDA, 2000)

In the inhospitable south-west region, the prosperous city of Khulna, known in history as 'Khalifatabad' was laid out by a little-known warrior saint Khan Jahan, in the mid-l5th century, at the present location of Bagerhat, the "abode of the tigers." Khan Jahan came from Delhi to settle a Muslim colony in this swampland in the early-15th century and was no doubt the earliest torchbearer of Islam in the south. Legend has it that he constructed about 360 mosques and as many freshwater tanks, as well as palaces, spices and other public buildings in a very short span of time. He also constructed a network of roads linking important centers in Bengal with his city.

6.3.2 City 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. 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. 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. Figure 6.2 shows the general layout of KCC.

6.3.3 Geography and climate

The soil of Khulna Statistical Metropolitan Area (SMA) is to a great extent uniform in character and varies only by admixture of sand. The soil in alluvial as it is formed by the deltaic action of the Ganges which brought sufficient muds. The land level of the SMA is comparatively high and formed mainly by the deltaic action of the river Padma (Lower Ganges). Its elevation is 7 feet above Mean Sea Level. Climate in the Khulna city is moderate. Air is humid. Full monsoon is from June to September. The annual average rainfall is between 65" to 70". During ebb tide the forest becomes bare by 6 to 7 feet and at high tide the entire territory of the forest floats on water.

6.3.4 Population and society

The total population in Khulna city area was 0.66 million in 1990, 0.85 million in 1998 (BBS, 2001) and estimated to 1.5 million in 2005 (KCC, 2005). The mean family size of KCC area was found to be 5.60 persons. Slightly more than a third of the household are joint family type, while rest, 63.79% are single family type. KCC is a highly densities area with 18,424 populations per square kilometer (KDA, 2002). 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.

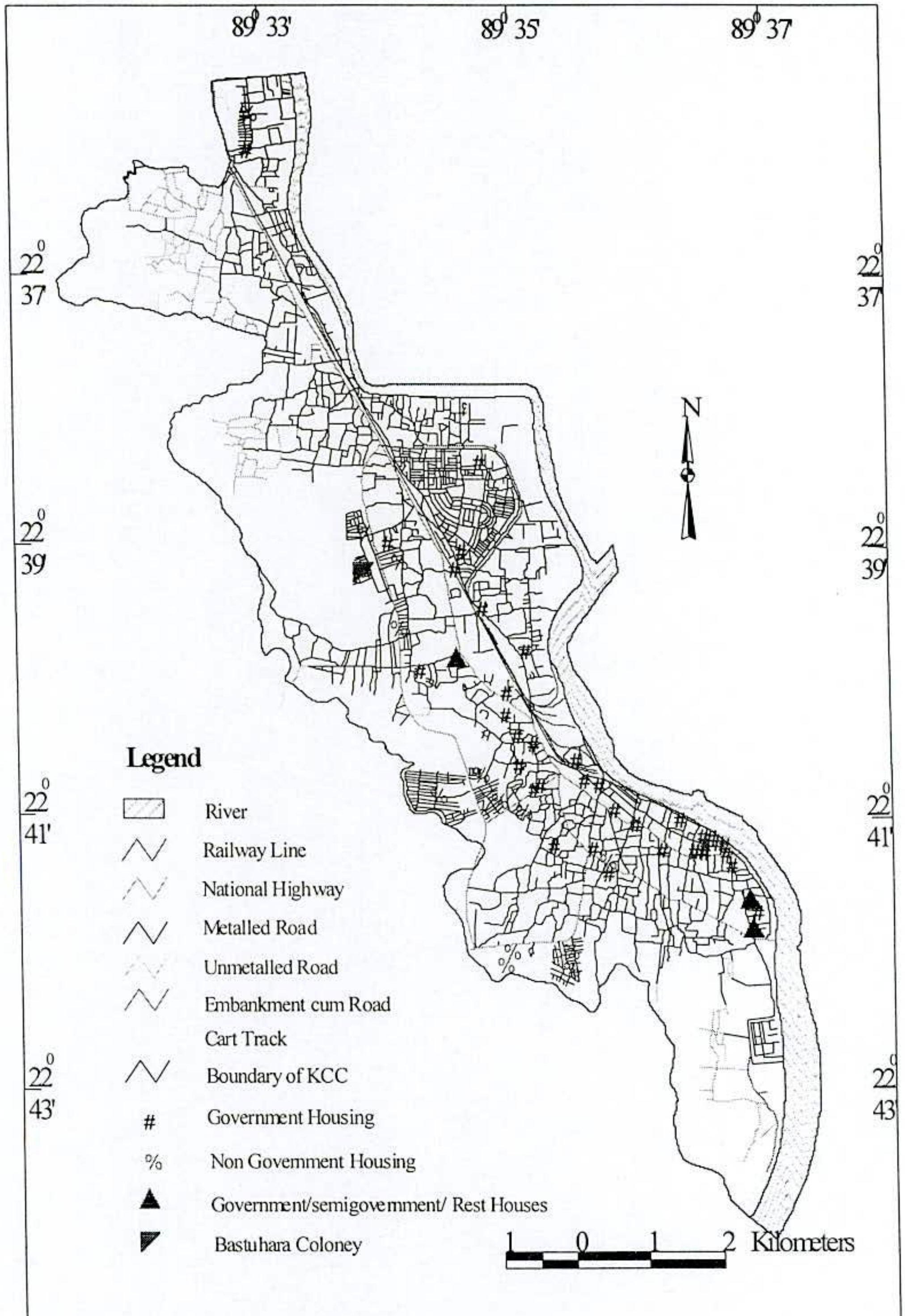


Figure 6.2 Layout of Khulna City Corporation (after KCC, 1995)

In KCC areas there are about 120 slum areas (KCC, 2006), among them ten are the largest in terms of the number household. In Table 6.1 the detail information of these ten slums are given. 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 Programme 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.

Khulna, as a divisional headquarters is suffering a moderate pressure of migrated people. 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, 2002).

Table 6.1 Major slum areas of KCC

Ward No.	Community Name	No. of household	Total Population
3	Kuli Bagan Slum	205	1047
7	Kashipur Bhatia Para Slum	490	1972
8	Crescent Katcha Lina Slum	376	1760
9	Syed Munshir Slum	605	2586
10	Nayabati Slum	260	1210
12	No. 1 Khema Slum	339	1825
13	Alam Nagar Rail Side Slum	550	2342
17	Sonadanga Poura Colony Slum	676	3127
22	Rupsha Char Slum	886	3987
25	North Khal Bank Road Side Slum	399	1748

Source: Local Partnerships for Urban Poverty Alleviation Project, KCC, April, 2006.

6.3.5 Environmental condition

Khulna City is located on a natural levee of the Rupsha and Bhairab rivers and characterized by Ganges tidal floodplains with low relief, criss-crossed by rivers and water channels and surrounded by tidal marshes and swamps. 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 the city. There is clear evidence that clean water is in short supply, there are unhygienic sanitation conditions, high incidence of diseases, along with violent crimes and social tensions in several towns and cities.

6.3.6 Socio-economic condition

Khulna City is strategically located in an important hub as far as its development potentialities are concerned. After late 1960, the economic condition of the city deteriorated. 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. It is equivalent to per capita yearly income of US$ 360. In Khulna City, more than 60 per cent use to earn US$ 58 to 167 per month.

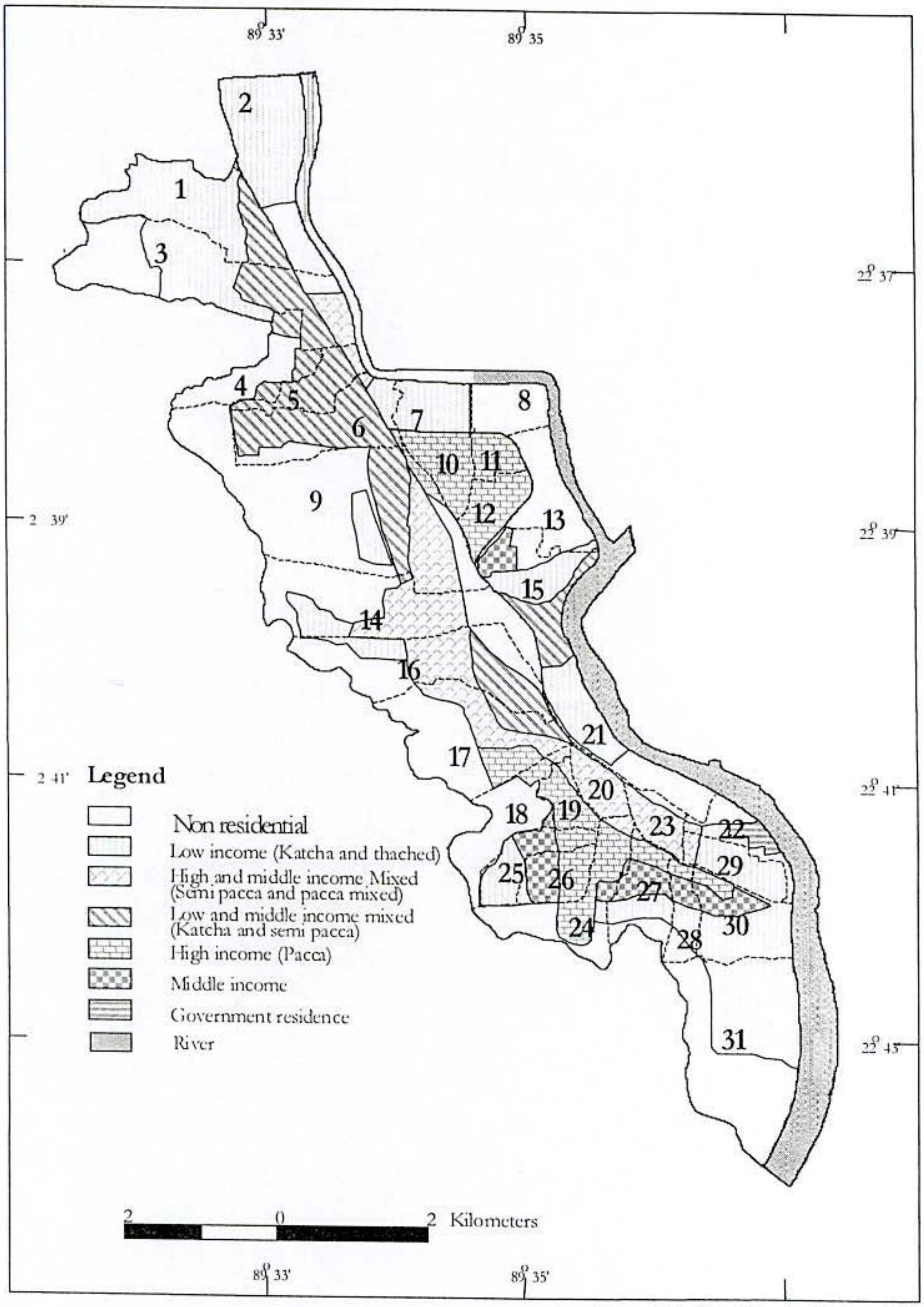
The export of shrimp and the related activities such as shrimp processing, packaging, transportation, shipping, banking, insurance etc. have further reinforced the development of Khulna City to a great extent. The construction of a Rupsha bridge over the Rupsha River and the starting of an Export Processing Zone at Mongla help to boost the overall socio-economic activities in Khulna City. The construction of proposed Airport at Khulna will further contribute in this development.

The main Socio-economic problems of the Khulna city Corporation 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; lack of job opportunities for the women; local resources not properly exploited; lack of transparency in the allocation of the Annual Development Programme (ADP) to the different agencies; and, lack of comprehensive information base of the city economy.

6.3.7 Land use and infrastructure

Khulna is the third largest metropolitan and industrial city of Bangladesh. 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.



Source: Municipal Services Project, 1995

Figure 6.3 Ward wise distribution of income groups and housing types of KCC

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.

Table 6.2 Land use pattern in Khulna city

Land use parameter	Planned allocated land area	Actually used 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%

Source: Field survey by KCC, 2003

In observed land use composition with respect to the standard are stated in Table 6.2. 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). This is the area where the real estate business is flourishing.

6.4 Overview of MSW management in Khulna City

In the subsequent articles characteristics of MSW, physical facilities and a brief description of management system of KCC are described.

6.4.1 General

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 MSW 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. The general waste stream scenario of KCC is presented in Figure 6.4.

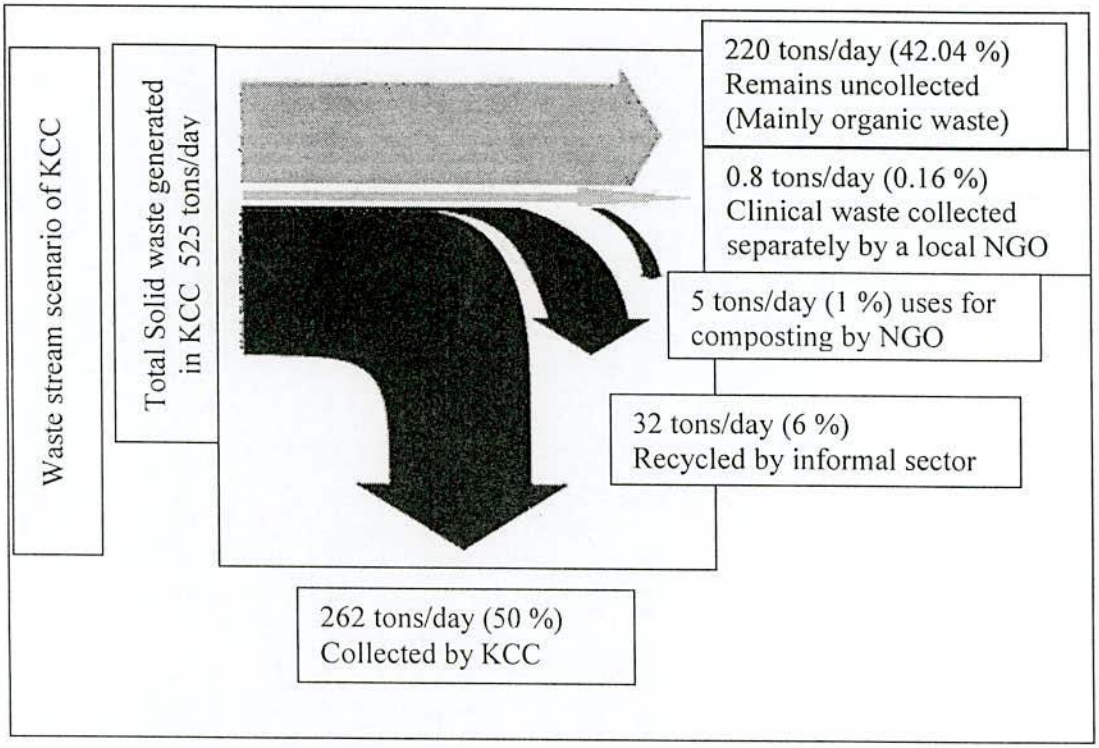


Figure 6.4 Waste stream scenario of KCC (after WasteSafe, 2005)

6.4.2 Characteristics of MSW in KCC

The average compositions of households waste are 90% organic and 10% inorganic. The inorganic waste has two categories, one is inorganic non-hazardous waste that is 6% and another is inorganic hazardous waste, which is 4%. Average organic wastes consist of 87% food & kitchen wastes, 6% paper & paper products, 1% plastic& polythene, 1% pet bottles & oil container glass, 1% wood and 4% other wastes. The specific weights of solid wastes in different location of KCC are ranges between 342 to 877 Kg/m^3.

6.4.3 Logistic facilities of the KCC

From Chapter four we get the types of vehicles are used for solid waste collection from SDS in KCC areas. There are 32 different types of motorized and 266 non-motorized vehicles available in the City Corporation. But out of them about 20% motorized vehicles are out of work. The repairing and maintenance facilities are not adequate and due to this shortage of vehicles is a common phenomenon here. The conservancy section is responsible for the collection, transportation and disposal of wastes along with street sweeping and drain cleaning. But it has shortage of manpower. In Table 6.3 the total manpower of the conservancy section are shown.

