Generation, Composition and Characteristics of Municipal Solid Wastes in Some Major Cities of Bangladesh

by

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

Khulna University of Engineering & Technology
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December 2005

Declaration

This is to certify that the thesis work entitled as "Generation, Composition and Characteristics of Municipal Solid Wastes in Some Major Cities of Bangladesh" has been carried out by Amimul Ahsan in the Department of Civil Engineering, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above research work or any part of this work has not been submitted anywhere for the award of any degree or diploma.

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Approval

This is to certify that the thesis work submitted by Amimul Ahsan entitled as "Generation, Composition and Characteristics of Municipal Solid Wastes in Some Major Cities of 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 December 2005.

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Acknowledgement

The author wishes to express his deepest and sincerest gratitude to his Supervisor Dr. Muhammed Alamgir, Professor, Department of Civil Engineering, KUET, for his incessant able guidance, spirited encouragement and constructive censure at every stage of this study.

The author expresses his heartfelt gratefulness to Dr. Quazi Hamidul Bari, Professor and Head, Department of Civil Engineering, KUET, for all his valuable suggestions, supports and cooperation. The author admits the worthy recommendations and advises of Dr. Md. Rezaul Karim, Professor, Department of Civil Engineering, KUET that enriched his thesis work and also grateful to Dr. Md. Abul Bashar, Professor, Department of Civil Engineering, KUET for his encouragement and inspirations.

The author wishes to convey honest gratefulness to Mr. KABM Mohiuddin, Lecturer, Civil Engineering Department, KUET for his continuous encouragement at every phase of his study and experiment. The author also grateful to Mr. K.H. Chowdhury, Lecturer, Civil Engineering Department, KUET for his encouragement and cooperation. Special thanks and grateful to Md. Rafiqul Islam, Programmer, IICT, BUET for his assistance and inspirations.

The author appreciatively remembers the assistance and encouragement of Project Coordinator, all Team Members and Partners, Research Assistants, of 'WasteSafe' project. The support provided in this research by Asia Pro Eco Programme of the European Commission under 'WasteSafe' project is gratefully acknowledged. The author is grateful to Dr. A. N. M. Mizanur Rahman, Professor and Head, Department of Mechanical Engineering, KUET, for giving permission to use Heat Engine Laboratory.

The author is indeed, thankful to Md. Abdul Malek, Md. Jalal Uddin and Md. Hasan Ahmed Khan Chowdhury, Scientific Officers, SRDI, Khulna for their kind assistances during the chemical analysis of wastes. Thanks are also extended to Md. Monirul Islam and Md. Kawsar Alam Mia, Laboratory Technicians, Geo Environmental Engineering Laboratory, KUET for their kind helps during the physical characterization of solid wastes. Finally, the author expresses a lot of gratefulness to his parents, brothers and sisters for their endless inspirations supports and all necessary helps during the course of this study.

- Amimul Ahsan, December 2005

To

my parents who taught me morality

and

my beloved younger brother and sisters

Abstract

Huge amount of Municipal Solid Waste (MSW) generation and its mismanagement has become one of the major concerned social and environmental issues in urban areas. Characteristics of MSW are important for evaluating infrastructure, technology and equipment needs, management programme and planning, especially with respect to the implementation of disposal as well as resource and energy recovery options. This study identifies the generation rate and total generation amount, composition, physical and chemical characteristics of MSW in four major cities of Bangladesh, namely, Dhaka, Khulna, Rajshahi and Barisal.

The MSW generation rates in residential, commercial and institutional areas are determined in each study city. The amount of MSW generations are 5340, 520, 170 and 130 tons/day for Dhaka, Khulna, Rajshahi and Barisal city, respectively and the percapita waste generation rates are varied from 0.325 to 0.485 kg/day for four major cities of Bangladesh. Food and vegetable waste is the predominant component in each sampling sources of residential areas due to the habit of food consumption and other inherent socio-economic aspects of the cities of Bangladesh. In MSW stream, food and vegetable waste range from 68.3 to 81.1%, while papers and plastics range from 7.2 to 10.7% and 3.1 to 4.3%, respectively. The remaining portions are rubber, cloth, metal, tin, glass, dust and others.

The important physical characteristics such as pH, moisture content, volatile solid content, bulk density and particle size are determined. It is observed that pH value varies from 7.70 to 8.69, while moisture and volatile solid content vary from 56 to 70% and 43 to 71%, respectively. The bulk density in loose state varies from 566 to 621 kg/m^3, while in medium and compact state, the bulk density varies from 764 to 951 kg/m^3 and 875 to 1127 kg/m^3, respectively. The important chemical characteristics are carbon, nitrogen, phosphorous, potassium and calorific value are also determined. The concentration of carbon ranges from 6.53 to 24.93%, while nitrogen, potassium and phosphorous vary from 0.56 to 1.62%, 0.38 to 1.37% and 0.31 to 0.41%, respectively. The highest and lowest calorific values are obtained as 20,467 kJ/kg for rubber and 5,907 kJ/kg for food wastes, respectively.

In the context of Bangladesh, MSW are suitable for composting since good concentration of carbon, nitrogen, phosphorous and potassium, while incompatible for incineration due to high moisture and organic contents.

Contents

List of Tables

List of Figures

List of Photographs

Abbreviations

ADB	:	Asian Development Bank
AR	:	Ash Residue
BBS	:	Bangladesh Bureau of Statistics
BCAS	:	Bangladesh Centre for Advanced Studies
BCC	:	Barisal City Corporation
BCSIR	:	Bangladesh Council of Scientific and Industrial Research
BUET	:	Dhaka University of Engineering and Technology
C	:	Carbon
CBO	:	Community Based Organization
CDS	:	Central Development Society
C/N	:	Carbon Nitrogen Ratio
DCC	:	Dhaka City Corporation
DMDP	:	Dhaka Metropolitan Development Program
EPA	:	Environmental Protection Agency
EPI	:	Extensive programme for Immunization
GOB	:	Government of Bangladesh
HCl	:	Hydrochloric acid
HCV	:	Higher Calorific Value
HH	:	Household
HII	:	Hospital Improvement Initiative
HNO_3	:	Nitric acid
ISWM	:	Integrated Solid Wastes Management
IWT	:	Indonesian Windrow Technique
JICA	:	Japan International Cooperation Agency
K	:	Potassium
KCC	:	Khulna City Corporation
KDA	:	Khulna Development Authority
KUET	:	Khulna University of Engineering and Technology
LCV	:	Lower Calorific value
LDACs	:	Least Developed Asian Countries
MC	:	Moisture Content
MSW	:	Municipal Solid Waste
N	:	Nitrogen
NGO	:	Non Governmental Organization
P	:	Phosphorous
PAS	:	Pan Asia Services

PCI	:	Pacific Consultants International
RAJUK	:	Rajdhani Unnayan Kartipakkha
RCC	:	Rajshahi City Corporation
RDA	:	Rajshahi Development Authority
RSWC	:	ROTEB - Solid Waste Consultancy
SDS	:	Secondary Disposal Site
SH	:	Shomobay Housing
SRDI	:	Soil Resource Development Institute
Tk.	:	Taka
UDS	:	Ultimate Disposal Site
UNDP	:	United Nations Development Programme
VS	:	Volatile Solid
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.

Solid waste management has become one of the major concerns in Bangladesh. This is mainly due to rapid urbanization taking place on an enormous scale in the cities and towns of the country. Rapid population growth and uncontrolled urbanization are severely degrading the urban environment and placing serious strains on natural resources and consequently, undermining equitable and sustainable development. Solid waste generation of urban areas of Bangladesh is increasing proportionately with the growth of its population, which is 5.6 percent per annum (JICA, 2004), while solid waste management capacity in cities and towns is lagging 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.

One of the main problems in solid waste management is to find out the generation of solid waste in a city as waste generation varies with each individual (Chan, 1993). The information of waste generation rate, trend of waste compositions and characteristics is important. This can make estimation for future generation rates and improve the efficiency of storage, collection, transportation and disposal so that a comprehensive solid waste management plan can be developed.

In this study, the solid waste generation, composition and basic characteristics are identified through in - depth study at four major cities of Bangladesh, namely, Dhaka, Khulna, Rajshahi and Barisal. Data are collected from different generation sources in a pre-set schedule basis and characterized by performing appropriate tests available. The wastes are analyzed in terms of generation sources, composition, physical and chemical characteristics by physical survey, field and laboratory experiments.

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, 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.

1.2 Background of the Study

In Bangladesh, specifically in the urban areas, appropriate measures for waste disposal are urgently needed due to the rapid population growth, which resulting the huge increase of MSW. 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.

In all major cities of Bangladesh, solid wastes are not segregated. All types of solid waste such as municipal waste, medical waste, industrial waste and agricultural waste are deposited and handle together, as a result the waste collection workers have suffered from a risk of getting infectious diseases. Soil and groundwater are also getting contaminated with toxic substances due to improper solid waste management. Various studies have been conducted by the assistance of Asian Development Bank (ADB), Japan International Cooperation Agency (JICA) and United Nations Development Program (UNDP) in only Dhaka city whereas no explicit study in other major cities of Bangladesh has been conducted so far.

Since the MSW information bank available in Bangladesh is lagging behind about the explicit characteristics of MSW, study considered four major cities of Bangladesh, namely Dhaka, Khulna, Rajshahi and Barisal, as case study sites to identify the generation rate, amount, composition and characteristics to get the complete picture of MSW in those cities and Bangladesh in general which is a Least Developed Asian Countries (LDACs).

The outcome of this research will clearly represent the present situation of MSW generation, composition and basic characteristics of these studied cities of Bangladesh. The findings will be beneficial for any responsible authority or concerned stakeholders who are interested for solid waste composting plant installation, power generation plant installation, fire wood (charcoal) production or any other cost effective sustainable solution of MSW. City authorities will also benefited in installation of integrated management of MSW and its safe disposal.

1.3 Objectives of the Study

This study is aimed at to estimate the rate and amount MSW generation in four major cities of Bangladesh and also to identifying the nature of MSW in term of composition and characteristics.

The major objectives of this study can be listed by the followings:

(i) To determine the MSW generation rate at residential, commercial and institutional areas in four major cities of Bangladesh.

(ii) To estimate the total amount of MSW generation in four major cities of Bangladesh.

(iii) To identify the composition of MSW through field survey and determine the physical and chemical characteristics of MSW by laboratory experiments.

(iv) To find out the change of MSW generation, composition and characteristics in four major cities by comparing with the data of previous studies.

(v) To compare the MSW generation, composition and characteristics with the data of recent studies in major cities of developed and developing countries.

1.4 Scope and Limitations of the Study

At present no effective MSW management is practiced even in major cities of Bangladesh. Generated MSW are partially collected and just dispose into open low-lying areas, known as Ultimate Disposal Site (UDS) by city authority. MSW generation rate, total amount of generation, composition, physical and chemical characteristics in four major cities of Bangladesh are determined through this study for cost effective technically sound and sustainable management. The reliable informations are collected and the relevant parameters are determined based on the data of primary and secondary sources. The change of MSW generation, composition, various physical and chemical characteristics are determined by compared with the data of previous studies in four major cities of Bangladesh.

The limitations faced in this research are mainly time and reliable data. Lack of time only allowed the waste sampling from residential, commercial and institutional areas. 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. Another two major cities of Bangladesh, Chittagong and Sylhet are not incorporate in this study due to time and cost constraints. Industrial wastes are not estimate in this study due to time constraint.

1.5 Organization of the Thesis

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

Chapter 1	:	This chapter includes general introduction, background, objectives, scope and limitations of the study.
Chapter 2	:	Literature review covering details about source and types of MSW, various methods of estimation of MSW generation, physical composition and various characteristics of MSW are described in this chapter. Brief reviews of relevant literatures are also discussed here.
Chapter 3	:	Overview of study areas including general informations and existing MSW management practices are described in this chapter.
Chapter 4	:	This chapter includes methodology of data collection, field survey & testing, and various laboratory experiments have been conducted.
Chapter 5	:	This chapter presents the MSW generation in four major cities of Bangladesh. Details of composition, physical and chemical characteristics of MSW of four major cities are provided in this chapter.
Chapter 6	:	The results obtained in this study including brief discussion on the results are presented in this chapter. Comparison of this results with previous studies and also with the recent studies of major cities of developed and developing countries are also described here.
Chapter 7	:	This chapter includes a precise list of conclusions of the findings as an outcome of this study and provides a number of recommendations for future research.
References	:	A list of relevant publications and reports, which may be useful for any future study in this context, is included at the end of the main chapters.
Abbreviations	:	Lists of abbreviations used in this thesis are provided here.

CHAPTER TWO

LITERATURE REVIEW

2.1 General

Since the beginning, humankind has been generating waste, be it the bones and other parts of animals that they slaughtered for their food or the wood that they cut to make their carts. With the progress of civilization, the waste generation became of a more complex nature. At the end of the 19th century the industrial revolution saw the rise of the world of consumers. Not only the air get polluted but the earth itself became more contaminated with the generation of non-biodegradable solid waste. The rapid increase of population and urbanization is largely responsible for the increase of solid waste (http://edugreen.teri.res.in/explore/solwaste).

The purpose of this chapter is to provide background of different sources and types of MSW, generation rates estimation and it's affecting factors, common methods of estimating MSW generation, methods of characterizing and sampling etc. Physical composition and other important physical, chemical, biological and mechanical characteristics of MSW are also described here.

2.2 Solid Wastes

Solid waste comprises all the wastes arising from human and animal activities that are normally solid which are 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:

a) Municipal Solid Waste (MSW)

b) Industrial waste

c) Agricultural waste

d) Municipal sludges and

e) Others waste

MSW comprises mainly residential, commercial, institutional, street sweeping, etc. Industrial waste includes waste from any factory or industrial process (excluding mines and quarries). Agricultural waste includes waste and residues resulting from diverse agricultural activities- such as the planting and harvesting of paddy, jute, trees and vine crops; the production of milk; the production of animals for slaughter, etc. Municipal sludge comprises human sludges and other types of sludges from wastewater treatment plant, water treatment plant, or air pollution control facility. Others waste includes rest of all solid, semi-solid materials resulting from industrial, commercial, mining and agricultural operations, and from community activities such as inert waste, civic amenity waste, construction and demolition waste, automobile bodies, etc. (Tchobanoglous et al., 1993).

Human and animals have used the resources of the earth to support life and dispose the waste from the days of primitive society. Disposal of human and other wastes did not pose a significant problem in early times, for the population was small and the amount of land available for the assimilation of wastes was large. Although emphasis is currently being placed on recycling the energy and fertilizer values of solid wastes, the farmer in ancient times probably made a bolder attempt at this. Indications of recycling may still be seen in the primitive, yet sensible, agricultural practices in many of the developing nations where farmers recycle solid wastes for fuel or fertilizer values.

The relationship between public health and the improper storage, collection and disposal of solid wastes is quite clear. Public health authorities have shown that the rats, flies and other disease vectors breed in open dumps, as well as in poorly constructed or poorly maintained housing, in food storage facilities and in many other places where food and garbage are available. The U.S. Public Health Service (US PHS) has published the results by tracing the relationship of 22 human diseases to improper solid waste management.

Ecological phenomena such as water and air pollution have also been attributed to improper management of solid wastes. For instance, liquid from open dumps and poorly engineered landfills has contaminated surface waters and groundwaters. In mining areas the liquid leached from waste dumps may contain toxic elements such as copper, arsenic and uranium, or it may contaminate water supplies with unwanted salts of calcium and magnesium. Although nature has the capacity to dilute, disperse, degrade, absorb or reduce the impact of unwanted residues in atmosphere, in waterways and on land; ecological imbalances have occurred where the natural assimilative capacity has been exceeded.

2.3 Municipal Solid Waste

MSW is normally assumed to include all the community wastes with the exception of industrial process wastes, agricultural solid wastes and sewage sludges. As defined by the U.S. Environmental Protection Agency (EPA), it includes durable goods, non-durable goods, containers and packaging, food wastes, yard wastes and miscellaneous inorganic wastes from residential, commercial and institutional sources. Examples from these categories include: appliances, newspapers, clothes, food scrapes, boxes, disposable tableware, office and classroom paper, wood pallets, rubber tires and cafeteria wastes. Waste-to-energy combustion and landfill gas are byproducts of MSW. The MSW industry has four components: recycling, composting, land filling, and waste-to-energy via incineration.

MSW does not include a wide variety of other non hazardous wastes that often are landfilled along with MSW. Examples of these other wastes are municipal sludges, combustion ash, hazardous and nonhazardous industrial process wastes, agricultural solid wastes, construction and demolition wastes and automobile bodies (Tchobanoglous et al., 2002).

2.4 Sources of Municipal Solid Waste

The sources and types of MSW along with the data of composition and generation rates are the basic parameters in the design and operation of the functional elements associated with the management of solid waste (Tchobanoglous et al., 2002). Sources of solid waste in a community are usually related to land use and zoning. In general, sources of MSW are categorized as: (1) Residential (2) Commercial (3) Institutional and (4) street sweepings (Chan, 1993).

Residential sources: Residential wastes are the main sources of MSW in Bangladesh. Major portion are generated due to household activities. The types of dwellings are single family, multifamily, low, medium, and high-rise apartments. These wastes include mainly food wastes, rubbish, paper, ashes and others.

Commercial sources: Solid wastes in commercial sources are generated from stores, restaurants, markets, hotels, service station and others. These wastes include mainly papers, plastics, packaging materials, food waste and others.

Institutional sources: The sources of these wastes are mainly universities, schools, hospitals, clinics, pathological laboratories, prisons and government centers. These wastes include mainly paper, plastics and medical waste.

Street sweepings: These wastes are mostly generated in open areas such as streets, alleys, parks, highways, vacant lots, playgrounds, beaches, recreational areas etc. Street sweepings include dust, rubbish and others.

2.5 Generators of Municipal Solid Waste

The term generator means any person, by site or location whose act or process, produces solid waste or first causes it to become regulated. Generators of MSW according to sources are given in Table 2.1.

2.6 Types of Municipal Solid Waste

There are different types of MSW, which are stated in Table 2.2. Some of MSW are categorized as the followings (Chan, 1993):

Food and vegetable wastes: Consist of food, fruit and vegetable residues resulting from the handling, preparation, cooking and food consuming. The characteristics of these wastes are highly moisture contents and decompose rapidly during hot climate, which will lead to emission of offensive odor.

Table 2.1 Typical location of solid waste generation associated with various sources	
Sources	**Locations where wastes are generated**
Residential	Slum, town houses, single family and multifamily detached dwellings, duplexes, low, medium and high-rise apartments, etc.
Commercial	Stores, restaurants, markets, shopping malls, city centers, hotels, motels, warehouses, print shops, service stations, airports, auto repair shops, etc.
Institutional	Schools, hospitals, prisons, medical facilities, governmental centers, etc.
Industrial	Packaging of components, office wastes, lunchroom and restroom wastes (but not industrial process wastes)
Open areas	Street cleaning, landscaping, catch basin cleaning, parks and beaches, other recreational areas, etc.

Source: Tchobanoglous et al., 1993

Table 2.2 Types of MSW associated with various sources within a community	
Sources	**Major types of wastes**
Residential	Food and vegetable wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, tin cans, aluminum, other metals, ashes, street leaves, special wastes (including bulky items, consumer electronics, white goods, yard wastes collected separately, batteries, oil, and tires), household hazardous wastes, etc.
Commercial	Paper, cardboard, plastics, wood, food waste, glass, metals, special wastes (including bulky items, consumer electronics, white goods, yard wastes collected separately, batteries, oil, and tires), hazardous wastes, etc.
Institutional	As above in commercial and hospital waste, etc.
Industrial	Packaging materials, food wastes, etc. (but not industrial process wastes)
Open areas	Dust, rubbish, landscape and tree trimmings, catch basin debris, general wastes from parks, beaches and recreational areas, etc.

Source: Tchobanoglous et al., 1993

Garbage: Solid waste consisting of putrescible animal and vegetable waste materials resulting from the handling, preparation, cooking and consumption of food, which includes waste materials from markets, storage facilities, handling; sale of produce and other food products. MSW are commonly known as trash or garbage.

Rubbish: Consists of combustible and non-combustible solid waste from households, institutions and commercial activities etc., excluding food waste or other putrescible wastes. Generally combustible rubbish includes materials such as paper, cardboard, plastics, textiles, rubber, wood, furniture and garden trimmings. Noncombustible rubbish consists of materials such as glass, crockery, tin cans, aluminum cans, ferrous metals, steel and dirt.

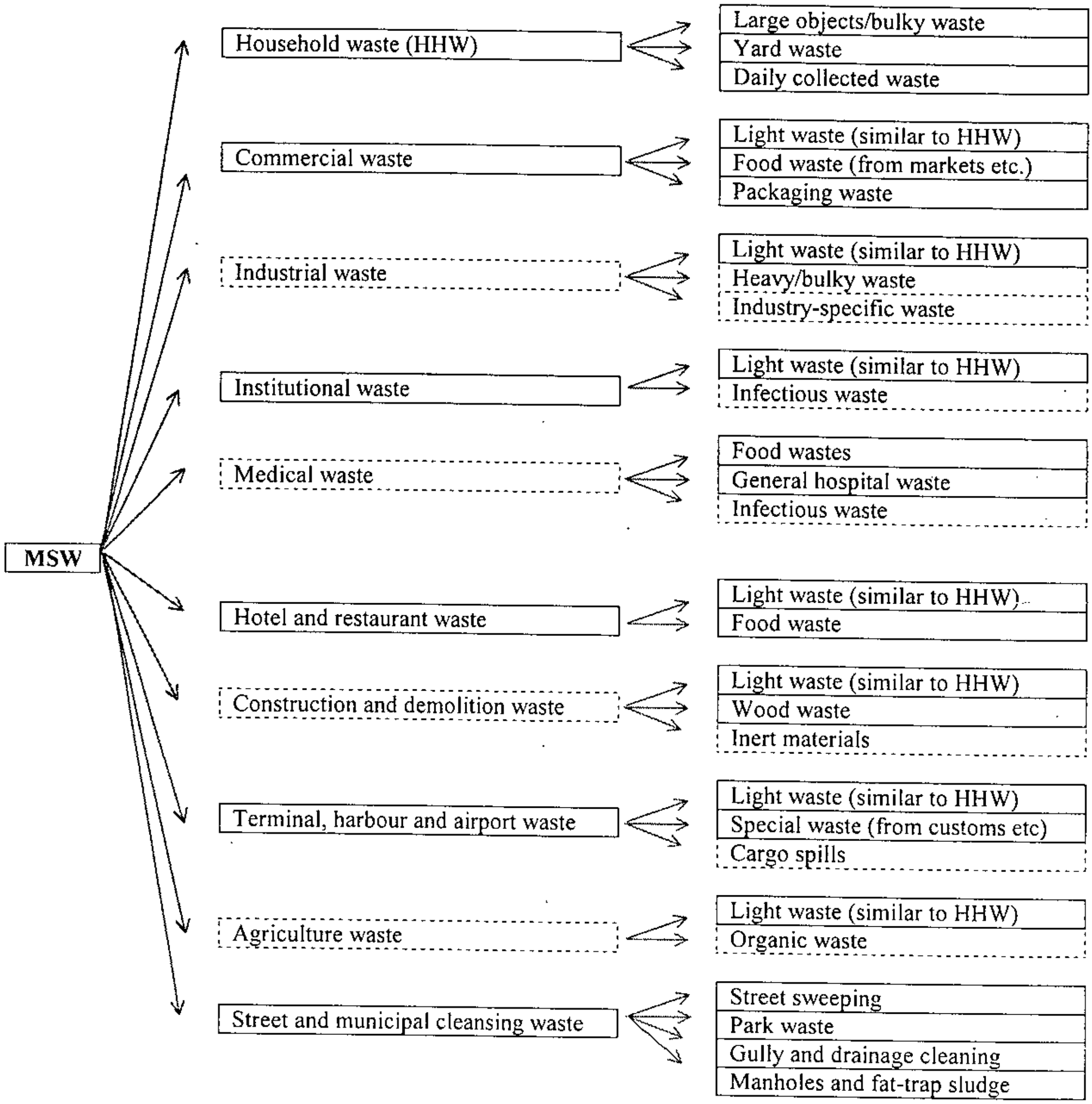
Ashes and residues: These are materials remaining from burning of wood, coal and other combustible wastes in home, stores, institutions and municipal facilities of heating and cooking. This category does not include the residue from power plant. Ashes and residues are normally composed of fine, powdery materials, cinders, clinkers and small amounts of burned materials.

Hospital Waste: (a) Any waste which consists wholly or partly of human or animal tissue, blood or other body fluids, excretions, drugs or other pharmaceutical products, swabs or dressings, syringes, needles or other sharp instruments, etc. which unsafe and may prove hazardous to any person coming into contact with it. (b) Any other waste arising from medical, nursing, dental, veterinary, pharmaceutical or similar practice, investigation, treatment, care, teaching or research, or the collection of blood for transfusion, etc. which may cause infection to any person coming into contact with it.

The breakdown of major types of MSW according to the generation sources is presented in Figure 2.1 as proposed by Jenson et al. (2004).

2.7 Generation Rates of Municipal Solid Waste

The generation rates and amount are counted as basic information required for the sustainable design of solid waste management. In addition, the economical and efficient design of collection task, on-site storage, waste processing and disposal are based on such data. The peak generation rate would seem to be the proper design parameter. However, a solid waste



Note: The waste types in dotted frames only partly enter the municipal waste stream

Figure 2.1 Breakdown of major waste types in MSW

management must be responsive to an input material flow rate beyond the control of its operators, the important parameters should be future generation rates. Thus measurable or estimatable of forecasting day-to-day or year-to-year should be included in the design, planning and implementation phases of solid waste management.

In general, the generation rate only indicates particular generator under study and the period of the study. Different activities have been conducted in different sources; therefore generation-rates can be expressed in different units in order to illustrate a scene of the generator. Considerable confusion has been arisen because generation rates are determined by different methods of measurement and lack of clarity in the waste categories included.

A study by U.S. EPA in 1969 (as quoted in Chan, 1993), derived the equation for estimating the quantity of solid waste generation rate (W) within a residential area. The equation is in the form as:

$$W = 35.8\ S - 7.25\ F - 6.44\ D + 0.82\ P - 0.4\ I + 89400$$

In the study from Shell and Shupe in 1972 (as quoted in Chan, 1993), the tons of MSW in a route (W) could be estimated as:

$$W = 0.0179\ S - 0.00376\ F - 0.00322\ D + 0.0071\ P - 0.0002\ I + 44.7$$

Where

S = Number of stops

P = Number of families

D = Number of single-family dwelling units

P = Population

I = Adjusted gross income per dwelling unit

Grossman et al. in 1974 (as quoted in Chan, 1993), developed a model for a town in New England and yielded the following results:

$$Y = 619\ X_1 + 655\ X_2 - 35\ X_3 + 37\ X_4 + 8.5\ X_5 + 626$$

Where

Y = gallons of uncompacted solid waste produced per week

The affecting factors are:

X_1 = blockfaces with low income

X_2 = blockfaces with middle income

X_3 = single-unit dwellings

X_4 = dwellings containing two to four living units

X_5 = dwellings with five or more living units

Hartono (1984) estimated the amount of solid waste of each sources in Bandung city of Indonesia, by the following empirical equations:

(a) Solid wastes from residential areas:

$$y_{11} = 1.75 + 2.26\ X_{11} - (6.9x10^{-1})\ X_{14} + (6.7x10^{-3})\ X_{17}$$

Where

y_{11} = generation rate, l/day

The affecting factors are:

X_{11} = number of people in the house

X_{14} = income level

X_{17} = population density of the area, number/km^2

(b) Solid wastes from streets:

$$y_{31} = 18.23 + (6x10^{-2})\ X_{31} + 6.38\ X_{32} + (17x10^{-3})\ X_{33}$$

Where the affecting factors are:

X_{31} = length of street, m

X_{32} = width of street, m

X_{33} = population density of the area, number/km^2

(c) Solid wastes from offices:

$$y_{51} = 573.63 + (35x10^{-2})X_{51} - 37.63X_{53} - 13.03X_{54}$$

Where the affecting factors are:

X_{51} = number of officers

X_{53} = number of storeys

X_{54}= number of work hours

JICA (1982) derived the relationship between solid waste generation volume and land used pattern as stated below:

$$g = 0.474\ X_1 + 0.611\ X_2 + 1.23\ X_3 + 0.487\ X_4$$

Where

g = generation unit by area, $m^3/km^2.d$

The affecting factors are:

X_1 = land use for residential, in percent

X_2 = land use for mixed use, high density, in percent

X_3 = land use for mixed use, low density, in percent

X_4 = land use for institutional, in percent

The study was carried out by Sridhar et al. (1985) to investigate the characteristics of refuse in Ibadan city of Nigeria. It showed that the waste generation in this city is affected by the economic development after the independence and the discovery of oil. The used of plastic and polythene were increased since that period. Also, the traditional lifestyle caused to the significant amount of garbage (59.3%) and leaves (7.9%), which were mainly used for preparing food while generation rates were varied with different socio-economic group.

Matsuto and Ham in 1989 (as quoted in Chan, 1993), illustrated the habits and lifestyle, which affected the household refuse generation in Sapporo (Japan) and Madison (USA). The two selected cities have many similarities except the lifestyle. The study showed that lower generation rate in Madison, due to the used of preprocessed food and less consumption of fish. Also, high metal generation in Madison was due to the ferrous cans for food, soup and aluminium for soft drink. In Sapporo, the high glass generation rate could be attributed to the wide use of returnable bottles.

According to the Annual Report of EPA of Taipei Municipal in 1991 (as quoted in Chan, 1993), the waste generation rates has increased from 2354 tons/day in 1985 to 3213 tons/day in 1991. Per capita rates in 1991 have reached to 1.23 kg/capita/day. Such situation was caused by the improvement of standard living and changes in living habits. From the previous studies carried out by the agency from 1979 to 1990, garbage varied from 28.28 to 27.69%, papers varied from 23.40 to 30.01% while plastics varied from 11.2 to 20.17%.

2.8 Affecting Factors for Municipal Solid Waste Generation

The generation rates and characteristics of MSW are varied in different countries and cities because of different influenced factors. The most important factors are listed as the followings:

2.8.1 Source reduction and recycling activities

Individual household waste reduction methods

This factor only reduces the waste collected while the generation rates from each household are remained a same level. The reduction methods are different in both the developed and developing countries. Home grinders are commonly applied in the former. Open burning or dumping into rivers is existed in the latter, which might cause to the air and water pollution.

The extent of recycling and sorting systems

Under this system, some reusable materials are sorted from the waste before sending to processing or treatment plants. Quantities of waste collected are reduced and the reusable materials such as papers and bottles may not exist in the waste stream.

2.8.2 Public attitudes and legislation

Public attitude

Significant reductions in the quantities of solid wastes will occur when public are willing to change their habits, life styles and with awareness in maintaining an aesthetic environment and national resources. The factors that affect MSW are important in planning the solid waste management system and can be considered into the development of national environment policies as well as other policies. Therefore, the impact of these factors in a city should be evaluated separately in each situation.

The habits and customs of living

These factors have greatly affected both the waste generation and composition from many aspects such as festivals, habits or life style. The waste characteristics are varying from city to city and also within the same city itself too. For example, generation rates during festival seasons are usually higher than normal because of the preparation and celebration. Also, different life style would perform its specific waste stream characteristic.

Legislation and regulation

The existence of local, state and federal regulations concerning the use and disposal of specific materials may have affected the generation of certain types of wastes.

2.8.3 Geographic and physical factors

Geographic location

This factor includes geographical characteristics of the land, climate and rainfall season. A significant situation of variation in the amount of garden waste generated, weight of refuse, moisture contents etc. are affected by the changes in seasons or climate. In some countries, the waste amount and characteristics are varied from spring to winter within a year. Furthermore, the raining and typhoon seasons in some tropical countries may have affected both quantity and composition of waste too.

Population density

Wastes are mainly produces through human activities. Therefore, the variation in population density and number has greatly influenced the amount of waste generated within a city and as whole in a country.