Table 6.3 Total manpower involved in conservancy department of KCC

Sl No.	Designation	Number
1	Conservancy Officer	1
2	Asst. Conservancy Officer	1
3	Conservancy Inspector	1
4	Conservancy Supervisor	23
5	Asst. Conservancy Supervisor	2
6	MLSS	3
7	Beet Sweeper (Mathor)	28
8	Truck Driver	15
9	Truck Helper	15
10	Truck Labors	25
11	Drain Cleaner	40
12	Spray Man	22
13	Street Sweeper	33
14	Kota Vehicle Labors	5
15	Dog Catching Labors	5
16	Van Driver	190
17	Wheel Barrow	76
18	Master Role Labors	30
19	Others	31
		Total = 546

Source: Budget book of KCC (2004-2005)

Adequate budgeting, cost accounting, financial monitoring and evaluations are essential for the effective management of solid waste systems. KCC authorities proposed a budget of Tk. 265.98 crore for 2004–2005 financial years. Total MSW management budget are Tk. 8.14 crore, which is 3.06 % of total budget. 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.

More than 60 (sixty) SDSs (local points) are available in KCC area. KCC authority places some Haul Containers (HCs) and permanent concrete/masonry bin in the secondary sites. Masonry bin are also placed some sites and other sites are open spaces for disposal of wastes near roadside. More than 50 HCs are available in KCC garage. But only 28 HCs are placed in secondary sites of different wards. Unpleasant and unhygienic conditions prevail in all SDS, situated in the KCC area. In most of the SDSs, solid wastes are thrown outside of HC or Masonry bin. Animal scavenging those sites and odor nuisance is a common/major problem.

Table 6.4 Private organizations involvement in MSWM at Khulna		
Private organizations name	Working Area (Ward No.)	Status
PRODIPAN	No specific area	National Organization
PRISM Bangladesh	No specific area	National Organization
RUSTIC	17 & 18 (Part*)	Local Organization & Member of NGO Forum
MUKTIR ALO	21 & 23	Do
SPS	9, 14, & 15	Do
BRIC	3 (Part), 4, 5,6 (Part), 7 & 8 (Part)	Do
RUPAYAN	19 & 20	Do
AOSED	25 & 26	Do
NABARUN SANGSAD	24 & 27 (Part)	Do
CHD	16	Do
PROTISRUTI	22	Do
PROSHANTI	30	Do
GOTI	20 (Part)	Do
WORLD VISION	18 (Part)	Local Organization
ISPAHANI BANANIPARA COMMUNITY	1 (Part) & 2 (Part)	Local Organization & Member of NGO Forum
SHABOLOMBI	10	Do
SAMADAN	8 (Part)	Do
CLANSHIP	16 (Part) & 17 (Part)	Do
NOBO JAGORAN	16 (Part)	Do
GINNA PARA COMMUNITY	31 (Part)	Local Organization
COMMITMENT	11	Local Organization
JUBO UNNAYAN SOGNGATAN	31 (Part)	Local Organization & Member of NGO Forum
**Part-Partial*		*Source: This Study*

6.4.4 Involvement of NGOs and CBOs

There are a wide range of individuals, groups and organizations involved in MSW 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 40-50% of the generated waste is actually collected. Collections of waste from sources are only dealing by private organizations in KCC. About 22 private organizations (NGOs and CBOs) are working in different wards of KCC. Every organization has some non-motorized van through which solid wastes are collected from sources in door-to-door collection system.

They take a small amount of payment from householders for collection services. Besides this, every ward commissioner (local representative of City Corporation) has some limited non-motorized van and hand trolley. These vans collect solid wastes from community bin (roadside, home side, besides market) to secondary disposal points, but not from houses. However, one private organization has been working in the ward number 29 of KCC and manages MSW from source collection to ultimate disposal.

There are many NGOs and CBOs working in different wards of KCC for SWM. But they limited their activities mainly to communal collection and small scale composting activates. In Table 6.4 a list of such organizations with their working areas and status are presented.

6.4.5 Management system

City corporation authority collect the wastes from SDSs and transport it by trucks and finally dumping them in ultimate open disposal site at Rajbandha, about 7 Km away from the main city hub (Figure 6.5). Though the authority try to provide regular services, but the overall collections and environmental conditions are not very good due to lack of proper maintenance/management system, lack of funding, lack of enforcement actions, lack of community involvement or participation.

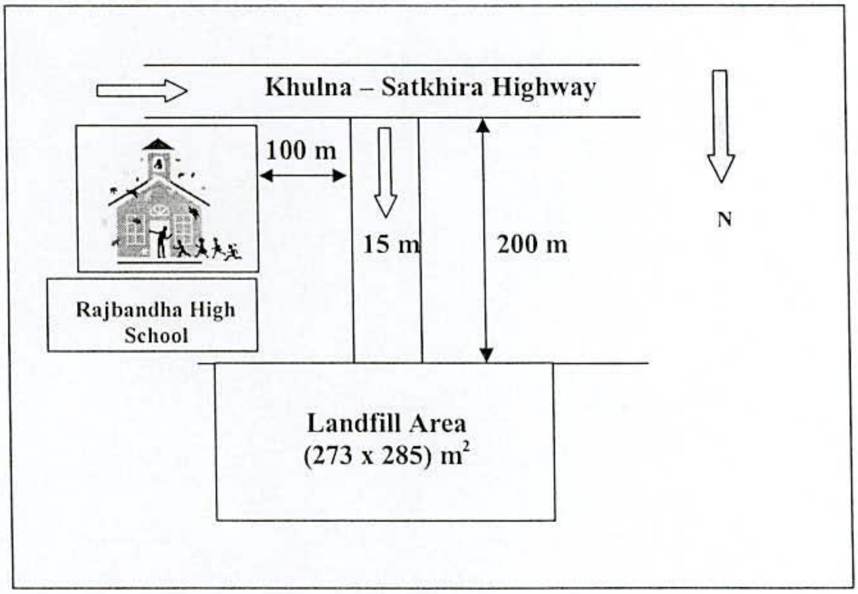


Figure 6.5 Existing dumping site at Rajbandha in Khulna (after KCC, 2005)

6.5 Integrated MSW management systems

By evaluation and selection of all the functional elements of the waste management services and all of the interfaces and connections between elements have for effectiveness and economy, an integrated waste management system for Khulna City will be developed here. At first from the study results, the key initial questions in the WasteCheck spreadsheet are selected which are presented in Table 6.5.

Table 6.5: Overall starting point for the KCC waste dialogue

WasteCheck - the Starting Point	SOURCES & STREAMS	COSTS & RETURNS	HEALTH & ENVIRONMENT	COMMUNITY & STRUCTURE
CONTAIN & COLLECT	What can be done to encourage people to take/send waste only to designated places? What can be done to ensure safe storage and handling of hazardous clinical wastes?	How can participation be increased in fee-based collection schemes? How can penalties be enforced for the unauthorized discarding of wastes?	How can SDSs be located, designed, equipped and operated so as to encourage use and discourage misuse, including prevention of litter and disease?	How can job opportunities in waste collection be protected and enhanced?
SORT & RECOVER	What can be done to promote the separation of wastes suitable for value recovery?	How can profitable and assured markets be developed for recycled products and materials?	How can health conditions be improved for waste recovery workers?	How can job opportunities in waste recovery be moved 'off-street' and into sustainable enterprises?
TRANSFER & TREAT	What can be done to ensure transfer of higher proportion of unrecoverable waste to treatment and/or disposal? What can be done to increase number and/or capacity of composting schemes?	How can waste facilities best be sized and located to minimize travel distances and avoid traffic congestion? How can vehicular use be made more efficient + cost effective?	How can disruption to waste transfers be minimized in flood conditions? How can composting schemes be designed, located and operated to avoid odor etc impacts for local community?	How can interfaces be improved between collection and disposal activities and responsibilities?
DISPOSE & MAKE SAFE	What can be done to provide adequate capacity for safe final disposal?	How can new technology be utilized to attract foreign aid for safe final disposal?	How can landfills be properly engineered and operated in flood-prone areas? How can hazardous clinical wastes be safely disposed of?	How can disposal facilities be made acceptable to receiving communities?

The following clusters of issues have been identified at this stage, giving rise to questions under various checks (system elements) and balances (aspects of evaluation):

(i) On the improvement of local collection points and encouraging/enforcing their use;

(ii) On improving the efficiency and reliability of waste transfers from collection points;

(iii) On increasing composting capacity and improving its acceptability and viability;

(iv) On the provision of adequate and safe final disposal facilities;

(v) On enhancing job opportunities and health conditions for waste workers;

(vi) On ensuring the separate handling and treatment of hazardous clinical wastes.

These issues and questions are closely inter-related and the spreadsheet gives an overview of a range of concerns, which need to be addressed together. The key questions asked for different system components with respective aspect evaluation components are shown in Table 6.5. This can be treated as a starting point to know the appropriate options relevant to the issue of ISWM.

6.5.1 Contain and Collect

From the study result of the KCC area, the WasteCase for contain and Collect are filled up. In this study a standardized modular '**MeterCube**' container is proposed rather than a fixed design of waste container. This standard container can be defined by means of a performance specification, relating to access, store, handling of wastes, etc, the cubic meter is only intended as an indicative dimension. '**ExistingMix**' is the present condition, where all the waste is mixed together without any source segregation. In WasteCase spreadsheet, the comparison is made between the '**MeterCube'** solutions with the '**ExistingMix**'.

From the study it is seen that the WastePoint with the ExistingMix condition cannot satisfactorily handle the entire waste stream. However, WastePoint with MeterCubes offer better options for waste handling and containment. The convenient locations of WastePoints will reduce the cost of waste collection.

The analysis of WasteCase for Contain and Collect are presented in Table 6.6. In the table for all the elements, detail options and/or assumptions are given. For source and stream WastePoint with ExistingMix and WastePoint with MeterCube options are considered. For evaluation of cost and return two different analyses are done for ExistingMix and MeterCube options. Issues to be considered for health and environment and community and structure for

WastePoint with ExistingMix and WastePoint with MeterCube options are highlighted in the table.

From this WasteCase it is concluded that it require further analysis and integration with the other elements and it is directly related to the next phases of Sort & Recover.

Table 6.6: WasteCase-the MeterCube proposal

WasteCase - the 'MeterCube' Proposal		SOURCES & STREAMS	COSTS & RETURNS		HEALTH & ENVIRONMENT	COMMUNITY & STRUCTURE
Element	Options/Assumptions		ExistingMix	MeterCubes		
CONTAIN & COLLECT						
Containers *(at source)*	Different varieties of bins, containers, baskets used at individual properties; assumed to continue.	• WastePoints with ExistingMix little better than now at satisfactorarily handling all waste streams. • WastePoints with MeterCubes offer a route to better handling and containment with: - ability to accept and assemble both collected and brought waste at same facilities - ability to provide a range of capacities, via a standard system, to match local waste generation rates - ability to easily adjust storage capacity at WastePoints, subject to space availability - ability to readily adjust throughput at WastePoints by increased frequency or automation of emptying - ability of supervisors to advise on earlier or later emptying in real time - ability to introduce separate MeterCubes for separate wastes to support recycling and recovery - ability to introduce special MeterCubes to securely store and handle specific streams such as clinical wastes.	Priority is to provide free bins in slum areas; standardization can come later.		WastePoints with ExistingMix present all existing environmental problems -except that smaller, more convenient communal bins may encourage greater use -otherwise simply renaming and regulating unlikely to result in a waste 'culture change'. •WastePoints with MeterCubes offer prospect of gradual upgrading to a more manageable system in which -skills can be focused on design and manufacture of user-friendly and environmental-friendly standardized containers -only sorting at WastePoints is into different MeterCubes -small modular containers offer range of stacking, handling and moving options without need to empty contents -imported clinical waste containers would give high visibility to this safety-critical stream.	• WastePoints with either ExistingMix or MeterCubes offer employment advantages of growth in collection services and the supervising system, plus educational benefits of latter. But both must face challenge of redeploying waste pickers from public places. • MeterCubes offer additional advantage of developing a solution using local skills which could become a regional industry - low-tech containers and handling might be constructed relying on local plastic and/or metal factory - mid-tech containers (e.g. incorporating recycled plastic composites) might be engineered with technical assistance - a few imported clinical waste containers would introduce local people to hi-tech principles.
Collection *(or drop-off)*	Door-to-door/curbside pick-up or drop-off all to go to appropriate public WastePoints.		More convenient WastePoints reduce collection costs and improve viability.			
Vehicles *(collection to first drop-off)*	All types of small primary collection vehicle to be accommodated at most WastePoints under both options; but tractor-trailer or truck loads taken direct to transfer stations etc.		Avoids novel investment but perpetuates inefficiencies.	Cost to modify flatbed vehicles to take MeterCubes, to realize full potential.		
WastePoints -ExistingMix	Present variety of containers and loading methods retained, but more and better sites sought; to be signed and supervised.		Little scope for economies of scale + standardization.			
WastePoints -MeterCubes *(proposed improvement)*	All WastePoints to be simple ground-level concrete pads, backed only by rear screening/safety wall where appropriate. Staged standardization to containers of around one cubic meter, able to fit on pedal rickshaw platform etc. Room for multiple containers at a WastePoint where possible and necessary. Room for trailers carrying multiple MeterCubes to be left at larger WastePoints. MeterCubes to be stackable if possible. Incoming waste to be emptied from smaller bins into the appropriate MeterCube, via closeable access/discharge door(s). Full MeterCubes to be moveable by two workers with the help of rollers and/or wheels and/or hoists. Options for full MeterCubes at pad level to either be lifted and tipped into a waste disposal vehicle, or to be swapped for an empty MeterCube via a ramp or hoist. Option for incoming loaded MeterCubes to be switched for empties at rickshaw-platform and trailer height. Each waste disposal tractor unit to operate with multiple trailers. No containers (collection bins or MeterCubes) normally emptied onto pad at WastePoint.			Minimal fixed investment at WastePoints. Can introduce gradually alongside existing systems. Economies of scale in acquiring and operating standard containers. Flexibility to develop and use containers of different design and materials. Flexibility to develop and use a range of different handling methods. Provision special MeterCubes for clinical waste could attract aid.		
Frequency *(onward movements)*	Collection from local WastePoints to be continuous, with frequencies and routes optimized so as to eliminate any overflows.		Manual tipping + reloading prevents rapid throughput.	Standardization facilitates cost-effective handling.		
Container & Collection Summary		On balance, WastePoints with MeterCubes appear to offer a solution well worth exploring further.				

6.5.2 Sort and Recover

The key questions for Sort & Recover are summarized in Table 6.5. Although the demonstration projects of NGOs and CBOs are very admirable, it will not be a practical solution for the bulk of MSW in KCC for the foreseeable future. It is felt that the informal sector was already doing a good job in retrieving value from dry recyclables via their door-to-door approach. Apart from thus supporting the informal sector, concentration is given on just two types of action. Given the high proportion of organics in KCC waste, it is revealed that priority should be given by the city authorities simply to separating out biodegradable, with increased composting in mind. Given the limited number of sources and high employee risks, the separate and secure handling of all hazardous clinical wastes, from source to disposal is also proposed. The separating of those two key elements would prevent cross-contamination of other dry recyclables and to reduce the health risks to waste recovery workers (waste pickers). This strategy is called here as **SimpleSorts** (SS). For this strategy the following assumptions are made:

(i) For generation, estimated figures of waste outputs at source are shown. These figures are estimated without any waste taken for recycling, treatment or disposal and show only potential recoverable, not the actual.

(ii) For sorting, estimated figures show actual tonnages recovered, or assumed recovered, rather than theoretical recovery potentials. Calculations are done by cumulating the row, for total waste, which is separated into each of three streams with mixed residue. For unaccounted waste figures give total unaccounted waste, followed by breakdown in its composition.

In the WasteCase for SimpleSort the findings can be summarized as present in Table 6.7. The strategy is based on the following data and assumptions:

(i) Major aim to halve unaccounted waste by 2010, eliminate by 2020.

(ii) For estimation, three different trends namely, present (2005), near future (2010) and far future (2020) trends are considered.

(iii) Population growth rate for Khulna city is taken as 1.46%. (BBS 2001)

(iv) Waste generation rate is taken as 0.35 kg/capita/day for present trend, which is expected to be 0.40 and 0.45 kg/capita/day for 2010 and 2020, respectively.

(v) Percentage of dry recyclable is taken as 6% for 2005 (KCC 2005), which is expected to be 10% in 2010 and 15% in 2020.

(vi) For composting, present facilities in KCC is 5 tons/day. It is expected to rise 10 tons/day in 2010 and 15 tons/day in 2020.