Economic conditions and standard of living

The economic status or conditions have affected the amount and types of goods that have been purchased. Usually, wealthier group with higher purchase ability, their goods tend to be higher quantity and more exquisite, thus produce higher amount of wastes and packaging materials.

Industrial, commercial and housing development planning

The rapid development of these planning within a city has main effects on the quantity of municipal wastes. Such urbanization activity may encourage the migrants and thus increase the population and amount of waste generation.

Increase in the use of new products

This trend has effects on the characteristics of waste such as density, moisture content and chemical compositions. The increase of packaging materials, pre-cooked or frozen foods and disposable diapers etc. would have changed the waste stream within a community.

Frequency of collection and service coverage

It is common that higher frequency of collection and thus more wastes are collected.

Fruit seasons

During these seasons, the portion of fruit wastes has usually increased the amount of garbage components and the moisture contents of the refuse.

Waste collection cost from waste producer

Increasing of collection cost would cause to reduce the waste generation rates. However, this may only effective for some bulky wastes, which are collected by special services. In some commercial and industrial areas, the payment by waste generators is due to the number of collection trips, therefore the payees always tend to limit the amount of waste generated.

2.9 Methods of Estimation of Municipal Solid Waste Generation

There are many different methods of measurement of solid waste generation. The measure of generation rate that can be used in determination the total amount of solid waste. Methods commonly used to assess solid waste quantities are:

(a) Load-Count Analysis
(b) Weight-Volume Analysis
(c) Materials Mass Balance Analysis
(d) Statistical Analysis

Usually, both the volume and weight are used for measuring the solid waste quantities. However the volume as a measure will always mislead the real situation because loose waste and compacted waste of a cubic meter will provide different volume readings. Thus the degree of compaction should be notify when the quantity are measured by volume (Tchobanoglous et al., 1993). In order to avoid confusion, solid waste quantity should be expressed in terms of weight because tonnage can be measured directly without consideration of the compaction.

2.9.1 Load-count analysis

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

Ibiebele (1986) recommended a rapid method for estimating solid waste generation rate in Port Hartcourt, Nigeria. In this method the study area divided into four sections, in each section select the points of location for the fixed size containers. These containers are monitored within certain period and observed the period (days) of filling each container. The generated wastes is determined by using the following equation:

$$W_L = \sum \frac{nVD}{y}$$

Where

W_L = mass of generated or collected in all fixed size containers per day, kg

n = total number of containers

V = volume of each container, m^3

D = density of waste, kg/m^3

y = average number of days required to fill a container.

2.9.2 Weight-volume analysis

In weight-volume analysis method, generated wastes are measured in any recognized method then the volumes of generated waste are ascertained. As specific weight or Bulk densities of MSW are varied in different region, so proper information of specific weight of MSW of that location are important factor in this method (Tchobanoglous et al., 1993).

2.9.3 Materials mass balance analysis

The only way to determine the generation and movement of solid waste with any degree of reliability is to perform a detailed materials balance analysis for each generation source, such as an individual home or a commercial or industrial activity. In some cases, the materials balance method of analysis will be required to obtain the data needed to verify compliance with state-mandated recycling programs. In practice, the most difficult aspect of applying a mass balance analysis for the determination of waste quantities is defining adequately all of the inputs and outputs crossing the system boundary (Tchobanoglous et al., 1993).

2.9.4 Statistical analysis

In developing solid waste management systems, it is often necessary to determine the statistical characteristics of the observed solid waste generation rates. For example, in many large industrial activities it would be impractical to provide container capacity to handle the largest conceivable quantity of solid wastes to be generated in a given day. The container capacity must be based on a statistical analysis of the generation rates and the characteristics of the collection system.

The first step in assessing the statistical characteristics of a series of observations is to determine whether the observations are distributed normally or are skewed (log normal). The nature of the distribution can be determined most readily by plotting the data on arithmetic and logarithmic probability graph paper. Once the nature of the distribution is known, statistical measures that are used to describe the distribution include: the mean, mode, standard deviation, coefficient of variation, coefficient of skewness and coefficient of kurtosis (Tchobanoglous et al., 1993).

Statistical relationship

The relationship for determining the generation rate from each source of solid waste generation is derived by statistical analysis (Chan, 1993) using the multiple linear regression analysis of the following form:

$$y = a + bX_1 + cX_2 + \dots\dots\dots\dots + n X_n$$

Where

y = the independent variable of solid waste generation, kg/day or l/day

$X_1, X_2 \dots\dots, X_n$ = the independent variables of each influenced parameters

a, b, c,............,n = constants

2.10 Methods of Characterizing Municipal Solid Waste

There are two basic methods for characterizing MSW

1. Material flows and
2. Sampling

Each method has some merits and drawbacks, which are given in Table 2.3. Not mentioned in this comparison is the fact that on-site sampling can be very expensive especially if done with large enough samples and with the frequency required for reasonable accuracy. To date, only the material flows method has been used to characterize the MSW stream nationwide. The idea for this methodology was developed at the EPA in the early 1970s. The following methodology has been further developed and refined for EPA and other organizations over the past two decades.

Data on domestic production of the materials and products in MSW provide the basis of the material flows methodology. Every effort is made to obtain data series that are consistent from year to year rather than a single point in time. This allows the methodology to provide meaningful historical data that can be used for establishing time trends (Tchobanoglous et al., 2002).

Table 2.3 Methods of characterizing MSW

Material Flows	Sampling
Characterizes residential, commercial, institutional and some industrial wastes	Characterizes wastes received at the sampling facility
Characterizes MSW nationwide	Is site-specific
Characterizes MSW generation as well as discards	Usually characterizes only discards as received
Characterizes MSW on an as-generated moisture basis	Usually characterizes wastes after they have been mixed and moisture transferred
Provides data on long-term trends	Provides only one point in time (unless multiple samples are taken over a long period of time)
Characterizes MSW on an annual basis	Provides data on seasonal fluctuations (if enough samples are taken)
Does not account for regional differences	Can provide data on regional differences

Source: Tchobanoglous et al., 2002

2.11 Methods of Municipal Solid Waste Sampling

There is no single method for solid waste sampling and analysis. Many studies in this field have applied different sampling methods, which are depending upon local situations and type of data required. Two approaches or sampling points are generally being applied:

1. Sampling directly from waste sources and
2. Sampling from trucks at the disposal sites

Quantity and quality of refuse should be assessed taking into account seasonal variation, zonal characteristics etc. Sampling points should be truly representative of the given occupation sub-group. In determining the sample size, studies had been carried in USA by Carruth and Klee in 1969 (as quoted in Chan, 1993), with 100 to 1000 kg samples; it was found that 100 kg sample gave as much accuracy than 1000 kg sample. When the collection point is small and a 100 kg sample cannot be obtained, smaller size sample can be used for analysis. Repetitive sampling and analysis would provide a more representative result (Chan, 1993).

After the study of household refuses in Kuala Lumpur, Malaysia, Kauffman in 1988 (as quoted in Chan, 1993), proposed some recommendations for the design of a sampling survey.

1. Zoning of the city improves the total estimation of solid waste generation and composition. The annual values and variations of quantities and qualities can be obtained carrying out waste sampling in different seasons throughout the year.

2. The amount of recycled materials should be weighed together with the waste during sampling period.

3. Samples size of 91 kg (200 Ib), which was recommended by Carruth and Klee in 1969 (as quoted in Chan, 1993), appeared adequate that they are taken carefully and large objects should be separated. Bags of waste should be opened and mixed with rakes.

4. In moisture content analysis, larger size samples taken from each waste category will improve the confidence of the values. Samples of 50 grams or more should be adequate.

Hartono (1984), described the sampling techniques for residential solid waste and commercial solid waste, separately, which are given below:

Residential solid waste: The solid wastes from each house are collected in the fixed size plastic bag. After measuring the weight and volume (compacted and uncompacted), the quartering method is used. About 150 – 200 liters are taken into sorting. Two different screens (mesh size 3.3 cm and 1.3 cm) are used for screening. The sample selection criteria are based on population density, number of persons in a house and income level.

Commercial solid waste: The solid wastes are collected from office, market and restaurants. The sample selection criteria are based on population density, working hours and population number etc.

2.12 Composition of Municipal Solid Waste

Composition is the term used to describe the individual components that make up a solid waste stream and their relative distribution, usually based on percent by weight. Information on the composition of solid wastes is important in evaluating equipment needs, systems and management programs and plans. For example, if the solid wastes generated at a commercial facility consist of only paper products, the use of special processing equipment such as shredders and balers may be appropriate. Separate collection may also be considered if the city or collection agency is involved in a paper-products recycling program (Tchobanoglous et al., 1993).

A full knowledge of the composition of the solid wastes is an essential element due to the following reasons:

1) To select most appropriate type of storage and transport facilities to a given situation,
2) To determine the potential of resource recovery,
3) To choose a suitable method of disposal, and
4) To determine of the environmental impact exerted by the wastes if they are improperly managed.

A reasonably realistic estimation of the composition of a community waste requires an analytical period of two weeks duration, repeated two to four times per year. All types of municipal wastes should be sampled, i.e., residential, commercial (offices and markets), institutional (school and hospital) and light industrial. To reduce the magnitude of errors arising from moisture change and from decomposition, analysis of the samples should be begun within two to three hours after collection (Diaz et al., 1996). Some definitions of physical components of MSW are given in Table 2.4.

Table 2.4 Definition of the physical components of MSW

Component	Definition	Example
Combustibles		
a) Garbage	Waste from food stuff	Food and Vegetable refuse, fruit skin, stem of green, corncob, etc.
b) Paper	Any materials and paper	Paper bags, cardboard, tissue, paper, etc.
c) Plastics	Any material and products made of plastics	Wrapping film, plastic bag, plastic bottle, plastic hose, plastic string, etc.
d) Grass, Wood and straw	Any material and products made of wood, bamboo and straw	Furniture such as desk, chair, bed board, toy, coconut shell, etc.
e) Leather and Rubber	Any material and products made of rubber or leather	Ball, shoes, purse, rubber band, etc.
f) Textile	Has its origin from yarn	Cotton, wool, nylon, etc.
Non-Combustibles		
a) Ferrous metal	Any material made of iron which can be attracted by magnets	Tin can, wire, fence, knife, bottle cover, etc.
b) Non-ferrous metal	Any material which can not be attracted by magnets	Aluminum can, foil, ware, etc.
c) Glass	Any material and products made of glass	Bottles, glassware, light bulb, etc.
d) Stone and ceramic	Any non-combustibles other than metals and glass	Shell, bone, brick, stone pottery.

Source: AIT, 1991

Composting method is mainly for disposing the organic wastes. Based on the decomposition nature, the components of solid wastes are categorized as organic and inorganic. The composting materials include garbage, grass, straw and papers. In incineration method, it is a process by means of which solid wastes are converted to residue through combustion. For this process, wastes are categorized into combustible and non-combustible components based on the combustion characteristics, moisture contents and heat value. Lists of combustible and non-combustible waste materials are given below:

(1) Combustible materials:

- garbage, food wastes
- papers
- textile
- rubber
- plastics
- wood
- leaves, grass
- leather, etc.

(2) Non-combustible materials:

- metals
- glass
- cement
- stone, gravel, soil, etc.

As for the aim of recycling process, there are many components in the refuse can be reused and recycled. The reusable materials are: papers, glass, plastics, ferrous and non-ferrous metals. However, some portion of the non-reusable materials can be recovered as raw materials for energy or fuel production.

2.13 Characteristics of Municipal Solid Waste

Generally, the MSW is identified by the following four major characteristics:

1. Physical Characteristics
2. Chemical Characteristics
3. Biological Characteristics and
4. Mechanical Characteristics

Determination of physical and chemical characteristics of solid wastes or its components would be necessary in order to ascertain the most appropriate type of treatment.

2.13.1 Physical characteristics

In addition to analyzing characteristics, it is strongly recommended that the sampling program includes provision for determining moisture content, bulk density and size distribution. The major physical characteristics of MSW are listed below and hence described in the following section:

1. pH
2. Moisture content
3. Volatile solid content and ash residue
4. Bulk density
5. Particle size distribution

2.13.1.1 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. It is defined as the negative logarithm of hydrogen ion activity and if pH < 7 represents acidic, while pH = 7 is neutral and pH > 7 is basic or alkaline. 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). The pH varies with time during the composting process and is a good indicator of the extent of decomposition within the compost mass. The optimum pH range for most bacteria is between 6.0 and 7.5. In aerobic composting process for optimum aerobic decomposition, pH remain at 7 to 7.5 ranges and to minimize the loss of nitrogen in the form of ammonia gas, should not rise above about 8.5 (Tchobanoglous et al., 1993).

2.13.1.2 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, as there is a close relationship between moisture and aeration - particularly in windrow composting (Diaz et al., 1996). The basis of the relationship is the fact that the principle source of the oxygen required by the microbial populations is the air entrapped in the voids; and there is an indispensable relation between moisture content and air (oxygen).

Moisture content varies widely which influenced by local climate conditions, refuse-storage practices, method of refuse collection and refuse composition. This parameter is calculated by the weight of moisture loss from the sample after drying at the temperature of 110°C for 1 hour and divided by the original wet weight of the sample. It is expressed as the percentage weight of moisture per unit weight of wet or dry material (Chan, 1993). Moisture content should be in the range of 50 – 60 % during the composting process, the optimum being about 55%. At moisture levels above 65%, water begins to fill the interstices between the particles of the wastes, reducing the interstitial oxygen and causing anaerobic conditions. This results in a rapid fall in temperature and at the same time production of offensive odors. When the moisture contents drops much below 50%, the composting process becomes slow (Tchobanoglous et al., 1993).

2.13.1.3 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 is usually expressed in two terms: 1) per unit of total solid, and 2) volatile solids introduced.

Gas production per unit of total solid depends both on the volatile solids content and on the extent to which the volatile (organic) solids are converted into gas. 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.

2.13.1.4 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. It should be noted that the different value between the compacted and uncompacted densities (Diaz et al., 1996).

In general, the lower income level of country, higher the concentration of putrescible matter, moisture, ash and dirt in solid waste as well as less likely the possibility of finding low density packaging materials (Diaz et al., 1996). Therefore, the lower level of income, higher the density of waste that are shown in Table 2.5.

Table 2.5 Variations of Bulk density of MSW with income level of country

Status of country	Loose bulk density (kg/m^3)
Low income developing countries	300 – 600
Middle income developing countries	200 – 300
Industrialized countries	100 - 150

Source: Diaz et al., 1996

2.13.1.5 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. Air-dried wastes with the lumps are passed through a number of sieves and finally cumulative percent passing though a given sieve is determined. This is generally referred to as percent finer. The particle - size distribution can be used to determine some of the basic waste parameter such as effective size, the uniformity coefficient and the coefficient of gradation. The screens can be easily made with lumber and wire and have square openings, and the sizes of the openings are 400, 300, 200, 100, 76.2, 38.2, 19.1, 9.52, 4.76 and 2.38 mm (Diaz et al., 1996).

2.13.2 Chemical characteristics

Information on the chemical characteristics of the components that constitute MSW is important in evaluating alternative processing and recovery options. For example, the feasibility of combustion depends on the chemical composition of the solid wastes. Typically, wastes can be thought of as a combination of semimoist combustible and noncombustible materials. Where the organic fraction of MSW is to be composted or is to be used as feedstock for the production of other biological conversion products, not only will information on the major elements (ultimate analysis) that compose the waste be important, but also information will be required on the trace elements in the waste materials (Tchobanoglous et al., 1993). If solid wastes are to be used as fuel, the following important aspects are to be considered. These aspects are also important to get idea about the rate and amount of gas generation.

2.13.2.1 Proximate analysis

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

1. Moisture content (loss of moisture when heated to 105°C for 1 h)
2. Volatile combustible matter (additional loss of weight on ignition at 950°C in a covered crucible)
3. Fixed carbon (combustible residue left after volatile matter is removed)
4. Ash (weight of residue after combustion in an open crucible)

Proximate analysis data for the combustible components of MSW as discarded are presented in Table 2.6. It is important to note that the test used to determine volatile combustible matter in a proximate analysis is different from the volatile solid test used in biological determinations (Tchobanoglous et al., 1993).

Table 2.6 Typical proximate analysis and energy data for materials found in residential, commercial and industrial solid wastes

Type of wastes	Proximate analysis (% by Wt.)				Energy content (Btu/lb)		
	M	VS	FC	NC	Wet	Dry	Dry*
Food and food products							
Fats	2.0	95.3	2.5	0.2	16135	16466	16836
Food wastes (mix)	70.0	21.4	3.6	5.0	1797	5983	7180
Fruit wastes	78.7	16.6	4.0	0.7	1707	8013	8285
Meat wastes	38.8	56.4	1.8	3.1	7623	12455	13120
Paper products							
Cardboard	5.2	77.5	12.3	5.0	7042	7428	7842
Magazines	4.1	66.4	7.0	22.5	5254	5478	7157
Newsprint	6.0	81.1	11.5	1.4	7975	8484	8612
Paper (mixed)	10.2	75.9	8.4	5.4	6799	7571	8056
Waxed cartons	3.4	90.9	4.5	1.2	11326	11724	11872
Plastics							
Plastics (mixed)	0.2	95.8	2.0	2.0	14101	14390	16024
Polyethylene	0.2	98.5	<0.1	1.2	18687	18724	18952
Polystyrene	0.2	98.7	0.7	0.5	16419	16451	16430
Polyurethane	0.2	87.1	8.3	4.4	11204	11226	11744
Polyvinyl chloride	0.2	86.9	10.8	2.1	9755	9774	9985
Textiles, rubber, leather							
Textiles	10.0	66.0	17.5	6.5	7960	8844	9827
Rubber	1.20	83.9	4.9	9.9	10890	11022	12250
Leather	10.0	68.5	12.5	9.0	7500	8040	8982
Wood, trees etc.							
Yard wastes	60.0	30.0	9.5	0.5	2601	6503	6585
Wood (gr. timber)	50.0	42.3	7.3	0.4	2100	4200	4234
Hardwood	12.0	75.1	12.4	0.5	7352	8354	8402
Wood (mixed)	20.0	68.1	11.3	0.6	6640	8316	8383
Glass, Metals etc.							
Glass and mineral	2.0	-	-	96-99+	84 [a]	86	60
Metal, tin cans	5.0	-	-	94-99+	301 [a]	319	317
Metal, ferrous	2.0	-	-	96-99+	-	-	-
Metal, nonferrous	2.0	-	-	94-99+	-	-	-
Miscellaneous							
Office sweepings	3.2	20.5	6.3	70.0	3669	3791	13692
Residential MSW	21.0 [b]	52.0 [c]	7.0 [d]	20.0 [e]	5000	6250	8333
Commercial MSW	15.0 [e]	-	-	-	5500	6470	-
MSW	20.0 [e]	-	-	-	4600	5750	-

Note: M -Moisture; VS - Volatile solid; FC - Fixed carbon; NC -Non combustible; * Ash-free; [a] energy content is from coatings, labels and attached materials; [b] range (15-40); [c] range (40-60); [d] range (4-15); [e] range (10-30); Btu × 1.0551= kJ

Source: Tchobanoglous et al., 1993

2.13.2.2 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).

2.13.2.3 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). Data on the ultimate analysis of individual combustible materials are presented in Table 2.7.

2.13.2.4 Energy content of solid waste component

The energy content of the organic components in MSW can be determined by:

1. Using a full-scale boiler as a calorimeter
2. Using a laboratory bomb calorimeter and
3. By calculation, if the elemental composition is known.

Because of the difficulty in instrumenting a full-scale boiler, most of the data on the energy content of the organic components of MSW are based on the results of bomb calorimeter tests (Tchobanoglous et al., 1993). Typical data for energy content and inert residue for the components of residential wastes are reported in Table 2.8. As shown, the energy content values are on as discarded basis. The Btu values given in Table 2.8 may be converted to a dry basis by using following equation:

$$\text{Btu/lb (dry basis)} = \text{Btu/lb (as discarded)} \times [100/(100 - \%\ \text{moisture})]$$

Table 2.7 Typical data on the ultimate analysis of the combustible components of residential MSW

Component	Type of waste	Percent by weight (dry basis)					
		C	H	O	N	S	Ash
Organic	Food waste	48.0	6.4	37.6	2.6	0.4	5.0
	Paper	43.5	6.0	44.0	0.3	0.2	6.0
	Cardboard	44.0	5.9	44.6	0.3	0.2	5.0
	Plastics	60.0	7.2	22.8	-	-	10.0
	Textiles	55.0	6.6	31.2	4.6	0.15	2.5
	Rubber	78.0	10.0	-	2.0	-	10.0
	Leather	60.0	8.0	11.6	10.0	0.4	10.0
	Yard wastes	47.8	6.0	38.0	3.4	0.3	4.5
	Wood	49.5	6.0	42.7	0.2	0.1	1.5
Inorganic	Glass [a]	0.5	0.1	0.4	<0.1	-	98.9
	Metals [a]	4.5	0.6	4.3	<0.1	-	90.5
	Dirt, ash, etc.	26.3	3.0	2.0	0.5	0.2	68.0

[a] energy content is from coatings, labels and attached materials

Source: Tchobanoglous et al., 1993

Table 2.8 Typical values for inert residue and energy content of residential MSW

Component	Type of waste	Inert residue,[a] percent		Energy,[b] Btu/lb	
		Range	Typical	Range	Typical
Organic	Food waste	2-8	5.0	1500-3000	2000
	Paper	4-8	6.0	5000-8000	7200
	Cardboard	3-6	5.0	6000-7500	7000
	Plastics	6-20	10.0	12000-16000	14000
	Textiles	2-4	2.5	6500-8000	7500
	Rubber	8-20	10.0	9000-12000	10000
	Leather	8-20	10.0	6500-8500	7500
	Yard wastes	2-6	4.5	1000-8000	2800
	Wood	0.6-2	1.5	7500-8500	8000
	Misc. organics	-	-	-	-
Inorganic	Glass	96-99+	98.0	50-100[c]	60
	Tin cans	96-99+	98.0	100-500[c]	300
	Aluminum	90-99+	96.0	-	-
	Other metal	94-99+	98.0	100-500[c]	300
	Dirt, ash, etc.	60-80	70.0	1000-5000	3000
MSW				4000-6000	5000

[a] after complete combustion, [b] as discarded basis, [c] energy content is from coatings, labels and attached materials; Btu/lb × 2.326 = kJ/kg

Source: Tchobanoglous et al., 1993

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. Depending upon the process, calorific value of a fuel may vary. The total heat released by complete burning of a fuel is called the HCV. Usually some fuel contains hydrogen, which produce water and heat during burning with oxygen. The water get evaporated by absorbing this heat and escaped with exhaust. The net heat available in the burning process of these fuels is obviously lower than the higher calorific value by the amount absorbed by water and thus called LCV (KUET, 1998).

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).

Analytical chemistry is divided into two parts, qualitative analysis and quantitative analysis. Qualitative analysis indicates the presence of an element, an ion or a group of complex compounds in a given substance. The aim of quantitative analysis is to determine the amount of these elements, ions or compounds present in a substance. The common procedures employed in the quantitative determination of a chemical substance are: (a) gravimetric (b) volumetric and (c) colorimetric methods (Alam et al., 1991). At present determination of certain substances are made accurately with a number of sophisticated instrumental methods such as:

(i) Polarographic method,

(ii) Emission spectrophotometric method,

(iii) Atomic absorption spectrophotometric method,

(iv) Chromatographic method

(v) Nuclear Magnetic Resonance (NMR) technique and

(vi) Flame photometric method etc.

1) *Gravimetric determination*

The principle of gravimetric method is based on the fact that a substance may either be precipitated into an insoluble compound by reacting with a suitable reagent(s) or be evaporated thereby allowing the analyst to observe the change in their weights. The weight of the element or radical may then is readily calculated from knowledge of the formula of the compound and the atomic weights of the constituent elements (Alam et al., 1991).

2) Volumetric determination

The volumetric determination may be defined as the quantitative estimation of the volume of a solution of accurately known concentration, which is required to react quantitatively with the solution or the substance, which is being tested. A solution of accurately known strength is called a standard solution, which contains a definite amount of solutes per unit of solution (Alam et al., 1991).

3) Colorimetric determination

The analytical method based on comparison of colour intensities is known as colorimetric analysis. Colorimetry is concerned with the determination of the concentration of an unknown substance, which forms characteristic colour with a suitable reagent(s). The intensity of the colour is measured/ by a spectrophotometer and is compared with that of a standard one. The intensity of the colour developed is proportional to a certain limit, to the concentration of the substance (Alam et al., 1991).

The important chemical characteristics of MSW that are measured by different method of chemical analysis are given below:

a) Carbon
b) Nitrogen
c) Hydrogen
d) Oxygen
e) Potassium
f) Phosphorous
g) Sulfur
h) Boron

The concentrations of carbon can be measured in three different methods such as dry combustion, dry oxidation and wet oxidation method. The concentrations of nitrogen are generally determined in most popular Kjheldhal method (Moqsud, 2003). Table 2.9 shows the nitrogen content and nominal C/N ratios of different matters of MSW as dry basis.

2.13.3 Biological characteristics

Excluding plastic, rubber and leather components, the organic fraction of most MSW can be classified as follows:

1. Water-soluble constituents, such as sugars, starches, amino acids and various organic acids
2. Hemicellulose, a condensation product of five- and six-carbon sugars
3. Cellulose, a condensation product of the six-carbon sugar glucose
4. Fats, oils and waxes, which are esters of alcohols and long-chain fatty acids
5. 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)
6. Lignocellulose, a combination of lignin and cellulose
7. Proteins, which are composed of chains of amino acids

Perhaps the most important a biological characteristic of organic fraction of MSW as almost all organic components can be converted biologically to gases and relatively inert organic and inorganic solids. The production of odors and the generation of flies are also related to the putrescible nature of the organic materials found in MSW (Tchobanoglous et al., 1993).

Table 2.9 C/N ratio of different matters of MSW			
Type of wastes	**Materials**	**Percent N**	**C/N ratio**
Food processing waste	Fruit waste	1.52	34.8
	Mixed slaughterhouse waste	7.0-10.0	2.0
	Potato tops	1.5	25.0
Manures	Cow manure	1.7	18.0
	Horse manure	2.3	25.0
	Pig manure	3.75	20.0
	Poultry manure	6.3	15.0
	Sheep manure	3.75	22.0
Sludges	Digested activated sludge	1.88	15.7
	Raw activated sludge	5.6	6.3
Wood and straw	Lumber mill wastes	0.13	170.0
	Sawdust	0.10	200.0-500.0
	Wheat straw	0.3	128.0
	Wood (pine)	0.07	723.0
Paper	Mixed paper	0.25	173
	Newsprint	0.05	983
	Brown paper	0.01	4490
	Trade magazines	0.07	470
	Junk mail	0.17	223
Yard wastes	Grass clippings	2.15	20.1
	Leaves (freshly fallen)	0.5-1.0	40.0-80.0
Biomass	Water hyacinth	1.96	20.9
	Bermuda grass	1.96	24

Note: N- Nitrogen, C- Carbon

Source: Spoken Solid, 1996

2.13.4 Mechanical characteristics

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:

1. Stress-strain behaviour
2. Absorptive and field capacities
3. Permeability of compacted waste

Analyses and testing of MSW are carried out using raw (fresh) MSW, fractions of MSW, as well as landfilled MSW generated in industrialized countries in Western Europe. Due to the sharp differences in the composition and characteristics between these wastes and those from economically developing countries, it is needed to modify to suit the conditions of the particular location (Diaz et al., 1996).

2.13.4.1 Stress-strain behaviour

The results of triaxial compression tests conducted on raw MSW and on mixtures of MSW and incinerator bottom ash are given in Figure 2.2. As shown by the curves in the figure, ash has a considerable impact on the behavior of refuse (Diaz et al., 1996).

Relationship between stress and dry density

The results of laboratory tests to ascertain the impact of normal stress on the dry density of different types of refuse are presented in Table 2.10. The data in the table demonstrate that the samples of old refuse were able to reach substantially higher densities than the samples of fresh refuse (Diaz et al., 1996).

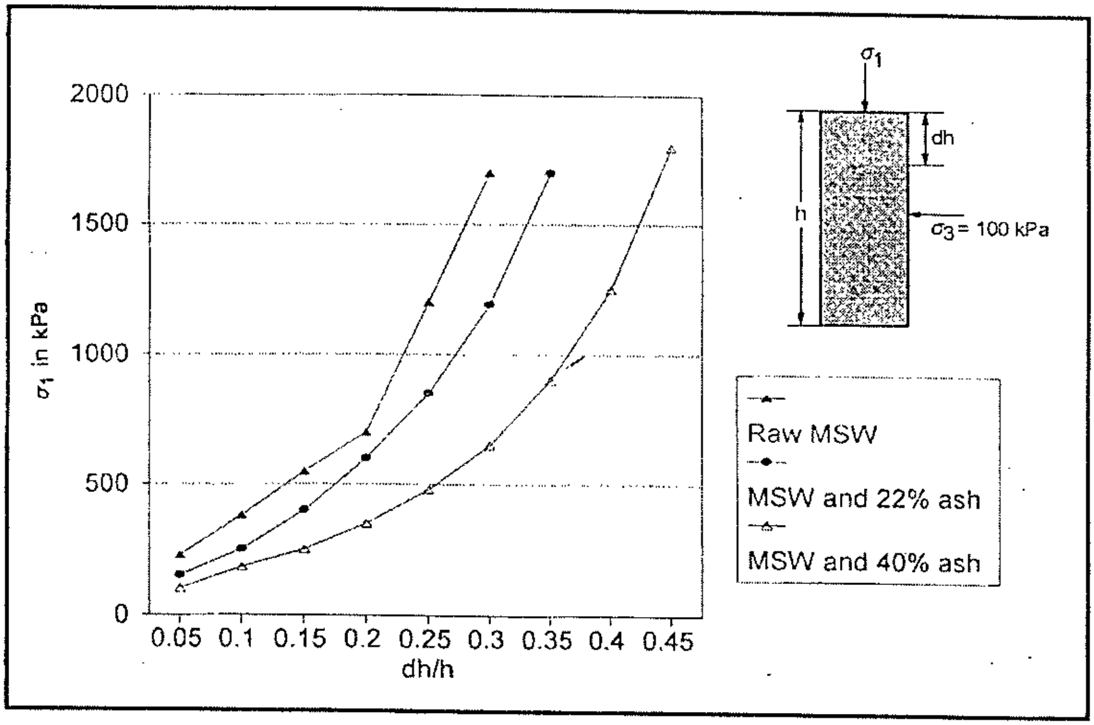


Figure 2.2 Stress-strain curves for MSW samples (*Source: Diaz et al., 1996)*

Table 2.10 Impact of normal stress on the dry density of refuse

Normal Stress (kN/m^2)	Dry Density (Mg/m^3)			
	Raw[a] Refuse	Residual[b] Refuse	Decomposed[c]	Mined[d]
100	0.54	0.58	0.89	-
200	0.64	0.65	0.95	1.04
300	0.72	0.72	1.01	1.00
400	-	-	-	1.10

Note: Mg- Megagram; [a] As collected, without separation; [b] Without organic components; [c] Raw refuse after 1.5 year of degradation in piles; [d] Excavated from landfill after 5 year

Source: Diaz et al., 1996

2.13.4.2 Absorptive and field capacities

The field capacity of MSW is the total amount of moisture that can be retained in a waste sample subject to downward pull of gravity. The field capacity of waste materials is of critical importance in determining the formation of leachate in landfills. It varies with the degree of applied pressure and the state of decomposition of waste. The field capacity of uncompacted commingled wastes from residential and commercial sources is in the range of 50 to 60 percent (Tchobanoglous et al., 1993).

2.13.4.3 Permeability of compacted waste

The hydraulic conductivity of compacted wastes is an important physical property that, to a large extent, governs the movement of liquids and gases in a landfill. The coefficient of permeability is normally written as:

$$K = Cd^2\gamma/\mu = k\gamma/\mu$$

Where

K = coefficient of permeability

C = dimensionless constant or shape factor

d = average size of the pores

γ = specific weight of the water

μ = dynamic viscosity of water

k = intrinsic permeability

Tests have been carried out using a large-scale compression cell to determine several hydrogeological and geotechnical properties of refuse. The results of these analyses are useful in the evaluation of leachate management systems (Diaz et al., 1996).