(vii) For hazardous clinical waste present production is taken as 1% for 2005 (KCC 2005). It is expected to increase 1.5% in 2010 and 2% in 2020.

(viii) Waste collection and sorting is about 60% of total generated wastes (KCC 2005) with average 10% increase in SimpleSorts Strategy.

It is felt that compostables and clinical wastes are presented quite different challenges. The study decided to develop a WasteCase to look at the sorting and recovery pros and cons of small-scale composting close to source, versus transport to large-scale compost plants. By contrast, the quantities of hazardous clinical wastes involved are modest, and safety is as important as speed in getting them to a proper disposal facility. It is decided to set out a WasteCase examining whether clinical wastes were best collected entirely separately from other wastes in KCC, or whether it was better just to keep them in separate containers on normal waste collection and transfer rounds. Thus the WasteCase spreadsheet is based on an analysis of waste generation in the streams of key concern, and where it made most sense, both economically and environmentally, for separation and recovery to take place for each stream. To provide following two ideas should be implemented.

(i) Get as many compostables as possible into proper composting plants; transport costs to remoter compost plants may not be as critical as neighborhood impacts of urban plants

(ii) Get all hazardous clinical wastes into separate secure streams--work with health and medical businesses, professionals, charities, plus religious and community organizations, to make successful the new provisions.

Table 6.7: WasteCase-the SinpleSorts Strategy

WasteCase - the 'SimpleSorts' Strategy		SOURCES & STREAMS											**COSTS & RETURNS HEALTH & ENVIRONMENT COMMUNITY & STRUCTURE**
Element	Options/assumptions	As at	Total Waste		Value Dry Recyclable		Compost-able Select		Hazardous Clinical		Mixed Residuals		
SORT & RECOVER		Tonnes per Day (average)											Key Considerations
Generation	Overall -- Expect increase through growth in population and income to outstrip waste avoidance and minimization achievements.	2005 actual: 2010 trend: 2020 trend:	05: 10tr: 20tr:	525 645 800	05: 10tr: 20tr:	030 065 120	05: 10tr: 20tr:	005 010 015	05: 10tr: 20tr:	005 010 016	05: 10tr: 20tr:	485 560 649	Emphasis of public expenditure to be upon basic standards of MSW management for public health; other desirables to be largely self funding.
	Slums -- First seek only to secure high level of collection as mixed waste, mostly from local communal bins, except for hazardous clinical sources.	2005 actual: 2010 trend: 2020 trend:	05: 10tr: 20tr:	100 110 140	Recyclables of value taken by collectors and merchants. Strategy to support role of informal and private sectors in this.		No priority, but separate drop-off facility where practicable.		Same high priority throughout city for separation and secure storage; dedicated containers, collection and disposal.		Focus only on increasing mixed intakes via local bins.		Work with community leaders in slum areas to improve drop-off locations, containers, supervision, with initial emphasis on mixed waste only.
	Elsewhere -- Aim to achieve high levels of basic separation, via source collection and local 'bring' sites, under Simple Sorts Strategy.	2005 actual: 2010 trend: 2020 trend:	05: 10tr: 20tr:	425 535 660			Controlled off-street separation as close to source as practicable.				No priority for further separation for time being.		Need to see how a two-bin strategy (whether a source or at local drop-off/SDS points) ties in with ideas of 'Contain & Collect' ideas.
Sorting	At source by property occupants or staff or by collector directly onto collection vehicle (then taken to local waste assembly points).	2005 actual: 2010 trend: 2010 sss: 2020 trend: 2020 sss:	05: 10tr: 10ss: 20tr: 20ss:	315 387 451 480 800	05: 10tr: 10ss: 20tr: 20ss:	025 028 052 035 055	05: 10tr: 10ss: 20tr: 20ss:	005 006 130 007 200	05: 10tr: 10ss: 20tr: 20ss:	001 002 010 004 016	05: 10tr: 10ss: 20tr: 20ss:	284 351 259 434 529	Twin priorities of SimpleSorts Strategy: • Get as many compostables as possible into proper composting plants; transport costs to remoter compost plants (e.g. at landfill sites) may not be as critical as neighborhood impacts of urban plants; • Get all hazardous clinical wastes into separate secure stream(s)- work with health and medical businesses, professionals, charities, plus religious and community organizations, to imbue respect for new provisions.
	At local waste assembly points (N.B. includes that separated at source, plus other waste sorted directly into SDS containers).	2005 actual: 2010 trend: 2010 sss: 2020 trend: 2020 sss:	05: 10tr: 10ss: 20tr: 20ss:	315 387 451 480 800	05: 10tr: 10ss: 20tr: 20ss:	035 039 065 049 090	05: 10tr: 10ss: 20tr: 20ss:	005 006 095 014 115	05: 10tr: 10ss: 20tr: 20ss:	001 002 010 004 016	05: 10tr: 10ss: 20tr: 20ss:	274 340 281 413 579	
	At bulk transfer stations, merchants or disposal sites (i.e. waste from local assembly points, plus waste sorted at these facilities).	2005 actual: 2010 trend: 2010 sss: 2020 trend: 2020 sss:	05: 10tr: 10ss: 20tr: 20ss:	315 387 451 480 800	05: 10tr: 10ss: 20tr: 20ss:	040 050 105 055 140	05: 10tr: 10ss: 20tr: 20ss:	005 006 160 014 200	05: 10tr: 10ss: 20tr: 20ss:	001 002 010 004 016	05: 10tr: 10ss: 20tr: 20ss:	269 329 176 407 444	

Table 6.7 Continued

WasteCase - the 'SimpleSorts' Strategy		**SOURCES & STREAMS**						**COSTS & RETURNS HEALTH & ENVIRONMENT COMMUNITY & STRUCTURE**
Element	Options/assumptions	As at	Total Waste	Value Dry Recyclable	Compost-able Select	Hazardous Clinical	Mixed Residuals	
SORT & RECOVER		Tonnes per Day (average)						Key Considerations
	Unaccounted waste - generated waste estimated to have by-passed containment, collection, sorting etc process.	2005 actual: 2010 trend: 2010 sss: 2020 trend: 2020 sss:	05: 210 10tr: 258 10ss: 194 20tr: 320 20ss: 000	05: 050 10tr: 085 10ss: 035 20tr: 045 20ss: 000	05: 025 10tr: 050 10ss: 150 20tr: 200 20ss: 000	05: 001 10tr: 002 10ss: 000 20tr: 004 20ss: 000	05: 134 10tr: 121 10ss: 069 20tr: 071 20ss: 000	Eliminating unaccounted waste to take precedence over increasing proportion composted: elimination of unauthorized tips more vital than composting targets.
Recovery	Subject to getting all waste into managed system, if only in mixed form, a.s.a.p. SimpleSorts Strategy is to give priority to: •separating biodegradable for composting •separation + secure disposal clinical waste Recovery/disposal methods have to be both affordable and environmentally acceptable.	Definitions:	'Unaccounted' = not within managed system from source to reuse or disposal.	'Value' = only materials with reuse value; merchants may be assumed to take them.	'Select' = believed fit for composting (if kept separate), and yielding a useful product.	'Hazardous' = clinical waste which does or may pose a risk to human health.	'Residuals' = left after recyclables, compostables and clinicals removed.	Linked with 'Transfer & Treat' plus 'Dispose & Make Safe' strategy on: • Compost plant capacity needs to be radically increased, in pace with waste separation, to make a difference. Will only be realistically achieved via large, well-managed plants well away from urban areas? Employment opportunities should be offered to local communities. • Until more sophisticated clinical waste treatment plant is affordable, look to single, remote, secure, incineration location with periodic supervised burn?
		Policies:	Aim to halve unaccounted waste by 2010, eliminate by 2020.	Need to facilitate local and national manufactures for proper marketing of the residuals.	Scale up as primary route to rendering safe and reducing landfill.	Focus on safe storage + disposal via special landfill or incineration.	Energy from waste potential via landfill gas; controlled incineration not yet viable.	
Sort & Recover Summary		On balance, Simple Sorts Strategy seems as much as Khulna can tackle for the foreseeable future.						

6.5.3 Transfer and Treat

Despite the benefits of treatment as close as possible to the source of waste, it is difficult to find and operate composting plant sites within the KCC urban areas. It is noted that a high proportion of the compostable wastes already delivered to Rajbandha (Figure 6.5 and 6.6) as a result the additional transport costs would not balance the locational advantages of out-of-town sites for composting plants. It is revealed that large scale composting plants could offer better conditions for waste recovery workers. Given the amounts of waste involved, major implications for the waste collection and waste transfer services are recognized.

As regards hazardous clinical wastes, the wastes are needed to be separated at source, and the limited quantities and number of collection points should be involved. This study identifies that a dedicated collection and disposal service would be most cost effective and secure. For this active involvement all the health-care interests are important, since their influence could be crucial both in getting the wastes delivered to the special containers (especially from clinics and pathological centers) and in educating the public not to misuse them for other types of waste.

For Transfer & Treat the key important questions are present in Table 6.5. Emphasis are mainly given upon transfer station and composting as a 'given', and focus upon how those priorities might best be implemented in KCC. In the case of WastePoints, the key questions need to be considered are how many points and where; and in the case of composting, how to scale up and replicate the successful community composting schemes etc.

Looking into the alternatives, it can be concluded that, in KCC the low-cost labor-intensive technologies can still be followed, as the fundamental challenge of scaling-up the composting throughout was unlikely to be meet within the development limits of KCC. The extra costs involved in taking compostables to sites outside the city might only be of a similar magnitude to the subsidies incurred in making limited city land available for urban compost plants. Yet the savings on ultimate disposal costs should still be there with extra-urban schemes. To represent all this study suggest the **'BacktotheLand'** approach which indicates a return of organic wastes, processing employment, and nutritional value to the KCC people from which much of it originated. The analysis and conclusions are summarized in Table 6.8.

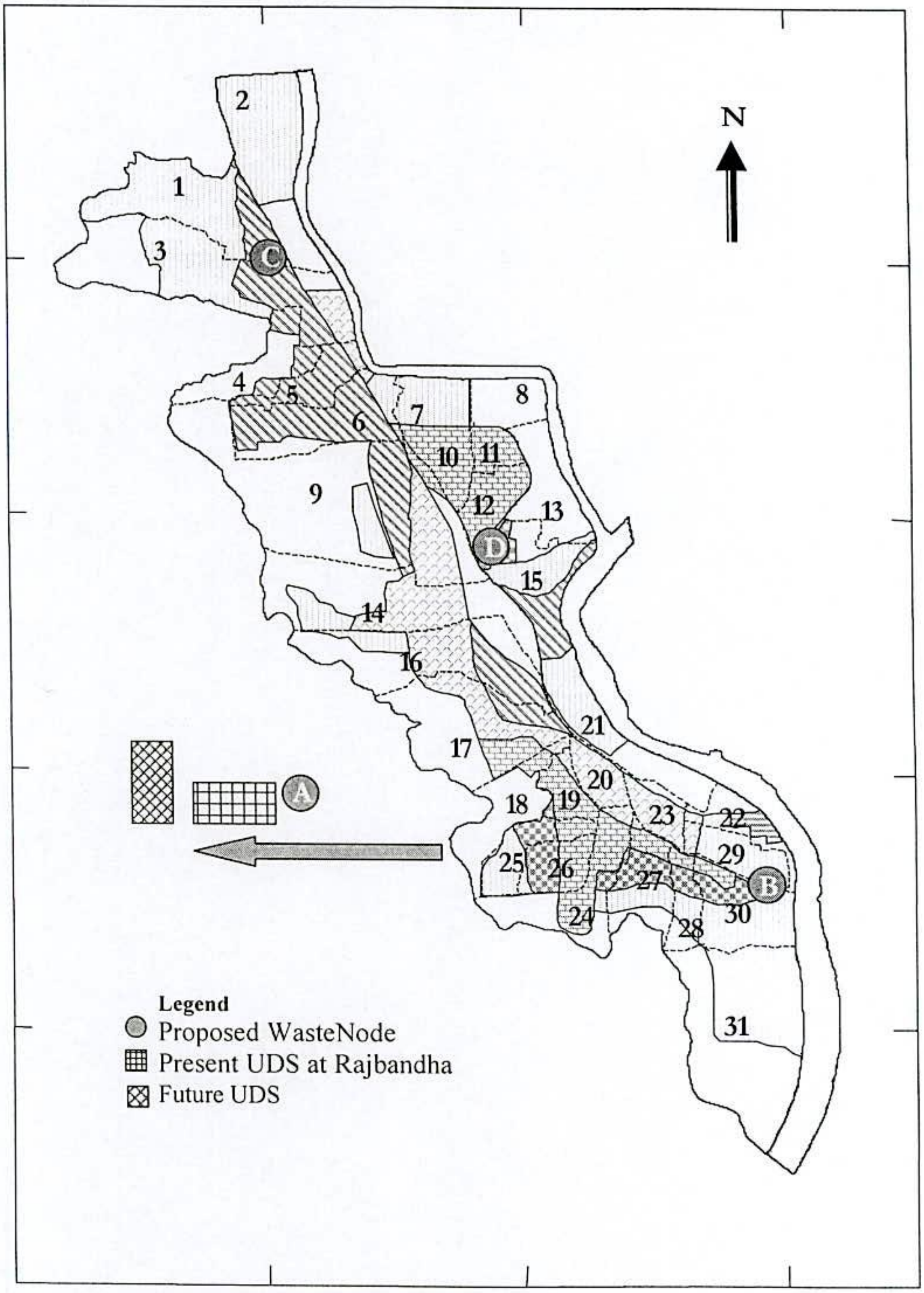


Figure 6.6 Proposed WasteNodes in KCC area

Table 6.8: WasteCase -Transfer & Treat– the 'BacktotheLand' Emphasis

WasteCase - the 'BacktotheLand' Aim		SOURCES & STREAMS	COSTS & RETURNS	HEALTH& ENVIRONMENT	COMMUNITY & STRUCTURE
Element	**Options/assumptions**				
TRANSFER & TREAT					
Waste Node (Transfer Station) *Scale + Number*	At 2020, net waste of 800 t.p.d. after dry recyclables recovery at source; c.120 t.p.d (approx 15%) considered compostables	WasteNodes av tonnes throughout: 4 No - 200 t.p.d. (30 compo, 170 not)	Considered that 4 WasteNodes would give adequate coverage for KCC, offering: --reasonable proximity from all WastePoints, and adequate economies of scale; --achievable demands in terms of finding sites and local traffic etc. impacts of each.		
Node Locations	Balanced distribution relative to generation; near major transport links, no cross-river movements; adequate land space	Node A to serve central business area. Nodes B to serve S-E residential area + Node C to serve N-W residential area. Node D to serve N-E low income areas	Node A high capacity densely populated residential + commercial mixed zone. Nodes B and C relatively low capacity sites in SE and NW residential middle income area. Node D low capacity site in the NE region.		
Waste In	Various collection vehicles from WastePoints + direct from major sources; manual tipping	Emphasis on building capacity to transfer all wastes reliably, plus compostables and non-compostables separately for different ends. Temporary provision for supervised sorting at WasteNodes by authorized waste pickers, in order to help redeploy from roadside scavenging, remove contraries from compostables, and recover value. To be phased out as source separation improves, and bays required for increased throughputs and/or further separation. Provide for secure clinical waste compound at one of the nodes, if dedicated service cannot find better accommodation.	Full cost-benefit appraisals still to be undertaken, but • financial benefits expected in lower costs per tones of onward transport, and access that gives to more acceptable sites on cheaper land, and economies of scale, for treatment and disposal facilities; • other performance benefits in providing a stable network of outlets and reliable removal service to the WastePoints and waste collection services.	Supports objectives of capturing and treating more waste, and doing so in ways which recover resources, and respect environment and waste workers' health. Does not minimize all travel distances, but helps avoid traffic congestion, using transport to achieve range of other benefits. Having a waterborne waste mode in flood-prone areas may help keep transfers moving if there is raised storage at that WasteNode.	A clear structure of WastePoints + WasteNodes could be instrumental in: • giving due attention to different elements of the waste transport task and their impacts; • defining a better division of responsibilities and enhancing coordination between waste collection and disposal activities; • allocating appropriate roles to public authority, private sector and community based interests.
Processing	6 - 15 bays, in groups of 3. Separate groups for compostables and other. Used in rotation: bay 1 for tipping incoming; bay 2 for limited sorting/picking; bay 3 for loading outgoing. Operations, rather than waste, moved from bay to bay by supervisor(s).				
Waste Out	By providing shovel loading arrangement into deep sided tipper truck/trailer. Shovel compacts non-compostables (only) as loaded. Future consideration of shredding/pulverizing compostables, at either WasteNodes or compost plants.				