2.14 Conclusion

The generation rates and amount are counted as basic information required for the sustainable design of solid waste management. Economical and efficient design of collection task, on-site storage, waste processing and disposal are based on such data. Composition of MSW is important in evaluating equipment needs, systems and management programs and plans. Determination of physical and chemical characteristics of MSW or its components would be necessary in order to ascertain the most appropriate type of treatment and also important in evaluating alternative processing and recovery options. It is also important to know the biological and mechanical characteristics of MSW. All of these properties of MSW are required for selection of most appropriate type of treatment or its proper management.

CHAPTER THREE

OVERVIEW OF THE STUDY AREAS

3.1 General

Bangladesh is one of the few countries in south Asia, which remains to be explored. It's 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 may be the reason as Bangladesh has seldom been highlighted in the World's tourist maps (www. discoverybangladesh.com).

This chapter describes the historical background and general information such as location, city layout, population, socio-economic and environmental condition of the study areas, four major cities of Bangladesh, namely, Dhaka, Khulna, Rajshahi and Barisal. 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 four major cities of Bangladesh, namely, Dhaka, Khulna, Rajshahi and Barisal are considered in this study. The administration of all these four cities is headed by a Mayor, elected directly voted by city dwellers of the respective city corporation. Brief accounts of historical development of these cities are described here. However, for details reference can be made as DCC (2005), KCC (2005), RCC (2005) and BCC (2005).

Dhaka, the capital city of Bangladesh is one of the densely populated cities of the world. The literal meaning of the name 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.

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

Table 3.1 Establishment of four city corporations of Bangladesh

City corporation	Establishment as municipal committee	Establishment as city corporation
Dhaka city corporation	1864	1990
Khulna city corporation	1884	1990
Rajshahi city corporation	1876	1991
Barisal city corporation	1869	1998

3.3 General Information

3.3.1 Location

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

Table 3.2 Location of four 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
Khulna[2]	22° 30' N	89° 20' E	South west region
Rajshahi[3]	24° 21' to 24° 23' N	88° 28' to 88° 38' E	North west region
Barisal[4]	22° 20' N	90° 15' E	South west region

Source: [1]DCC (2005), [2]KCC (2005), [3]RCC (2005), [4]BCC (2005)

3.3.2 City layout

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

3.3.3 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

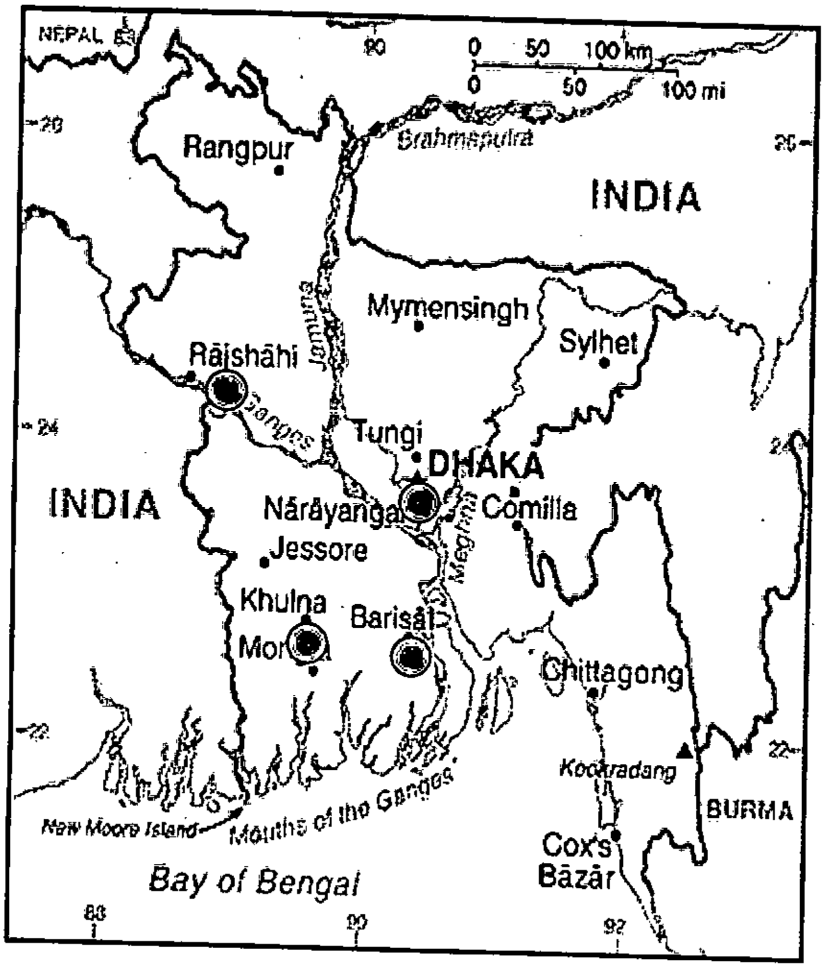


Figure 3.1 Location of study areas in Bangladesh

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. 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 7,73,000. Khulna city, with a population of about 1.5 million as claimed by city authority in the year of 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 is 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 is 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 is 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%. Table 3.3 shows total population in four major cities of Bangladesh with city area and number of wards.

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
Khulna[2]	47	1.50	31
Rajshahi[3]	48	0.45	30
Barisal[4]	45	0.40	30

Source: [1]DCC (2005), [2]KCC (2005), [3]RCC (2005), [4]BCC (2005)

3.3.4 Socio-economic condition

Bangladesh is one overpopulated 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.

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.

3.3.5 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.

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 four major cities of Bangladesh.

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

City corporation	Annual avg. rainfall (mm)	Temperature (summer)	Temperature (winter)
Dhaka	1824	30 to 37°C	10 to 20°C
Khulna	1714.50	30°C (avg.)	15°C (avg.)
Rajshahi	1624.67	43.3°C (max.)	8.8°C to 25.9°C
Barisal	1526	32°C (avg.)	12°C (avg.)

Source: DOE (2005)

3.4 Overview of MSW Management in the Study Areas

Presently, the solid waste management system in Bangladesh is not well organized. However, efforts are under way to improve the organizational structure for solid waste management in the major cities. For instance, DCC recently established a 'solid waste management cell' to improve the waste management services in the city. In most of the city corporations, there is no separate department for solid waste management. Solid waste management 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, garbage management and other facilities.

3.4.1 Source storage and separation

Residential wastes are the main sources of MSW in Bangladesh. The other important sources are commercial wastes including markets, hotels, restaurants wastes, etc. Institutional wastes including schools, colleges, universities, government offices, hospital and clinic wastes, etc. and municipal services wastes such as street sweeping, drain cleaning but excluding the wastes of treatment facilities. 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. Householders store the wastes at their own responsibility; however, some NGOs and CBOs even supply the bins to motivate people for cooperating waste management system. Moreover, due to lack of motivation, awareness and commitment, a considerable portion of wastes, 40-60%, 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. Study reveals that source storage and separation of organic, inorganic and hazard wastes are highly neglected by the city dwellers. Generally, single bin is practiced and the collection van also has single compartment, so the waste becomes mixed.

3.4.2 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 actually collected by door-to-door collection systems introduced by NGOs and CBOs in late 90's. Waste collection workers collect the source storage container and then emptied it into the collection van. Where door-to-door collection system is not available, house dwellers or servant carry wastes to nearby community bins/secondary sites with their own responsibility. Waste collection trucks collect wastes from these locations at regular interval for ultimate disposal. Experiences reveal that proper storage and dispose in proper hand/place are first steps to achieve the desired goal. Door-to-door solid wastes 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 facilities, more responsibilities to collect wastes daily directly from generation sources and require proper planning and tight schedule (Ahsan et al., 2005). However, Chittagong and Rajshahi city authorities (Chowdhury et al., 2005) are involved in door-to-door collection system. In Khulna, one ward out of 31, total management including door-to-door collection has been conducted by a private sector for the last 10 years, through a contact with KCC.

3.4.3 On-site storage

On-site storage is the Secondary Disposal Sites (SDS), transfer station and handover points, which receives wastes from primary source and transferred 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. In Dhaka city, there are more than 846 SDS, 640 community bins and 206 waste containers. For the last 2 years, in 6 wards two private organizations have been disposed the wastes from SDS to ultimate disposal sites. In Khulna city, there are more than 60 SDS, around 1200 community bins and 28 haul containers, located on roadsides throughout the city. In Rajshahi city, there are 44 open space types SDS and about 190 community bins spreading over the whole city. There is no dustbin in RCC areas; recently all the dustbins have been removed from SDS. Rickshaw van pullers collect wastes from different sources and dump to the open spaces randomly at SDS. In Barisal city, there are 150 SDS are spreading unevenly over the whole city, as a result, no secondary sites in some wards. Table 3.5 shows the total amount of MSW generation with generation rate in four major cities of Bangladesh.

Table 3.5 MSW generation in four major cities of Bangladesh			
City Corporation	Population (million)	Wastes generation rate (kg/capita/day)	Total generation (tons/day)
Dhaka	11.00	0.485	5340
Khulna	1.50	0.346	520
Rajshahi	0.45	0.378	170
Barisal	0.40	0.325	130

Source: This study

3.4.4 Secondary collection and transportation

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. Only city authorities are responsible for collecting wastes from secondary points and transported it by motorized vehicles/trucks and finally disposed in the designated ultimate disposal site of the city. Conservancy department setup the time-schedule and types of vehicle for collection and transportation. Generally, collection vehicles such as dump truck, normal truck, open truck, tractor with trolley, tipping truck (container carrier), De-sledging vacuum tanker with tractor, power tiller with trolley stands in the road nearest to the SDS for operation. 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. Table 3.6 shows the total number of motorized vehicles, number of dumping site and amount of wastes daily collected, transported and dumped in ultimate disposal sites.

Table 3.6 Number of motorized vehicles, dumping site and amount of waste daily dumped in ultimate disposal site			
City	Number of motorized vehicles	Amount collect, transport and dump (tons/day)	Ultimate disposal site
Dhaka	373	2000-2400	2
Khulna	32	240-260	1
Rajshahi	15	60-80	1
Barisal	7	30-40	1

Source: Alamgir et al., 2005a

3.4.5 Reuse, recycling and treatment

MSW industry covers the four components in waste management, these are recycling, composting, land filling and waste-to-energy via incineration. Waste-to-energy combustion and landfill gas are byproducts of MSW are not practiced in Bangladesh. Recycling is the reprocessing of wastes, either into the same material (closed loop recycling) or a different material (open loop recycling) or a different material (open loop recycling). It is the key mechanism to recover useful products and reduction in wastes quantity. Source separation is the best process where different categories of recyclables and organics are separated at source, i.e. at the point of generation, to facilitate reuse, recycling and composting. Informal sectors by various groups of community are playing an important role in recycling of solid waste in Bangladesh. However in the study areas, it is not practiced widely and effectively except in certain urban areas.

In Bangladesh, generally recycling is carried out in three phases. Phase one is the source separation, where the generators separate refuse of higher market value such as papers and paper products, bottles, fresh containers, plastic materials, tin, glass, metal, old clothes, shoes etc. and sell to street hawkers. Hawkers are collected reusable and recyclable materials from houses and sell them to nearer 'Vangari Dokans' - recycling shops. 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, 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 ultimate disposal site. Ultimately all reclaimed materials are supply to the factories for reuse as raw materials or appropriate processing. Commonly non-hazardous wastes are recycled in Bangladesh however there is a strong need for recycling of hazardous or special wastes (e.g. solvents).

3.4.6 Composting

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 natural way of recycling organic wastes into new soil, used in vegetable and flower gardens, landscaping and many other applications. The MSW of Bangladesh is suitable for composting due to its high moisture and organic contents. In Bangladesh, mainly NGOs are involved in composting of organic wastes in Dhaka, Khulna and Rajshahi city. There are no composting plants in Barisal city. Besides the city areas, composting plants are also set-up in some municipalities with technical supports from experienced NGOs, financial support from donor agencies with the collaboration of local city authorities. 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.

3.4.7 Ultimate disposal site

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. The sites are located in and around the city areas. All types of MSW are disposed including some portions clinical/hospital wastes. Crude open dumping sites are always incompatible with the surroundings. The exposed wastes 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 pond 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. 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 (Alamgir et al., 2005b; Mohiuddin et al., 2005). Table 3.7 shows the general features of active ultimate disposal sites in the study areas (Alamgir et al., 2005c).

3.5 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

Table 3.7 General features of ultimate disposal sites in four major cities of Bangladesh					
City	Dhaka[1]	Dhaka[2]	Khulna[3]	Rajshahi[4]	Barisal[5]
Ownership	DCC	DCC	KCC	RCC	BCC
Area (acre)	50	10	20	15	6.0
Year of start	1993	2001	1977	2004	2004
Status	AC	AC	AC	AC	AC
Capacity	UN	UN	UN	UN	UN
Accepted wastes (tons/day)	1200	380	240	75	35
% of generated wastes	24	13	53	43	30

Note: [1] Matuail; [2]Gabtoli; [3]Rajbandh; [4]Sishu park; [5]North Kawnia; UN – Unknown; AC – Active

capabilities; technological capabilities, public awareness and motivation; economic and finances and ineffective legislation and enforcement, etc. as discussed briefly in the followings:

Organizational: In some cities, conservancy inspector, the key person of MSW management, is a non-technical person; so appropriate decision making for proper management of MSW in some cases to be difficult. In other case, coordination between engineering and conservancy department is not coherent, resulting less structural development to proper management. Increasing pressure of MSW day-by-day, sometimes unable to achieve the goal due to lack of statistical previous record of MSW (i.e. generation etc.).

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.

Human resource and capabilities: Manpower in respect of existing MSW management is not sufficient. Most of the labors are unskilled and they involved in temporary basis. This uncertainty sometimes lessens the working efficiency.

Public awareness and motivation: Due to lack of awareness, motivation and commitment, people does not cooperate as desired to storage of waste and disposal. Unmanaged wastes are somewhere crude open dumping or some places the reason of drain clogging.

Economic and finances: Budget for MSW management in major cities of Bangladesh is very little and there is no scope for further financial assistance/aid in this sector. So it is very difficult to proper management of MSW to clean the city.

Ineffective legislation and enforcement: There are no effective rules and regulations for the storage, separation and dumping of MSW in Bangladesh. Peoples can storage and dump wastes in any places at any time. These practices could not achieve a clean and healthy city. Generally wastes are dumped indiscriminately at various places such as on roads; into open drains even authority also agree to dump wastes at vacant places in locality. There is no example of punishment on behalf of the government or local authority for indiscriminate dumping of wastes.

Others: NGOs and CBOs are only involved in a part of solid waste management, so its involvement does not yet able to change the overall scenario as desired by the city dwellers. Marketing of compost product is a great concern of NGOs, as the market of compost yet to be established in Bangladesh.

CHAPTER FOUR

MATERIALS AND METHODS

4.1 General

MSW generation, composition and characteristics were ascertained in this study through in depth field and laboratory studies conducted in the four major cities in Bangladesh, namely, Dhaka, Khulna, Rajshahi and Barisal. This chapter describes the working procedure of the various stages of this study, conducted in fields and laboratories. MSW generation rate determination and composition analysis in different sources such as residential, commercial, institutional and open areas in each city are described here. The physical and chemical characteristics of MSW determined in the fields and laboratories are also illustrated here.

4.2 Methodology

The methodology employed in this study was the combination of following four tasks:

1. Data Collection from Sources
2. Direct Field Survey
3. Field Tests and
4. Laboratory Experiments

Relevant data were collected from both the primary and secondary sources. Direct field survey and field testing includes MSW generation, composition analysis and physical characteristics determination in field. Laboratory experiments include MSW sampling procedure, physical and chemical characteristics of MSW determined in the laboratories.

4.3 Data Collection

The generation rate and amount of MSW in four major cities of Bangladesh, namely, Dhaka, Khulna, Rajshahi and Barisal were estimated by collecting various relevant data in which some data were collected directly by field survey and some data/information were collected from secondary sources for more understanding. Previous studies data relevant to Bangladesh and other countries were also collected to compare the findings of this study.

4.3.1 Primary sources

MSW generation and composition data were ascertained from primary sources such as residential, commercial and institutional areas. MSW generation and composition in different sources are described in article 4.4.1 and 4.4.2, respectively.

4.3.2 Secondary sources

The background data in the aspects of MSW generation such as population, population growth rate, socio-economic condition were collected from secondary sources in each city. Population and economic status were the most related parameters in solid waste generation. Review of government/non government reports and previous studies on MSW management by local/international organization were also studied. The interview with the relevant government officials had provided information of the data sources, which also guided the personal observations during the study.

The secondary sources of data were:

- Dhaka/Khulna/Rajshahi/Barisal City Corporation
- RAJUK, Dhaka
- Khulna/Rajshahi Development Authority
- Department of Environment, Dhaka/ Khulna/Rajshahi/Barisal
- Bangladesh Bureau of Statistics, Dhaka/Khulna/Rajshahi/Barisal
- NGOs/CBOs involved in MSW management in the study areas

4.4 Direct Field Survey and Testing

Field survey and testing includes the determination of MSW generation, composition analysis and physical properties in field. For accurate determination, MSW generation and composition analysis were done in different sources such as residential, commercial and institutional areas. Physical composition and bulk density of MSW were also determined in field.

4.4.1 MSW generation

In this research, MSW were sampled from different sources such as residential, commercial, institutional and open areas in each city. Samples from each point were analyzed for 1 to 5 times. The schedule for each city is shown in Table 4.1.

Table 4.1 Solid waste sampling sources and frequency

Sources	Sampling sources	Sampling frequency	Total number of samples per source
Residential:			
High socio-economic	1	5	5
Middle upper socio- economic	1	5	5
Middle socio- economic	1	5	5
Middle lower socio- economic	1	5	5
Low socio- economic	1	5	5
Commercial:			
Wet market	1	1	1
Shopping complex	1	1	1
Institutional:			
School/University	1	1	1
Hospital/Clinic	1	1	1
Open areas:			
Street sweepings	1	1	1

4.4.1.1 Residential areas

The preliminary survey was conducted to find out 5 representative wards in each city on the basis of city corporation office location, commercial, residential and low-income areas. Then

5 different income level households were selected in each ward depending on different socio - economic status as shown in Table 4.2 (A to E in descending order).

Table 4.2 Household category and the selection criteria

Category	Socio - economic status	Criteria of Selection	Income level (Tk. /family /month)
A	High	Independent bungalow type of home, with at least a vehicle and parking space, at least one servant is present.	≥ 30,000
B	Middle upper	Independent home, few rooms of the building could be on rent, at least one servant is present.	≥ 20,000
C	Middle	Family owning a flat on rent	≥ 10,000
D	Middle lower	Family living a flat in cheap rent or family with a small grocery shop	≥ 5,000
E	Low	A group of workers (daily wage) sharing a single room and having a common kitchen; peoples lives in slum areas.	≤ 5,000

Total 25 households waste generation rates were investigated in each city by supplying 2 bins in each household. One bin for rapidly biodegradable waste (Blue colour) and another for slowly biodegradable and non - biodegradable waste (Red colour). During the supply of bins, the household owners and family members were requested to store the waste separately. For simplicity, a list of waste separation (Table 4.3) was pasted on outer surface of each bin. Waste generation data were collected for 7 days and evaluated the average generation rate in each household with percapita generation. Then estimate the total amount of MSW generation from residential areas by knowing total population in each city. A sample data sheet was used to determine waste composition as given in Annexure E.

4.4.1.2 Commercial areas

The commercial establishments were categorized as wet market, shopping complex, hotels and restaurants. For the survey of MSW generation from commercial areas, one wet market and one shopping complex were selected in each city. Waste generation data were collected for 3 days and the daily average generation per shop for wet market and shopping complex were evaluated individually. Total numbers of commercial establishments with number of shops were collected from city corporation authorities, especially from trade license section.

Table 4.3 Waste separation list for blue and red supplied bin

Blue bin	Red bin
Biodegradable wastes: ➢ Food and vegetables wastes	Non - biodegradable wastes: ➢ Paper and paper products ➢ Plastic/polythene ➢ Pet bottles/Oil containers ➢ Textile/Clothes/Rags ➢ 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 ➢ Others (bone, rope etc.)

Total number of hotels and restaurants within the city areas were also collected from the concerned authority. Then estimation of total amount of MSW generated from commercial establishments in each city was determined.

4.4.1.3 Institutional areas

For the survey of MSW generation from institutional areas, one educational institution and one hospital/clinic were selected in each city. The educational institutions were categorized as school, college and university. Waste generation data were collected for 3 days and the daily average generation per student for educational institutions was evaluated. Similarly, the daily average generation rates per bed for hospital/clinic were measured. Total numbers of health care centers such as hospital/clinics with number of beds were collected from city corporation authorities. Some data/information were collected from related government authorities and NGOs involved in hospital waste management. Total numbers of educational institutions with number of students within the city areas were also collected from their information. Then estimate the total amount of MSW generated in institutional areas in each city was estimated.

4.4.1.4 Open areas

For the survey of MSW generation from street sweepings, one-paved road was selected in each city. Waste generation data were collected for 3 days and the daily average generation per 100 m of road length was calculated. All paved roads were not swept daily. Only certain important paved roads were swept daily and many others swept on alternate days or twice in a week, and some were swept occasionally or not at all. Total length of daily sweeping paved roads (on an average) was collected from the respective city corporation authority. The total amount of MSW generated from street sweepings in each city was then estimated.

4.4.2 MSW composition

The analyses to identify the composition of MSW were done in different waste generation sources such as residential, commercial and institutional areas in each city. In residential areas, 5 categorized based on socio-economic conditions such as high, middle upper, middle, middle lower, low families were considered for the analysis of waste generation in each city. In commercial areas, waste generated in one wet market and one shopping complex were analysed in each city. In institutional areas, one educational institution and one hospital/clinic were considered in each for such analysis of waste generation.

Sample (10 to 25 kg) was sorted into two categories such as organic and inorganic waste. Organic waste includes food and vegetables; paper and paper products; polythene and plastics; textile and woods; rubber and leathers, etc. Inorganic waste includes metal and tins; glass and ceramics; brick, concrete and stone; dust, ash and mud products, etc. Then the weight of each component was measured. Samples from each source were analyzed for 1 to 5 times. To determine the composition of MSW in field, samples were analyzed in 10 different SDS of each city after determining field bulk density. Three samples were analyzed for the determination of physical composition of MSW in each SDS and the average value of composition was measured.

4.4.3 Physical property

MSW have physical, chemical, biological and mechanical properties. But in this study, in field only bulk density was measured in loose state (in-situ condition) at 10 different SDS of each city. Three samples were analyzed in each SDS and the average value of bulk density was determined. Loose state means just fill up the bucket/mold without any compaction or input energy. Bulk density of MSW was determined in field as same procedure of laboratory testing, which describe in article 4.5.2.

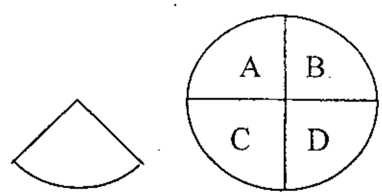
4.5 Laboratory Experiments

Determination of physical and chemical characteristics of solid waste was necessary to ascertain the most appropriate type of treatment. Total 10 waste samples (20 to 30 kg) were collected from different SDS of each city. Laboratory experiments include the sampling procedure of MSW and characterization of physical and chemical properties. Physical characteristics of MSW such as pH, moisture content, volatile solid content, ash residue, bulk density and particle size distribution were tested in laboratories. Chemical characteristics of MSW such as nitrogen, carbon, phosphorous, potassium and calorific value were determined.

4.5.1 Sampling procedure

The following procedures were maintained for sampling the MSW for the required analysis (AIT, 1991):

a) Dump the collected solid waste on the floor.
b) Thoroughly mix the wastes.
c) Pile the waste into a cone shape.
d) Cut the cone into 4 equal sections and mix the two diagonal sections (A + D) and (B + C)



Top View **Side View**

e) Divide each combined diagonals into two equal parts.
f) Combine the diagonals to get 2 piles, and then take 1/2 portion from each of the combinations for determination of its characteristics.

4.5.2 Physical characteristics

In addition to analyzing for composition, the sampling program includes provisions for determining the following important physical characteristics of MSW:

a) pH
b) Moisture content
c) Volatile solid content and ash residue
d) Bulk density and
e) Particle size distribution

4.5.2.1 pH

Weighing 10 gm waste into a small beaker then add 25 mL water (i.e. waste: water = 1: 2.5) and stir frequently about 50 minutes (Peterson, 2002). Leave the mixture 10 minutes without stirring. Rinse the pH meter (Model: HANNA HI 9210N ATC) electrode with waste suspension and immerse the electrode in the suspension. Read the pH value from the display when the reading has become stable. For each 10 gm waste samples or less: checked the pH meter by measuring pH in the buffer solution. Sometimes the calibration procedures were repeated for accuracy, while required.

4.5.2.2 Moisture content

Placing 1.5 to 2 kg waste sample on a muffle furnace and weighing as received (wet weight). It was then keep in an oven at the temperature 105°C for 24 hours (Tchobanoglous et al., 2002) and then reweighing (dry weight). The percent of moisture content was then obtained through the following formula:

$$\text{Moisture Content} = \frac{W_w - W_D}{W_w} \times 100\ \%$$

Where

W_w = wet weight of sample and
W_D = dry weight of sample

The process was repeated for three times and the average value of moisture content was measured. A sample data sheet (Data Sheet: 02) of moisture content determination is given in Annexure E.

4.5.2.3 Volatile solid content and ash residue

After the moisture content determination, sample was taken (300 to 500 gm) for volatile solid content determination. Sample was kept in oven at 550°C for 5 hours (Tchobanoglous et al., 2002) and then measured its weight. The percent of volatile solid content was then obtained through the following formula:

$$\text{Volatile Solid Content} = \frac{W_1 - W_2}{W_1} \times 100\ \%$$

Where

W_1 = dry weight of sample at 105°C and

W_2 = dry weight of sample at 550°C

The process was repeated for three times and the average value of volatile solid content was measured. A sample data sheet (Data Sheet: 03) of volatile solid content determination is given in Annexure E. The percent of ash residue were determined through the following formula:

$$\text{Ash Residue} = (100 - \text{volatile solid content})\%$$

4.5.2.4 Bulk density

The bulk densities of waste were determined in three conditions that were designated as loose, medium and compact by using a mold (container) and used in Standard Proctor Test of soils for compaction. The result was expressed as kg/m^3. The specifications of mold were given below:

1. Total length of mold = 221 mm
2. Effective length of mold = 179 mm
3. Thickness of collar = 42 mm
4. Diameter of mold = 153 mm
5. Area of mold, = $18.385 \times 10^{-3}\ m^2$
6. Volume of mold = $\pi/4 \times 0.153^2 \times 0.179 = 3.29 \times 10^{-3}\ m^3$
7. Weight of mold = 8358 gm

(a) Loose

The bulk densities in loose condition were measured by normally filling the mold without any compaction or input energy. But the mold was constantly shaken during filling until lightly filled up to the mold brim and then weigh the loaded mold. The bulk density was calculated by dividing the net weight of the waste (weight of loaded container minus weight of empty container) by its volume (Diaz et al., 1996). The process was repeated three times and the average value of bulk density in loose condition was determined.

(b) Medium

The bulk densities in medium condition were measured by compacting the waste in 3 layers providing 12 blows per layer using a hammer of 5.5 pounds in 12" free fall until lightly filled up to the mold brim and then weigh the loaded mold. The bulk density was calculated by dividing the net weight of the waste (weight of loaded container minus weight of empty container) by its volume. The process was repeated three times and the average value of bulk density in medium condition was determined.

(c) Compact

The bulk densities in compact condition were measured by compacting the waste in 3 layers providing 25 blows per layer using a hammer of 5.5 pounds in 12" free fall (Das, 1983) until lightly filled up to the mold brim and then weigh the loaded mold. The bulk density was calculated by dividing the net weight of the waste (weight of loaded container minus weight of empty container) by its volume. The process was repeated three times and the average value of bulk density in compact condition was determined. A sample data sheet (Data Sheet: 04) of bulk density determination is given in Annexure E.

4.5.2.5 Particle size distribution

Particle sizes of constituent of MSW were determined with the use of a set of locally manufactured sieves. The sieves have square openings, and the sizes of the openings were 400, 300, 200, 100, 76.2, 38.2, 19.1, 9.52, 4.76 and 2.38 mm (Diaz et al., 1996). The sieves were made of lumber and wire. Air-dried wastes with the lumps were passed through a number of sieves and finally cumulative percent passing though the sieve was determined. The samples used for particle size distribution through the sieves were range from 20 to 30 kg. Particle size distributions were established by sieve analysis for 10 samples collected from each city at the regular interval of time. The samples were collected from different secondary locations of the study areas as per designated period.

Waste sample was placed on the largest of the sieve (400 mm) and shaken until particles of refuse no longer pass through the openings. Material remaining on the sieve (oversize) was collected and weighed. The material that has passed through the sieve (undersize) was placed on the sieve with the 300 mm openings, which was shaken as in the preceding step. The process was repeated until all sieves have been used. The weight of the dry waste retained on each sieve was determined and based on these weights the cumulative percent passing through a set of sieves was determined. This was generally referred to as percent finer. Typically, the size distribution was plotted as percent finer versus sieve size. A sample data sheet (Data Sheet: 05) of particle size distribution is given in Annexure E.

4.5.3 Chemical characteristics

Information on the chemical characteristics of the components that constitute MSW is important in evaluating appropriate processing and recovery options. Chemical characteristics of MSW were determined by chemical analysis.

4.5.3.1 Preparation of waste samples for chemical analysis

Plant materials of waste samples were need special preparation for chemical analysis. Plant materials were first dried and then grinded akin to powder. The following procedures were maintained for drying and grinding of plant materials:

Drying

Place a clean container (dish or beaker) into an oven at a temperature of 105°C for overnight. Allow the container to cool in a desiccator and weigh it. Put the sample into the container and weigh the container with the sample. Place the container into the oven at a temperature of 105°C for 24 hours. Allow the container to cool in a desiccator and weigh it. Again, place the container in the oven at 105°C for 2 hours. Cool it in a desiccator and weigh it again. Repeat drying, cooling and weighing until the weight becomes constant. Store the dried sample in an airtight container (Peterson, 2002).

Grinding

If necessary, cut the dried plant material into small pieces with a knife or scissors. Grind the sample in a plant grinder fitted with a suitable screen. If the grinding takes a long time, the sample will absorb moisture and it was necessary to dry the sample again in the oven at a temperature of 105°C for overnight (Peterson, 2002).

4.5.3.2 Evaluated chemical properties

In this study the following important chemical properties of MSW, were determined at the laboratory:

a) Carbon
b) Nitrogen
c) Phosphorous and Potassium, and
d) Calorific value

a) Carbon (C)

The concentration of carbon was measured in wet oxidation method. Take 2 gm waste sample (W), which has been passed through a 2 mm sieve. Add 2 mL normal potassium dichromate and then add 10 mL concentrated sulphuric acid with sample. If the colour changes to green, add additional 10 mL of potassium dichromate solution. Then add 3 mL of diphenylamine indicator solution and colour changes to deep violet and after completing titration the colour of solution will change to deep green at the end point (Alam et al., 1991). The percent of organic carbon was then obtained using the following formula:

$$\text{Organic carbon (\%)} = \frac{(B-T) \times f \times 0.003 \times 100}{W}$$

Where

B = amount of normal $FeSO_4$ solution required in blank experiment, mL

T = amount of normal $FeSO_4$ solution required in experiment with waste, mL

f = strength of normal $FeSO_4$ solution (from blank experiment)

W = weight of waste taken, gm

b) Nitrogen (N), Total

The concentrations of nitrogen were determined as total nitrogen in most popular Kjheldhal method, which has 3 steps such as digestion, distillation and titration (Peterson, 2002). The procedures of these steps were described in the followings:

Digestion

1. Turn on the digester so it reaches the digestion temperature at 390°C by the time the samples were ready for digestion.

2. Place 40 clean and dry digestion tubes in the digestion rack. Weigh 3 gm waste sample into 38 tubes and 2 remaining tubes serve as blanks. Add 1 gm catalyst mixture and 5 mL concentrated H_2SO_4 to each tube including the blanks.