Table 6.8 Continued

WasteCase - the 'BacktotheLand' Aim		**SOURCES & STREAMS**	**COSTS & RETURNS**	**HEALTH& ENVIRONMENT**	**COMMUNITY & STRUCTURE**
Element	**Options/assumptions**				
TRANSFER & TREAT					
Composting *Common Features*	More labor-intensive methods as valid in rural as in urban composting plants. Crucial to develop sustainable markets for both urban and rural compost applications.	WastePoint + WasteNode system offers more flexible way of scaling up separate collection of compostables than dedicated NGO collections.	Good demand in rural agricultural land and urban and sub-urban gardens, need regularity of supply.	Returns nutrients and enhances soil structure. Supervised composting at right temperature controls many pathogens.	Composting, at any scale, is essentially an agrarian activity and skill. Farming applications are a major market for the compost. There is as much poverty and under employment in surrounding countryside as in Khulna itself; worker wage rates could be lower. Compensation for waste-receiving communities.
Urban Sites	Continue to encourage decentralized household and community composting, but accept the difficulties in scaling up sufficiently within urban area.	While urban area is major waste generator, many of the compostables originated in organic rural produce. Look more positively on Khulna's relationships with rural locality.	Assumed land rental costs of urban sites (estimated at 130 Tk. per feedstock tones) are same order of magnitude as extra costs (about 130 Tk. per tones) of taking waste to rural fringe. More spacious low cost rural sites also offer significant operational economies of scale.	Not easy to prevent impacts on close neighbors on continuous basis. NIMBY makes difficult to find acceptable sites.	
Rural Fringe	Long-haul transport advantages of WasteNode network improve prospects of rural compost plants, including their potential co-location with landfill and land improvement projects.	Once returned to rural fringe, some compostables may be more valuable separated for use as animal feed.		Rural communities less disturbed and more accustomed to odors etc. NIMBY is not so bad.	
Transfer & Treatment Summary		On balance, WasteNodes supporting the 'BacktotheLand' emphasis appear to offer credible way forward.			

6.5.4 Dispose and Make Safe

The Dispose & Make Safe key questions are summarized in Table 6.5. The success of any final disposal strategy would be crucially dependent upon finding acceptable sites for properly engineered schemes, and it is decided that the evaluation should focus on alternative approaches to that.

The first approach is **'pragmatic sites'**, where the site location would be based largely on convenience and availability of land, and motivated by short-term demand or crisis requirement or political commitment.

The second approach is '**strategic sites**', which is a long-term site and can provide all the activities of an integrated waste management services. However, it is felt that the city authority can only think about such a strategic sites if there are very influential long-term benefits to counter-balance the short-term problems of establishing them. So the assessment of the possible contribution of remote landraising projects in delivering such benefits is essential for such strategy. Such a strategy will never work unless significant reassurances and compensations are given to the rural communities within which remote landraising projects would have to be located. In this regard this study suggest the '**LevellingUp**' approach where both the physical activity of landraising, plus enhancement of the living and economical conditions of the local people should be done together as a follow up of the project. '**LevellingUp**' will provide major capacity advantages on large strategic sites and potential after use benefits. The transportation cost for this site will be higher due to the remote location, but on-site handling costs significantly less due to available space and economical scale.

Due to small area of KCC, for '**LevellingUp**' the location of the sites seems to be in the rural fringes, where land is cheap and available. This site will be suitable for composting and landraising.

The findings and inputs of WasteCase for LevellingUp are presents in the Table 6.9.

Table 6.9: WasteCase-the LevellingUp Strategy

WasteCase - the 'LevellingUp' Idea		SOURCES & STREAMS	COSTS & RETURNS	HEALTH & ENVIRONMENT	COMMUNITY & STRUCTURE
Element	Options/assumptions				
DISPOSE & MAKE SAFE					
Landform Planning	Involves system and project planning and phasing, including scale of landfill/landraising schemes, and trade-offs between transport distance and land costs.	The main streams at issue for the moment are: hazardous clinical waste compostable waste non-compostable residue	Prospects of carbon credit funding open to all landfill gas conversion schemes, but large long-term projects more likely to attract sponsors, and more cost-effective in generating gas and energy income/subsidy.		Under the 'LevellingUp' concept it is envisaged that the Strategic Sites element would be achieved by securing the use of large areas of land in the rural fringes, for composting and landraising schemes designed to bring a range of employment, land improvement, energy provision and flood relief benefits to the local countryside communities.
Pragmatic Sites	Difficult to see providing adequate capacity; but strategic view need not exclude all pragmatic sites.	With pragmatic sites, each waste stream finds its own, sometimes competing for the best, with co-location occurring incidentally. Sites are introduced as needs dictate or opportunities arise. Scale and location are secondary to availability; and sites convenient to the urban waste generators are taken, even if relatively small. The engineering preparation (if any) is adapted to the site.	Planning and political costs of many small sites much greater than of equivalent few large sites.	Environmental impacts of many small urban sites much greater than few large remote rural sites.	
Strategic Sites	'LevellingUp' in terms of landraising provides major capacity advantages on large strategic sites, as well as potential flood relief and afteruse benefits.		Target under-utilized low-lying and/or low-grade land capable of improvement or development.	Landraising minimizes land requirement and offers land drainage and flood relief benefits.	
Engineering Preparation	Involves detailed design and construction of containment cells and associated infrastructure. For KCC, encapsulation will rely primarily on geological barriers and/or compacted clays.		Either type site could include special repository for hazardous clinical wastes; but strategic sites likely to offer more secure disposal option, or sufficiently remote location for high temperature incineration.		A true partnership is envisaged with the rural local government units, who would be suitably involved with the organization and running of projects on their own patches, but could not do so without the guaranteed waste streams, plus the resources and technical support, of the city authorities. Concerted efforts would be made to bring in the entire rural community as 'co-owners' from the outset.
Pragmatic Sites	Each site requires individual study and solution.		Costs per cubic meter high in small sites without landraising.	Same standards difficult to reach in constrained urban situations.	
Strategic Sites	Strategic view offers opportunities to integrate with development land, clay working, infrastructure schemes etc., with material/muck shift savings.	With strategic sites, the establishment of an adequate long-term site for all the activities of an integrated waste management service is seen as fundamental. Under the 'levelling up' concept it is envisaged that this would be achieved by securing large areas of relatively cheap land in the rural fringes, suitable for combined composting and landraising schemes. Such sites are seen as offering great flexibility to change the way KCCs waste streams are dealt with over time.	Landraising involves additional engineering costs and risks, especially in floodplains or earthquake regions, but these can be readily managed, afforded, designed and constructed under a properly run large scheme.		
Landfill Operation	Involves reception, placement, compaction and covering of the waste, plus operation and maintenance of all the associated gas, leachate and general site facilities and infrastructure.		All sites face the environmental concerns and mitigation costs of leachate and gas controls; both urban and rural sites in KCC can present the special challenges of landfill in flood prone areas.		
Pragmatic Sites	Each site requires individual operational plan and management arrangements.		Control costs per tonne of waste higher on smaller than larger sites.	Management of few large sites easier than many small sites.	In the absence of such a partnership, Pragmatic Sites which come up in the rural fringes of KCC are only likely to attract relatively uninformed NIMBY concerns, and the bitter opposition of the rural government units and others as 'outsiders' to the process.
Strategic Sites	Transport costs higher to remoter sites; but on-site handling costs significantly less due to available space, and economies of scale and mechanization.		Gas recovery and conversion more viable on large landraising sites.	Landraising operations relatively unaffected in flood conditions.	

Table 6.9 Continued

WasteCase - the 'LevellingUp' Idea		**SOURCES & STREAMS**	**COSTS & RETURNS**	**HEALTH & ENVIRONMENT**	**COMMUNITY & STRUCTURE**
Element	Options/assumptions				
DISPOSE & MAKE SAFE					
Completion & Afteruse	Involves closure to waste intakes, maintaining and monitoring gas and leachate provisions, restoration and aftercare, and sometimes afteruse infrastructure.		Final capping and restoration/preparation for afteruse required. Development needs most costly and demanding precautions; land values should pay for that in urban areas, but cannot ensure it.		
Pragmatic Sites	Each site requires individual solution, negotiated with community, developer or other interests.		Little influence over diverse afteruse (and misuse) potentials.	Monitoring of few large sites easier than many small sites	
Strategic Sites	Co-locating composting and landraising gives a valuable outlet for lower-grade or unmarketable composts in site restoration and land improvement.		Opportunity to plan, specify and implement to improve land value for community or economic uses.	Ability to achieve high restoration standard and public awareness of afteruse potentials + limitations.	
Disposal and Safety Summary		On balance, felt strategic landraising able to deliver a worthwhile 'LevellingUp' in more than one sense.			

6.5.5 Evaluation and Modification

This study for KCC has already touched upon numerous non-technical considerations, because one cannot progress realistic decision making on technical grounds alone. Now the study approaches the same issues more consciously and systematically from evaluation viewpoint. As we now develop the WasteCase for the integrated SWM, it will need extensive evaluation before taken to the implemented phase. In this study, based on the study data and available information, the theoretical evaluation is done. During this evaluation, some new points are highlighted, and to adjust them, the WasteCase spreadsheets need some modifications. These modifications can be summarized as follows,

(i) ***On Contain & Collect***: While endorsing the MeterCube and WastePoints strategy, the facility to accommodate further separation should be watched over during its detail implementation. For handling MeterCube manual or motorized hydraulic tail-lifts as a cost effective, robust and flexible technology can be added to the options. In terms of landfill requirements, the elimination of unaccounted waste would offset the diversion of biodegradable to composting.

(ii) ***On Sort & Recover***: The potential of recycled plastics in the construction and/or lining of MeterCube can be a good choice. It will be probably much safer to empty and sort waste containers at a few secure WasteNodes than at many open WastePoints. A separate stream for clinical wastes will be a good prospect in terms of reducing health risks at sorting/landfill sites.

(iii) ***On Transfer & Treat***: It should be checked how to make empty MeterCube stackable for storage and transport, and over which WasteNodes are to serve which WastePoints, whether manual sorting at the WasteNode bays might be undertaken at waist height rather than floor level. For flexibility, at least some of the vehicles operating between WasteNodes and StrategicSites should be capable of handling various types of waste or container.

(iv) ***On Dispose & Make Safe***: The need for selection of the best biodegradable for composting should be checked, while the remainder goes to landfill. The cleaning of waste vehicles and containers should be in mind.

Considering the above aspects the proposed new WasteCheck is present in Table 6.10. Its row headings (the Checks) have moved on from Contain & Collect, Sort & Recover, Transfer

& Treat, and Dispose & Make Safe to focus on MeterCube, WastePoints, WasteNodes and StrategicSites as Checks, with sub-headings listing all the main system components which need to be addressed in progressing them. The column headings (the Balances) have also been modified to reflect various considerations which are discussed below.

Table 6.10: New starting point of the KCC waste management

WasteCheck	TECHNICAL & MONITORING	RESOURCES & IMPLEMENTATION	REGULATION & ENFORCEMENT	RESPONSIBILITIES & MOTIVATION
Starting Point for 2nd phase	Device choice + action plans on key tasks and issues:	Undertake cost-benefit and investment appraisals:	Advance draft proposals for regulations and standards:	Promote organizational and procedural change:
MeterCubes (including OrganicsCubes, ClinicalsCubes, ResidualsCubes)	• design + specification? • numbers + locations? • funding + procurement? • ownership + management? • user education? (both drop-off + pick-up)	• provide starting point of - strategy assumptions? - tonnage forecasts? - unit costs? • outline + investigate phasing options for introducing WasteSafe strategies (assuming high/mid/low funds) - whole system in one sector? - part system across whole city? • compare costs and benefits (capital and operating) of 'do-one' vs. 'do-all' options - what combination(s) of the four proposals yield(s) best benefits for given investment? - does return on investments in the various system elements differ by socio-economic area? - are any costs/outcomes particularly long or short term? • commence site search within city for WastePoints and Nodes - on basis of objective locational and space criteria? - starting with all land in city authority ownership?	• proposals to address safeguards + incentives on - duty of care for waste? - no unauthorized disposal? - separation + recovery? - frequency of collections? - hazardous wastes? - destiny of wastes? - tariffs for wastes? - waste worker safety? - enforcement? • proposals to cover both - law and regulation, and - contractual performance and to ask which approach is most suitable for each? • package as main focus for next stages of stakeholder dialogue - how can we refine? - would you then support? leading to establishment of supervision committee for implementation + delivery.	• establishing Waste Collection and Waste Disposal arms - achieving scope to specialize with ability to liaise? - Collection responsible for WasteCubes + WastePoints? - Disposal responsible for WasteNodes + StrategicSites? - handover of waste at WastePoints or WasteNodes? - NGO/CBO participation in work of Collection Service? - private companies involved in work of Disposal Service? • improving quality of KCC's waste management dialogue - internal team building and external confidence building? - weekly open-house? Rolling to-do and contact lists? major strategy launch event? - Waste Supervisor to be key resource on Collection side? - early start to Waste Supervisor recruitment + training? - rural administrations to be key partner on Disposal side? - involve them in liaison groups for each side of the river?
WastePoints (including OrganicsPoints, ClinicalsPoints, ResidualsPoints, often combined)	• site planning + acquisition? • operations + layouts? • container handling? • preparation + signing? • management + supervising?			
WasteNodes (including Segregated Storage, Transfer to Bulk Haul, Interim Sorting, often combined)	• site planning + acquisition? • point-to-node transportation? • offload + reload? (including compaction etc) • interim sorting? (eventual multi-streams) • bulk onward transportation? • plant + equipment? (layout + installation)			
Strategic Sites (including Composting Plant, Clinical Incineration, Landfill/landraising, Energy Recovery, often combined)	• site planning + acquisition? • overall scheme design + phasing? • site preparation + infrastructure? • composting plant + depot? • landfill cell engineering? • clinical waste disposal facility? • restoration + afteruse?			

The 'Technical & Monitoring' replace the 'Sources & Streams' column heading, as implementation of MeterCube and education of the people to adapt to the new system need technical attention and regular monitoring of the process.

The 'Resources & Implementation' replace the 'Costs & Returns' column heading, in which the cost-benefit analysis and possible source of investment will be discussed.

'Regulation & Enforcement' replace the 'Health & Environment' column heading where new rules and regulations need to be draft to manage the new systems according to the standard.

'Responsibilities & Motivation' replace the 'Community & Structure' column heading, where organizational and procedural changes are discussed for all the concerned stakeholder.

A responsible group from the city corporation should investigate and report upon all aspects of the MeterCube, WastePoint, WasteNodes and StrategicSites proposals, their modification and testing, and their implementation and monitoring for further technical development of an ISWM system for KCC. It is speculated that the following key tasks and issues would require in-depth study and action for each of the main elements:

(i) **MeterCubes:** Design and specification? Numbers and locations? Funding and procurement? Ownership and management? User education?
(ii) **WastePoints**: Site planning and acquisition? Operation and layouts? Container handling? Preparation and signing? Management and supervising?
(iii) **WasteNodes**: Site planning and acquisition? Point-to-transfer station transportation? Offload and reload? Interim sorting? Bulk onward transportation? Plant and equipment?
(iv) **StrategicSites**: Site planning and acquisition? Overall scheme design and phasing? Site preparation and infrastructure? Composting plant and storage? Landfill cell engineering? Clinical waste disposal facility? Restoration and after use?

Each set of questions was to be asked for biodegradable, clinical and residual waste streams.

The group should consider the following issues:

(i) Whether to try to implement the whole system of MeterCubes + WastePoints + WasteNode + StrategicSite for one sector of the city at a time, or whether it was better to, say, introduce MeterCubes throughout the city first, then WastePoints, then WasteNodes, then StrategicSites. The first approach might demonstrate system integration to best effect. The second approach might be seen as fairer, and might concentrate resources to better effect.

(ii) What combination of the four proposals will yield the greatest benefits for the available investment?

(iii) On protecting human health and nature, could there be scope to extend the clinical waste service to cover certain similar threats, such as those from animal waste? While it was considered important to implement a system confined to clinical wastes as first priority, would an extension to cover a wider range of hazards enhance or detract from its value and viability?

(iv) On regulation and enforcement, concerns were being expressed about the security issues associated with MeterCubes and other equipment, how could they be tackled?

(v) Should KCC establish a separate Waste Management Agency, with Collection and Disposal Divisions? Or should it convert the existing Conservancy Department into a Conservancy and Waste Management Service, with Waste Collection, Waste Disposal and Conservancy Divisions? Did it matter much, provided Collection and Disposal functions were given the scope and means to specialize, and the ability to liaise closely by being kept within a unified top tier of management?

(vi) Should the principle be that the Collection service should oversee the MeterCube and WastePoint elements, and the Disposal services the WasteNode and StrategicSites elements? If that principle was adopted, would there be two main points of handover of waste and responsibilities for waste: either upon loading into Disposal Service vehicles at the WastePoints, or upon discharge from Collection Service vehicles when taken directly to WasteNodes or StrategicSites? Would there not be advantages in having the flexibility to use either option, depending upon locations and operating conditions?

(vii) While exceptions might be made in specific cases, should the broad approach in KCC be to encourage NGO/CBOs participation in the work of the Collection service, and seek private company involvement in the Disposal function? Would that simplification help all sides to concentrate on getting on with the urgent job together?

(viii) As regards the Disposal side, how could confidence and co-operation be built with the rural administrations and communities?

6.5.6 Summary of the proposed approach

The difference between the existing system and the proposed integrated MSW system can be present as Figure 6.7. The introduction of MeterCube, WastePoint, WasteNode and StrategicSite are the main key points of the proposed system.

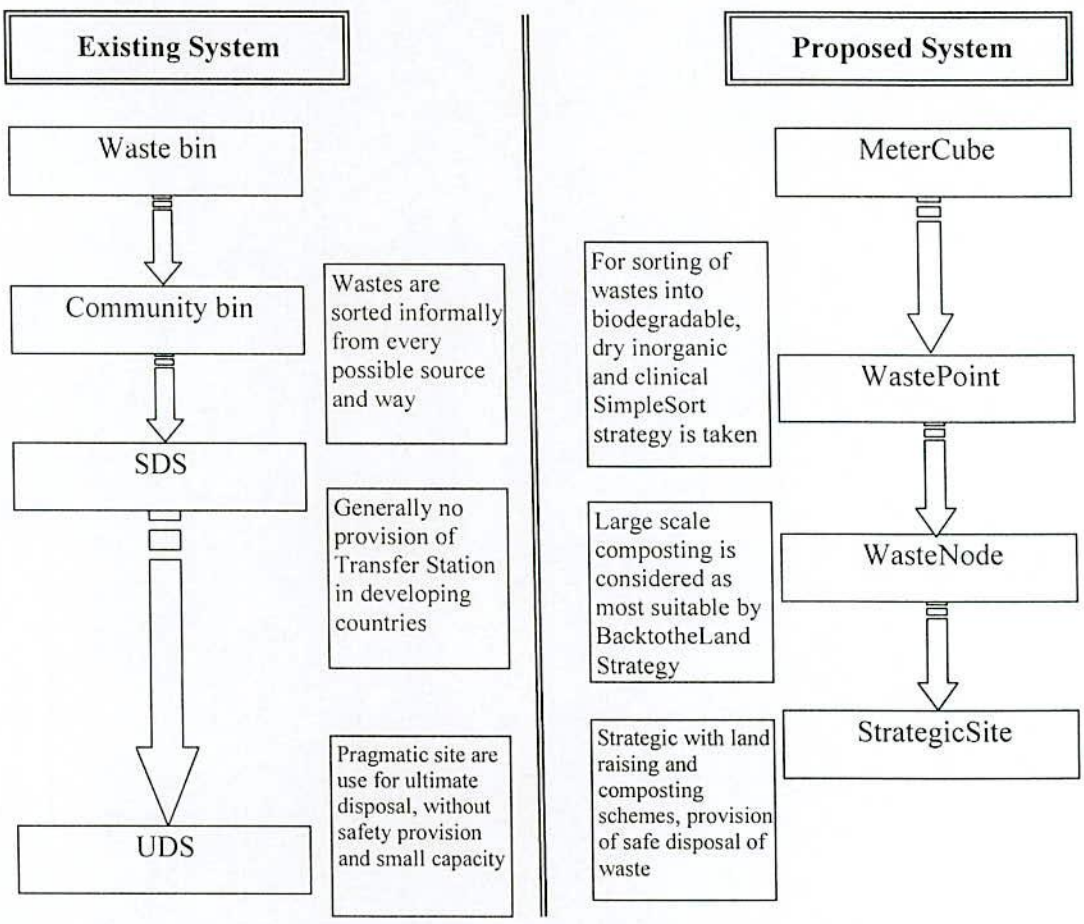


Figure 6.7 Difference between the existing and proposed system

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

7.1 General

The overview of the municipal solid waste management (MSWM) in the six study cities shows a striking degree of similarity with respect to financial aspects, technical aspects and human resources development that are an essential part of sustainable integrated solid waste management (ISWM). For a successful ISWM system all important issues have to be addressed to successfully implement changes in waste management: and not only within technical requirements, but also as regards economics & finance, legislation & enforcement, institutional and environmental aspects, public awareness, motivation & participation and the roles of concerned stakeholders. So, though in this study a detail analysis of KCC is considered, it can be easily extendable for other city corporations of Bangladesh as well.

7.2 Conclusions

During the study and the hypothetical application of the evaluation approach some considerations have been revealed. The following propositions may be useful for each study city:

(i) Proper storage and source separation is the key to recover useable and recyclable materials. Laws should be made to restrict throw out of wastes, but stored in bins and transferred to designated places.

(ii) Many city dwellers in the study areas are interested in door-to-door waste collection services, and are also prepared to pay for them. NGOs, CBOs and private companies should be encouraged to provide door-to-door collection systems, under the general co-ordination and supervision of the city authorities.

(iii) The location and design of the SDS are crucial in terms of health, hygiene and environmental impact. Special attention should be given to large 'community bins', as SDS is a major source of environmental degradation.

(iv) The WastePoints (or groups of smaller WastePoints) should be staffed with uniformed attendants responsible for assisting with loading and unloading, keeping neat and clean, and advising the public on the rules of use. Such Waste Supervisors might also in due course be given a role in enforcing certain health and environmental regulations.

(v) Limited source separation of wastes should be introduced as soon as practicable, with initial emphasis on compostables and hazardous clinical waste streams. The former involves storing in separate containers: for the rapidly biodegradable organic fraction, and for the non-biodegradable or slowly biodegradable fractions. Hazardous clinical waste is best dealt with as a separate, secure stream throughout.

(vi) Primary sorting of waste should take place at source on waste collection vehicles, or in containers at a WastePoint. No sorting should be done on the surface of the street or other public places including at the WastePoints. Any secondary sorting, away from the waste source, should take place in areas of transfer stations, material recovery centers, treatment plants or disposal sites provided, equipped and supervised for that purpose. Separation is pointless unless the separated wastes subsequently follow distinct pathways and processes in recovery, treatment and/or disposal.

(vii) The bulk handling capabilities of WasteNodes also enable wastes to be taken economically to more remote treatment and disposal facilities, typically outside the urban area, they may even offer the option of using alternative transport modes, such as rail or waterway, with additional range-economies and environmental benefits. Such long-haul options can open up site availability, land improvement, and scale-economy opportunities, which simply cannot be found nearer the city. The farsighted planning of adequate networks of WasteNodes can thus prove invaluable to the future of waste management in the study areas.

(viii) Composting should be considered the key option for waste treatment in the study areas. A properly located, well-designed and well-managed composting plant can convert organic wastes into a valuable product, and need not create major environmental impacts of its own. However, there are great difficulties finding and operating sufficient composting plant sites within the urban areas. It will be more suitable to establish large-scale composting facilities in the urban-rural fringes, which can outweigh the additional waste transport costs. These include better conditions for waste recovery workers, and economic spin-offs for the local rural communities.

(ix) A significant portion of residual waste must still be dealt with in an ultimate disposal facility. Such a facility has two basic requirements: (a) safe holding or encapsulation of the waste and its reaction products, while it is decomposing or being stabilized; and (b) control of the reaction processes, so as to improve the rate or products of stabilization, render emissions harmless, and recover value. While it may have a role for clinical and other hazardous wastes, the costs of incineration (with proper emission controls) are currently prohibitive for other wastes in the study areas. But the above requirements can be met by modern sanitary landfill reactors.

(x) The major landraising schemes would not only provide a practical solution to the requirements for final disposal of MSW, but could offer significant land improvement and flood relief afteruse potentials in low-lying regions like Bangladesh. The priority should be given to reserving and establishing large strategic landraising schemes in less populated locations, having favorable geological conditions, with good transport links to the cities, and adequate capacity for many years of predicted demand.

(xi) Regular monitoring and review of door-to-door collection service by different organizations should be undertaken by the city corporation, whether run by public authorities and agencies, or by NGOs, CBOs or the private sector.

(xii) The financial problems of the city authorities can be alleviated by seeking of international aid and of extension of central government support for the improvement of MSW management. In addition, maximum advantage should be taken of potential community and private sector contributions. The outcomes of alternative actions need to be compared, using all the techniques of economic analysis and investment appraisal.

(xiii) Full compliance with the ISWM will never be achieved without the backing of effective health and environmental legislation and law enforcement. No charging system can be fully effective until penalties are also imposed and enforced for by-passing the proper waste management services, or for neglecting health and safety precautions for waste workers.

(xiv) MSW management is usefully subdivided into Waste Collection and Waste

Disposal functions. Most NGOs and CBOs participation should then be focused on the Waste Collection services, since grassroots and community level organizations are well suited to the intensive public contacts which contain & collect and sort & recover activities require. Most private sector involvement should be within the Waste Disposal role, since such companies tend to be better suited to the challenge of developing and running the sort of facilities and technologies required for the transfer & treat and dispose & make safe components.

7.3 Recommendations for Future Studies

The following recommendations are suggested for future studies:

1. The spreadsheet tools should be implemented by physical demonstration in KCC in practical, to check its sustainability and necessary modifications.
2. Software modeling can be done based on these spreadsheet tools, which can assist the user and can make these tools more users friendly.
3. It is needed to extend the study in the aspect of recyclable materials and the implementation of recyclable programs in major cities of Bangladesh. This will be a guideline for establishing the relevant regulations of waste recycling programs of the city in future.
4. Detail study on MSW reduction, reuse, recycling, recovery and their effect on the management cost should be conducted.
5. Composting in a large commercial scale should be considered due to the waste characterization and its market values.

REFERENCES

1. Ahmed, M. F. and Rahman, M. M., 2000, Water Supply & Sanitation: Rural and Low Income Urban Communities. ITN-Bangladesh, Centre for Water Supply and Waste Management, BUET, Dhaka, Bangladesh.

2. Ahsan, A., Alamgir, M., Islam, R. and Chowdhury, K.H., 2005, Initiatives of Nongovernmental Organization in Solid wastes Management at Khulna City. Proc. *Third Annual Paper Meet and International Conference on Civil Engineering*, March 9 – 11, IEB, Dhaka, Bangladesh. pp. 185-196.

3. Ahsan, A., 2006, Generation, Composition and Characterization of Municipal Solid Waste in Some Major Cities of Bangladesh, M. Sc. Engg. Thesis, Department of Civil Engineering, Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh.

4. AIT (2004). Comparative Study on Municipal Solid Waste Management in Asia, Asian Regional Research Programme on Environmental Technology, Environmental Engineering and Management, AIT, Thailand.

5. Alamgir, M., Ahsan, A., McDonald, C.P., Upreti, B.N. and Islam, R., 2005a, Present Status of Municipal Solid Wastes Management in Bangladesh. Proc. *International Conference on Waste - The Social Context*, May 11 – 14, Edmonton, Alberta, Canada. pp. 11-20.

6. Alamgir, M., Chowdhury, K.H., Roehl, K.E., Stentiford, E.I. and Bari, Q.H., 2005b, Basic Characteristics of Municipal Solid Wastes of Bangladesh. Proc. *International Conference on Waste - The Social Context*, May 11 – 14, Edmonton, Alberta, Canada. pp. 21-26.

7. Alamgir, M., Mohiuddin, K.M., Czurda, K.A., Glawe, U. and Karim, M.R., 2005c, Situation of Ultimate Disposal Sites of Municipal Solid Wastes in Bangladesh. Proc. *International Conference on Waste - The Social Context*, May 11 – 14, Edmonton, Alberta, Canada. pp. 27-35.

8. Alamgir, M., 2003, Current status of waste containment in Bangladesh. Proc. *Seminar & Workshops on Geoenvironmental Engineering, Asia-Link Programme of EC*, March 11-12, KUET, Khulna, Bangladesh. pp. 185-207.

9. Alamgir, M., Chowdhury, K.H. and Hossain, Q.S., 2003, Management of Clinical Wastes in Khulna City, Proc. *Seminar on The Role of Renewable and Alternative Energy Sources for National Development*, December 19-20, KUET, Khulna. pp. 146-155.

10. Ali, M. (2004) Sustainable Composting. Water, Engineering and Development Center (WEDC), Loughborough University, UK. ISBN No. 1843800713.

11. Ali, M.R., 2000, Progress Report on Clinical Waste Management Service, Prodipan, Khulna.

12. Ali, M.A., 2001, Unmanageable Solid Waste. *People's Report on Bangladesh Environment 2001*: *Main Report*, Unnayan Shamannay, UPL, Dhaka, Bangladesh. Vol. 1, pp. 209-215.

13. BBS (1997) Bangladesh Bureau of Statistics, *"Bangladesh Population Census* 1991. *Urban Area Report".* Statistics Division, Ministry of Planning, GOB, Dhaka, Bangladesh.

14. BBS (2001) Bangladesh Bureau of Statistics, *"Population Census 2001, Preliminary Report" Dhaka:* Statistical Division, Ministry of Planning, GOB, Dhaka, Bangladesh.

15. BCC, 2005, *Personal Communication.* Interview taken by the authors to Barisal City Corporation (BCC) personnel, Barisal, Bangladesh.

16. BCSIR, 1998, Refuse Quality Assessment of Dhaka City Corporation for Waste to Electrical Energy Project, Institute of Fuel Research and Development, Bangladesh Council of Scientific and Industrial Research, World Bank, GOB, Dhaka, Bangladesh.

17. BMA (2002). Final Report on Solid Waste Management Study for Bangkok, Bangkok Metropolitan Administration, Sogreah, Bangkok, Thailand.

18. Bradshaw, A.D., Southwood, S.R. and Warner, S.F. eds. (1992) The Treatment and Handling of Wastes. Published by Chapman anf Hall for Royal Society, New York, USA.

19. Bureau of Statistics (2000) Report of the Urban Poverty Monitoring Survey April 1998. Dhaka: Statistics Division, Ministry of Planning, GOB, Dhaka, Bangladesh.

20. BUET, 2000, Characterization of Municipal Solid Waste and Preliminary Environmental Impact Assessment of Collection and Disposal Works in Dhaka City, Department of Civil Engineering, Bureau of Research, Testing and Consultation, BUET, Dhaka.

21. CCC, 2005, *Personal Communication.* Interview taken by the authors to Chittagong City Corporation (CCC) personnel, Dhaka, Bangladesh.

22. CDM (2004) Clean Development Mechanism and its Opportunities in Bangladesh. Waste Concern, Dhaka, Bangladesh.

23. Chowdhury, K. H., Alamgir, M., Bari, Q. H. and Chowdhury, M. K., 2005, Collection System of Solid Waste from Sources in Rajshahi City of Bangladesh. Proc. *Third Annual Paper Meet and International Conference on Civil Engineering*, March 9 – 11, IEB, Dhaka, Bangladesh. pp. 25-34.

24. Chan, S.P., 1993, Estimation of Solid Waste Generation Rates and Composition in Kuala Lumpur, Malaysia, M. Sc. Engg. Thesis, School of Civil Engineering, AIT, Thailand. Thesis No. EV 93-33.

25. DCC (2000) Solid Waste Management Project of Dhaka City Corporation. Final Report, prepared in cooperation with Japan International Cooperation Agency (JICA) Expert and counterparts of DCC, Dhaka, Bangladesh.