3. Put the rack with the tubes beside the digester and place the exhaust manifold on the tubes. Make sure that all stoppers were properly inserted into the tubes. Start the exhaust pump and open the regulating valve fully.

4. Place the tubes in the digester, which has already been heated at the temperature of 390°C. After 5 minutes, the suction rate was reduced by almost closing the regulating valve. Continue digestion for 2 hours.

5. Turn off the digester, remove the rack with the tubes from the digester and place it beside the digester for cooling. Continue suction for 5 minutes, remove the exhaust manifold from the tubes and turn off the exhaust pump.

Distillation

Distillation has three steps such as distill start-up, distillation of samples and distill closing down. During distillation measure 20 mL 0.05 molarity HCl from a burette or a dispenser into a conical flask and place the flask on the platform in distill. Push the platform up. Carefully add 25 mL water to one of the digestion tubes from the digestion rack. Close the safety door. Dispense 25 mL 33% NaOH into the digestion tube by gently pulling the alkali handle to its DOWN position and release it. Open the steam valve by pulling it to its DOWN position, and set the timer to 3 minutes. When the alarm sounds, lower the platform with the receiver flask and continue the distillation for about 30 seconds. Close the steam valve by pushing it up, open the safety door and replace the receiver flask with another.

Titration

After removal of the receiver flask, add 4 drops of indicator solution to the content in the flask and titrate with 0.05 molarity NaOH until the colour changes from violet to green.

Calculation

After conducting distillation and titration, the amount of nitrogen presents in the samples of MSW was calculated by the following equation:

$$\% \text{ N in the waste} = \frac{(A\ M_{HCl} - B\ M_{NaOH}) \times 1.401}{W}$$

Where

A = HCl measured into the conical flask in the distill (usually 20 mL)
B = NaOH used for titration of the content in the conical flask, mL
M_{HCl} = molarity of the HCI measured into the conical flask
M_{NaOH} = molarity of the NaOH used for titration
W = amount of waste used for the analysis, gm

c) Potassium (K) and phosphorous (P)

Organic matter was digested and K and P were released by digestion with nitric acid. K was determined by flame photometry and P was determined by spectrophotometry (Peterson, 2002).

Digestion

1. Weigh 0.5 gm dried waste material into each of 38 nitrogen digestion tubes. The two remaining tubes were blanks. Add 5 mL 68% nitric acid to each of all 40 tubes. Mix the content in each tube and leave the tubes overnight. Place the tubes in the digester and cover the tubes with the exhaust manifold. Set the temperature to 125°C. Turn on the digester and continue the digestion for 4 hours after boiling has started.

2. After cooling, transfer the digestion mixture with distilled water to a 100 mL volumetric flask. Then filtrate on a dry filter into a bottle, which can be closed with a screw cap. Keep the filtrate in the closed bottle.

Measurement of K (Total)

Using a pipette, transfer 20 mL filtrate to a 100 mL volumetric flask. Transfer 10 mL diluted filtrate into a 50 mL volumetric flask using a pipette. Measure the content of K by flame photometer. If the reading was higher than the reading of the highest standard solution, make a larger dilution, e.g. 5 mL filtrate into a 50 mL volumetric flask. In this case 1: 100 diluted HNO_3 must be added to the volumetric flask to make the total volume of 1: 100 diluted HNO_3 and filtrate 10 mL (Peterson, 2002).

Measurement of P (Total)

Using a pipette, transfer 20 mL filtrate to a 100 mL volumetric flask. Transfer 5 mL diluted filtrate (pipette) to a 50 mL volumetric flask. Add water approx. 30 mL and mix then add 10 mL ammonium molybdate-ascorbic acid solution and mix. After 15 minutes, measure the absorbance on a spectrophotometer at 890 nm. If the absorbance was higher than that of the highest standard solution then needed repeatation. In this case 1: 100 diluted HNO_3 must be added to the flask to make the total volume of 1: 100 diluted HNO_3 and filtrate 5 mL.

If the content of P was very high, it was necessary to dilute the filtrate further before the transfer to the 50 mL flask. The dilution was made with water using pipette and volumetric flask. After transfer of 5 mL diluted filtrate to the 50 mL volumetric flask, 1:100 diluted HNO_3 and water approx. 30 mL were added. Then 10 mL ammonium molybdate ascorbic acid was added and the absorbance was measured at 890 nm after 15 minutes (Peterson, 2002).

Calculation

After conducting digestion and titration, the amount of K or P presents in the samples of MSW was calculated by the following equation:

$$\text{K or P} = \frac{\text{A} \times 25000}{\text{B} \times \text{C}} \quad \text{(mg/kg)}$$

Where

A = K or P measured by flame photometer or spectrophotometer, mg/L

B = diluted filtrate transferred into the 50 mL volumetric flask for determination of K or P, mL

C = waste material weighed into the digestion tube, gm

If an additional dilution was made before transfer to the 50 mL volumetric flask, the result was multiplied with the dilution factor.

d) Calorific value

Using a bomb calorimeter in laboratory, higher calorific values of major components of MSW were determined. A certain amount of waste was burnt in a crucible, placed inside a strong container called bomb, submerged in a thermal calorimeter filled with water. Oxygen was also filled in the bomb. An electric spark was used to ignite the sample. Released heat was absorbed by all the components of the calorimeter and some heat was lost to the surrounding. At first put the waste sample (oven dry) in the crucible inside the bomb. Attach the fuse wire of known mass in such a way that it touches maximum surface of the sample.

Drop 1 mL of distilled water in the bomb by the pipet. Now, close the bomb and after charging oxygen in the bomb at a maximum pressure of 30 bar then immerse it in water in the calorimeter (KUET, 1998).

The water in the calorimeter was constantly stirred before ignition of the sample and the temperature was recorded at an interval of one minute. As the temperature of the water becomes steady for exactly 5 minutes, the electric circuit was closed to make a spark in the presence of abundant oxygen. The temperature of water begins to rise and with the help of magnifying lens, precision temperature was read in every half minute till the maximum temperature was reached. After wards, it can be recorded every minute till the drop in temperature for about 5 successive observations were uniform. After the experiment was completed, the unburnt fuse wire was to be collected from the bomb and weighed. The higher calorific value was then determined by using the following formula:

$$Cx + C_1x_1 = (M + W)(\Delta\theta + 0.5\,\Delta t r^o)$$

Where

C = Higher calorific value of the waste burnt (Kcal/kg)

x = Mass of the fuel burnt, gm

C_1 = Calorific value of the fuse weir burnt (2.79 cal/cm)

x_1 = Length of the fuse weir burnt, cm

M = Mass of water contained in the calorimeter, mL

(specific heat of water is assumed 1 cal/gm.°C)

θ_1 = Steady temperature before the combustion, °C

θ_2 = Observed maximum temperature after the combustion, °C

$\Delta\theta = \theta_2 - \theta_1$ = Observed rise in temperature, °C

r^o = Time rate of the temperature drop after the maximum temperature was reached

Δt = Time elapsed for maximum temperature to reached

W = Water equivalent (206 gm/°C) of the bomb calorimeter etc.

(Consistent unit must be used for each term)

CHAPTER FIVE

WASTE QUANTITY, COMPOSITION AND CHARACTERISTICS

5.1 General

The estimation of solid waste generation and composition are the basis of design and operation of the functional elements associated with the management of solid waste. In other words, these informations are necessary and desirable from the point of view of optimal planning and design to handle MSW. Any future system for collection and disposal of the wastes will have to be related to the quantity of wastes produced. The system selected will also depend on the characteristics of generated MSW.

This chapter describes the generation, composition and basic characteristics of MSW in four major cities of Bangladesh, namely, Dhaka, Khulna, Rajshahi and Barisal. The MSW generation rates in residential, commercial and institutional sources and finally estimation of MSW generation in each city are provided here. The compositions as encountered in the above sources and the physical and chemical characteristics of MSW in those cities are also described here in details.

5.2 Estimation of MSW Generation

Solid waste generation is an inevitable consequence of production and consumption activities in any economy. Generally, it is positively related to the level of income and urbanization, with higher income and more urbanized economies generating higher levels of solid wastes per capita. In this study, MSW generations are estimated in four major cities, namely, Dhaka, Khulna, Rajshahi and Barisal, as described in the following sections:

5.2.1 Dhaka city corporation areas

The rates of MSW generation in residential, commercial, institutional areas and for street sweeping are determined in Dhaka city. It is observed that major portion of MSW is generated from residential areas. The generation of MSW in Dhaka city corporation areas is described in the following sections:

5.2.1.1 Residential areas

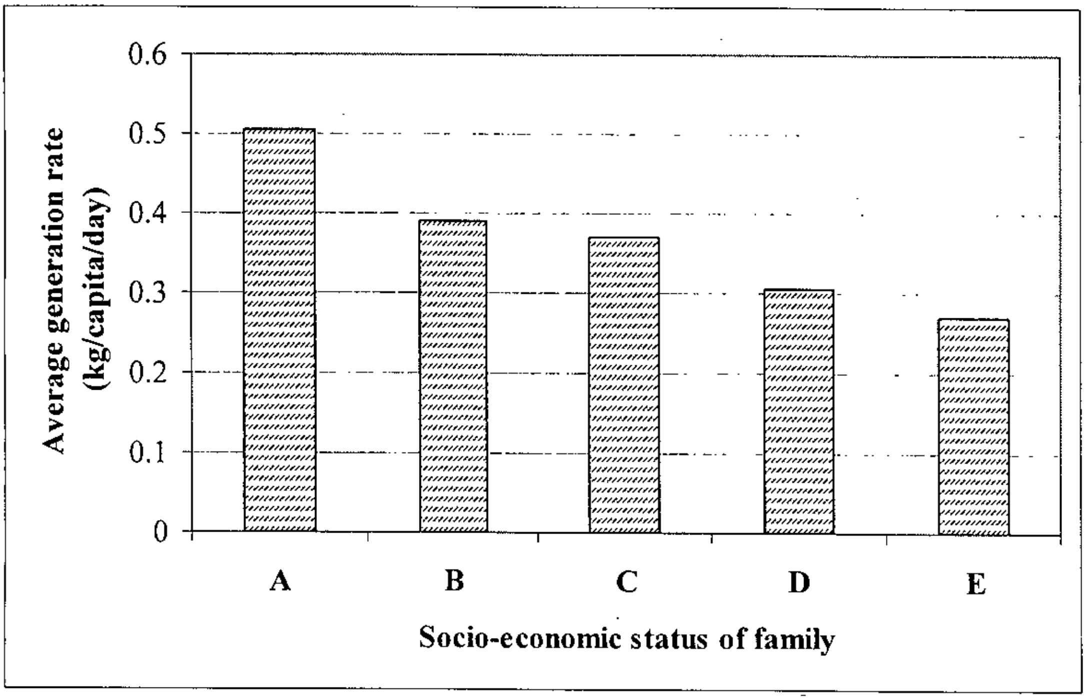
The waste generation rates of 25 sampled households in Dhaka city, where all figures are the average values of 7 days data are indicated in Table 5.1. Maximum generation rate is found to be 0.760 kg/capita/day in ward number 41 for high socio-economic (A) family and minimum is 0.116 kg/capita/day in ward number 56 for low socio-economic (E) family. The average highest generation rate is found to be 0.495 kg/capita/day in ward number 26 whereas average lowest generation rate is 0.257 kg/capita/day in ward number 56. Little variations of percapita MSW generations are observed in different wards due to seasonal variations mainly. High generation rates are found in ward numbers 26, 41 and 45, which are surveyed in Monsoon period (July-Oct) and relatively low generation rates are found in ward numbers 40 and 56, which are surveyed in Winter period (Nov-Dec).

In high socio-economic family, daily waste generation rates are generally higher than the other lower socio-economic families. The mean generation rate for high socio-economic (A) families is estimated as 0.504 kg/capita/day, while the generation rates are 0.389, 0.371, 0.305 and 0.270 kg/capita/day for middle upper socio-economic (B) families, middle socio-economic (C) families, middle lower socio-economic (D) families and low socio-economic (E) families, respectively. Figure 5.1 shows the per capita waste generation rates at residential areas in Dhaka city.

The mean generation rate as obtained from direct survey for 25 households of different income level with different living standard, is estimated as 0.368 kg/capita/day. The populations of Dhaka city are about 11 millions claimed by different mass media. So it can be estimated that the total MSW generated from residential areas is about 4048 tons/day. As different income level wise population data is not available, so simply estimate the generated amount of MSW in residential areas.

Table 5.1 Solid waste generation rates at residential areas in Dhaka city

Income level	Generation rate (kg/cap/day)					Average (kg/cap/day)	Standard deviation (kg/cap/day)
	Ward No. 26	Ward No. 40	Ward No. 41	Ward No. 45	Ward No. 56		
A	0.735	0.260	0.760	0.411	0.356	0.504	0.229
B	0.361	0.456	0.449	0.350	0.331	0.389	0.059
C	0.646	0.202	0.460	0.281	0.268	0.371	0.181
D	0.340	0.191	0.421	0.359	0.215	0.305	0.098
E	0.397	0.180	0.370	0.289	0.116	0.270	0.121
Average	**0.495**	**0.258**	**0.491**	**0.337**	**0.257**	**0.368**	**0.137**



Note: A-High class; B-Middle upper class; C-Middle class; D-Middle lower class; E-Low class

Figure 5.1 Per capita waste generation rates at residential areas in Dhaka city

5.2.1.2 Commercial areas

The generation rate for wet market is estimated as 6.17 kg/stall/day whereas 4.56 kg/stall/day for shopping complex, given in Table A.1 in Annexure A. There are 96 vegetable markets, 350 shopping complex with more than 1,54,500 trade licensee shops, 704 large restaurants, 1000 small restaurants and 642 hotels/guest houses within the city areas (DCC, 2005). The estimated MSW generation from commercial areas is about 1177.61 tons/day are shown in Table 5.2.

Table 5.2 Generation of MSW at commercial areas in Dhaka city		
Sources	**Total generation (tons/day)**	**% of generation**
Shopping complex	704.52	59.83
Wet market	414.13	35.17
Restaurants (large)	21.12	1.79
Hotel/Guest houses	12.84	1.09
Restaurants (small)	5.00	0.42
Others (station, etc.)	20.00	1.70
Total	**1177.61**	**100**

5.2.1.3 Institutional areas

It is being estimated that the solid waste generation rate for high school is 0.017 kg/student/day, given in Table A.2 in Annexure A. Sampling point is an ordinary secondary school, which classes usually started from 9:00 AM to 4:00 PM (6 to 7 hours). Total number of students in Dhaka city areas is about 18,85,000 (DCC, 2005). It can be estimated that the MSW generated from educational institutions is about 32.05 tons/day.

There are more than 712 hospitals, private clinics and pathological/ diagnostic laboratory in Dhaka city. Among them 13 are specialized hospitals and 5 are medical college hospitals under the control of Directorate General of Health Service (DGHS). Total number of beds in these two types hospitals is 4,620 as recorded in April 2004. The number of a private registered without bed and with bed clinic, with a diagnostic are 244 and number of beds is 6,196 as recorded in the month of September 2003. Considering other governmental hospitals under various ministries, there are more than 12,000 beds in the health care establishments in Dhaka city. In addition, there exist more than 450 diagnostic centers without beds as a potential source of hospital wastes (JICA, 2004).

It is being estimated that the generation rate for medical waste is 1.55 kg/bed/day, given in Table A.2 in Annexure A. The estimation of generated medical wastes is 30,400 kg/day whereas 18,600 kg/day comes from hospitals and clinics and rest amount are comes from 450 pathological/ diagnostic centers. Major portion of hospital wastes are dumped to the nearest municipal bins indiscriminately although 20% of this hospital wastes are infectious and hazardous. As a result waste collectors; neighbors and peoples will be infected from these materials. So the estimated MSW generation from institutional areas (educational institutions and health care centers) is about 62.45 tons/day (= 32.05 + 30.4).

5.2.1.4 Street sweeping

There are 5779 cleaners sweeps street wastes daily in Dhaka city. It was estimated that on an average one sweeper sweeps 110 m of road length (JICA, 2004). Total length of road network is 1970 km within the city areas but only 636 km (= 5779 × 110/1000) are swept daily. It is being estimated that the generation rate 4.45 kg/100m/day, given in Table A.3 in Annexure A. So it can be estimated that MSW generated from street sweeping is about 28.30 tons/day.

5.2.1.5 Others

It is estimated that about 20 tons MSW are generated daily within the city area from other sources such as public halls, community centers, motels, campgrounds, slaughterhouses, etc., given in Table A.4 in Annexure A.

5.2.1.6 Total amount of generation in Dhaka city

Table 5.3 indicates that the daily MSW generation amount is estimated as 5336.36 tons or 5340 tons as round figure within the Dhaka city whereas the volume of generated wastes are 10,680 m^3. The volume is calculated on the basis of specific weight as 0.5 tons/m^3. Major source of generated MSW are residential areas, which is 75.86% of total generated MSW whereas 22.07% in commercial areas, 1.17% in institutional areas, 0.53% in street sweeps and 0.37% in other areas. In street sweeps, MSW generation due to daily street sweeping by sweepers/cleaners is only considering, so the percentage of generation is slightly lower than other sources. Figure 5.2 shows the total generation of MSW from different sources in Dhaka city.

Table 5.3 Total generation of MSW in Dhaka city		
Sources of generation	**Total generation (tons/day)**	**% of total generation**
Residential areas	4048.00	75.86
Commercial areas	1177.61	22.07
Institutional areas	62.45	1.17
Street sweeps	28.30	0.53
Others	20.00	0.37
Total	**5336.36 ~ 5340**	**100**

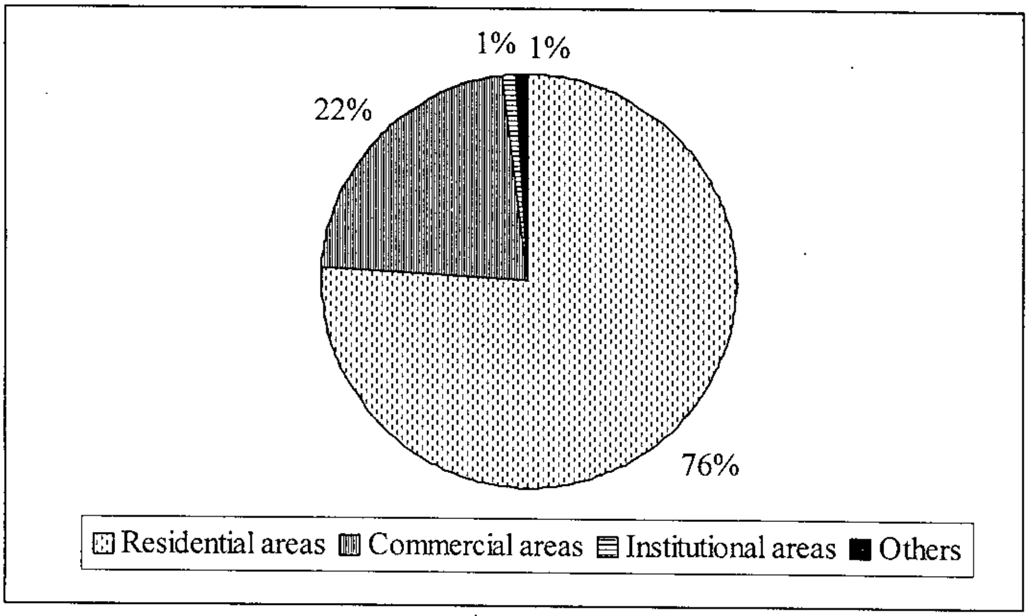


Figure 5.2 Generation of MSW from different sources in Dhaka city

5.2.1.7 Rate of generation

The daily-generated MSW within the city is about 5340 tons and the populations of Dhaka city are about 11 millions, so MSW generation rate as estimated as 0.485 kg/capita/day.

5.2.2 Khulna city corporation areas

The rates of MSW generation in residential, commercial, institutional areas and for street sweeping are determined in Khulna city. It is observed that major portion of MSW is generated from residential areas. The generation of MSW in Khulna city corporation areas is described in the following sections:

5.2.2.1 Residential areas

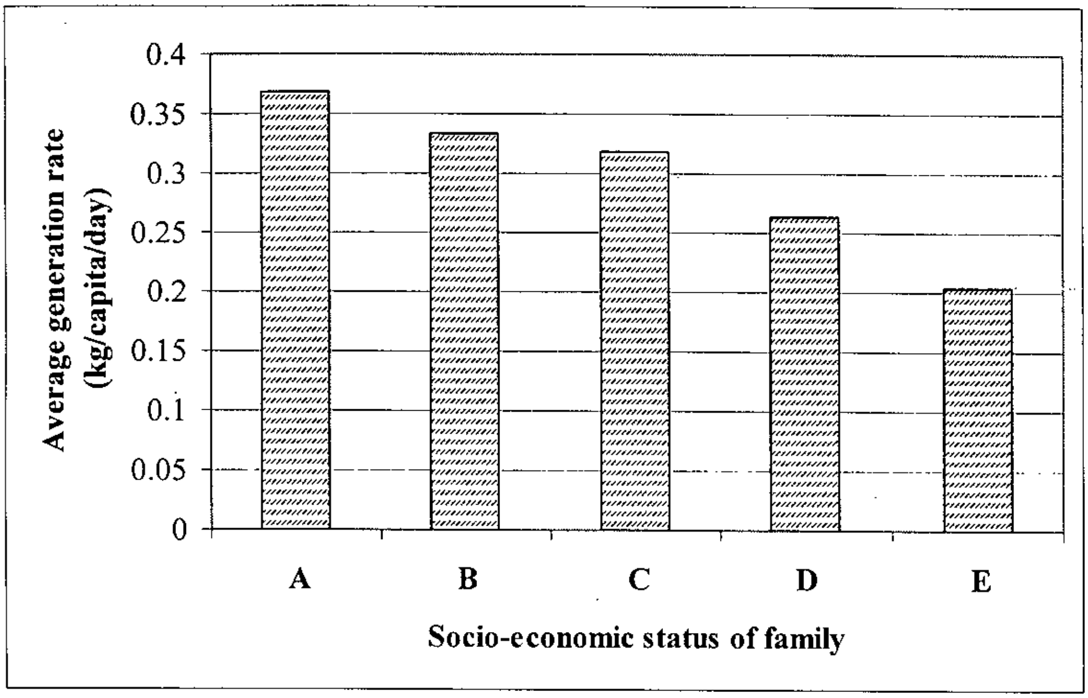
The waste generation rates of 25 sampled households in Khulna city, where all figures are the average values of 7 days data are indicated in Table 5.4. Maximum generation rate is found to be 0.480 kg/capita/day in ward number 17 for high socio-economic (A) family and minimum is 0.101 kg/capita/day in ward number 23 for low socio-economic (E) family. The average highest generation rate is found to be 0.356 kg/capita/day in ward number 17 whereas average lowest generation rate is 0.223 kg/capita/day in ward number 23. Little variations of percapita MSW generations are observed in different wards due to seasonal variations mainly. High generation rates are found in ward numbers 1, 17 and 18, which are surveyed in Monsoon period (July-Oct) and relatively low generation rates are found in ward numbers 21 and 23, which are surveyed in Winter period (Nov-Dec).

In high socio-economic family, daily waste generation rates are generally higher than the other lower socio-economic families. The mean generation rate for high socio-economic (A) families is estimated as 0.368 kg/capita/day, while the generation rates are 0.333, 0.319, 0.264 and 0.203 kg/capita/day for middle upper socio-economic (B) families, middle socio-economic (C) families, middle lower socio-economic (D) families and low socio-economic (E) families, respectively. Figure 5.3 shows the per capita waste generation rates at residential areas in Khulna city.

Table 5.4 Solid waste generation rates at residential areas in Khulna city

Income level	Generation rate (kg/cap/day)					Average (kg/cap/day)	Standard deviation (kg/cap/day)
	Ward No. 1	Ward No. 17	Ward No. 18	Ward No. 21	Ward No. 23		
A	0.440	0.480	0.341	0.320	0.261	0.368	0.090
B	0.384	0.371	0.349	0.254	0.306	0.333	0.053
C	0.403	0.386	0.301	0.307	0.198	0.319	0.082
D	0.278	0.320	0.257	0.216	0.251	0.264	0.038
E	0.180	0.221	0.341	0.171	0.101	0.203	0.088
Average	**0.337**	**0.356**	**0.318**	**0.253**	**0.223**	**0.297**	**0.070**

The mean generation rate as obtained from direct survey for 25 households of different income level with different living standard, is estimated as 0.297 kg/capita/day. The populations of Khulna city are about 1.5 millions (KCC, 2005). So it can be estimated that the total MSW generated from residential areas is about 445.50 tons/day.



Note: A-High class; B-Middle upper class; C-Middle class; D-Middle lower class; E-Low class

Figure 5.3 Per capita waste generation rates at residential areas in Khulna city

5.2.2.2 Commercial areas

The generation rate for wet market is estimated as 3.09 kg/stall/day whereas 1.57 kg/stall/day for shopping complex, given in Table A.1 in Annexure A. There are 18 vegetable markets, 45 shopping complex with different types of trade licensee shops, 750 restaurants (small and large) and 95 hotels/guest houses within the city areas (KCC, 2005). The estimated MSW generation from commercial areas is about 60.14 tons/day are shown in Table 5.5.

Table 5.5 Generation of MSW at commercial areas in Khulna city

Sources	**Total generation (tons/day)**	**% of generation**
Shopping complex	27.48	45.69
Wet market	19.16	31.86
Restaurants	9.75	16.21
Hotel/Guest houses	0.76	1.26
Others (station, etc.)	3.00	4.99
Total	**60.14**	**100**

5.2.2.3 Institutional areas

It is being estimated that the solid waste generation rate for university is 0.012 kg/student/day, given in Table A.2 in Annexure A. Sampling point is a university, which classes usually started from 8:00 AM to 5:00 PM (8 to 9 hours). Total number of students in Khulna city areas is about 2,54,868 (KCC, 2005). It can be estimated that the MSW generated from educational institutions is about 3.06 tons/day.

There are more than 129 hospitals, private clinics and pathological laboratories in Khulna city. Among them 5 are government hospitals and 59 are private clinics with more than 2000 beds, and 65 are different types of pathological laboratories and diagnostic centers. Prodipan initiated clinical waste management project since 2000 and 47 hospitals, clinics and laboratories are now under their service. Among them 2 are government hospitals, 35 are private clinics and 10 are different types of pathological laboratories. It is being estimated that the generation rate for medical waste is 0.87 kg/bed/day, given in Table A.2 in Annexure A. The wastes collection from these institutes is 800 kg/day, while the total generated medical wastes is 2200 kg/day. Only 37% of total generated clinical wastes are collected and then managed by Prodipan. So the estimated MSW generation from institutional areas (educational institutions and health care centers) is about 5.26 tons/day (= 3.06 + 2.20).

5.2.2.4 Street sweeping

Total paved road length is 160 km within the city area and it is considered that on an average 50 km length of road are swept daily (KCC, 2005). It is being estimated that the generation rate is 2.86 kg/100m/day, given in Table A.3 in Annexure A. Both sides of the roads are sweeps, so it can be estimated that MSW generated from street sweeping is about 2860 kg/day.

5.2.2.5 Others

It is estimated that about 5 tons MSW are generated daily within the city area from other sources such as public halls, community centers, motels, campgrounds, slaughterhouses, etc.

5.2.2.6 Total amount of generation in Khulna city

Table 5.6 indicates that the daily MSW generation amount is estimated as 518.75 tons or 520 tons as round figure within the Khulna city whereas the volume of generated wastes are 1040 m^3. The volume is calculated on the basis of specific weight as 0.5 tons/m^3. Major source of generated MSW are residential areas, which is 85.87% of total generated MSW whereas 11.60% in commercial areas, 1.02% in institutional areas, 0.55% in street sweeps and 0.96% in other areas. Figure 5.4 shows the total generation of MSW from different sources in Khulna city.

Table 5.6 Total generation of MSW in Khulna city

Sources of generation	Total generation (tons/day)	% of total generation
Residential areas	445.50	85.87
Commercial areas	60.14	11.60
Institutional areas	5.26	1.02
Street sweeps	2.86	0.55
Others	5.00	0.96
Total	**518.75 ~ 520**	**100**

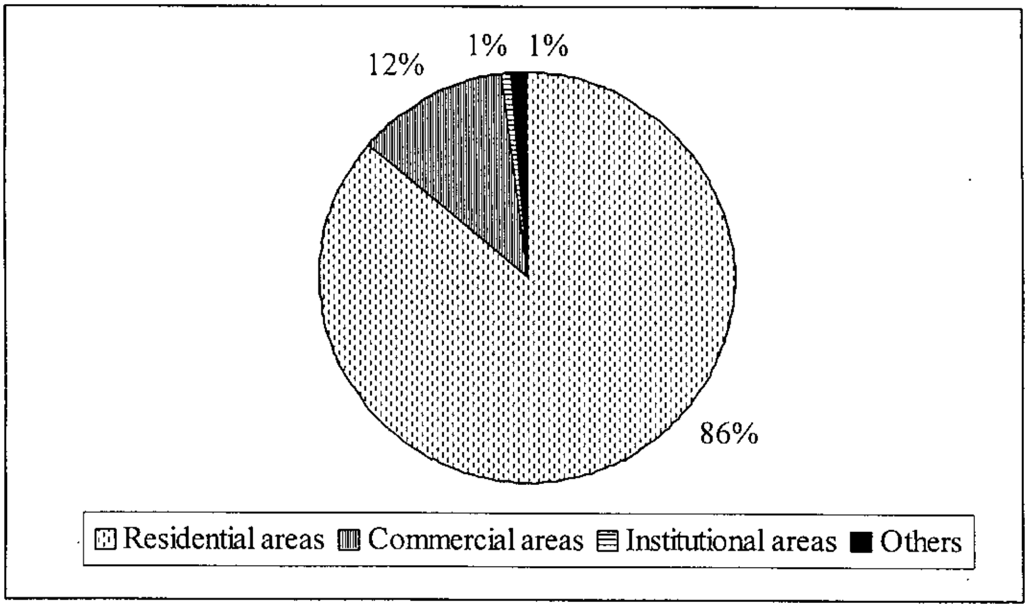


Figure 5.4 Generation of MSW from different sources in Khulna city

5.2.2.7 Rate of generation

The daily-generated MSW within the city is about 520 tons and the populations of Khulna city are about 1.5 millions so MSW generation rate as estimated as 0.346 kg/capita/day.