26. DCC (2004) The Study on the Solid Waste Management in Dhaka City. *Progress Report of Clean Dhaka Master Plan.* prepared in cooperation with Japan International Cooperation Agency (JICA) Experts and counterparts of DCC, Dhaka, Bangladesh.

27. DCC, 2005, *Personal Communication.* Interview taken by the authors to Dhaka City Corporation (DCC) personnel, Dhaka, Bangladesh.

28. Diaz, L.F., Eggerth, L.L. and Golueke, C.G. (1996) Solid Waste Management for Economically Developing Country. The World Bank, Washington DC, U.S.A.

29. Diaz et al. (1998) Sectoral Analysis in Bangladesh. Draft Report, The World Bank, Washington DC, USA.

30. DOE, 2005, *Personal Communication.* Interview taken by the authors to Department of Environment (DOE) personnel, Dhaka, Bangladesh.

31. EEA (2004) Waste and Material Flows 2004. European Topic Center on Waste and Material Flows, European Environment Agency, Copenhagen, pp. 76.

32. Enayetullah, I. and Sinha, A.M. (2003) Decentralized Composting- Through Public-Private-Community Partnership: Experience of Waste Concern. 1st Ed. Waste Concern, Dhaka, Bangladesh.

33. Enayetullah, I. and Sinha, A.H.M.M., 2000, Community Based Solid Waste Management: The Asian Experience. 1st Ed. Waste Concern, Dhaka, Bangladesh.

34. EPA (2005) Environmental Protection Agency, U.S.A. Available of the website: http://www.epa.gov/epaoswer/non-hw/muncpl/facts.htm (March 2006).

35. EPA (2005) Environmental Protection Agency, U.S.A. Available of the website: http:// (March 2006).---C-2, Page-23

36. EPA (2005) Environmental Protection Agency, U.S.A. Available of the website: http:// (March 2006).---C-5, Page-97

37. Guitouni, A., Martel, J., 1998, Tentative Guidelines to Help Choosing an Appropriate MCDA Method, European Journal of Operational Research 109, 501-521.

38. Hartono, D. M., 1984, Estimation of Solid Waste Generation Rates in The City of Bandung in Indonesia, M. Sc. Engg. Thesis, School of Civil Engineering, AIT, Thailand. Thesis No. EV 84 -5.

39. Ibiebele, D.D., 1986, Rapid Method for estimating Solid Waste generation Rate in Developing Countries, Waste Management & Research, Nigeria. Vol. 4, pp. 361-365.

40. Integrated Management and Safe Disposal of Municipal Solid Waste in Least Developed Asian Countries, 2005, A feasibility study, WasteSafe, Department of Civil

Engineering, Khulna University of Engineering & Technology, Khulna, Bangladesh

41. JICA, 2000, Solid Waste Management Project of Dhaka City Corporation, Final Report, Japan International Cooperation Agency Expert, Dhaka, Bangladesh.

42. JICA, 2004, The Study on the Solid Waste Management in Dhaka City. *Progress Report of Clean Dhaka Master Plan,* Japan International Cooperation Agency, Dhaka, Bangladesh.

43. KCC, 2005, *Personal Communication.* Interview taken by the authors to Khulna City Corporation (KCC) personnel, Khulna, Bangladesh.

44. KCC, 2006, *Local Partnerships for Urban Poverty Alleviation Project*, Khulna, Bangladesh.

45. KDA, 2004, *Personal Communication.* Interview taken by the authors to Khulna Development Authority (KDA) personnel, Khulna, Bangladesh.

46. KDA (2000) *Draft Structure plan* Map 4.8; Khulna city Structure plan area: Proposed areas of expansion (Khulna, Aqua-sheltech Consortium and KDA)

47. Keeny, R., Raiffa, H., 1976, Decisions with Multiple Objectives: Preferences and Value Tradeoffs, Wiley, New York, USA.

48. KUET, 1998, Laboratory Instruction Sheet, Heat Engine Laboratory, Mechanical Engineering Department, Khulna University of Engineering and Technology (KUET), Khulna, Bangladesh.

49. Lohani, B. N. and Thanh, N. C. (1980) Problems and Practices of Solid Waste Management in Asia, Journal of Environmental Science, pp.29-33

50. Ludwig, C., Hellweg, S. and Stucki, S., 2003, Municipal Solid Waste Management: Strategies and Technologies for Sustainable Solutions, Switzerland.

51. McDougall, F., White, P., Franke, M., Hindle, P., 2001, Integrated Solid Waste Management: A Life Cycle Inventory, Blackwell Science, London, UK.

52. Mohiuddin, K.M., Alamgir, M. and Roehl, K.E., 2005, Present Scenario of Solid Wastes Disposal Sites in Khulna City of Bangladesh. Proc. *Third Annual Paper Meet and International Conference on Civil Engineering*, March 9 – 11, IEB, Dhaka, Bangladesh. pp. 429-438.

53. MOHFW, 2004, Ministry of Health and Family Welfare, Main Report, GOB, Dhaka, Bangladesh.

54. Moniruzzaman, S. M., Bari, Q. H., Chowdhury, K. H., Hasan, M. & Raihan, M. (2005), 'Recycling of Inorganic Solid Wastes in Khulna City, Bangladesh'. Proc. 3rd APM & International Conference on Civil Engineering, Civil Engineering Division, IEB, March 9-11, Dhaka, pp. 197-204.

55. Moqsud, M.A., 2003, A Study on Composting of Solid Waste, M. Sc. Engg. Thesis,

Department of Civil Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh. Thesis No. 99072.

56. Polprasert, C. 1996, Composting. In *Organic Waste Recycling Technology and Management*, John Wiley & Sons, New York, 2nd ed., pp. 69-114.

57. Qureshi, M.E., Harrison, S.R., Wegener, M.K., 1999, Validation of Multicriteria Analysis Models, Agricultural Systems, 62, 105-116.

58. Rahman, M.H., 1993a, Waste Management in Greater Dhaka City, The International Journal of Environmental Education & Information. UK. Vol. 12, No. 2.

59. Rahman, M.H., 1993b, Recycling of Solid Waste in Bangladesh, The International Journal of Environmental Education & Information. UK. Vol. 12, No. 4.

60. RCC, 2005, *Personal Communication.* Interview taken by the authors to Rajshahi City Corporation (RCC) personnel, Rajshahi, Bangladesh.

61. Rogers, M., Grist, B., 2001, Sidelining Politicians and Community Groups:the Site Selection Process for a Non-hazardous Landfill Facility in County Galaxy, Municipal Engineer 145 (2), 1-4.

62. Rogers, M., 2001, Engineering Project Appraisal, Blackwell Science, London

63. Roy, B., 1991, The outranking approach and the fondations of ELECTRE methods. Theory and Decision 31(1), pp. 49-73.

64. Salminen, P., Hollanen, J., Lahdelma, R., 1998, Comparing multicriteria methods in the context of environmental problems, European Journal of Operational Research 104, pp. 485-496.

65. Simon, H., 1976, Administrative Behaviour, New York Free Press, New York, USA.

66. Spoken Solid, 1996, Spoken Solid: Regional Solid Waste System, Dhaka, Bangladesh. Available of the website: www. Solidwaste.org/combenefit.htm (February 2005).

67. Sridhar, M.K.C., Bammeke, A.O. and Omishakin, M.A., 1985, A Study on the Characteristics of Refuse in Ibandan, Waste Management & Research, Nigeria. Vol. 3, pp. 191-201.

68. SCC, 2005, *Personal Communication.* Interview taken by the authors to Sylhet City Corporation (SCC) personnel, Dhaka, Bangladesh.

69. Sinha, A.H.M.M. and Enayetullah, I. (2000a) Study on Resource Recovery from Solid Waste in Khulna City. Water and Sanitation Program South Asia, Dhaka, Bangladesh.

70. Sinha, A.M. and Enayetullah, I. (2000b) Community Based Solid Waste Management: The Asian Experience. 1st Ed. Waste Concern, Dhaka, Bangladesh. ISBN No. 984-750-000-2.

71. Southern States Energy Board, Georgia, USA (2000), Management of Municipal Solid

Waste: A Handbook for Local Officials.
72. Tchobanoglous, G., Theisen, H. and Vigil, S.A., 1993, Integrated Solid Waste Management, McGraw-Hill, Inc., International editions, U.S.A.

73. Tchobanoglous, G. and Kreith, F., 2002, Handbook of Solid Waste Management, 2nd Ed., McGraw-Hill, U.S.A.

74. http://www.TheFreeDictionary.com accsees 12th March, 2006

75. United Nations Environment Programme (2001), State of the Environment Bhutan, 2001, UNEP, RRC, AP.

76. Visvanathan, C., Trankler, J., Gongming, Z., Joseph, K., Basnayake, B.F.A., Chiemchaisri C., Kuruparan, P., Norbu, T. and Shapkota, P., 2004, Municipal Solid Waste Management in Asia, Asian Regional Research Program on Environmental Technology (ARRPET), AIT, Thailand.

77. Waste Concern, 2000, Aborjona o Paribesh. A Newsletter on solid waste management in Bangladesh, Issue-5, Edited by I. Enayetullah & A.H.M.M. Sinha. Available of the website: http://www.wasteconcern.org/newsletters/issue5/issue5.html (June 2005).

78. Yang, W.S., 1994, Solid Waste Management: A Case Study in Tainan, Taiwan, M. Sc. Engg. Thesis, School of Civil Engineering, AIT, Thailand. Thesis No. EV 94-35.

ANNEXURE-A

সমন্বিত ও নিরাপদ পৌর আবর্জনা ব্যবস্হাপনা জরিপ-২০০৪ ইং

নিম্নের প্রশ্নগুলো ভালোভাবে পড়ে উত্তর দিন, উত্তর দেবার জন্য এক/একাধিক টিক (√) চিহ্ন ব্যবহার করতে পারেন।

নামঃ .... লিঙ্গঃ................বয়সঃ ....শিক্ষাগত যোগ্যতাঃ................................

পেশাঃ ....মাসিক আয়ঃ ....টাকা, পরিবারের সদস্য সংখ্যাঃ.................জন (১৮ এর উপরে=.......... জন, ১৮ এর নীচে=........... জন)

Household Solid Waste Segregation, Storage and Disposal (বাসায় আবর্জনা সংরক্ষণ ও অপসারণ)

১. আপনার বাসার আবর্জনা কি ভাবে সংরক্ষণ করেন? ☐ ডাস্টবিন ☐ পলিথিন/ব্যাগ ☐ খোলা জায়গায় ☐ সংরক্ষণ করি না

২. বাসায় কি ধরনের ডাস্টবিন ব্যবহার করেন? ☐ প্লাস্টিক ☐ ধাতব ☐ ঝুড়ি ☐ অন্যান্য ☐ ডাস্টবিন ব্যবহার করি না

৩. আপনার ডাস্টবিন কিনতে কত টাকা খরচ হয়েছিল? ☐ ৫০ টাকার নীচে ☐ ৫০-১০০ টাকার মধ্যে ☐ ১০০-১৫০ টাকার মধ্যে ☐ ১৫০ টাকার উপরে

৪. বাসার ডাস্টবিনের আবর্জনার ধরন কি? ☐ সব ধরনের আবর্জনা এক সাথে ☐ যেগুলো আবার ব্যবহার করি সেগুলো আলাদা করি

৫. পেট বোতল, তেলের কন্টেইনার, কোক/পেপসির ক্যান, মিনারেল পানির খালি বোতল কিভাবে ফেলেন? ☐ রান্নাঘরের ময়লার সাথে ☐ ব্যবহার করি ☐ বিক্রি করি

৬. আপনার বাসায় ব্যবহৃত বিভিন্ন প্লাস্টিক/পলিথিন কি ভাবে ফেলেন? ☐ রান্নাঘরের ময়লার সাথে ☐ ঝাড়ু দিয়ে ফেলে দেই ☐ নর্দমা দিয়ে ফেলি

৭. বাসার ডাস্টবিনে আবর্জনা কিভাবে রাখেন? ☐ সরাসরি ☐ পলিথিন ব্যবহার করি ☐ কাগজ ব্যবহার করি

৮. আপনার বাসার ব্যবহৃত ব্যাটারি/বিভিন্ন স্প্রের খালি বোতল ইত্যাদি কোথায় ফেলেন? ☐ রান্নাঘরের ময়লার সাথে আলাদা ভাবে ফেলি ☐ বিক্রি করি

৯. আপনার মতে কি ধরনের ডাস্টবিন আপনার বাসার জন্য ভালো? ☐ গোলাকার প্লাষ্টিক ☐ আয়াতাকার প্লাষ্টিক ☐ ধাতব ☐ অন্যান্য

১০. আপনার বাসার ডাস্টবিন এর ঢাকনার ব্যাপারে আপনার মতামত কি? ☐ সহজে লাগানো যায় এমন ঢাকনা থাকা উচিত ☐ নিজে নিজে আটকে এমন ঢাকনা থাকা উচিত ☐ খোলা থাকলেই ভালো

On-Site Storage and Disposal (এলাকায় আবর্জনা সংরক্ষণ ও অপসারন)

১১. আপনার বাসার আবর্জনা কিভাবে ফেলেন? ☐ কাজের লোকের মাধ্যমে ☐ নিজে নিয়ে যাই ☐ বাসা থেকে নিয়ে যায়

১২. আপনি আবর্জনা কোথায় ফেলেন? ☐ ডাস্টবিন ☐ বাসা থেকে নিয়ে যায় ☐ বাসার পাশে খোলা জায়গায় ☐ নর্দমা ☐ যেখানে-সেখানে

১৩. আবর্জনা কখন ফেলতে যান? ☐ সকাল ৬-১০ টা ☐ সকাল ১০-দুপুর ২ টা ☐ দুপুর ২টা-সন্ধ্যা ৬ টা ☐ সন্ধ্যা ৬ টা-রাত ১০ টা ☐ ঠিক নেই

১৪. আপনার এ বাবদ মাসিক কোন খরচ আছে কিনা? ☐ না ☐ আছে, ৫-১০ টাকা ☐ ১০-২০ টাকা ☐ ২০-৩০ টাকা ☐ ৩০ টাকার উপর

১৫. আপনার বাসা থেকে আবর্জনা নিয়ে যাবে, এর জন্য আপনি খরচ করতে কি রাজী? ☐ হ্যাঁ ☐ না

১৬. এ বাবদ আপনি মাসে কত টাকা খরচ করতে পারবেন? ☐ ৩০ টাকার উপর ☐ ৩০ টাকা ☐ ২০ টাকা ☐ ১০ টাকা ☐ কোন টাকা খরচ করতে পারব না

১৭. যদি টাকা খরচ করতে না পারেন এর কারন কি অর্থনৈতিক? ☐ হ্যাঁ ☐ না

Waste Management (আবর্জনা ব্যবস্থাপনা)

১৮. আপনার এলাকায় কি সিটি কর্পোরেশনের ডাস্টবিন আছে? ☐ হ্যাঁ ☐ না

১৯. ডাস্টবিন থাকলে তা কত দুরে? ☐ কাছে (২৫০ গজ এর কম) ☐ মোটামুটি দুরে (২৫০-১০০০ গজ) ☐ দুরে (১০০০ গজ এর বেশি দুরে)

২০. বাসা থেকে ডাস্টবিন কত দুরে থাকলে ভালো হয়? ☐ খুব কাছে (৫ মি: হাঁটা পথের মধ্যে) ☐ মোটামুটি দুরে (৫-১০ মি: হাঁটা পথের মধ্যে) ☐ অনেক দুরে (১০ মি: এর বেশী মি: হাঁটা পথের মধ্যে)

২১. আপনার এলাকায় কোন ব্যবস্হা থাকলে ভালো? ☐ ডাস্টবিন এ আবর্জনা ফেলা ☐ বাসা থেকে আবর্জনা নিয়ে যাওয়া ☐ ডাস্টবিন না থাকা

২২. বাসা থেকে আবর্জনা কখন নিয়ে গেলে ভালো হয়? ☐ সকাল ☐ দুপুর ☐ বিকাল ☐ সন্ধ্যা

২৩. বাসা থেকে আবর্জনা কয় বার নিয়ে গেলে ভালো হয়? ☐ দিনে একবার ☐ দিনে দুইবার ☐ একদিন পর পর ☐ দুই দিন পর পর