5.2.3 Rajshahi city corporation areas

The rates of MSW generation in residential, commercial, institutional areas and for street sweeping are determined in Rajshahi city. It is observed that major portion of MSW is generated from residential areas. The generation of MSW in Rajshahi city corporation areas is described in the following sections:

5.2.3.1 Residential areas

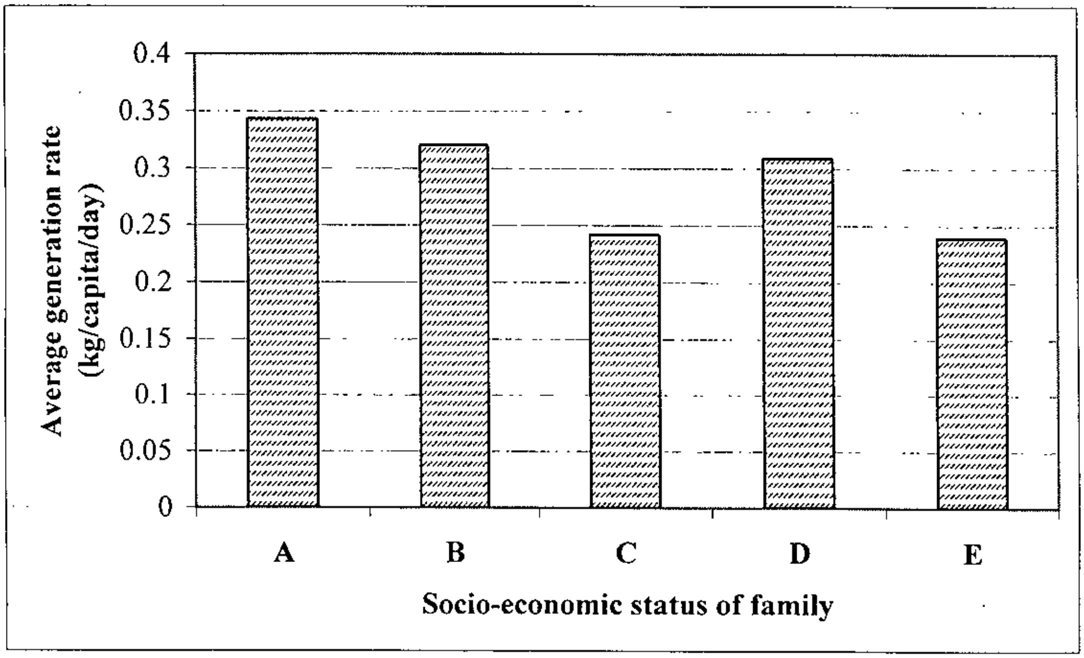
The waste generation rates of 25 sampled households in Rajshahi city, where all figures are the average values of 7 days data are indicated in Table 5.7. Maximum generation rate is found to be 0.510 kg/capita/day in ward number 23 for middle upper socio-economic (B) family and minimum is 0.189 kg/capita/day in ward number 6 for middle socio-economic (C) family. The average highest generation rate is found to be 0.354 kg/capita/day in ward number 23 whereas average lowest generation rate is 0.217 kg/capita/day in ward number 6. Little variations of percapita MSW generations are observed in different wards due to seasonal variations mainly. High generation rates are found in ward numbers 14, 21 and 23, which are surveyed in Monsoon period (July-Oct) and relatively low generation rates are found in ward numbers 6 and 9, which are surveyed in Winter period (Nov-Dec).

In high socio-economic family, daily waste generation rates are higher than the other lower socio-economic families. The mean generation rate for high socio-economic (A) families is estimated as 0.343 kg/capita/day, while the generation rates are 0.320, 0.242, 0.309 and 0.239 kg/capita/day for middle upper socio-economic (B) families, middle socio-economic (C) families, middle lower socio-economic (D) families and low socio-economic (E) families, respectively. Figure 5.5 shows the per capita waste generation rates at residential areas in Rajshahi city.

The mean generation rate as obtained from direct survey for 25 households of different income level with different living standard, is estimated as 0.291 kg/capita/day. The populations of Rajshahi city are about 0.45 millions (RCC, 2005). So it can be estimated that the MSW generated from residential areas is about 130.95 tons/day.

Table 5.7 Solid waste generation rates at residential areas in Rajshahi city

Income level	Generation rate (kg/cap/day)					Average (kg/cap/day)	Standard deviation (kg/cap/day)
	Ward No. 6	Ward No. 9	Ward No. 14	Ward No. 21	Ward No. 23		
A	0.249	0.342	0.264	0.439	0.422	0.343	0.087
B	0.253	0.295	0.232	0.310	0.510	0.320	0.111
C	0.189	0.269	0.301	0.221	0.232	0.242	0.043
D	0.198	0.256	0.399	0.318	0.375	0.309	0.083
E	0.195	0.272	0.269	0.232	0.230	0.239	0.032
Average	**0.217**	**0.287**	**0.293**	**0.304**	**0.354**	**0.291**	**0.071**



Note: A-High class; B-Middle upper class; C-Middle class; D-Middle lower class; E-Low class

Figure 5.5 Per capita waste generation rates at residential areas in Rajshahi city

5.2.3.2 Commercial areas

The generation rate for wet market is estimated as 4.68 kg/stall/day whereas 1.31 kg/stall/day for shopping complex, given in Table A.1 in Annexure A. There are 14 vegetable markets, 31 shopping complex with various types of trade licensee shops, 380 restaurants (small and large) and 55 hotels/guest houses within the city areas (RCC, 2005). The estimated MSW generation from commercial areas is about 31.54 tons/day are shown in Table 5.8.

Table 5.8 Generation of MSW at commercial areas in Rajshahi city

Sources	Total generation (tons/day)	% of generation
Shopping complex	13.76	43.63
Wet market	10.76	34.42
Restaurants	4.56	14.46
Hotel/Guest houses	0.33	1.15
Others (station, etc.)	2.00	6.34
Total	**31.54**	**100**

5.2.3.3 Institutional areas

It is being estimated that the solid waste generation rate for high school is 0.008 kg/student/day, given in Table A.2 in Annexure A. Sampling point is an ordinary secondary school, which classes usually started from 9:00 AM to 5:00 PM (7 to 8 hours). Total number of students in Rajshahi city areas is about 1,20,316 (RCC, 2005). It can be estimated that the MSW generated from educational institutions is about 962.53 kg/day.

There are more than 285 health care centers in Rajshahi city. Among them 1 are Medical college hospital, 35 are private clinics, 1 are Jail hospital, 1 Christian mission hospital and 1 T.B. hospital with more than 1600 beds; 210 EPI centers and 36 are different types of pathological laboratories and diagnostic centers. One non-motorized rickshaw van is used to collect clinical wastes within the city areas. City authority collects waste from 25 private clinics, 1 hospital and some diagnostic centers on daily basis. It is being estimated that the generation rate for medical waste is 0.60 kg/bed/day, given in Table A.2 in Annexure A. The wastes collection from these institutes is 450 kg/day, while the total generated medical wastes is 1100 kg/day. Only 40% of total generated medical wastes are collected and then managed by city authority. So the estimated MSW generation from institutional areas (educational institutions and health care centers) is about 2062.53 kg/day (= 962.53 + 1100).

5.2.3.4 Street sweeping

Total paved road length is 120 km within the city area and it is considered that on an average 30 km length of road are swept daily (RCC, 2005). It is being estimated that the generation rate 2.64 kg/100m/day, given in Table A.3 in Annexure A. Both sides of the roads are sweeps, so it can be estimated that MSW generated from street sweeping is about 2112 kg/day

5.2.3.5 Others

It is estimated that about 3 tons MSW are generated daily within the city area from other sources such as public halls, community centers, motels, campgrounds, slaughterhouses, etc.

5.2.3.6 Total amount of generation in Rajshahi city

Table 5.9 indicates that the daily MSW generation amount is found as 169.66 tons or 170 tons as round figure within the Rajshahi city whereas the volume of generated wastes are 340 m^3. The volume is calculated on the basis of specific weight as 0.5 tons/m^3. Major source of generated MSW are residential areas, which is 77.18% of total generated MSW whereas 18.59% in commercial areas, 1.22% in institutional areas, 1.24% in street sweeps and 1.77% in other areas. Figure 5.6 shows the total generation of MSW from different sources in Rajshahi city.

Table 5.9 Total generation of MSW in Rajshahi city

Sources of generation	Total generation (tons/day)	% of total generation
Residential areas	130.95	77.18
Commercial areas	31.54	18.59
Institutional areas	2.06	1.22
Street sweeps	2.11	1.24
Others	3.00	1.77
Total	**169.66 ~ 170**	**100**

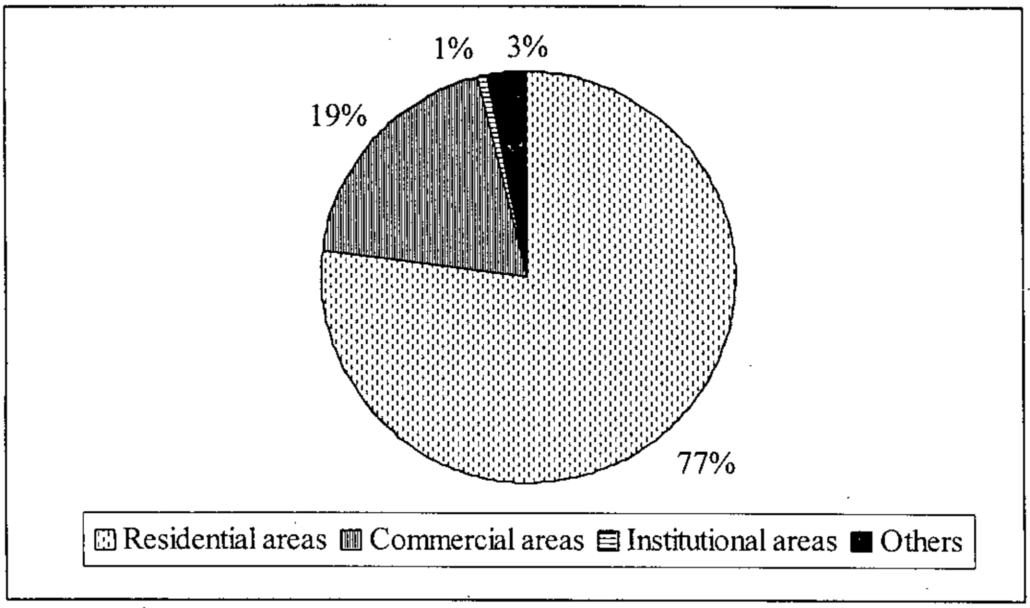


Figure 5.6 Generation of MSW from different sources in Rajshahi city

5.2.3.7 Rate of generation

The daily-generated MSW within the city is about 170 tons and the populations of Rajshahi city are about 0.45 millions so MSW generation rate as estimated as 0.378 kg/capita/day.

5.2.4 Barisal city corporation areas

The rates of MSW generation in residential, commercial, institutional areas and for street sweeping are determined in Barisal city. It is observed that major portion of MSW is generated from residential areas. The generation of MSW in Barisal city corporation areas is described in the following sections:

5.2.4.1 Residential areas

The waste generation rates of 25 sampled households in Barisal city, where all figures are the average values of 7 days data are indicated in Table 5.10. Maximum generation rate is found to be 0.513 kg/capita/day in ward number 2 for middle lower socio-economic (D) family and minimum is 0.127 kg/capita/day in ward number 10 for low socio-economic (E) family. The average highest generation rate is found to be 0.323 kg/capita/day in ward number 9 whereas average lowest generation rate is 0.201 kg/capita/day in ward number 19. Little variations of percapita MSW generations are observed in different wards due to seasonal variations mainly. High generation rates are found in ward numbers 2 and 9, which are surveyed in Monsoon period (July-Oct) and relatively low generation rates are found in ward numbers 10, 15 and 19, which are surveyed in Winter period (Nov-Dec).

In high socio-economic family, daily waste generation rates are generally higher than the other lower socio-economic families. The mean generation rate for high socio-economic (A) families is estimated as 0.327 kg/capita/day, while the generation rates are 0.278, 0.247, 0.269 and 0.172 kg/capita/day for middle upper socio-economic (B) families, middle socio-economic (C) families, middle lower socio-economic (D) families and low socio-economic (E) families, respectively. Figure 5.7 shows the per capita waste generation rates at residential areas in Barisal city.

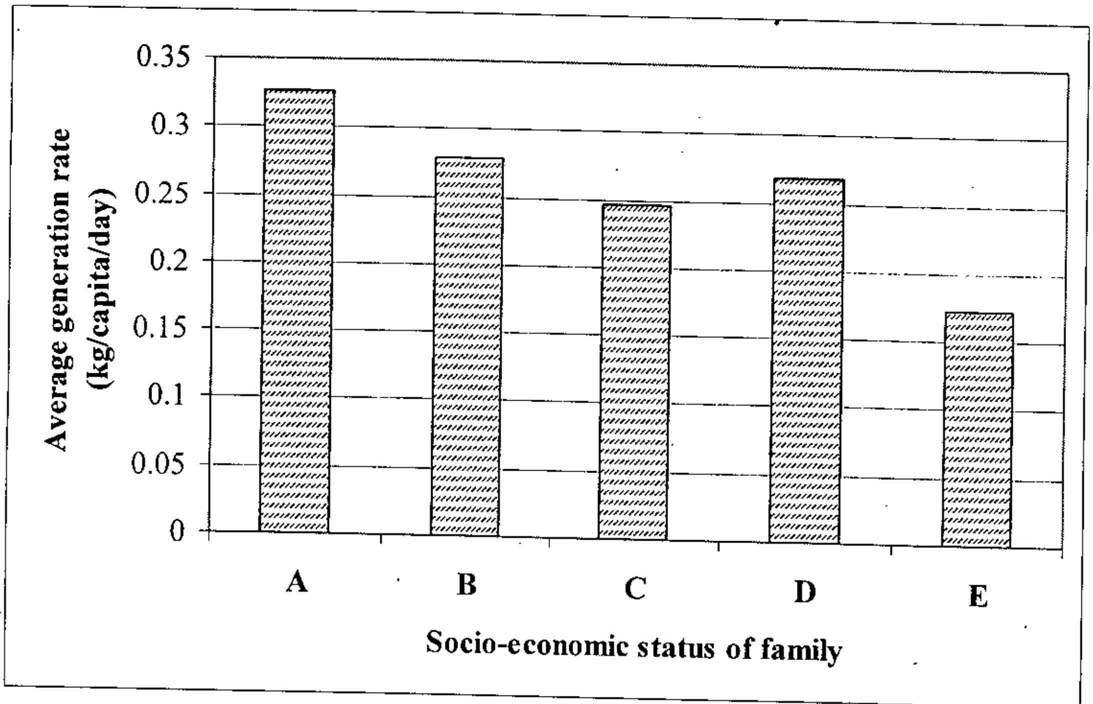
The mean generation rate as obtained from direct survey for 25 households of different income level with different living standard, is estimated as 0.258 kg/capita/day. The populations of Barisal city are about 0.4 millions (BCC, 2005). So it can be estimated that the MSW generated from residential areas is about 103.20 tons/day.

Table 5.10 Solid waste generation rates at residential areas in Barisal city

Income level	Generation rate (kg/cap/day)					Average (kg/cap/day)	Standard deviation (kg/cap/day)
	Ward No. 2	Ward No. 9	Ward No. 10	Ward No. 15	Ward No. 19		
A	0.262	0.428	0.505	0.206	0.217	0.327	0.135
B	0.326	0.360	0.240	0.290	0.174	0.278	0.073
C	0.236	0.305	0.214	0.225	0.258	0.247	0.036
D	0.513	0.310	0.197	0.140	0.188	0.269	0.150
E	0.197	0.212	0.127	0.157	0.169	0.172	0.033
Average	**0.306**	**0.323**	**0.257**	**0.207**	**0.201**	**0.258**	**0.085**

5.2.4.2 Commercial areas

The generation rate for wet market is estimated as 4.16 kg/stall/day whereas 1.02 kg/stall/day for shopping complex, given in Table A.1 in Annexure A. There are 6 vegetable markets, 20 shopping complex with various types of trade licensee shops, 280 restaurants (small and



Note: A-High class; B-Middle upper class; C-Middle class; D-Middle lower class; E-Low class

Figure 5.7 Per capita waste generation rates at residential areas in Barisal city

large) and 26 hotels/guest houses within the city areas (BCC, 2005). The estimated MSW generation from commercial areas is about 20.14 tons/day are shown in Table 5.11.

Table 5.11 Generation of MSW at commercial areas in Barisal city

Sources	**Total generation (tons/day)**	**% of generation**
Shopping complex	8.16	40.52
Wet market	6.66	33.07
Restaurants	3.64	18.07
Hotel/Guest houses	0.18	0.89
Others (station, etc.)	1.50	7.45
Total	**20.14**	**100**

5.2.4.3 Institutional areas

It is being estimated that the solid waste generation rate for high school is 0.015 kg/student/day, given in Table A.2 in Annexure A. Sampling point is an ordinary secondary school, which classes usually started from 9:00 AM to 5:00 PM (7 to 8 hours). Total numbers of students in Barisal city areas are about 73,145 (BCC, 2005). It can be estimated that the MSW generated from educational institutions is about 1097.18 kg/day.

There are more than 36 hospitals, private clinics and pathological laboratories in Barisal city. Among them 3 are hospitals and 11 are private clinics with more than 700 beds and 22 are different types of pathological laboratories and diagnostic centers. Prodipan, a national NGO only initiated clinical waste management project in the month of July 2002 and 11 hospitals and clinics are now under their service. Among them 2 are hospitals and 9 are private clinics. It is being estimated that the generation rate for medical waste is 0.95 kg/bed/day, given in Table A.2 in Annexure A. The wastes collection per day from these institutes is 350 kg/day whereas the total generated medical wastes is 800 kg/day. Only 44% of total generated clinical wastes are collected and then managed by Prodipan. So the estimated MSW generation from institutional areas (educational institutions and health care centers) is about 1897.18 kg/day (=1097.18 + 800).

5.2.4.4 Street sweeping

Total paved road length is 72 km within the city area and it is considered that on an average 25 km length of road are swept daily (BCC, 2005). It is being estimated that the generation rate approximately 2.98 kg/100m/day, given in Table A.3 in Annexure A. Both sides of the roads are sweeps, so it can be estimated that MSW generated from street sweeping is about 1490 kg/day.

5.2.4.5 Others

It is estimated that about 3 tons MSW are generated daily within the city area from other sources such as public halls, community centers, motels, campgrounds, slaughterhouses, etc.

5.2.4.6 Total amount of generation in Barisal city

Table 5.12 indicates that the daily MSW generation amount is estimated as 129.73 tons or 130 tons as round figure within the Barisal city whereas the volume of generated wastes are 260 m^3. The volume is calculated on the basis of specific weight as 0.5 tons/m^3. Major source of generated MSW are residential areas, which is 79.55% of total generated MSW whereas 15.52% in commercial areas, 1.46% in institutional areas, 1.15% in street sweeps and 2.32% in other areas. Figure 5.8 shows the total generation of MSW from different sources in Barisal city.

Table 5.12 Total generation of MSW in Barisal city		
Sources of generation	**Total generation (tons/day)**	**% of total generation**
Residential areas	103.20	79.55
Commercial areas	20.14	15.52
Institutional areas	1.89	1.46
Street sweeps	1.49	1.15
Others	3.00	2.32
Total	**129.73 ~ 130**	**100**

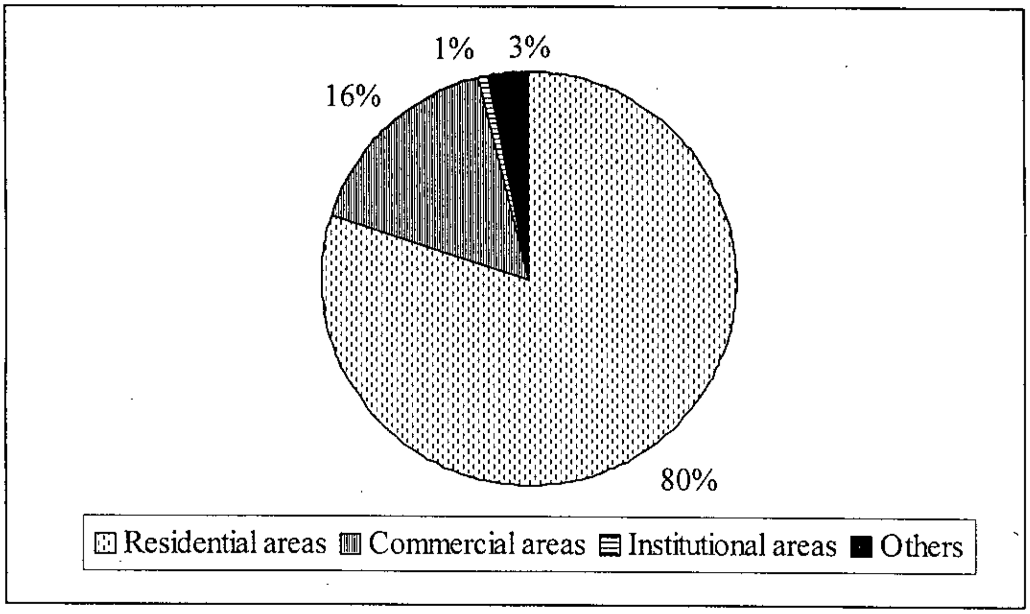


Figure 5.8 Generation of MSW from different sources in Barisal city

5.2.4.7 Rate of generation

The daily-generated MSW within the city is about 130 tons and the populations of Barisal city are about 0.4 millions so MSW generation rate as estimated as 0.325 kg/capita/day.

5.3 Physical Composition of MSW

A complete picture about the composition of MSW is an essential part for selection of the appropriate type of storage and transport system, determination of the potential resource recovery, choice of a suitable method of disposal, and the determination of the environmental impact exerted by MSW. In major cities of Bangladesh, it is observed that the food and vegetable wastes are the predominant component in the waste stream. The habit of food consumption is common and important in each city. The evaluations of composition of MSW at the study areas are described in the following sections.

5.3.1 Composition in sources

The MSW composition for each city is estimated by the ratio of waste generation to each source. In Dhaka city, the total MSW generation is 5340 tons/day, in which residential is 75.9%, commercial is 22.1% and institutional and others is 2%. Each component of MSW for Dhaka city is estimated as:

$$W = R \times 0.759 + C \times 0.221 + I \times 0.020$$

Where

W = Particular component for each city, %

R = Average value of particular component from residential areas, %

C = Average value of particular component from commercial areas, %

I = Average value of particular component from institutional and other areas, %

Similarly,

For Khulna city, $W = R \times 0.859 + C \times 0.116 + I \times 0.025$

For Rajshahi city, $W = R \times 0.772 + C \times 0.186 + I \times 0.042$

For Barisal city, $W = R \times 0.795 + C \times 0.155 + I \times 0.050$

The values of R, C, I and W in wet weight basis and composition of MSW in school areas is considered as the composition in institutional areas for calculation. Composition of MSW in commercial areas is established by sampling in two places for each city. One in wet market area and another is shopping complex area. The composition of MSW in wet market, shopping complex and hospital areas in six major cities of Bangladesh are given in Table B.1, Table B.2 and Table B.4, respectively, in Annexure B.

5.3.1.1 Dhaka city

Table 5.13 indicates that the food and vegetable waste are 68.3% for the whole city whereas paper with a portion of 10.7%, which is largely lower than food waste in Dhaka city. Plastic are 4.3%, have indicated the packaging materials are not densely related to the daily life. Metal component is only 2.0%, which is very low quantity, and its major portion comes from soft drink cans while the dust and ashes are 6.7% resulting from the daily street, house and yard sweepings.

Table 5.13 Physical composition of MSW in Dhaka city (in wet weight %)

MSW Composition	R	C	I	W
Food and Vegetables	77.0	43.3	17.0	68.3
Paper and Paper Products	5.0	26.7	49.0	10.7
Polythene and Plastics	3.0	7.8	14.0	4.3
Textile and Woods	2.0	3.1	1.0	2.2
Rubber and Leathers	1.5	1.4	0.5	1.4
Metal and Tins	2.0	1.6	4.0	2.0
Glass and Ceramics	0.5	1.4	0.5	0.7
Brick, Concrete and Stone	2.0	0.7	4.0	1.8
Dust, Ash and Mud Products	5.0	12.3	9.0	6.7
Others (bone, rope etc.)	2.0	1.7	1.0	1.9
Total	**100.0**	**100.0**	**100.0**	**100.0**

Note: R-Residential area, C-Commercial area, I-Institutional area, W - The whole city

5.3.1.2 Khulna city

Table 5.14 indicates that the food and vegetable waste are 78.9% for the whole city whereas paper with a portion of 9.5%, which is largely lower than food waste in Khulna city. Plastic are 3.1%, have indicated the packaging materials are not densely related to the daily life. Metal component is only 1.1%, which is very low quantity, and its major portion comes from soft drink cans while the dust and ashes are 3.7% resulting from the daily street, house and yard sweepings.

Table 5.14 Physical composition of MSW in Khulna city (in wet weight %)				
MSW Composition	**R**	**C**	**I**	**W**
Food and Vegetables	86.0	40.1	16.0	78.9
Paper and Paper Products	6.0	27.2	48.0	9.5
Polythene and Plastics	2.0	9.1	14.0	3.1
Textile and Woods	1.0	3.3	3.0	1.3
Rubber and Leathers	0.5	0.8	0.0	0.5
Metal and Tins	1.0	1.6	2.0	1.1
Glass and Ceramics	0.5	0.6	0.0	0.5
Brick, Concrete and Stone	0.5	1.0	1.0	0.1
Dust, Ash and Mud Products	2.0	13.9	14.0	3.7
Others (bone, rope etc.)	0.5	2.4	2.0	1.2
Total	**100.0**	**100.0**	**100.0**	**100.0**

Note: R-Residential area, C-Commercial area, I-Institutional area, W - The whole city

5.3.1.3 Rajshahi city

Table 5.15 indicates that the food and vegetable waste are 71.1% for the whole city whereas paper with a portion of 8.9%, which is largely lower than food waste in Rajshahi city. Plastic are 4.0%, have indicated the packaging materials are not densely related to the daily life. Metal component is only 1.1%, which is very low quantity, and its major portion comes from soft drink cans while the dust and ashes are 6.5% resulting from the daily street, house and yard sweepings.

Table 5.15 Physical composition of MSW in Rajshahi city (in wet weight %)				
MSW Composition	**R**	**C**	**I**	**W**
Food and Vegetables	79.0	50.5	18.0	71.1
Paper and Paper Products	4.0	20.5	47.0	8.9
Polythene and Plastics	3.0	6.6	12.0	4.0
Textile and Woods	1.0	5.8	2.0	1.9
Rubber and Leathers	1.0	2.0	0.0	1.1
Metal and Tins	1.0	1.4	1.0	1.1
Glass and Ceramics	1.0	1.6	1.0	1.1
Brick, Concrete and Stone	3.0	2.2	4.0	2.9
Dust, Ash and Mud Products	6.0	6.9	13.0	6.5
Others (bone, rope etc.)	1.0	2.6	2.0	1.3
Total	**100.0**	**100.0**	**100.0**	**100.0**

Note: R-Residential area, C-Commercial area, I-Institutional area, W - The whole city

5.3.1.4 Barisal city

Table 5.16 indicates that the food and vegetable waste are 81.1% for the whole city whereas paper with a portion of 7.2%, which is largely lower than food waste in Barisal city. Plastic are 3.5%, have indicated 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 and ashes are 3.1% resulting from the daily street, house and yard sweepings.

Table 5.16 Physical composition of MSW in Barisal city (in wet weight %)

MSW Composition	R	C	I	W
Food and Vegetables	91.0	48.8	24.0	81.1
Paper and Paper Products	2.0	23.2	41.0	7.2
Polythene and Plastics	1.0	10.5	21.0	3.5
Textile and Woods	1.5	1.0	3.0	1.9
Rubber and Leathers	0.5	0.7	0.0	0.1
Metal and Tins	1.0	1.8	2.0	1.2
Glass and Ceramics	0.5	0.5	1.0	0.5
Brick, Concrete and Stone	0.5	0.2	1.0	0.1
Dust, Ash and Mud Products	1.0	12.3	7.0	3.1
Others (bone, rope etc.)	1.0	1.0	0.0	1.3
Total	**100.0**	**100.0**	**100.0**	**100.0**

Note: R-Residential area, C-Commercial area, I-Institutional area, W - The whole city

5.3.2 Composition in secondary disposal sites

The average physical composition of MSW at SDS in four major cities of Bangladesh is shown in Table 5.17. The average food and vegetable wastes are 70.8% whereas paper with a portion of 6.3%, which is largely lower than food waste in secondary sites. Plastics are 4.3%, which indicates the packaging materials are not densely related to the daily life. Metal component is only 1%, which is very low quantity, and its major portion comes from soft drink cans while the dust and ashes are 2.3% resulting from the daily street, house and yard sweepings.

Table 5.17 Physical composition of MSW at SDS in four major cities of Bangladesh (in wet weight %)					
MSW Composition	**Dhaka**	**Khulna**	**Rajshahi**	**Barisal**	**Average**
Food and Vegetables	70	68	69	76	70.8
Paper and Paper Products	7	7	7	4	6.3
Polythene and Plastics	3	6	5	3	4.3
Textile and Woods	5	7	6	6	6.0
Rubber and Leathers	2	3	2	1	2.0
Metal and Tins	1	1	1	1	1.0
Glass and Ceramics	2	1	1	2	1.5
Brick, Concrete and Stone	2	3	2	2	2.0
Dust, Ash & Mud Products	2	2	3	1	2.3
Others (bone, rope etc.)	6	2	4	4	4.0
Total	**100**	**100**	**100**	**100**	**100**

5.4 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 5.18 represents the physical characteristics of MSW in four major cities of Bangladesh where all figures are the average values of 10 tests, which are given in Table C.1 and Table C.2 in Annexure C. The measured values for different physical parameters are described in the following sections:

5.4.1 pH

The pH values of MSW are measured as 8.69, 7.76, 7.72 and 7.70 for Dhaka, Khulna, Rajshahi and Barisal city, respectively, as presented in Table 5.18. So it can be clearly observed that the MSW of four 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). Table 5.18 shows that the values of pH in MSW below or near 8.5 for four major cities of Bangladesh.

5.4.2 Moisture content

The moisture contents of MSW measured in the laboratory are measured as 70, 68, 56 and 57% for Dhaka, Khulna, Rajshahi and Barisal city, respectively, as presented in Table 5.18. The highest moisture content is measured as 70%, while the lowest value is 56% for Dhaka and Rajshahi city, respectively. In aerobic composting process, moisture content should be in the range between 50 and 60% during the composting process (Tchobanoglous et al., 1993). At moisture levels above 65%, reducing the interstitial oxygen during composting and causing anaerobic conditions, which produce offensive odors.

5.4.3 Volatile solid content and ash residue

The volatile solid contents are measured as 71, 56, 48 and 43%, while the ash residues are obtained as 29, 44, 52 and 57% for Dhaka, Khulna, Rajshahi and Barisal city, respectively, as presented in Table 5.18. The highest volatile solid content is measured as 71%, while the lowest value is 43% for Dhaka and Barisal city, respectively.

5.4.4 Bulk density

Bulk densities of MSW in four major cities of Bangladesh are measured by both field and laboratory testing as described in the followings.

5.4.4.1 Bulk density by field-testing

Bulk density in loose state is determined in field at four major cities of Bangladesh. The bulk densities in loose state are measured as 578, 610, 588 and 621 kg/m^3 for Dhaka, Khulna, Rajshahi and Barisal city, respectively, as presented in Table 5.18. The highest bulk density value in field in loose state is measured as 621 kg/m^3, while the lowest value is 578 kg/m^3 for Barisal and Dhaka city, respectively. However these differences can be neglected and an average bulk density of MSW for four major cities of Bangladesh can be considered as 599 kg/m^3 or 600 kg/m^3 as round figure.

5.4.4.2 Bulk density by laboratory testing

In this study, the bulk densities are categorized into three groups such as loose, medium and compact as explained earlier. The bulk densities in loose state are measured as 621, 566, 568 and 577 kg/m^3 where in medium state 951, 764, 921 and 926 kg/m^3 whereas in compacted state 1127, 875, 1052 and 1048 kg/m^3 for Dhaka, Khulna, Rajshahi and Barisal city, respectively, as presented in Table 5.18. The highest bulk density value in loose state is measured as 621 kg/m^3 for Dhaka city, while the lowest value is 566 kg/m^3 for Khulna city.

Table 5.18 Physical characteristics of MSW in four major cities of Bangladesh

Characteristics	Dhaka	Khulna	Rajshahi	Barisal	Average
pH	8.69	7.76	7.72	7.70	8.0
Moisture content (%)	70	68	56	57	63
Volatile solid (%)	71	56	48	43	55
Ash residue (%)	29	44	52	57	46
B. Density^a (loose)* kg/m^3	578	610	588	621	599
B. Density^b (loose)* kg/m^3	621	566	568	577	583
B. Density^b (medium)* kg/m^3	951	764	921	926	891
B. Density^b (compact)* kg/m^3	1127	875	1052	1048	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.

5.4.5 Particle size distribution

Table 5.19 represents the particle size distribution of MSW in four major cities of Bangladesh, which are established by sieve analysis of 10 samples from each city, given in Table C.3 in Annexure C. The average percent finer for four major cities are 100% in 200 mm sieve openings whereas 84% in 100 mm, 72% in 76.2 mm, 54% in 38.2 mm and 35% in 19.1 mm and gradually decreases for smaller sieve openings. In 100 mm sieve opening, the average highest value is 92% for Khulna city, while the lowest value is 78% for Dhaka city.

Table 5.19 Particle size distribution of MSW in four 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
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
Average	**100**	**84**	**72**	**54**	**35**	**24**	**18**	**11**	**0**

5.5 Chemical Characteristics of MSW

Chemical characteristics of MSW are especially important to determine its possible environmental impacts. The important chemical characteristics of MSW are carbon, nitrogen, carbon nitrogen ratio, phosphorous, potassium is presented in Table 5.20 and the calorific value is given in Table 5.21.

5.5.1 Carbon

In MSW, paper is the main source of carbon. Thus higher the ratio of paper to vegetable/putrescible matters, higher the concentration of carbon can be obtained. The percentages of carbon are measured as 9.02, 24.93, 6.53 and 15.15 for Dhaka, Khulna, Rajshahi and Barisal city, respectively, as presented in Table 5.20. The highest value of carbon is measured as 24.93%, while the lowest value is 6.53% for Khulna and Rajshahi city, respectively. In aerobic composting of solid waste, the higher percentages of carbon are superior as bacteria uses carbon as an energy source.

5.5.2 Nitrogen

In MSW, the main source of nitrogen is the vegetables/putrescible matter, which is very high percentage in MSW of Bangladesh. The percentages of nitrogen are measured as 0.89, 1.62, 0.56 and 1.23 for Dhaka, Khulna, Rajshahi and Barisal city, respectively, as presented in Table 5.20. The highest value of nitrogen is 1.62% whereas the lowest is 0.56% for Khulna and Rajshahi city, respectively. In aerobic composting of solid waste by Indonesian Windrow Technique (IWT), the optimum value of nitrogen appears to be about 1.4% in compost

(Enayetullah and Sinha, 2000). Nitrogen as inorganic nutrient needed by microorganism during composting of solid waste and bacteria use nitrogen for cell building in aerobic composting.

5.5.3 Carbon nitrogen ratio

An optimum balance between carbon (C) and nitrogen (N) content is necessary because the bacteria need a minimum supply of nutrients to survive in composting of solid waste. The ratios of C/N are obtained as 10.17, 16.08, 12.15 and 12.44 for Dhaka, Khulna, Rajshahi and Barisal city, respectively, as presented in Table 5.20. The highest ratio of C/N is obtained as 16.08, while the lowest value is 10.17 for Khulna and Dhaka city, respectively. In aerobic composting of solid waste, the ideal C/N ratio is between 30 and 35 and if it exceeds 50, the time required increases considerably and if the excess of carbon over nitrogen is too great, reproduction and growth decline in proportion to the exhaustion of nitrogen from the substrate. At lower C/N ratios ammonia is given off and biological activity is also impeded (Moqsud, 2003).

5.5.4 Potassium

Potassium is one of the principle inorganic nutrients needed by microorganism during composting of solid waste. The percentages of potassium are measured as 0.62, 1.37, 0.38 and 1.18 for Dhaka, Khulna, Rajshahi and Barisal city, respectively, as presented in Table 5.20. The highest value of potassium is measured as 1.37%, while the lowest value is 0.38% for Khulna and Rajshahi city, respectively and the average value is 0.887% for four major cities of Bangladesh. In aerobic composting of solid waste by IWT, the optimum value of potassium appears to be about 0.66% in compost (Enayetullah and Sinha, 2000).

5.5.5 Phosphorous

Phosphorous is another principle inorganic nutrient needed by microorganism during composting of solid waste. The percentages of phosphorous are measured as 0.31, 0.41, 0.31 and 0.40 for Dhaka, Khulna, Rajshahi and Barisal city, respectively, as presented in Table 5.20. The highest value of phosphorous is measured as 0.41% for Khulna, while the lowest value is 0.31% for Dhaka and Rajshahi city. In aerobic composting of solid waste by IWT, the optimum value of phosphorous appears to be about 0.36% in compost (Enayetullah and Sinha, 2000).

Table 5.20 Chemical characteristics of MSW in four major of Bangladesh

City	C	N	C/N	K	P
	(%)	(%)	-	(%)	(%)
Dhaka	9.02	0.89	10.17	0.62	0.31
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
Average	**13.91**	**1.08**	**12.71**	**0.89**	**0.36**

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

5.5.6 Calorific value

The calorific values for major components of MSW are shown in Table 5.21. The highest calorific value is 20,467 kJ/kg for rubber where 20,077 kJ/kg for plastics whereas 14,578 kJ/kg for wood and the lowest is 5,907 kJ/kg for food wastes. In Bangladesh, the composition of food wastes is very high, while paper, plastic, rubber and wood are comparatively very low in MSW. Calorific value for MSW is estimated by the percent of components in MSW with developing a formula. The average compositions of food wastes are 74.9% for four major cities, while papers are 9.1%, plastics are 3.7%; textile and woods are 1.8%; rubber and leathers are 0.8%; and others are 9.7%. The calorific value for MSW is estimated by using the following formula:

$$M = F \times 0.749 + PP \times 0.091 + PL \times 0.037 + W \times 0.018 + R \times 0.008 + O \times 0.097$$

Where

M = Calorific value of MSW, kJ/kg

F = Average calorific value of food waste, kJ/kg

PP = Average calorific value of papers, kJ/kg

PL = Average calorific value of plastics, kJ/kg

W = Average calorific value of wood and textiles, kJ/kg

R = Average calorific value of rubber and leathers, kJ/kg

O = Average calorific value of other wastes, kJ/kg

The values of F, PP, PL, W and R as oven dry basis and average calorific value of other wastes is considered as same as food waste.

Table 5.21 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

CHAPTER SIX

RESULTS AND DISCUSSION

6.1 General

This chapter represents the results of this study including discussion and comparison. Generation rate, total amount of generation, composition, physical and chemical characteristics of MSW as evaluated in four major cities of Bangladesh, namely, Dhaka, Khulna, Rajshahi and Barisal are illustrated in the following sections. The results are also compared with the data obtained from previous studies for some major cities of developed and developing countries.

6.2 Generation of MSW in Four Major Cities of Bangladesh

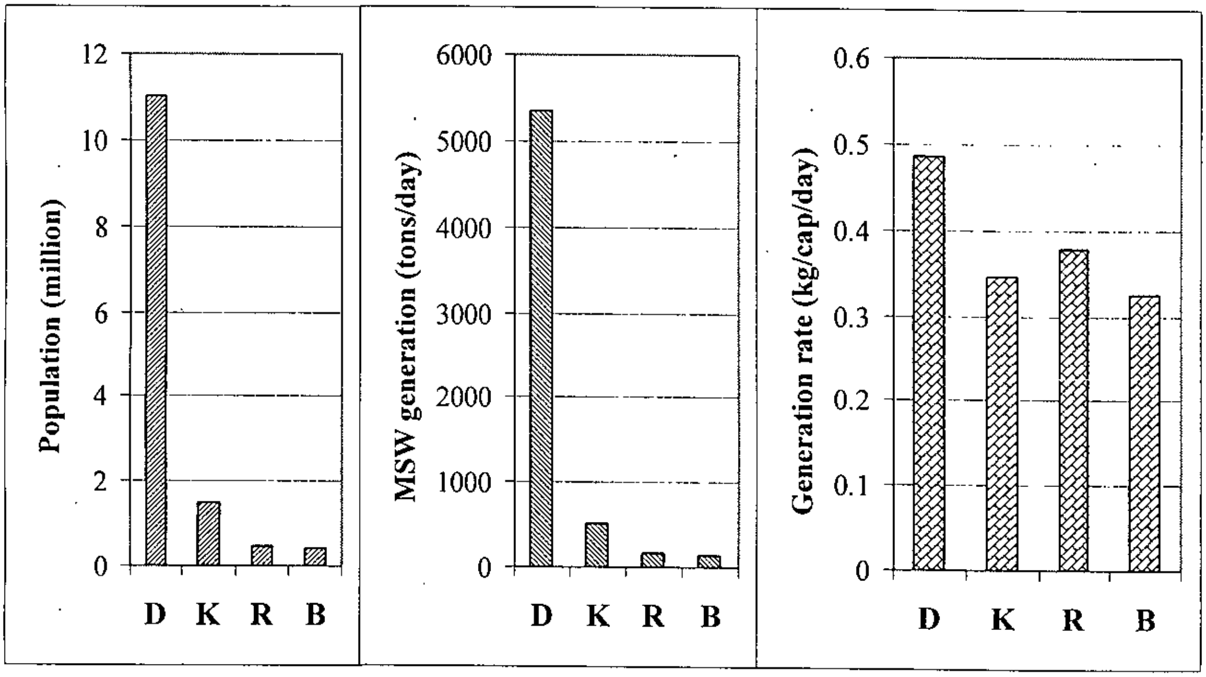
Rapid urbanization of the developing countries has increased the urban population significantly resulting in growth of industrial enterprises for the production of different consumer products. As a result, huge amounts of solid wastes are being generated daily from urban areas that have put pressure on environmental management.

Table 6.1 and Figure 6.1 indicate that the total MSW generation with per cipita waste generation in four major cities of Bangladesh where 5340 tons are daily generated in Dhaka city, while only 820 tons are daily generated from rest three major cities. Per capita waste generation rate range from 0.325 to 0.485 kg/day where high per capita waste generation rate is 0.485 kg/day in Dhaka city and low generation rate is 0.325 kg/day in Barisal city. Figure 6.2 indicates the MSW generations according to sources in four major cities of Bangladesh. Figure indicates that the major portion of MSW is generated in residential areas in each city.

Figure 6.3 shows the variation of per capita waste generation rate with respect to income level in four major cities of Bangladesh. The graph shown that the solid waste generation rate is increased mostly with respect to the increased of income level. It is due to the higher purchasing capacity of the peoples of high-income group.

Table 6.1 Generation of MSW in four major cities of Bangladesh

MSW Generation	Dhaka	Khulna	Rajshahi	Barisal
Population (Millions)	11	1.5	0.45	0.40
MSW generation (tons/day)	5340	520	170	130
Generation rate (kg/capita/day)	0.485	0.346	0.378	0.325



Note: D-Dhaka; K- Khulna; R- Rajshahi; B-Barisal

Figure 6.1 Population, total and per capita generation rate of MSW in four major cities of Bangladesh

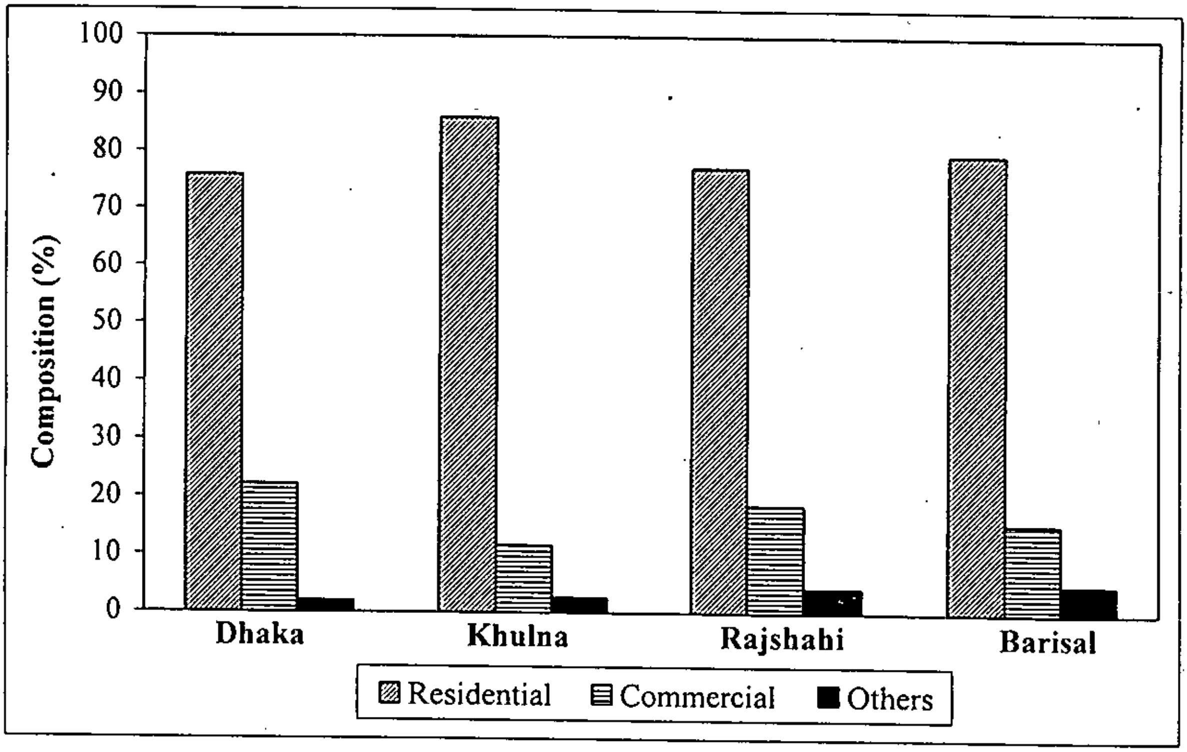


Figure 6.2 MSW generations according to sources in four major cities of Bangladesh

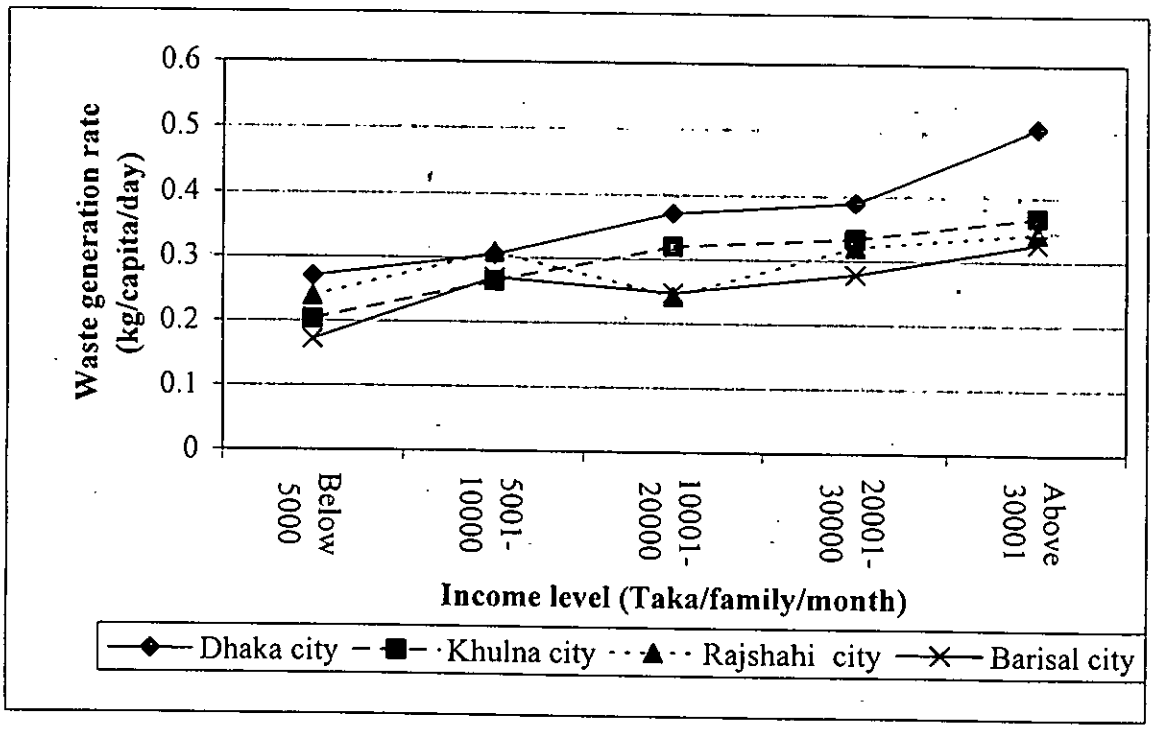


Figure 6.3 Variation of per capita waste generation rate with respect to income level in four major cities of Bangladesh

6.2.1 Comparison with previous studies

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. Reported estimates of solid waste generation vary widely as shown in Table 6.2, ranging from 1,040 tons/day in 1985-86 to 5,000 tons/day in 2004 for Dhaka city. Most of the reported values have been derived rather empirically with assumptions regarding population, number of trucks available for transportation of wastes and capacities of trucks; some estimates (e.g., BCAS, 1998) have been made on the basis of limited monitoring of truck movement at the final dumping sites. Reported solid waste density values, used in calculating waste quantity, also vary over a wide margin, ranging from 0.35 ton/m^3 (350 kg/m^3) to 0.80 ton/m^3 (800 kg/m^3).

According to DCC's estimation (DCC, 1999), the total daily MSW generation is 3,500 tons, in which 1,800 tons are collected and dumped by DCC, 900 tons go to backyard and land filling, 400 tons go to roadside and open spaces, 300 tons are recycled by the Tokais and 100 tons are recycled at the generation point. According to JICA's estimation, the total daily MSW generation is 4,700 tons in the year of 2000 and waste generation increases by 10 % per year. JICA experts forecasting the MSW generation are 5,000 tons for the year of 2004, while it is 7,649 tons for the year of 2005 and 9,256 tons for the year of 2007. According to this study MSW generation is 5,340 tons for Dhaka city in the year of 2005 and the estimated generation is much lower than JICA's prediction.

BCAS (1998) also made prediction of future waste generation based on predicted future population (assuming a growth rate of 2.74 percent) and according to these prediction, generation of solid waste would be around 15,000 tons/day for Dhaka city by the year 2020. It should be considered that the waste generation rate varies with the season of the year. During the wet season and the fruit season (when jackfruit and mangoes are available), waste generation is higher than dry winter season and the variation may be as high as 20 percent (BCAS, 1998). Table 6.3 provides waste generation data in some major cities of Bangladesh for comparison. MSW generation in Dhaka city from 1991 to 2005 is shown in Figure 6.4.

Per capita waste generation

In order to determine per capita generation of MSW from an estimated of total generation, one would require a good estimation of the population. Conversely, if reasonable estimations (present and future) of per capita generation are available, one could estimate present generation and predict future generation from reliable estimation of present and future population. However, there appears to be considerable differences among researchers on the estimation of city population, in the cities of LDACs.

Reported per capita waste generation varies over a wide margin ranging from 0.19 to 0.52 kg/capita/day for Dhaka city as presented in Table 6.2. There is a wide variation in the estimation of waste generation as well as of population in all-previous studies. BCAS (1998) and DCC (1999) provide the estimation of per capita waste generation. Based on the 1981 and 1991 census data, BCAS (1998) calculated a compound growth rate of 2.74 percent for Dhaka city and estimated a population of 4.64 million for the year of 1998. With an estimated daily generation of 2,398 tons, which gives a per capita MSW generation of 0.52 kg/day.

DCC (1999), on the other hand, reported a population of 7 million for Dhaka city, which is almost 1.5 times higher than that estimated value of BCAS (1998). However, DCC estimated the waste generation is 3,500 tons/day where per capita generation of 0.50 kg/day, which is very close to the value reported by the BCAS (1998). However in the year of 2000, JICA reported a population of 9.5 million for Dhaka city and per capita generation is 0.50 kg/day, which is very close to the value considered in this study.

Assuming an annual GAP (Gross Area Product) of 4 percent and assuming that 70 percent of the additional income would go into consumption, a waste generation growth factor of 2.8 percent (= 0.70 × 4) was estimated by BCAS (1998). Based on this growth rate, waste generation rate was estimated as 0.52 kg/capita/day in the year of 1998.

Table 6.2 Estimated quantity of MSW generation in Dhaka city of Bangladesh

Study by/ Data source	Year	Population (Millions)	MSW (tons/day)	Per capita waste generation (kg/day)
BKH[1]	1985-86	-	1,040	-
DCC[1]	1985	-	1,776	-
LBI[1]	1990	3.0	2,500	0.83
WHO[1]	1990	3.0	2,210	0.73
MMI[1]	1991	3.4	1,300	0.38
JICA[1]	1991	3.4	1,540	0.45
BCAS[1]	1991	3.4	1,590	0.47
PAS[1]	1997	4.2	3,000-5,000	0.71 - 1.19
RSWC[1]	1998	4.64	1,200-1,600	0.26 - 0.34
BCAS[1]	1998	4.64	2,398	0.52
DCC[1]	1999	7	3,500	0.50
JICA, 2000	2000	9.5	4,750	0.50
JICA, 2000[a]	2004	10	5,000	0.50
Newspaper[2]	2004	10	4,000-5,000	0.4 - 0.5
This study	2005	11	5,340	0.48
JICA, 2000[a]	2005	-	7,649	-
JICA, 2000[a]	2007	-	9,256	-

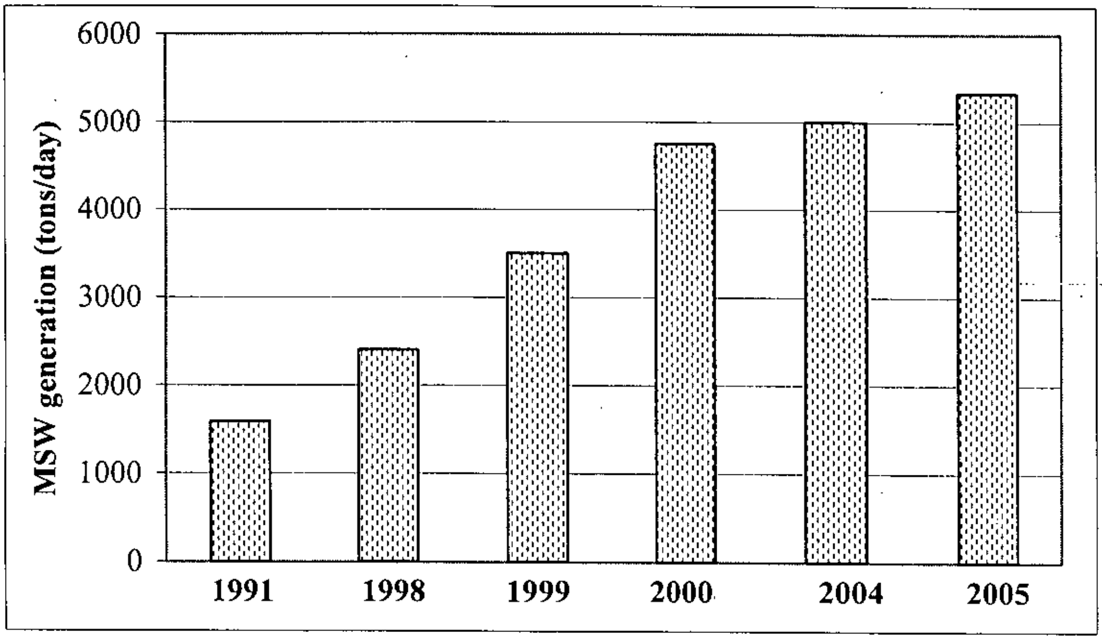
Note: [a] Forecasting value

Source: [1]Ali, 2001; [2]Bhorerkagoj, 2005

Table 6.3 Estimated quantity of MSW generation in some major cities of Bangladesh

City	Year	Population (millions)	MSW (tons/day)	Per capita generation (kg/day)
Khulna[1]	2000	9.09	201	0.22
Khulna[2]	2004	1.30	300	0.23
Khulna[3]	2005	1.50	520	0.35
Rajshahi[4]	1999	0.50	200 -300	0.4-0.6
Rajshahi[3]	2005	0.40	170	0.38
Barisal[3]	2005	0.45	130	0.33

Source: [1]Waste Concern, 2000; [2]New Age, 2004; [4]Ali, 2001; [3]This study



Source: 1991 & 1998 – BCAS; 1999 – DCC; 2000 – JICA; 2004 – JICA (forecast); 2005 – This study

Figure 6.4 MSW generation in Dhaka city of Bangladesh

6.2.2 Comparison with major cities of Asian countries

There exists a wide variation in the per capita solid waste generation in the Asian countries due to geographical locations, climate factors, economy disparity and consumption pattern. Table 6.4 provides waste generation in the capital cities of some Asian countries for comparison and then illustrates the acceptability of the present study. Population is a great concern in MSW generation, so comparison would be more plausible when the comparable cities have identical population. Table 6.5 shows the waste generation in major cities of some Asian countries for comparison.

6.3 Composition of MSW in Four Major Cities of Bangladesh

The composition of MSW differs in 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 etc.

Table 6.4 Estimated quantity of MSW generation in capital cities of some Asian countries

Country	City	Year	Population (millions)	MSW (tons/day)	Per capita generation (kg/day)
Indonesia[1]	Jakarta	1986	7.3	4,930	0.68
Japan[2]	Tokyo	1987	8.6	12,305	1.44
Singapore[2]	Singapore	1987	2.6	5,132	1.96
Thailand[1]	Bangkok	1990	5.7	5,043	0.88
Malaysia[3]	Kuala Lumpur	1993	1.2	1,913	1.55
Philippines[1]	Manila	1997	9.5	5,345	0.57
Viet Nam[1]	Hanoi	2000	1.3	1,752	1.33
Nepal[4]	Kathmandu	2000	0.7	212	0.30
Myanmar[5]	Yangon	2000	5.7	3,000	0.52
China[6]	Beijing	2002	12.9	12,181	0.94
Sri Lanka[6]	Colombo	2002	2.4	2,927	1.22
India[6]	Delhi	2002	8.4	4,000	0.48
Bangladesh[7]	Dhaka	2005	11	5,340	0.48

Source: [1]JICA, 2004; [2]Ali, 2001; [3]Chan, 1993; [4]KMC, 2000; [5]YMC, 2000; [6]Visvanathan et al., 2004; [7]This study

There is a little variation in MSW composition at some 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 6.6 indicates MSW composition in four major cities of Bangladesh, in which food and vegetables waste ranges from 68 to 81%, while paper and plastics are 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. Organic wastes are the major portions in the generated solid waste with compare to small amount of inorganic and among the organic wastes, food and vegetables wastes are dominated portion. Physical composition of MSW in four cities of Bangladesh according to source and SDS are also given in Table 6.6 for comparison. Physical composition of MSW in four major cities of Bangladesh is shown in Figure 6.5. Figure 6.6 shows the average composition of MSW for four major cities of Bangladesh. It is observed that food and vegetables waste is the dominated portion of the total waste, which is different from other developed city of the world.

Table 6.5 Estimated quantity of MSW generation in major cities of some Asian countries

Country	City	Year	Population (millions)	MSW (tons/day)	Per capita generation (kg/day)
India[1]	Nagpur	2002	1.6	443	0.28
India[1]	Jaipur	2002	1.5	580	0.39
India[1]	Lucknow	2002	1.6	1,010	0.63
India[1]	Surat	2002	1.5	900	0.32
Sri Lanka[1]	Kalutara	2002	1.3	316	0.24
Sri Lanka[1]	Kandy	2002	1.6	648	0.41
Sri Lanka[1]	Kurunagala	2002	1.5	264	0.18
China[1]	Yingquang	2002	1.1	623	0.57
China[1]	Haikou	2002	1.1	795	0.72
China[1]	Xining	2002	1.3	2,118	1.63
Bangladesh[2]	Khulna	2005	1.5	520	0.35
India[1]	Kochi	2002	0.70	347	0.50
India[1]	Vishakapatnam	2002	0.80	300	0.38
India[1]	Coimbatore	2002	0.80	350	0.44
India[1]	Patna	2002	0.9	330	0.37
Sri Lanka[1]	Ampara	2002	0.50	184	0.37
Sri Lanka[1]	Batticaloa	2002	0.60	500	0.83
Sri Lanka[1]	Monaragala	2002	0.40	92	0.23
Sri Lanka[1]	Nuwaraeliya	2002	0.50	180	0.36
Sri Lanka[1]	Matale	2002	0.5	64	0.13
Thailand[1]	Phatum Thani	2002	0.30	479	1.62
Thailand[1]	Samut Prakarn	2002	0.77	781	1.02
China[1]	Lasha	2002	0.30	449	1.50
Bangladesh[2]	Rajshahi	2005	0.45	170	0.38
Bangladesh[2]	Barisal	2005	0.40	130	0.33

Source: [1]Visvanathan et al., 2004; [2]This study

6.3.1 Comparison with previous studies

Since solid waste from different sources is typically dumped into the same container/truck, the waste obviously get mixed. The composition in Table 6.7 represents the average composition of solid waste from different sources. A number of studies have been conducted (e.g. Rahman, 1993a; IFRD & BCSIR, 1998) to determine the composition of solid waste generated in Dhaka city. Food wastes are varied over a wide margin ranging from 58.72 to 88% whereas paper and plastics vary from 1 to 9.59% and 1 to 6.76%, respectively, as reported in the previous studies in Dhaka city. The remaining portions of waste are rubber, cloth, metal, tin, glass, dust and others. The composition represents in Table 6.7 as an out come of this study, is very close to the values of previous studies.