২৪. আপনার এলাকায় ডাস্টবিন থেকে কি সময়মত আবর্জনা পরিস্কার করা হয়? ☐ হ্যাঁ ☐ না

২৫. আবর্জনা পরিস্কার করার কাজ কি দিনের বেলায় করা হয়? ☐ হ্যাঁ ☐ না

২৬. আপনার এলাকা থেকে আবর্জনা কোথায় যায় সে সম্পর্কে আপনার কোন ধারনা আছে? ☐ হ্যাঁ ☐ না

২৭. সিটি কর্পোরেশনগুলো আবর্জনা সংগ্রহ করে চুড়ান্ত ভাবে একটি খোলা জায়গায় ফেলে, এটা কি ঠিক? ☐ হ্যাঁ ☐ না

২৮. খোলা জায়গায় আবর্জনা ফেলায় পরিবেশ দূষিত হয়, আপনি কি এ ব্যাপারে সচেতন? ☐ হ্যাঁ ☐ না

২৯. আবর্জনা থেকে আপনি কোন কোন অংশ পুন: ব্যবহার/বিক্রি করেন? ☐ পেপার ☐ প্লাষ্টিক বোতল ☐ লোহা/টিন/এলুমিনিয়াম ☐ রবার/চামড়া ☐ পুরনো কাপড় ☐ অন্যান্য ☐ করি না

৩০. পুন: ব্যবহার/বিক্রি বাবদ মাসে আনুমানিক কত টাকা পান/কত টাকা সাশ্রয় করেন? ☐ ২৫ টাকার নীচে ☐ ২৫-৫০ টাকার মধ্যে ☐ ৫০ টাকার উপর ☐ করি না

৩১. আপনি কি জানেন, আবর্জনা থেকে জৈব সার তৈরি করা যায়, যা ভালো সার হিসাবে ব্যবহৃত হয়? ☐ জানি ☐ জানি না

৩২. আপনার বাসায় দুটি ডাস্টবিন রাখার প্রস্তাব করা হলো, একটিতে সহজে পঁচে এমন আবর্জনা, অন্যটিতে সহজে পঁচে না এমন আবর্জনা, আপনি সহজে পঁচে না এমন আবর্জনা কিছু দিন পর-পর ডাস্টবিনে ফেললেন বা ফেরীওয়ালার কাছে বিক্রি করলেন, আর অন্য ডাস্টবিন এর আবর্জনা এক/দুই দিন পর পর ফেললেন, এ ব্যাপারে আপনার মতামত কি ? ☐ ভালো হয় ☐ ঝামেলা হবে ☐ খরচ বেশী হবে

৩৩. আপনার এলাকার বর্তমান আবর্জনা ব্যবস্হাপনা কেমন? ☐ বেশ ভালো ☐ ভালো ☐ সন্তোষজনক ☐ সন্তোষজনক না

৩৪. যদি না হন তবে এই ব্যবস্হাপনার কোথায় ত্রুটি আছে? ☐ ধরন অনুযায়ী আবর্জনা পৃথক না করা ☐ সিটি কর্পোরেশনের ডাস্টবিনের ধরন এবং অবস্হান ☐ সিটি কর্পোরেশনের গৃহীত পদক্ষেপ ☐ অর্থনৈতিক কারণ ☐ সচেতনতার অভাব

৩৫. আপনার এলাকা ময়লা-আবর্জনা মুক্ত ও পরিছন্ন থাকবে এই রকম ব্যবস্হা ☐ খুব ভালো হবে ☐ ভালো হবে ☐ না হলেও হয়

৩৬. আবর্জনা ব্যবস্হাপনা সম্পর্কে জনসচেতনতা কি ভাবে বৃদ্ধি করা যায়? ☐ টিভি/রেডিওর/পত্রিকার সাহায্যে ☐ মিটিং করে ☐ বাড়ী বাড়ী গিয়ে বুঝিয়ে ☐ কোন কিছুর দরকার নেই

Survey on Integrated Management
(English Translation)

Answer the following questions using (√) sign, one or more (where applicable)

Name: ....Gender: .... Age: .... Educational Qualification: .... Profession: .... Monthly Income: ...... No. of Family Member......... (Adult...... Child........)

Household Solid Waste Segregation, Storage and Disposal

1. How do you store your household waste? □ Dustbin □ Polythene/bag □ Open Space □ Do not Store
2. What type of dustbin do you use in the house? □ Plastic □ Metal □ Basket □ Others □ Do not use dustbin
3. What is the cost of your dustbin? □ Below 50 Taka □ 100-150 Taka □ Above 150 Taka
4. What type of waste stored in your dustbin? □ Mixed wastes □ Separate them for reuse
5. How do you dispose pet bottle/container/Coke can/ water bottle? □ With kitchen waste □ Reuse □ Sell
6. How do you dispose plastic/polythene? □ With kitchen waste □ By sweeping □ By through drain
7. How do you store wastes in dustbin? □ Directly □ Using polythene □ Using paper
8. Where do you dispose used battery/ bottles of spray? □ With kitchen waste □ Separated from others □ Sell
9. What type of dustbin do you prefer? □ Round plastic □ Rectangular plastic □ Metal □ Others
10. What is your suggestion about the cover of your dustbin? □ Easy handle □ Automatic cover □ Open

On-site Storage and Disposal

11. How do you dispose your household waste? □ By servant □ By self □ Door to door collection
12. Where do you dispose the waste? □ Dustbin □ Door to door collection □ Drain □ Haphazardly
13. When do you dispose waste? □ 6 - 10am □ 10am - 2pm □ 2 - 6pm □ 6 - 10pm □ No fixed time
14. Do you pay monthly for this? □No □Yes, Taka 5-10 □Taka 10-20 □Above Taka 30
15. Do you agree to pay for door to door waste collection? □ Yes □ No
16. How much you can pay monthly for this? □Above Taka 30 □Taka 30 □Taka 20 □Taka10 □Nothing
17. If you can not pay - is it only for economical reason? □ Yes □No

Waste Management

18. In your area, is there any dustbin of City Corporation? □ Yes □ No
19. If yes, what is the distance from your house? □ Near (below 250 yd) □ 250-1000 yd □ Above 1000 yd
20. What is the preferable walking distance of dustbin from your house? □ 5mins. □ 5-10mins. □ Over 10mins.
21. Which type of waste disposal system do you prefer? □ Dispose in dustbin □ Door to door □ No dustbin
22. Which is the suitable waste collection time from your home? □ Morning □ Noon □ Afternoon □ Evening
23. How many times do you prefer to collect waste? □ Once a day □ Twice a day □ After 1 day □ After 2 days

24. Does the waste collect regularly from your local dustbin? □ Yes, □ No
25. Does the cleaning activities of waste done in daylight? □ Yes, □ No
26. Do you have any idea where is the ultimate destination of collected wastes? □ Yes □ No
27. City Corporation disposes the collected wastes in an open place, is it a good system? □ Yes □ No
28. The environment is polluted by the open dumping of wastes, are you aware of it? □ Yes □ No
29. Which part of waste do you reuse/sell? □Paper □Plastic □Metal □Rubber/Leather □Cloth □Others □Don't sell/reuse
30. How much you can earn monthly by reuse/sell? □ Below Taka 25 □ Taka 25-50 □ Above Taka 50 □ Nothing
31. Do you know humus can be produced from waste which is used as fertilizer? □ Yes □ No
32. It is proposed that you will use 2 dustbins, one for kitchen wastes needs to dispose daily or after 1 day and the other is for low biodegradable & inorganic wastes which you can store for some days or sell, what is your opinion? □ Good □Management problems □Cost will increase
33. What is the present waste management system in your area? □ Very Good □ Good □ Satisfied □ Not satisfied
34. Where is the problem if you are not satisfied with this system? □ Lack of proper segregation □ Type and location of dustbin □ Steps taken by the City Corporation □ Economical Condition □ Lack of awareness
35. If there is a system by which your area will be clean and waste free, it is. □ Very good □ Good □ No need
36. How the people's participation/motivation can be increased in waste management? □ By TV/ Radio/ Newspaper □ By meeting □ Personal motivation □ Nothing.

ANNEXURE-B

Data Sheet: 01

Time: Date: Ward No: City Corporation:	Address:

Solid Waste Composition Data

N: **IL:**

Waste Type	Weight (kg/day)
Organic Waste	
Food & Vegetables Wastes	
Paper & paper Products	
Plastic/Polythene	
Pet Bottles/Oil container	
Textiles/Clothes/Rags	
Rubber	
Leather	
Wood	
Rope/Straw/Coconut	
Animal Bones	
(Others)	
Total Household Organic Wastes=	
In-Organic Waste	
Glass/Bottles	
Metal/Tin Can	
Ceramic/Crockery	
Bricks/Concrete/Demolition	
Dust/Ashes	
(Others)	
Total Household In-organic Non-hazardous=	
Battery	
Aerosol bottles	
Cleaner (Liquid/Shoe Polish/Remover etc.)	
Personal Care (Shampoo/Shaving/Nail Polish etc.)	
Paint Items (Container/Thinner)	
(Others)	
Total Household Inorganic Hazardous=	
Total In-organic=	
Total Generated Wastes=	
Per Capita Generation (kg/Capita/Day)=	

Name & Signature of Surveyors:	Name & Signature of House Owner:

Note: N - Family member/ No. of students/ No. of shops; IL – Income level (for only Residential areas)

Data Sheet: 02

Determination of Moisture Content in Laboratory

Date:				Sample No.:			
City Corporation:				Location:			
Sample No.	Dish (A)	Dish + Wet sample (B)	Dish + Dry sample (105 $^{\circ}$C) (C)	Wet Sample Ww= B-A	Water w = B-C	Moisture content (%)	Average (%)

Data Sheet: 03

Determination of Volatile Solid Content in Laboratory

Date:				Sample No.:			
City Corporation:				Location:			
Sample No.	Dish (A)	Dish + Oven dry (105 $^{\circ}$C) (B)	Dish + Oven dry (550 $^{\circ}$C) (C)	Solid wt of sample W=B-A	Loss of weight w =B-C	Volatile Solid (%)	Average (%)

Data Sheet: 04

Determination of Bulk Density in Laboratory

Date:				Sample No.:			
City Corporation:				Location:			
Condition	Sample No.	Empty Container Wt. (gm) (A)	Container + Sample, (gm) (B)	Weight of Waste, (gm) W=B-A	Volume of Container V (m^3)	Bulk density (W/V) kg/m^3	Average (Kg/m^3)
Loose							
Medium							
Compact							

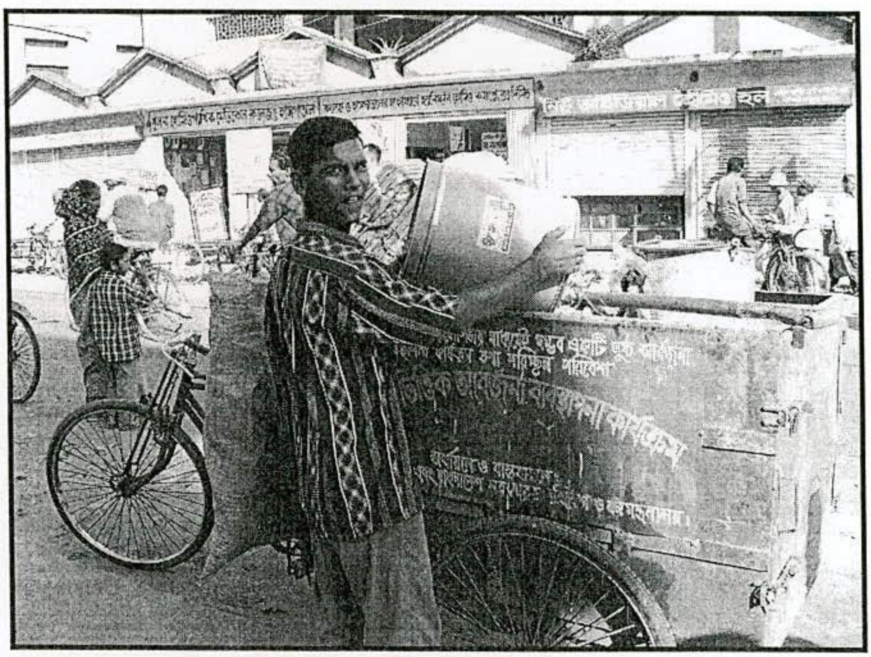
Data Sheet: 05

Particle Size Distribution in Laboratory

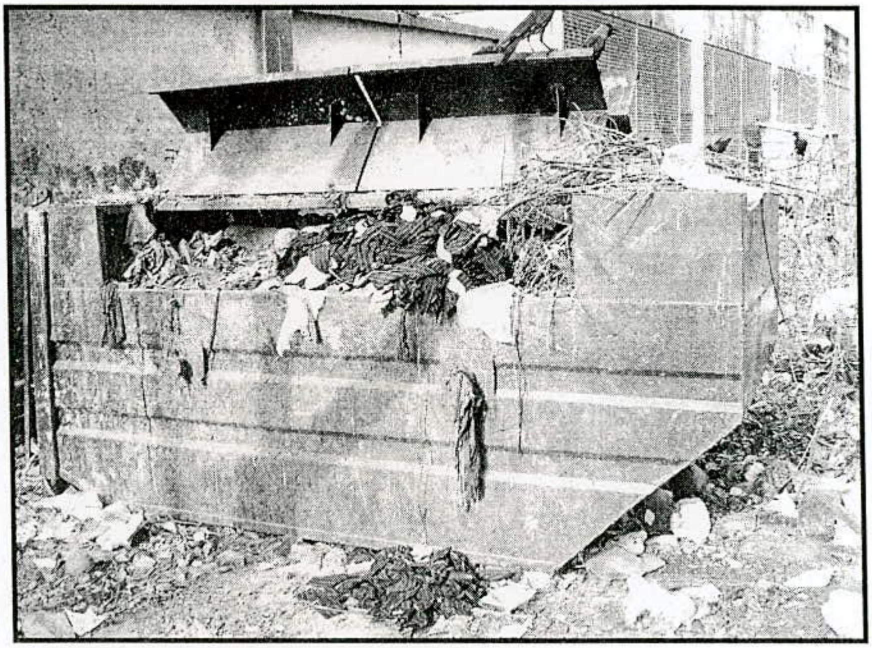
Date:			Sample No.:		
City Corporation:			Sample Condition:		
Location:			Dry weight of Sample:		
Sieve No.	Sieve Opening (mm)	Net weight Retained by screen (gm)	Percent Retained	Cumulative Percent Retained	Percent Finer

ANNEXURE C

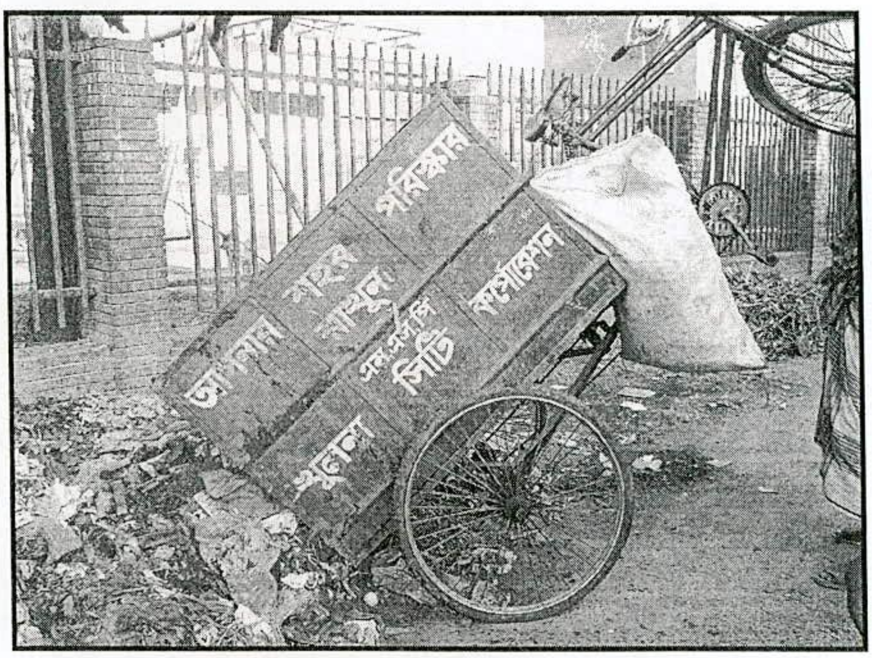
Photograph C.1 Separation of wastes in household level