Table 6.6 Physical composition of MSW in four major cities of Bangladesh (in wet weight %)

MSW Composition	Dhaka	Khulna	Rajshahi	Barisal	Average	SDS
Food & Vegetables	68.3	78.9	71.1	81.1	74.9	70.8
Paper & Paper Products	10.7	9.5	8.9	7.2	9.1	6.3
Polythene & Plastics	4.3	3.1	4.0	3.5	3.7	4.3
Textile & Woods	2.2	1.3	1.9	1.9	1.8	6.0
Rubber & Leathers	1.4	0.5	1.1	0.1	0.8	2.0
Metal & Tins	2.0	1.1	1.1	1.2	1.3	1.0
Glass & Ceramics	0.7	0.5	1.1	0.5	0.7	1.5
Brick, Concrete & Stone	1.8	0.1	2.9	0.1	1.2	2.0
Dust, Ash & Mud Products	6.7	3.7	6.5	3.1	5.0	2.3
Others (bone, rope etc.)	1.9	1.2	1.3	1.3	1.4	4.0
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

SDS -Secondary Disposal Site (average values of four cities)

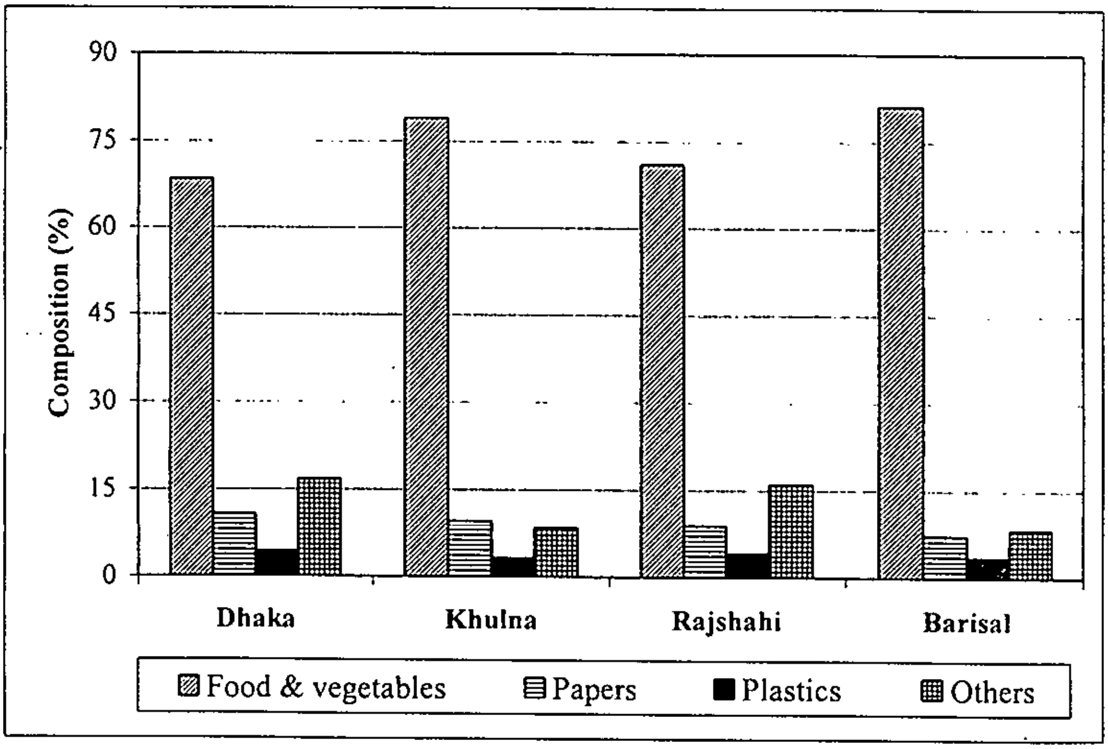


Figure 6.5 Physical composition of MSW in four major cities of Bangladesh

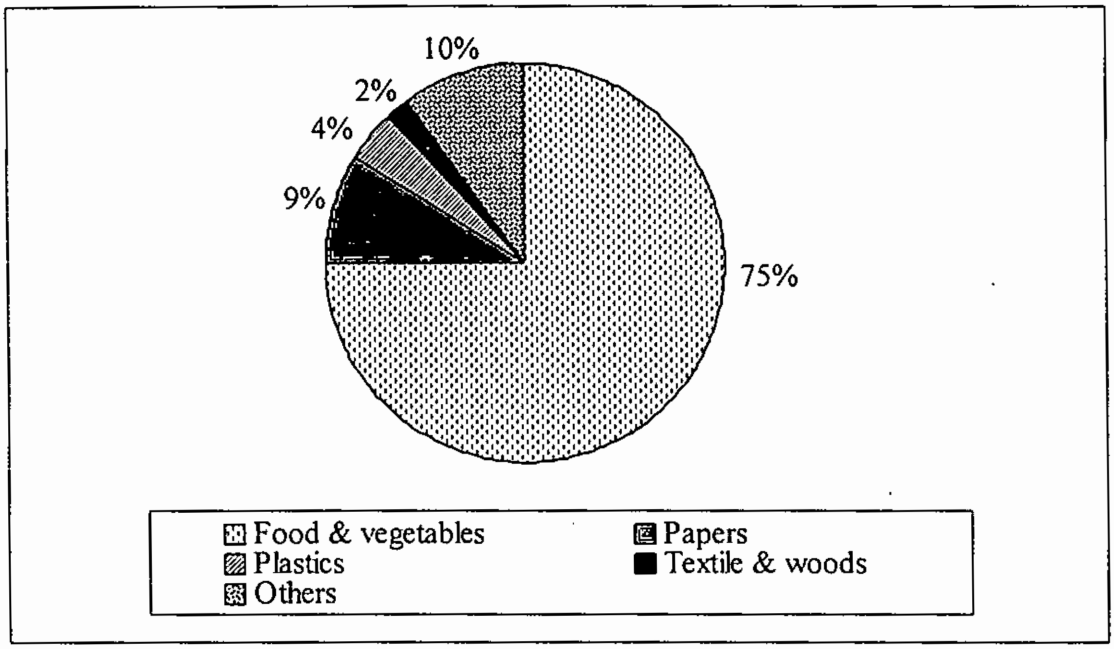


Figure 6.6 Average composition of MSW for four major cities of Bangladesh

Table 6.7 Comparison of physical composition of MSW in four major cities of Bangladesh (in wet weight %)

City	Year	Composition (% by wet wt.)							
		Food waste	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[4]	2005	68.30	10.70	4.30	2.20	1.40	2.00	0.70	10.40
Khulna[4]	2005	78.90	9.50	3.10	1.30	0.50	1.10	0.50	5.10
Rajshahi[4]	2005	71.10	8.90	4.00	1.90	1.10	1.10	1.10	10.80
Barisal[4]	2005	81.10	7.20	3.50	1.90	0.10	1.20	0.50	4.50

Note: *Includes glass, metal & others; ^ Includes metal, glass & woods

Source: [1]Rahman, 1993a; [2]IFRD and BCSIR, 1998; [3]BCSIR, 1998; [4]This study

6.3.2 Comparison with major cities of some developed and developing countries

The major portions of the MSW stream in the cities of Asian countries are dominated by organic wastes generated from households, markets and other places. Food wastes are the major portions of organic fraction. But in developed cities like Paris, New York and Vienna, paper and paper products fraction are dominated and food waste portion are largely lower than paper due to various reasons persisting in the developed city. Table 6.8 indicates the composition of MSW in capital cities of some developed and developing countries. In Asian capital cities, food wastes are vary over a wide margin ranging from 22 to 70%, whereas paper and plastics vary from 1 to 16% and 1 to 18%, respectively, from previous studies. The remaining portions of waste are rubber, cloth, metal, tin, glass, dust and others. The values of recent study represent the similarity in MSW composition with Asian cities. Table 6.9 indicates MSW composition in major cities of some developed and developing countries, for comparing with other major cities of Bangladesh.

Table 6.8 Physical compositions of MSW in the capital cities of some developed and developing countries (in wet weight %)

Capital City	Year	Composition (% by wet weight)							
		Food waste	Paper	Plastic	Textile, Wood	Rubber, Leather	Metal	Glass	Others
Manila, P[1]	1985	45.50	14.50	8.60*	1.30		4.90	2.70	31.10
Paris, F[1]	1994	16.30	40.90	8.40*	4.40		3.20	9.40	25.80
Vienna, A[1]	1994	23.30	33.60	7.00*	3.10		3.70	10.4	25.90
Seoul, K[1]	1985	22.30	16.20	9.60*	3.80		4.10	10.60	43.00
Mexico, M[1]	1992	59.80[a]	11.90	3.50*	0.40		1.10	3.30	83.30
Kuala Lumpur, Ma[2]	1993	32.50	28.40	17.70	9.80	0.30	3.30	2.20	5.80
Kathmandu, Nepal[3]	2000	69.80	8.50	9.17	3.20	0.66	0.87	2.5	5.30
Yangon, My[4]	2000	58.00	1.00	4.00	-	-	-	-	3.70
Beijing, C[5]	2002	50.79	4.91	5.88	3.43	-	0.04	0.74	34.21
Delhi, I[5]	2002	31.78	6.60	1.50	4.00	0.60	2.50	1.20	51.82
Colombo, S[5]	2002	68.15	5.99	6.69	5.02	-	1.85	1.64	10.66
Dhaka, B[6]	2005	68.30	10.70	4.30	2.20	1.40	2.00	0.70	10.40

Note: P- Philippine; F- France; A-Austria; K-Korea; M- Mexico; Ma-Malaysia; My-Myanmar; C-China; I-India; S- Sri Lanka; B-Bangladesh; * Value for Plastic, rubber and leather; [a] Includes small amounts of wood, hay and straw

Source: [1]Diaz et al., 1996; [2]Chan, 1993; [3]KMC, 2000; [4]YMC, 2000; [5]Visvanathan et al., 2004; [6]This study

Table 6.9 Physical compositions of MSW in major cities of some developed and developing countries (in wet weight %)

City	Year	Composition (% by wet weight)							
		Food waste	Paper	Plastic	Textile, Wood	Rubber, Leather	Metal	Glass	Others
Olongapo, P[1]	1987	44.40	17.50	8.70*	2.90	-	3.10	2.00	30.10
California, U[1]	1993	45.50	14.50	8.60*	1.30	-	4.90	2.70	31.10
Texas, U[1]	1993	43.80	34.00	7.50*	2.00	-	4.30	5.50	10.40
Shanghai, C[2]	2002	68.15	9.11	13.26	4.17	-	0.86	3.33	1.12
Tianjin, C[2]	2002	78.43	8.84	8.00	2.33	-	0.21	0.97	1.22
Hat Yai, T[2]	2002	56.50	5.25	14.20	0.73	1.66	3.50	2.58	15.58
Pattaya, T[2]	2002	64.30	2.80	20.89	1.10	2.76	1.47	1.10	5.58
Bangalore, I[2]	2002	45.00	8.00	6.00	5.00	-	3.00	6.00	27.00
Kolkata, I[2]	2002	40.00	10.00	8.00	3.00	1.00	-	3.00	35.00
Chennai, I[2]	2002	44.00	10.00	3.00	5.00	5.00	-	-	33.00
Mumbai, I[2]	2002	40.00	10.00	2.00	3.60	0.20	-	0.22	43.98
Jaffna, S[2]	2002	54.85	12.80	7.21	5.58	-	8.49	2.21	8.86
Kandy, S[2]	2002	54.83	11.08	4.02	6.36	-	4.46	5.35	13.90
Khulna, B[3]	2005	78.90	9.50	3.10	1.30	0.50	1.10	0.50	5.10
Rajshahi, B[3]	2005	71.10	8.90	4.00	1.90	1.10	1.10	1.10	10.80
Barisal, B[3]	2005	81.10	7.20	3.50	1.90	0.10	1.20	0.50	4.50

Note: P- Philippine; U- USA; C-China; T-Thailand; I-India; S- Sri Lanka; B-Bangladesh;
*Value for Plastic, Rubber and Leather

Source: [1]Diaz et al., 1996; [2]Visvanathan et al., 2004; [3]This study

6.4 Characteristics of MSW in Four Major Cities of Bangladesh

The characteristics of MSW are generally heterogeneous and very seasonally. The pH values range from 7.70 to 8.69 for four major cities of Bangladesh, while the moisture content, volatile solid content and ash residue range from 56 to 70%, 43 to 71% and 29 to 57%, respectively. Figure 6.7 shows the comparison of pH values of MSW in four major cities of Bangladesh where the highest pH value is found in Dhaka city. The bulk density in loose state ranges from 566 to 621 kg/m^3, while in medium and compact state ranges from 764 to 951 kg/m^3 and 875 to 1127 kg/m^3, respectively by laboratory testing. The bulk density in loose state for four major cities ranges from 578 to 621 kg/m^3 in field. Loose bulk density for low-income developing countries are varied from 300 to 600 kg/m^3 is shown in Table 2.5 (Diaz et al., 1996). The maximum values of bulk density of this study are remaining within the range except some values.

The average particle size distribution curve of MSW for four major cities of Bangladesh is shown in Figure 6.8. The average percent finer of four major cities of Bangladesh are 100% in 200 mm sieve openings, while 84% in 100 mm, 72% in 76.2 mm, 54% in 38.2 mm, 35% in 19.1 mm and gradually decreases for smaller sieve openings.

The concentration of carbon for four major cities of Bangladesh ranges from 6.53 to 24.93%, while nitrogen, potassium and phosphorous range from 0.56 to 1.62%, 0.38 to 1.37% and 0.31 to 0.41%, respectively. Figure 6.9 shows the concentration of moisture, volatile solid, carbon and nitrogen in percent for MSW in four major cities of Bangladesh. Comparison of C/N ratios of MSW in four major cities of Bangladesh is shown in Figure 6.10 where the highest C/N ratio is found in MSW of Khulna city. Figure 6.11 shows the calorific values of major components of MSW. The highest calorific value is found in rubber, while the lowest value in food waste.

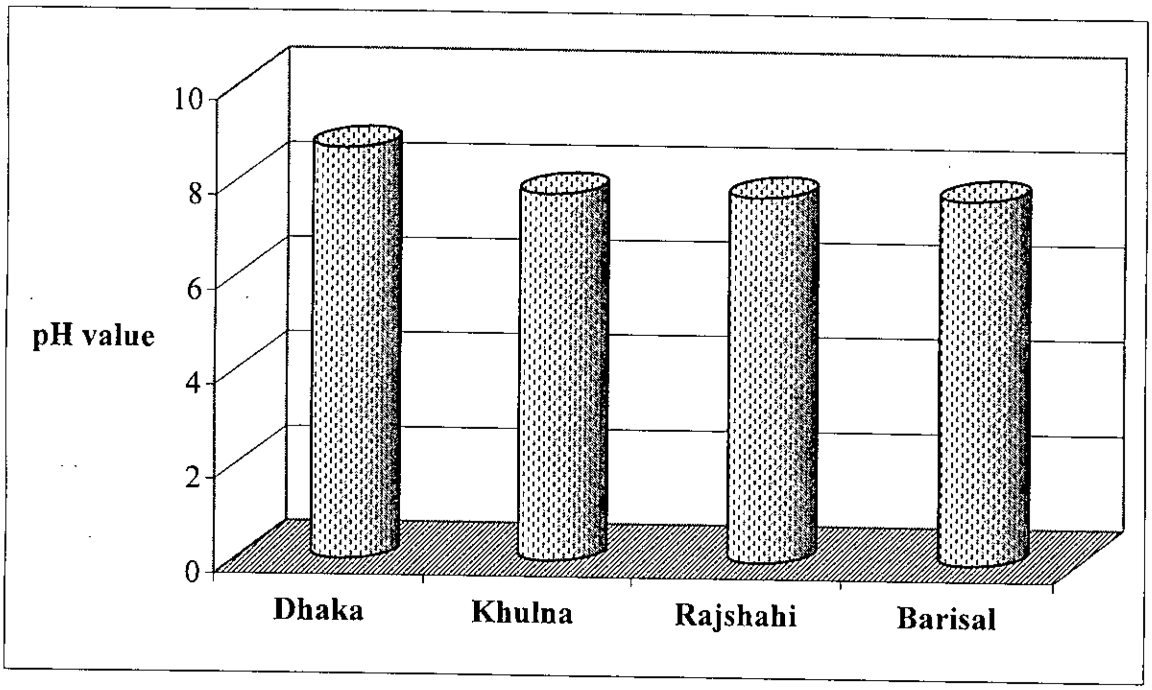


Figure 6.7 Comparison of pH values of MSW in four major cities of Bangladesh

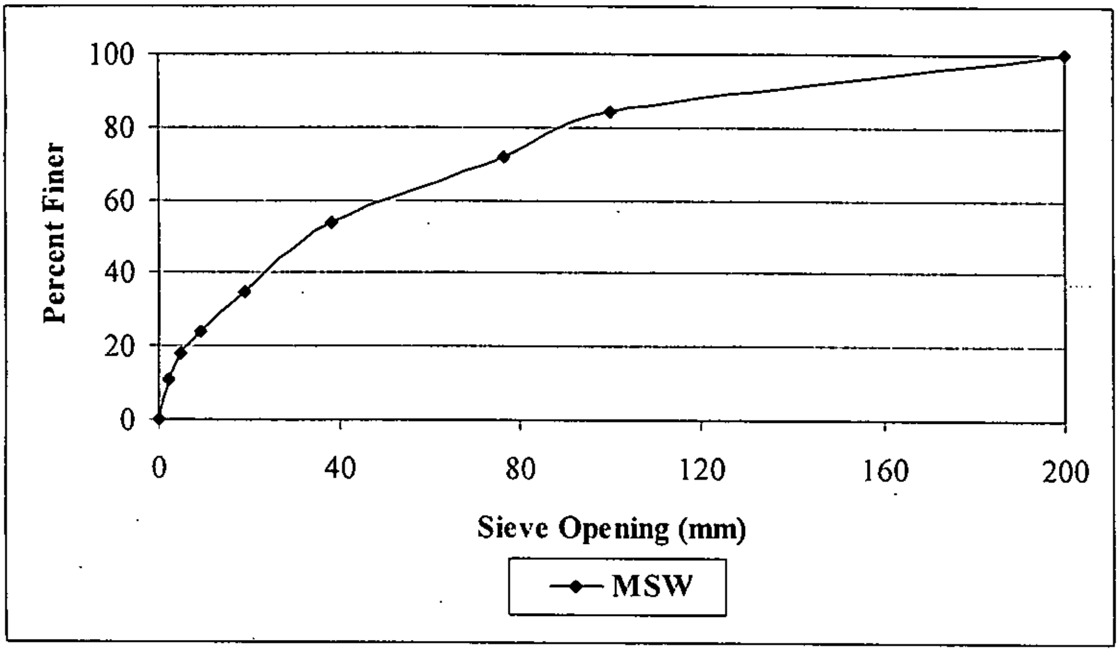


Figure 6.8 Average particle size distribution curve of MSW for four major cities of Bangladesh

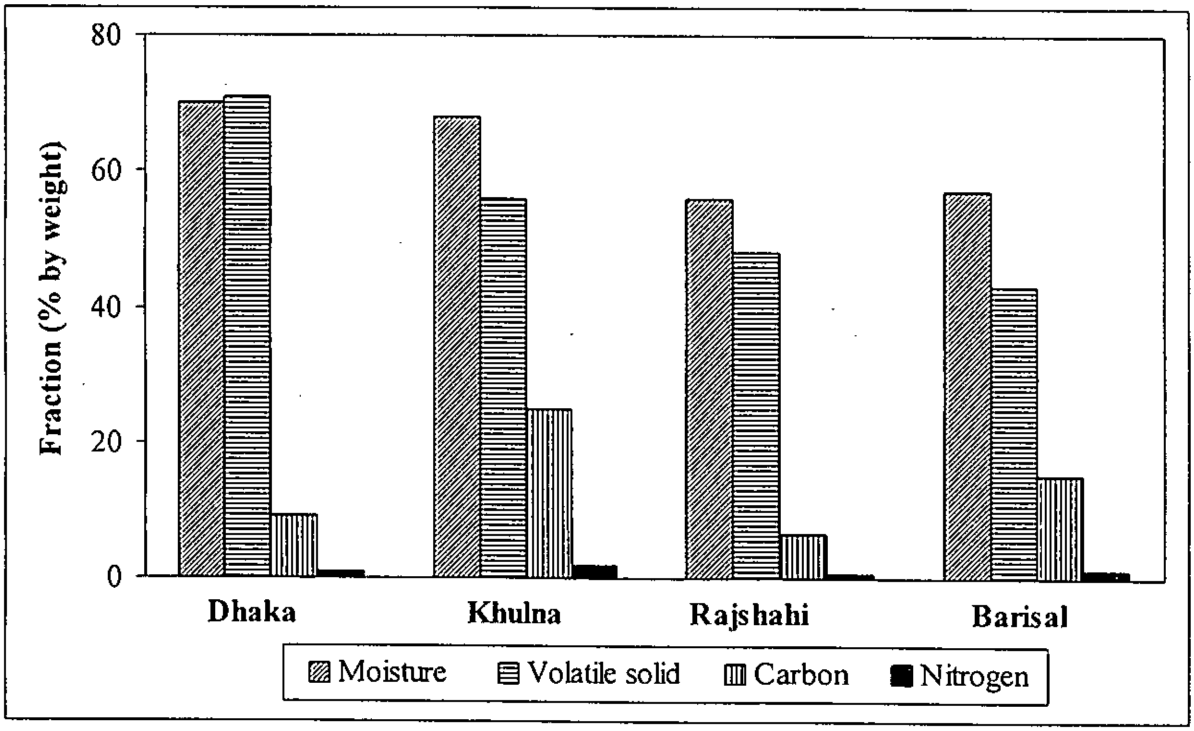


Figure 6.9 Major characteristics of MSW in four major cities of Bangladesh

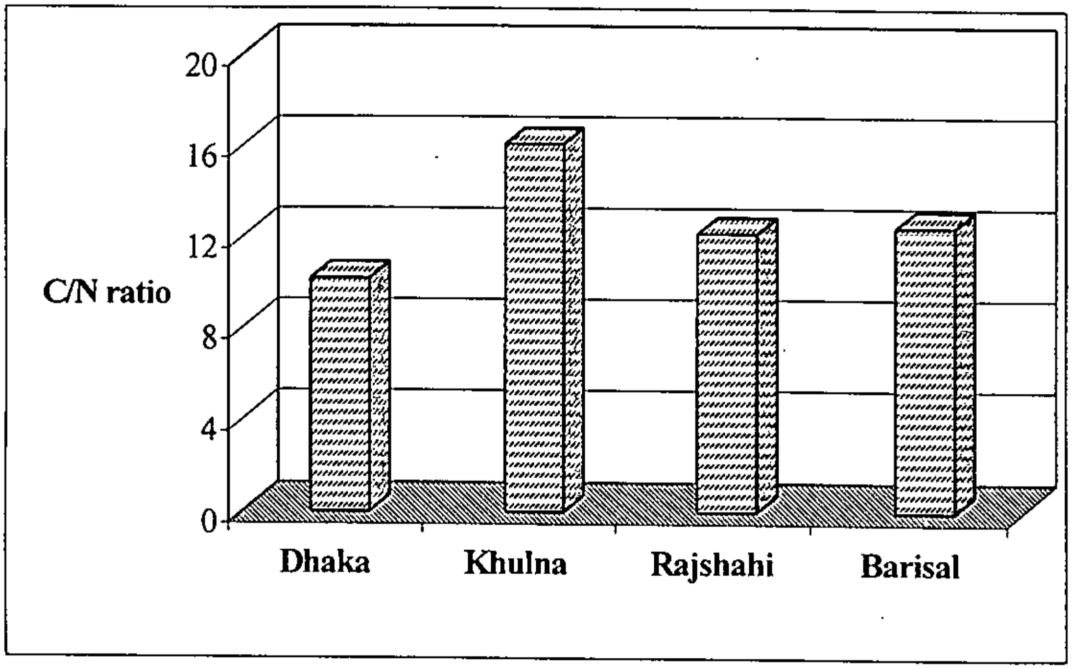


Figure 6.10 C/N ratios of MSW in four major cities of Bangladesh

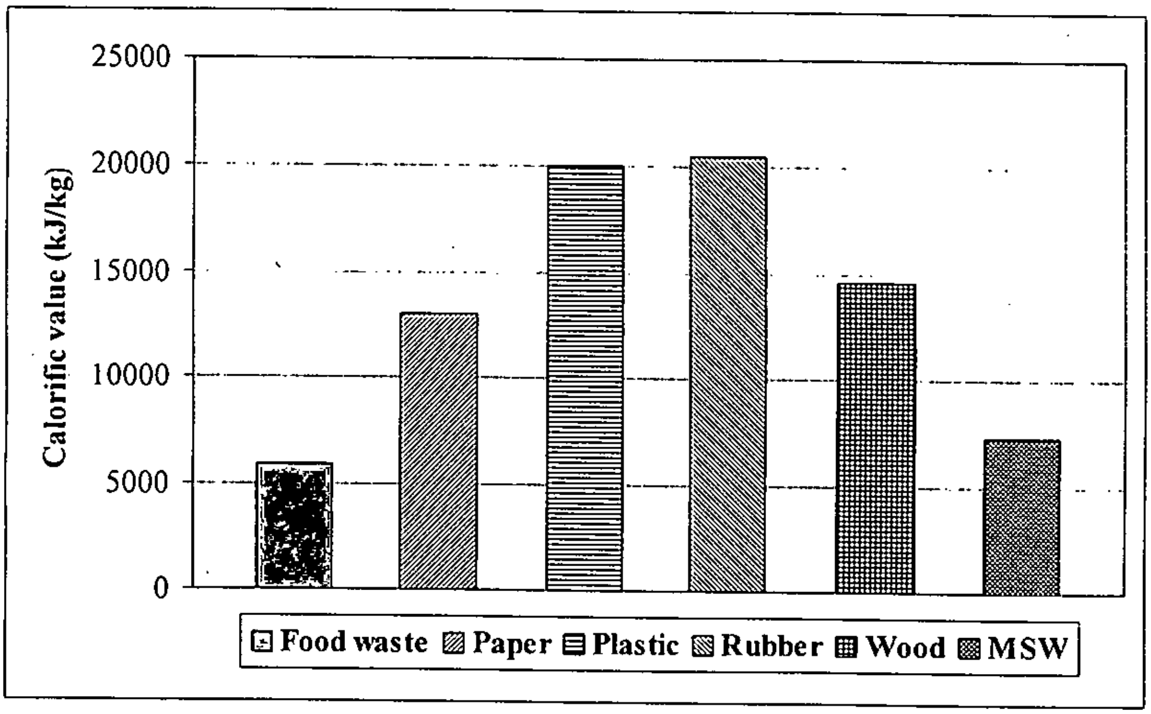


Figure 6.11 Calorific values of major components of MSW in four major cities of Bangladesh

6.4.1 Comparison with previous studies

BCSIR (1998) conducted several studies in Dhaka city to identify the physical and chemical characteristics of MSW. Table 6.10 shows the comparison of MSW characteristics of Dhaka city obtained in this study with previous studies. In Dhaka city, moisture content varies from 59 to 70%, while volatile solid content varies from 56 to 67.2%, carbon and nitrogen vary from 11.31 to 12.70 and 0.54 to 0.85, respectively, and the bulk density ranges from 453 to 656 kg/m^3 from previous studies. The physical and chemical characteristics of MSW obtained in this study as presented in Table 6.10 are very close to the values of previous studies.

Table 6.10 Comparison of MSW characteristics of Dhaka city

Year	pH	MC	VS	AR	C	N	C/N	K	P	S	BD
	-	(%)	(%)	(%)	(%)	(%)	-	(%)	(%)	(%)	kg/m^3
1998[1]	-	-	62.2	37.8	-	-	-	-	-	-	563
1998[1]	-	-	67.2	32.8	-	-	-	-	-	-	466
1998[1]	-	-	61.0	39.0	-	-	-	-	-	-	566
1998[1]	-	-	56.0	44.0	-	-	-	-	-	-	453
1998[1]	-	67	-	-	12.56	0.64	19.60	-	-	0.01	538
1998[1]	-	70	-	-	11.68	0.54	21.60	-	-	0.01	566
1998[1]	-	69	-	-	11.31	0.85	13.30	-	-	-	656
1998[1]	-	59	-	-	12.70	0.62	20.50	-	-	-	575
2005[2]	8.69	70.0	71.0	29.0	9.02	0.89	10.17	0.62	0.31	-	621*

Note: MC-Moisture Content, VS-Volatile Solid, AR-Ash Residue, C-Carbon, N-Nitrogen, C/N-Carbon nitrogen ratio, K-Potassium, P-Phosphorous, S-Sulfur, BD-Bulk Density; * By laboratory testing

Source: [1]BCSIR, 1998; [2]This study

6.4.2 Comparison with major cities of some developed and developing countries

Table 6.11 indicates the characteristics of MSW in some major cities of Asian countries. In Kolkata and Delhi cities, pH value ranges from 7.0 to 8.5. In major cities of Asian countries, moisture content varies from 16 to 50%, volatile solid content from 17.7 to 36%, carbon from 8.9 to 21%, nitrogen from 0.24 to 0.90%, carbon nitrogen ratio from 16.7 to 76.3, potassium from 0.35 to 0.40% and bulk density for MSW are 325 and 400 kg/m^3 for Seoul and Mexico city, respectively. The few values of physical and chemical characteristics of MSW obtained in this study as presented in Table 6.11 are nearly close and few values are very wide range variation with the values of major cities of Asian countries. Table 6.12 shows the calorific values for major components of MSW in major cities of some developed and developing countries for comparing with this study. BCSIR conducted several studies in Dhaka city to determine the calorific value of MSW in 1998. The value ranges from 7,676 to 14,421 kJ/kg, while it is 7,349 kJ/kg obtained in this study. In India, calorific value of MSW ranges from 10,816 to 16,282 kJ/kg. The calorific values for major components of MSW (i.e. food, paper, plastic, rubber etc.) in USA are nearly close to the values obtained in this study except some components.

Table 6.11 Characteristics of MSW in some major cities of Asian countries

Cities	Year	pH	MC	VS	AR	C	N	C/N	K	P	BD
		-	(%)	(%)	(%)	(%)	(%)	-	(%)	(%)	kg/m^3
Manila, P[1]	1982	-	42.6	33.8	23.6	18.3	0.24	76.3	-	-	-
Seoul, K[1]	1985	-	44.2	17.7	38.1	8.9	0.47	18.9	-	-	325
Mexico, M[1]	1992	-	50	32.5	33	15	0.90	16.7	-	-	400
Kolkata, I[2]	2002	7.0 -7.3	40-45	31-35	65-69	17.5-19.5	0.5-0.60	31-37	0.35-0.40	-	-
Delhi, I[2]	2002	8.50	16	36	64	21.0	0.6	34.0	0.40	0.65	-
Dhaka, B[3]	2005	8.69	70	71	29	9.02	0.89	10.17	0.62	0.31	621*
Khulna, B[3]	2005	7.76	68	56	44	24.93	1.62	16.08	1.37	0.41	566*
Rajshahi, B[3]	2005	7.72	56	48	52	6.53	0.56	12.15	0.38	0.31	568*
Barisal, B[3]	2005	7.70	57	43	57	15.15	1.23	12.44	1.18	0.40	577*

Note: P- Philippine, K-Korea, M- Mexico, I-India, B-Bangladesh; MC-Moisture Content, VS-Volatile Solid, AR-Ash Residue, C-Carbon, N-Nitrogen, C/N- Carbon nitrogen ratio, K-Potassium, P-Phosphorous, BD-Bulk Density; * By laboratory testing

Source: [1]Diaz et al., 1996; [2]Visvanathan et al., 2004; [3]This study

Table 6.12 Calorific values for major components of MSW in major cities of some developed and developing countries

Country	City	Year	Calorific value (kJ/kg)					
			Food	Paper	Plastic	Rubber	Wood	MSW[a]
USA	New York (R/A)[1]	1977	4652	16747	32564	23260	18608	11630
Bangladesh	Dhaka[2]	1998	-	-	-	-	-	7676
	Dhaka[2]		-	-	-	-	-	13956
	Dhaka[2]		-	-	-	-	-	10002
	Dhaka[2]		-	-	-	-	-	14421
	Dhaka[2]		-	-	-	-	-	13026
	Dhaka[2]		-	-	-	-	-	11863
	Dhaka[2]		-	-	-	-	-	11165
	Dhaka (R/A)[2]		-	-	-	-	-	12095
	Dhaka (C/A)[2]		-	-	-	-	-	11397
	Dhaka (I/A)[2]		-	-	-	-	-	9769
India	Kolkata (R/A)[3]	2003	-	-	-	-	-	10816-13526
	Delhi (R/A)[3]		-	-	-	-	-	13793
	Delhi (C/A)[3]		-	-	-	-	-	16282
	Delhi (I/A)[3]		-	-	-	-	-	12979
Bangladesh	Study area[4]	2005	5907	12994	20077	20467	14578	7349

[a] as oven dry basis; R/A- Residential area; C/A-Commercial area; I/A-Industrial area;
Btu/lb × 2.326 = kJ/kg

Source: [1]Tchobanoglous et al., 1993; [2]BCSIR, 1998; [3]Visvanathan et al., 2004; [4]This study

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Based on this study, the following conclusions can be made:

1. The MSW generation rates in residential areas are 0.368, 0.297, 0.291 and 0.258 kg/capita/day, while in commercial areas, for wet market the rates are 6.17, 3.09, 4.68 and 4.16 kg/stall/day and for shopping complex 4.56, 1.57, 1.31 and 1.02 kg/shop/day in Dhaka, Khulna, Rajshahi and Barisal city, respectively.

2. In institutional sources, the generation rates in educational institution are 0.017, 0.012, 0.008 and 0.015 kg/student/day, while for medical waste the rates are 1.55, 0.87, 0.60 and 0.95 kg/bed/day and for street sweeping 4.45, 2.86, 2.64 and 2.98 kg/100m/day in Dhaka, Khulna, Rajshahi and Barisal city, respectively.

3. The amount of MSW generations are 5340, 520, 170 and 130 tons/day for Dhaka, Khulna, Rajshahi and Barisal city, respectively and the percapita waste generation rates are varied from 0.325 to 0.485 kg/day and the average value is 0.384 kg/day for four major cities of Bangladesh.

4. Food and vegetable wastes are the major portions in residential areas, but paper and paper products are the major portions in some commercial and institutional areas. In MSW stream, food and vegetable wastes range from 68.3 to 81.1%, while papers ranges from 7.2 to 10.7% and plastics from 3.1 to 4.3% for four major cities of Bangladesh.

5. The pH value ranges from 7.70 to 8.69 for four major cities of Bangladesh, while moisture content ranges from 56 to 70%, volatile solid from 43 to 71% and ash residue from 29 to

57%. The bulk density in loose state ranges from 566 to 621 kg/m^3 but in medium and compact state, the value ranges from 764 to 951 kg/m^3 and 875 to 1127 kg/m^3, respectively, as obtained by laboratory testing. The bulk density in loose state for four major cities ranges from 578 to 621 kg/m^3 as obtained by field-testing.

6. Bulk density of MSW in loose and compact state indicates that volume can be reduced 50% by normal compaction, which is a cost-effective aspect in case of landfilling.

7. In particle size distribution, the average percent finer for four major cities are 100% in 200 mm sieve openings, whereas 84% in 100 mm, 72% in 76.2 mm, 54% in 38.2 mm, 35% in 19.1 mm and gradually decreases for smaller sieve openings.