Photograph C.2 Door to door solid waste collection by NGOs in Khulna city



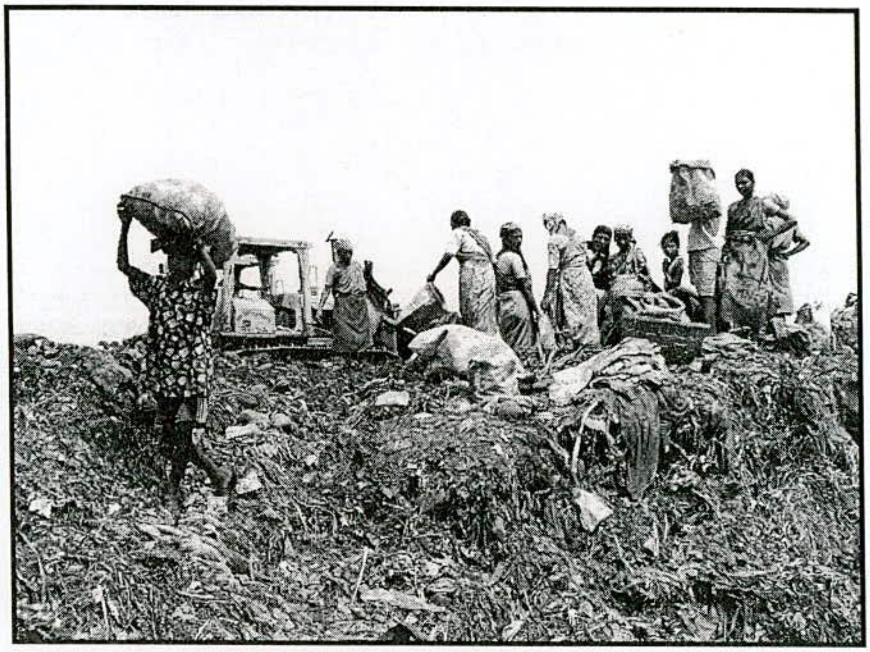
Photograph C.3 Condition of Secondary disposal site in Dhaka city



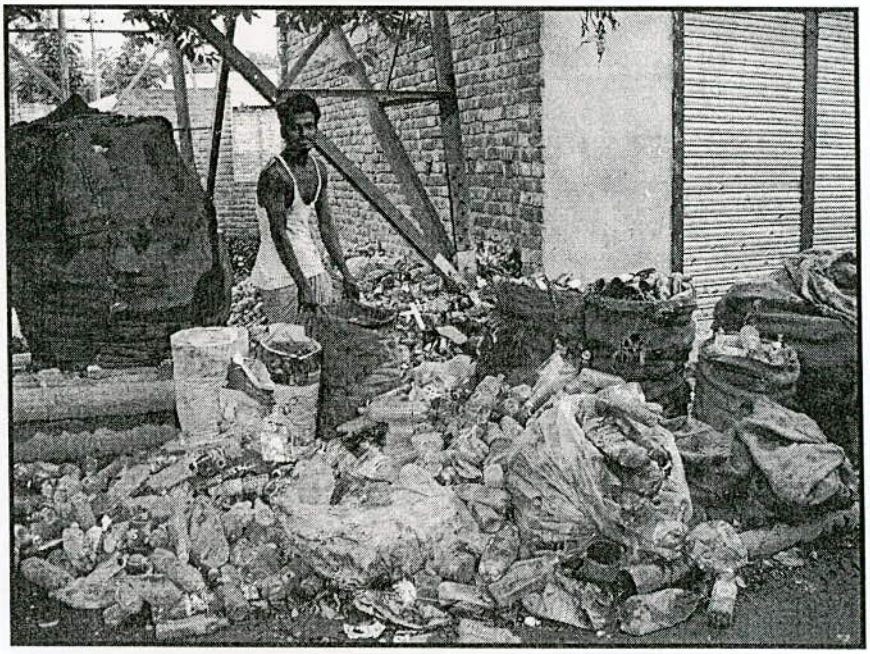
Photograph C.4 Collected wastes are disposed at secondary disposal site in Khulna city

Photograph C.5 MSW transfer from secondary disposal site to final disposal site in Chittagong city

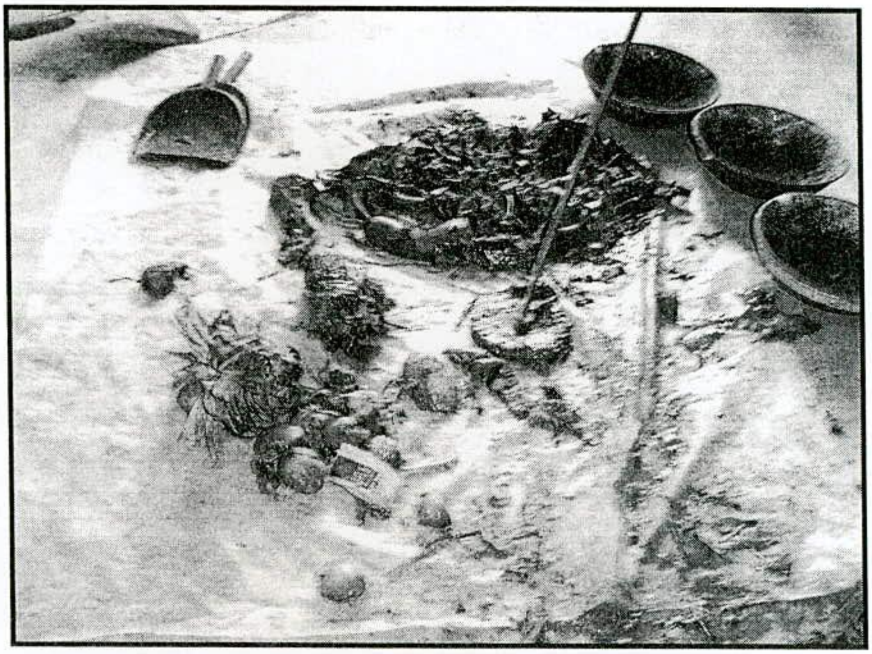
Photograph C.6 MSW is open dumped at ultimate disposal site in Khulna city



Photograph C.7 Waste scavenging at ultimate disposal site in Dhaka city



Photograph C.8 Recycling activities in Rajshahi City



Photograph C.9 Sample preparation for physical characteristics determination in laboratory

Photograph C.10 Composting activities in Khulna city

Photograph C.11 Ultimate disposal site in Rajshahi city

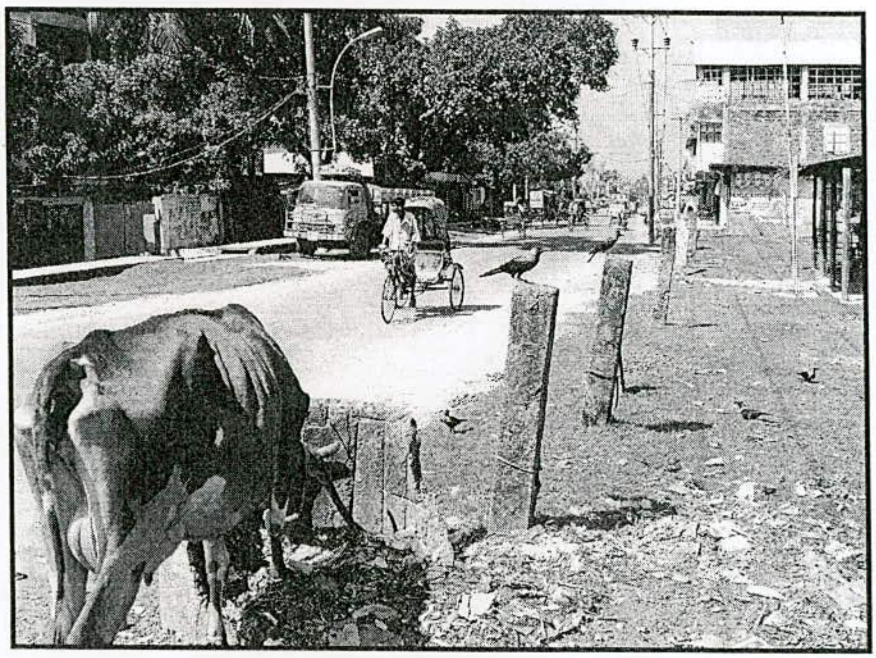
Photograph C.12 Ultimate disposal site in Chittagong city

Photograph C.13 Different sizes sieves for particle size distribution

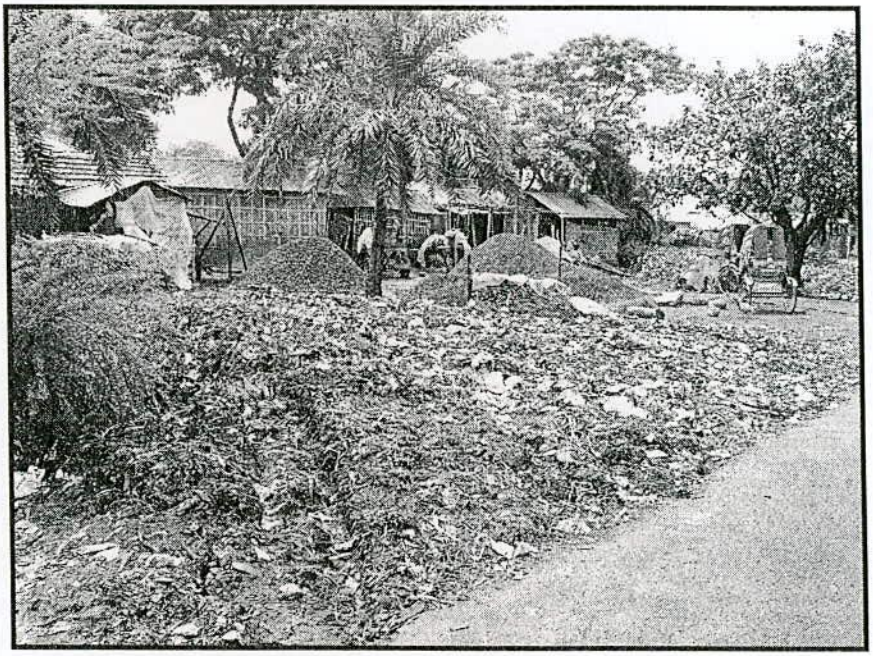
Photograph C.14 Disposal of wastes in Sylhet city

Photograph C.15 Collection of wastes in Khulna city

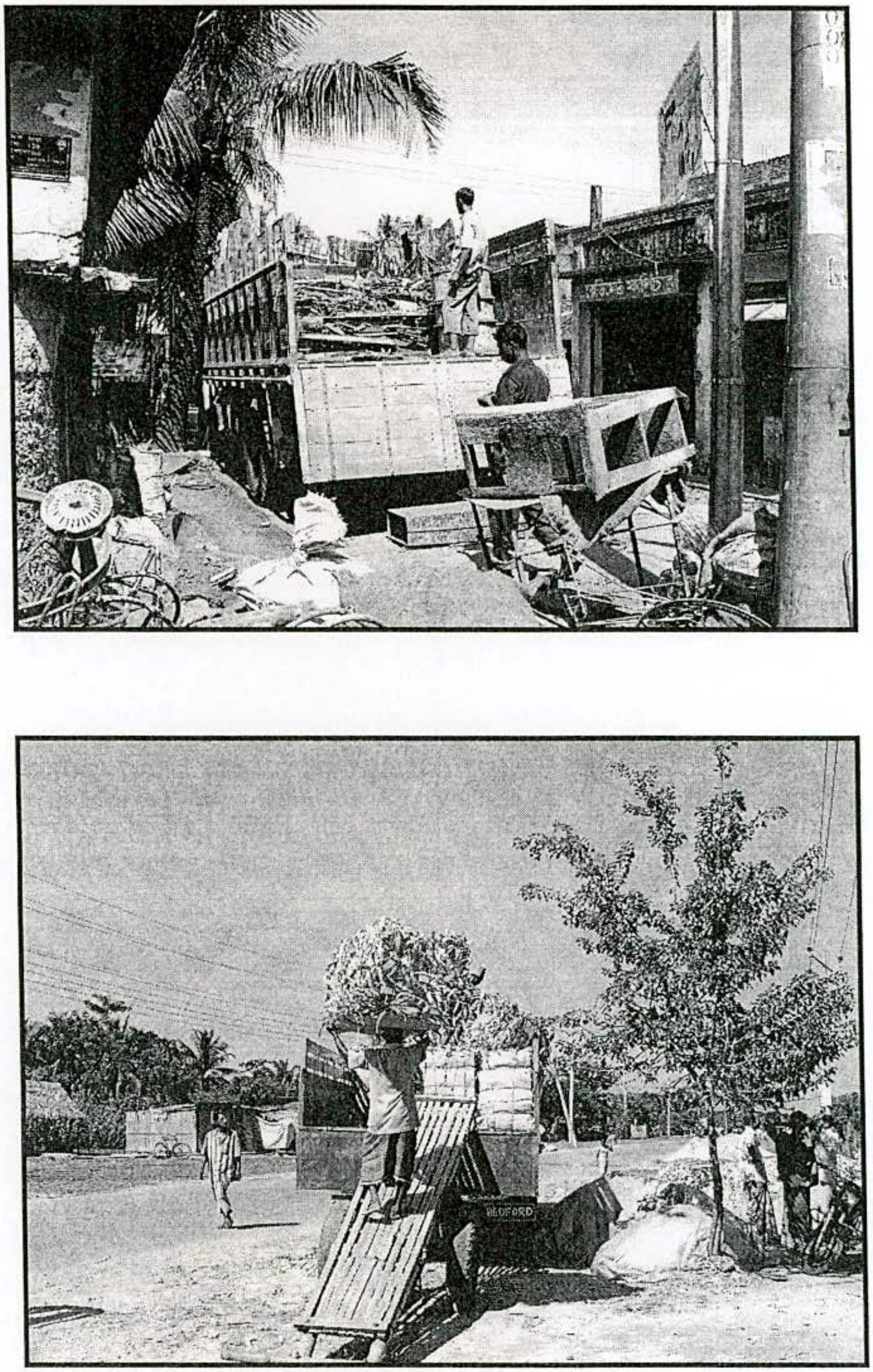
Photograph C.16 Condition of ultimate disposal site in Dhaka city



Photograph C.17 Animal scavenging at secondary disposal site in Khulna

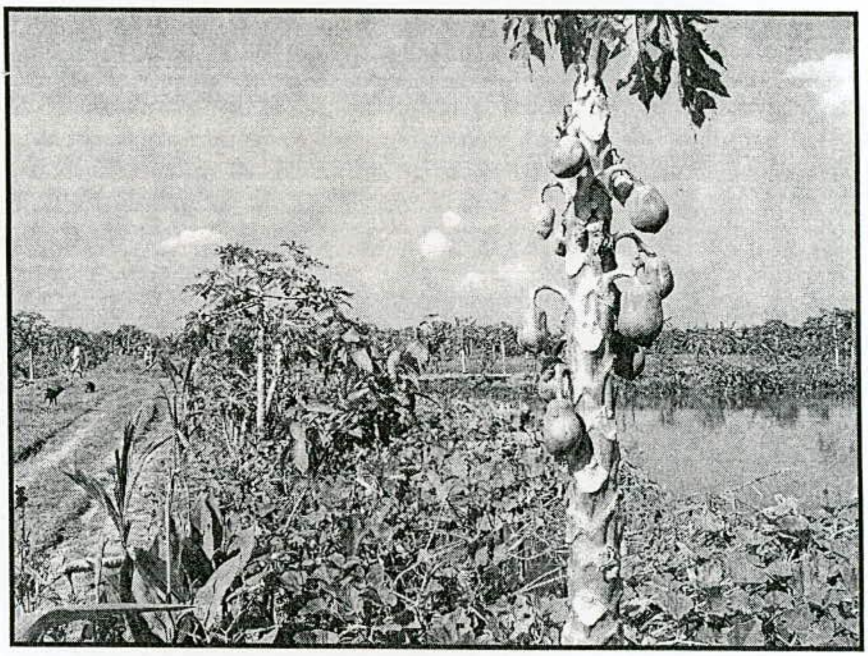


Photograph C.18 Unmanaged municipal wastes at roadside in Khulna city area



Photograph C.19 Transportation of recyclable materials to Dhaka from Khulna

Photograph C.20 Present situation of the disposal site in Khulna



Photograph C.21 View of future disposal site at Rajbandha in Khulna