8. The concentration of carbon for four major cities ranges from 6.53 to 24.93%, while nitrogen ranges from 0.56 to 1.62%, potassium and phosphorous range from 0.38 to 1.37% and 0.31 to 0.41%, respectively. The highest calorific value is obtained as 20,467 kJ/kg for rubber but 20,077 kJ/kg for plastics, 14,578 kJ/kg for wood and the lowest value of 5,907 kJ/kg for food wastes. The estimated overall value for MSW is 7,349 kJ/kg.

9. Considering all properties of MSW i.e. higher concentration of carbon, carbon nitrogen ratio and good NPK values, it can be concluded that MSW of Bangladesh are suitable for composting. Calorific values of MSW constituents indicate that MSW are incompatible as energy recovery option. High moisture and organic contents depicts that MSW are not suitable for incineration.

7.2 Recommendations for Future Studies

The following recommendations are suggested for future studies:

1. Study is needed throughout the year to obtain the seasonal variations of quantity as well as characteristics of MSW, which might indicate the tangible scenario.

2. If solid wastes are to be used as the raw materials of fuel, the four most important properties are to be analyzed such as 1) proximate analysis 2) fusing point of ash

3) ultimate analysis (major elements) 4) energy content, which might be an interesting future research.

3. Industrial wastes are needed to be estimate for determination of total solid waste generation in each city.

4. It is needed to extend the study in the aspect of recyclable materials and the implementation of recyclable programme in major cities of Bangladesh. This will be a guideline for establishing the relevant regulations of waste recycling programme of the city in future.

5. Detail study on MSW reduction, reuse, recycling, recovery and their effect on the management cost should be conducted.

6. It is needed to establish a relationship between waste generation amount and the affecting factors, which are positively related.

7. Heavy metal content in MSW such as Arsenic (As), Mercury (Hg), Cadmium (Cd), Chromium (Cr), Cobalt (Cu) and Lead (Pb) are needed to ascertain, which also affect the environment of natural resource.

8. It is needed to extend the study for other two major cities of Bangladesh to obtain more actual situation about MSW for whole the country.

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ANNEXURE A

Table A.1 MSW generation rates at commercial areas in four major cities of Bangladesh

Dhaka city corporation areas

Area	Shokrabad wet market			Mouchak shopping complex		
Date	02.08.04	03.08.04	04.08.04	10.08.04	11.08.04	12.08.04
Stall/Shops	200	200	200	600	600	600
Waste generation, kg	1340	1120	1240	2650	2830	2720
Generation rates, (kg/unit/day)	6.70	5.60	6.20	4.42	4.72	4.53
Average	6.17			4.56		

Khulna city corporation areas

Area	Fulbarigate wet market			Janata Market		
Date	08.08.04	09.08.04	10.08.04	15.08.04	16.08.04	17.08.04
Stall/Shops	150	150	150	25	25	25
Waste generation, kg	420	500	470	35	38	45
Generation rates, (kg/unit/day)	2.80	3.33	3.13	1.40	1.52	1.80
Average	3.09			1.57		

Rajshahi city corporation areas

Area	Binudpur wet market			Rajshahi new market		
Date	01.08.04	02.08.04	03.08.04	9.08.04	10.08.04	11.08.04
Stall/Shops	300	300	300	500	500	500
Waste generation, kg	1350	1580	1280	670	580	710
Generation rates, (kg/unit/day)	4.50	5.27	4.27	1.34	1.16	1.42
Average	4.68			1.31		

Barisal city corporation areas

Area	Bangla wet market			Venus shopping complex		
Date	01.09.04	02.09.04	03.09.04	13.09.04	14.09.04	15.09.04
Stall/Shops	120	120	120	100	100	100
Waste generation, kg	500	600	400	125	105	75
Generation rates, (kg/unit/day)	4.17	5.00	3.33	1.25	1.05	0.75
Average	4.16			1.02		

Table A.2 Total generation of MSW at commercial areas in four major cities of Bangladesh

Dhaka city corporation areas

Sources	No. of units	Rate of generation (kg/unit/day)	Total generation (tons/day)
Shopping complex	154500	4.56	704.52
Wet market	67120	6.17	414.13
Restaurants (large)	704	30	21.12
Hotel/Guest houses	642	20	12.84
Restaurants (small)	1000	5	5.00
Others (station, etc.)	Lump sum		20.00
		Total	**1177.61**

Khulna city corporation areas

Sources	No. of units	Rate of generation (kg/unit/day)	Total generation (tons/day)
Shopping complex	17500	1.57	27.48
Wet market	6200	3.09	19.16
Restaurants	750	13	9.75
Hotel/Guest houses	95	8	0.76
Others (station, etc.)	Lump sum		3.00
		Total	**60.14**

Rajshahi city corporation areas

Sources	No. of units	Rate of generation (kg/unit/day)	Total generation (tons/day)
Shopping complex	10500	1.31	13.76
Wet market	2300	4.68	10.76
Restaurants	380	12	4.56
Hotel/Guest houses	55	6	0.33
Others (station, etc.)	Lump sum		2.00
		Total	**31.54**

Barisal city corporation areas

Sources	No. of units	Rate of generation (kg/unit/day)	Total generation (tons/day)
Shopping complex	8000	1.02	8.16
Wet market	1600	4.16	6.66
Restaurants	280	13	3.64
Hotel/Guest houses	26	7	0.18
Others (station, etc.)	Lump sum		1.50
		Total	**20.14**

Table A.3 MSW generation rates at institutional areas in four major cities of Bangladesh

Dhaka city corporation areas

Area	Monipur high school			Lake view clinic		
Date	07.09.04	08.09.04	09.09.04	14.09.04	15.09.04	16.09.04
No. of Students/beds	2500	2500	2500	40	40	40
Waste generation, kg	35	45	50	70	50	65
Generation rates, (kg/day/student or bed)	0.014	0.018	0.020	1.75	1.25	1.63
Average	0.017			1.55		

Khulna city corporation areas

Area	KUET			Patients nursing home		
Date	19.09.04	20.09.04	21.09.04	26.09.04	27.09.04	28.09.04
No. of Students/beds	1300	1300	1300	10	10	10
Waste generation, kg	20	16	12	7	8	11
Generation rates, (kg/day/student or bed)	0.015	0.012	0.009	0.70	0.80	1.10
Average	0.012			0.87		

Rajshahi city corporation areas

Area	Seroil high school			Christian mission hospital		
Date	05.09.04	07.09.04	08.09.04	28.09.04	29.09.04	30.09.04
No. of Students/beds	1500	1500	1500	115	115	115
Waste generation, kg	12	10	15	70	80	58
Generation rates, (kg/day/student or bed)	0.008	0.007	0.010	0.61	0.70	0.50
Average	0.008			0.60		

Barisal city corporation areas

Area	Barisal zilla school			Seba clinic		
Date	10.08.04	11.08.04	12.08.04	22.08.04	23.08.04	24.08.04
No. of Students/beds	1200	1200	1200	30	30	30
Waste generation, kg	18	22	14	25	25	35
Generation rates, (kg/day/student or bed)	0.015	0.018	0.012	0.83	0.83	1.17
Average	0.015			0.95		

Table A.4 MSW generation rates for street sweepings in four major cities of Bangladesh

Dhaka city corporation areas				
Date	Shah Jahan Road, Mohammadpur			Average
	Waste generation (kg/day)	Road length (m)	Rate of generation (kg/100m/day)	(kg/100m/day)
19.10.04	1.85	40	4.63	4.45
20.10.04	2.56	60	4.27	
21.10.04	2.23	50	4.50	
Khulna city corporation areas				
Date	Khan Jahan Ali Road			Average
25.10.04	1.72	70	2.50	2.86
26.10.04	1.89	65	2.90	
27.10.04	2.58	80	3.20	
Rajshahi city corporation areas				
Date	Haji Mohsin Road			Average
17.10.04	1.21	65	1.90	2.64
18.10.04	1.89	50	3.80	
19.10.04	1.36	60	2.30	
Barisal city corporation areas				
Date	Kawnia Main Road			Average
12.10.04	1.65	70	2.40	2.98
13.10.04	1.85	45	4.10	
14.10.04	1.24	50	2.50	

Table A.5 MSW generation from others area in Dhaka city

Sources	**Rate of generation**	**Total generation** (tons/day)
Offices	Lump sum	12
Community centers	Lump sum	3
Slaughterhouses	Lump sum	2
Others (motel, etc.)	Lump sum	3
	Total	20

Table A.6 Solid waste generation rates at residential areas in four major cities of Bangladesh

City corporation	Dhaka city corporation areas														
Ward No.	Ward No. 26					Ward No. 40					Ward No. 41				
Income level of family	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
No. of family member (N)	N=2	N=7	N=6	N=8	N=6	N=7	N=6	N=5	N=7	N=9	N=6	N=8	N=6	N=8	N=7
Waste type															
Organic waste															
Food & Vegetables Wastes	7.034	13.454	16.630	13.774	12.612	9.042	15.585	4.735	5.364	6.825	23.564	18.569	15.570	18.412	12.421
Paper & paper Products	0.921	1.470	1.148	2.888	0.784	0.866	1.491	0.302	0.925	1.605	0.456	0.275	0.491	0.825	0.781
Plastic/Polythene	0.008	0.100	0.518	0.077	0.042	0.119	0.225	0.046	0.511	0.040	0.010	0.069	0.225	0.263	0.124
Pet Bottles/Oil container	0.224	0.091	0.252	0.076	0.175	0.084	0.060	0.105	0.490	0.119	0.230	0.187	0.060	0.001	0.241
Textiles/Clothes/Rags	0.002	0.420	0.098	0.133	0.091	0.004	0.254	0.056	0.210	0.034	0.110	0.371	0.112	1.400	0.008
Rubber	0.004	0.112	0.001	0.007	0.028	0.001	0.221	0.045	0.012	0.024	0.056	0.112	0.257	0.251	0.022
Leather	0.378	0.002	0.002	0.110	0.581	0.005	0.241	0.021	0.490	0.025	0.561	0.210	0.254	0.434	0.560
Wood	0.003	0.003	0.420	0.120	0.294	0.008	0.254	0.700	0.113	0.175	0.110	0.110	0.568	0.001	0.254
Rope/Straw/Coconut	0.448	0.001	0.077	0.042	0.063	0.350	0.005	0.120	0.011	0.024	0.050	0.032	0.008	0.120	0.035
Animal Bones	0.008	0.420	0.840	0.041	0.399	0.000	0.008	0.110	0.214	0.001	0.320	0.210	0.007	0.110	0.024
(Others)	0.002	0.002	0.004	0.110	0.000	0.875	0.009	0.105	0.002	0.088	0.035	0.110	0.008	0.025	0.025
Total organic wastes =	**9.032**	**16.075**	**19.990**	**17.378**	**15.069**	**11.354**	**18.353**	**6.345**	**8.342**	**8.960**	**25.501**	**20.255**	**17.560**	**21.842**	**14.495**
In-organic waste															
Glass/Bottles	0.147	0.539	0.490	0.140	0.194	0.100	0.050	0.210	0.120	0.022	0.003	0.070	0.050	0.090	0.015
Metal/Tin Can	0.004	0.210	0.420	0.438	0.231	0.455	0.007	0.112	0.001	0.026	0.305	0.030	0.708	0.008	0.014
Ceramic/Crockery	0.000	0.004	0.060	0.088	0.047	0.000	0.000	0.007	0.002	0.029	0.000	0.010	0.007	0.110	0.010
Bricks/Concrete/Demolition	0.007	0.001	4.480	0.008	0.399	0.201	0.251	0.009	0.004	0.024	2.356	0.005	0.452	0.458	0.621
Dust/Ashes	0.631	0.252	0.770	0.056	0.028	0.000	0.110	0.110	0.210	2.014	3.678	4.760	0.280	0.589	1.925
(Others)	0.000	0.231	0.000	0.009	0.000	0.000	0.008	0.004	0.320	0.025	0.000	0.000	0.011	0.025	0.009
In-organic non-hazardous =	**0.789**	**1.237**	**6.220**	**0.738**	**0.899**	**0.756**	**0.426**	**0.452**	**0.657**	**2.139**	**6.342**	**4.875**	**1.508**	**1.280**	**2.594**
Battery	0.001	0.002	0.315	0.123	0.210	0.498	0.110	0.007	0.110	0.120	0.025	0.015	0.110	0.008	0.008
Aerosol bottles	0.002	0.002	0.378	0.350	0.175	0.120	0.001	0.110	0.009	0.045	0.040	0.005	0.007	0.112	0.070
Cleaner (Liquid/Shoe Polish/Remover etc.)	0.021	0.315	0.042	0.018	0.012	0.002	0.008	0.021	0.110	0.021	0.000	0.001	0.008	0.110	0.008
Personal Care (Shampoo/Shaving/Nail Polish etc.)	0.091	0.049	0.161	0.263	0.098	0.004	0.007	0.008	0.112	0.001	0.002	0.001	0.110	0.089	0.450
Paint Items (Container/Thinner)	0.350	0.001	0.004	0.175	0.098	0.008	0.120	0.110	0.008	0.021	0.000	0.001	0.012	0.045	0.075
(Others)	0.000	0.001	0.001	0.001	0.101	0.010	0.110	0.008	0.007	0.020	0.020	0.002	0.008	0.081	0.410
Inorganic hazardous =	**0.465**	**0.370**	**0.901**	**0.929**	**0.694**	**0.642**	**0.356**	**0.264**	**0.356**	**0.229**	**0.088**	**0.025**	**0.255**	**0.445**	**1.021**
Total in-organic =	**1.254**	**1.607**	**7.121**	**1.667**	**1.593**	**1.398**	**0.782**	**0.716**	**1.013**	**2.368**	**6.430**	**4.900**	**1.763**	**1.725**	**3.615**
Total generated wastes =	**10.286**	**17.682**	**27.111**	**19.044**	**16.662**	**12.752**	**19.135**	**7.061**	**9.355**	**11.327**	**31.931**	**25.155**	**19.323**	**23.567**	**18.110**
Per capita generation (kg/capita/day) =	**0.735**	**0.361**	**0.646**	**0.340**	**0.397**	**0.260**	**0.456**	**0.202**	**0.191**	**0.180**	**0.760**	**0.449**	**0.460**	**0.421**	**0.370**

Table A. 6 (Continued)

City corporation	Dhaka city corporation areas											Khulna city corporation areas						
Ward No.	Ward No. 45					Ward No. 56					Average composition in percent	Ward No. 1					Ward No. 17	
Income level of family	A	B	C	D	E	A	B	C	D	E		A	B	C	D	E	A	B
No. of family member (N)	N=10	N=4	N=7	N=5	N=7	N=10	N=4	N=4	N=5	N=9		N=4	N=5	N=6	N=5	N=8	N=4	N=5
Waste type																		
Organic waste																		
Food & Vegetables Wastes	23.617	8.624	12.924	11.589	12.001	23.256	7.671	14.845	5.502	6.510	77.430	11.450	12.020	14.084	8.049	8.400	11.231	11.314
Paper & paper Products	0.250	0.434	0.014	0.005	1.659	0.578	0.133	0.589	0.722	0.025	4.749	0.250	0.175	0.700	0.215	0.170	0.540	0.040
Plastic/Polythene	0.135	0.012	0.011	0.000	0.075	0.001	0.035	0.096	0.007	0.082	0.684	0.075	0.100	0.000	0.075	0.025	0.100	0.010
Pet Bottles/Oil container	0.280	0.014	0.095	0.060	0.000	0.007	0.042	0.074	0.035	0.026	0.732	0.115	0.075	0.100	0.020	0.035	0.000	0.075
Textiles/Clothes/Rags	0.214	0.001	0.035	0.455	0.000	0.080	0.014	0.002	0.024	0.000	0.998	0.012	0.035	0.200	0.025	0.012	0.053	0.018
Rubber	0.254	0.000	0.001	0.010	0.000	0.000	0.214	0.000	0.021	0.020	0.405	0.020	0.210	0.010	0.210	0.110	0.010	0.013
Leather	0.126	0.002	0.010	0.000	0.000	0.000	0.032	0.000	0.031	0.000	0.986	0.011	0.012	0.000	0.007	0.210	0.005	0.025
Wood	0.013	0.000	0.002	0.000	0.000	0.185	0.214	0.000	0.294	0.000	0.929	0.014	0.025	0.000	0.100	0.114	0.000	0.028
Rope/Straw/Coconut	0.014	0.003	0.001	0.015	0.000	0.220	0.231	0.343	0.112	0.015	0.566	0.010	0.125	0.060	0.125	0.018	0.008	0.125
Animal Bones	0.120	0.004	0.100	0.050	0.000	0.240	0.025	0.000	0.076	0.000	0.805	0.013	0.020	0.009	0.120	0.210	0.320	0.210
(Others)	0.008	0.025	0.000	0.000	0.000	0.000	0.065	0.000	0.001	0.025	0.369	0.012	0.008	0.000	0.110	0.008	0.035	0.110
Total organic wastes =	**25.031**	**9.119**	**13.193**	**12.184**	**13.735**	**24.567**	**8.676**	**15.949**	**6.825**	**6.703**	**88.653**	**11.982**	**12.805**	**15.163**	**9.056**	**9.312**	**12.301**	**11.967**
In-organic waste																		
Glass/Bottles	0.004	0.028	0.100	0.001	0.074	0.002	0.070	0.098	0.025	0.030	0.646	0.060	0.025	0.160	0.210	0.014	0.000	0.365
Metal/Tin Can	0.987	0.024	0.111	0.112	0.000	0.004	0.000	0.125	0.012	0.072	1.068	0.061	0.050	0.007	0.060	0.075	0.000	0.060
Ceramic/Crockery	0.000	0.010	0.140	0.070	0.000	0.080	0.056	0.000	0.011	0.000	0.179	0.031	0.012	0.120	0.120	0.021	0.000	0.000
Bricks/Concrete/Demolition	1.258	0.014	0.120	0.077	0.064	0.001	0.025	0.004	0.068	0.098	2.662	0.009	0.210	0.310	0.014	0.113	0.750	0.008
Dust/Ashes	1.269	0.280	0.006	0.112	0.000	0.220	0.011	0.201	0.210	0.280	4.354	0.008	0.125	0.840	0.024	0.010	0.000	0.450
(Others)	0.002	0.050	0.008	0.000	0.015	0.002	0.025	0.000	0.005	0.000	0.181	0.000	0.000	0.120	0.120	0.110	0.300	0.000
In-organic non-hazardous =	**3.520**	**0.406**	**0.485**	**0.372**	**0.153**	**0.309**	**0.188**	**0.428**	**0.331**	**0.480**	9.090	**0.169**	**0.422**	**1.557**	**0.548**	**0.343**	**1.050**	**0.883**
Battery	0.008	0.025	0.025	0.015	0.015	0.001	0.028	0.100	0.001	0.074	0.472	0.007	0.025	0.009	0.050	0.023	0.018	0.060
Aerosol bottles	0.120	0.000	0.040	0.005	0.000	0.005	0.024	0.111	0.112	0.000	0.446	0.065	0.000	0.008	0.010	0.009	0.018	0.012
Cleaner (Liquid/Shoe etc.)	0.004	0.000	0.000	0.001	0.110	0.002	0.210	0.140	0.070	0.000	0.298	0.012	0.110	0.050	0.010	0.210	0.000	0.003
Personal Care	0.045	0.073	0.002	0.001	0.110	0.001	0.014	0.120	0.077	0.064	0.472	0.016	0.013	0.010	0.025	0.011	0.063	0.043
Paint Items (Container etc.)	0.012	0.000	0.000	0.001	0.045	0.003	0.080	0.006	0.112	0.000	0.311	0.014	0.010	0.009	0.010	0.112	0.000	0.018
(Others)	0.012	0.168	0.020	0.002	0.005	0.001	0.050	0.008	0.000	0.015	0.257	0.055	0.060	0.120	0.009	0.055	0.000	0.000
Inorganic hazardous =	**0.202**	**0.266**	**0.088**	**0.025**	**0.284**	**0.013**	**0.406**	**0.485**	**0.372**	**0.153**	2.257	**0.169**	**0.218**	**0.206**	**0.114**	**0.420**	**0.098**	**0.135**
Total in-organic =	3.722	**0.672**	**0.573**	**0.397**	**0.437**	**0.322**	**0.594**	**0.913**	**0.703**	**0.633**	11.347	**0.338**	**0.640**	**1.763**	**0.662**	**0.763**	**1.148**	**1.018**
Total generated wastes =	**28.752**	**9.791**	**13.766**	**12.580**	**14.172**	**24.888**	**9.270**	**16.862**	**7.529**	**7.336**	**100.000**	**12.320**	**13.445**	**16.926**	**9.718**	**10.074**	**13.448**	**12.985**
Generation (kg/cap/day) =	**0.411**	**0.350**	**0.281**	**0.359**	**0.289**	**0.356**	**0.331**	**0.268**	**0.215**	**0.116**		**0.440**	**0.384**	**0.403**	**0.278**	**0.180**	**0.480**	**0.371**

Table A. 6 (Continued)

City corporation	Khulna city corporation areas																	
Ward No.	Ward No. 17			Ward No. 18					Ward No. 21					Ward No. 23				
Income level of family	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
No. of family member (N)	N=4	N=4	N=7	N=6	N=7	N=6	N=7	N=7	N=4	N=8	N=7	N=9	N=6	N=9	N=5	N=8	N=9	N=5
Waste type																		
Organic waste																		
Food & Vegetables Wastes	9.801	7.812	9.547	11.587	15.675	10.167	9.949	15.538	6.455	12.419	12.158	11.679	5.953	14.097	8.982	6.706	13.386	3.126
Paper & paper Products	0.360	0.200	0.150	1.200	1.065	1.725	1.175	0.049	1.265	1.065	1.388	1.763	0.156	0.236	1.275	0.725	0.815	0.087
Plastic/Polythene	0.090	0.075	0.100	0.160	0.050	0.015	0.068	0.035	0.050	0.018	0.015	0.007	0.021	0.133	0.007	0.069	0.008	0.002
Pet Bottles/Oil container	0.048	0.105	0.004	0.045	0.001	0.085	0.088	0.014	0.100	0.009	0.075	0.000	0.049	0.056	0.000	0.140	0.105	0.004
Textiles/Clothes/Rags	0.000	0.005	0.003	0.075	0.013	0.023	0.000	0.030	0.013	0.020	0.100	0.008	0.000	0.003	0.007	0.040	0.005	0.003
Rubber	0.002	0.010	0.120	0.018	0.001	0.050	0.007	0.210	0.025	0.063	0.013	0.007	0.012	0.120	0.008	0.029	0.010	0.120
Leather	0.001	0.005	0.001	0.150	0.001	0.060	0.115	0.120	0.183	0.065	0.065	0.000	0.000	0.001	0.000	0.000	0.005	0.001
Wood	0.005	0.000	0.211	0.000	0.018	0.100	0.687	0.020	0.018	0.245	0.088	0.013	0.021	0.211	0.210	0.095	0.000	0.000
Rope/Straw/Coconut	0.043	0.042	0.050	0.225	0.063	0.000	0.007	0.110	0.063	0.001	0.063	0.015	0.000	0.480	0.000	0.043	0.042	0.120
Animal Bones	0.070	0.000	0.200	0.038	0.004	0.100	0.001	0.080	0.000	0.009	0.005	0.000	0.011	0.065	0.007	0.000	0.200	0.000
(Others)	0.000	0.005	0.038	0.005	0.025	0.005	0.005	0.053	0.000	0.005	0.038	0.000	0.000	0.088	0.007	0.000	0.075	0.010
Total organic wastes =	**10.419**	**8.259**	**10.424**	**13.502**	**16.914**	**12.330**	**12.101**	**16.259**	**8.170**	**13.918**	**14.005**	**13.491**	**6.223**	**15.490**	**10.503**	**7.846**	**14.650**	**3.473**
In-organic waste																		
Glass/Bottles	0.115	0.135	0.100	0.100	0.045	0.015	0.060	0.014	0.045	0.063	0.125	0.015	0.021	0.028	0.007	0.040	0.046	0.000
Metal/Tin Can	0.045	0.065	0.085	0.063	0.025	0.025	0.175	0.075	0.025	0.038	0.063	0.025	0.007	0.807	0.010	0.035	0.005	0.000
Ceramic/Crockery	0.000	0.000	0.000	0.050	0.025	0.015	0.100	0.021	0.025	0.013	0.215	0.001	0.035	0.070	0.021	0.063	0.068	0.000
Bricks/Concrete/Demolition	0.004	0.000	0.000	0.001	0.007	0.002	0.010	0.113	0.055	0.063	0.068	0.000	0.453	0.000	0.007	0.038	0.063	0.021
Dust/Ashes	0.045	0.073	0.002	0.001	0.002	0.001	0.014	0.010	0.113	0.000	0.008	0.004	0.191	0.000	0.001	2.830	0.343	0.000
(Others)	0.000	0.000	0.000	0.110	0.000	0.000	0.000	0.000	0.000	0.000	0.075	0.000	0.001	0.000	0.000	0.150	0.165	0.020
In-organic non-hazardous =	**0.209**	**0.273**	**0.187**	**0.325**	**0.104**	**0.058**	**0.359**	**0.233**	**0.263**	**0.175**	**0.553**	**0.045**	**0.708**	**0.905**	**0.046**	**3.155**	**0.689**	**0.041**
Battery	0.018	0.060	0.065	0.040	0.010	0.015	0.001	0.014	0.138	0.007	0.073	0.007	0.000	0.000	0.000	0.025	0.125	0.015
Aerosol bottles	0.065	0.112	0.110	0.075	0.000	0.060	0.004	0.055	0.225	0.004	0.155	0.000	0.055	0.021	0.008	0.040	0.055	0.001
Cleaner (Liquid/Shoe etc.)	0.018	0.018	0.000	0.030	0.015	0.015	0.018	0.049	0.015	0.030	0.015	0.018	0.049	0.014	0.006	0.000	0.049	0.002
Personal Care	0.063	0.070	0.025	0.083	0.001	0.095	0.005	0.000	0.038	0.001	0.125	0.004	0.000	0.000	0.077	0.002	0.000	0.002
Paint Items (Container etc.)	0.018	0.110	0.003	0.080	0.007	0.060	0.001	0.098	0.063	0.085	0.068	0.004	0.098	0.000	0.000	0.000	0.098	0.000
(Others)	0.000	0.068	0.003	0.200	0.050	0.015	0.105	0.000	0.050	0.004	0.050	0.040	0.049	0.014	0.070	0.020	0.147	0.001
Inorganic hazardous =	**0.180**	**0.437**	**0.206**	**0.508**	**0.083**	**0.260**	**0.134**	**0.216**	**0.528**	**0.131**	**0.485**	**0.073**	**0.251**	**0.049**	**0.161**	**0.088**	**0.474**	**0.021**
Total in-organic =	**0.389**	**0.710**	**0.393**	**0.832**	**0.187**	**0.318**	**0.493**	**0.449**	**0.791**	**0.306**	**1.038**	**0.118**	**0.959**	**0.954**	**0.207**	**3.243**	**1.163**	**0.062**
Total generated wastes =	**10.809**	**8.968**	**10.817**	**14.334**	**17.101**	**12.648**	**12.593**	**16.709**	**8.961**	**14.224**	**15.043**	**13.608**	**7.182**	**16.444**	**10.710**	**11.089**	**15.813**	**3.535**
Generation (kg/cap/day) =	**0.386**	**0.320**	**0.221**	**0.341**	**0.349**	**0.301**	**0.257**	**0.341**	**0.320**	**0.254**	**0.307**	**0.216**	**0.171**	**0.261**	**0.306**	**0.198**	**0.251**	**0.101**

Table A. 6 (Continued)

City corporation	Khulna	Rajshahi city corporation areas																
Ward No.	Average	Ward No. 6					Ward No. 9					Ward No. 14					Ward No. 21	
Income level of family	composition	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B
No. of family member (N)	in percent	N=5	N=7	N=6	N=7	N=7	N=5	N=4	N=4	N=10	N=5	N=5	N=7	N=5	N=7	N=7	N=3	N=7
Waste type																		
Organic waste																		
Food & Vegetables Wastes	86.518	6.867	11.342	6.570	7.870	7.791	10.770	7.280	6.510	16.810	8.420	7.588	9.779	8.360	15.780	10.359	8.270	12.721
Paper & paper Products	5.424	0.210	0.140	0.296	0.273	0.231	0.350	0.310	0.210	0.440	0.215	0.333	0.212	0.292	0.143	0.697	0.333	0.225
Plastic/Polythene	0.422	0.350	0.147	0.180	0.125	0.116	0.135	0.102	0.082	0.087	0.205	0.181	0.167	0.168	0.096	0.221	0.070	0.193
Pet Bottles/Oil container	0.435	0.049	0.077	0.105	0.014	0.130	0.010	0.050	0.125	0.000	0.080	0.049	0.032	0.133	0.072	0.028	0.029	0.057
Textiles/Clothes/Rags	0.226	0.196	0.006	0.098	0.067	0.088	0.000	0.000	0.000	0.078	0.000	0.012	0.024	0.029	0.008	0.049	0.008	0.087
Rubber	0.454	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.000	0.000	0.000	0.000	0.013	0.000	0.000	0.000	0.000
Leather	0.337	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.123	0.000	0.000
Wood	0.718	0.063	0.000	0.011	0.035	0.175	0.055	0.020	0.000	0.000	0.000	0.054	0.067	0.036	0.000	0.032	0.000	0.053
Rope/Straw/Coconut	0.593	0.067	0.016	0.013	0.014	0.007	0.009	0.033	0.015	0.075	0.050	0.027	0.044	0.018	0.011	0.082	0.026	0.029
Animal Bones	0.546	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
(Others)	0.207	0.018	0.161	0.084	0.392	0.245	0.025	0.084	0.025	0.025	0.030	0.026	0.049	0.032	0.750	0.786	0.028	0.028
Total organic wastes =	**93.880**	**7.819**	**11.889**	**7.356**	**8.789**	**8.782**	**11.355**	**7.879**	**6.987**	**17.515**	**9.000**	**8.268**	**10.373**	**9.080**	**16.860**	**12.376**	**8.764**	**13.393**
In-organic waste																		
Glass/Bottles	0.584	0.000	0.140	0.070	0.203	0.070	0.085	0.034	0.130	0.150	0.170	0.205	0.097	0.288	0.049	0.242	0.055	0.050
Metal/Tin Can	0.609	0.091	0.012	0.035	0.105	0.030	0.090	0.012	0.072	0.000	0.100	0.066	0.030	0.083	0.027	0.035	0.017	0.032
Ceramic/Crockery	0.331	0.133	0.000	0.000	0.000	0.210	0.000	0.000	0.000	0.000	0.000	0.053	0.000	0.000	0.000	0.000	0.000	0.000
Bricks/Concrete/Demolition	0.749	0.070	0.000	0.000	0.000	0.000	0.150	0.000	0.000	0.000	0.000	0.000	0.321	0.000	0.572	0.000	0.000	0.040
Dust/Ashes	1.646	0.560	0.362	0.434	0.560	0.434	0.198	0.210	0.180	0.215	0.240	0.364	0.335	0.642	1.875	0.461	0.277	1.650
(Others)	0.378	0.000	0.000	0.000	0.000	0.000	0.045	0.000	0.000	0.000	0.000	0.075	0.137	0.137	0.088	0.028	0.032	0.000
In-organic non-hazardous =	**4.297**	**0.854**	**0.514**	**0.539**	**0.868**	**0.744**	**0.568**	**0.256**	**0.382**	**0.365**	**0.510**	**0.762**	**0.920**	**1.150**	**2.611**	**0.765**	**0.379**	**1.772**
Battery	0.259	0.000	0.000	0.000	0.014	0.000	0.000	0.070	0.074	0.000	0.000	0.000	0.000	0.029	0.010	0.015	0.046	0.000
Aerosol bottles	0.377	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.049	0.054	0.000	0.000	0.000	0.000
Cleaner (Liquid/Shoe etc.)	0.244	0.000	0.000	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.053	0.000	0.000	0.000	0.028	0.000	0.000
Personal Care	0.249	0.042	0.000	0.029	0.015	0.015	0.000	0.010	0.064	0.000	0.005	0.144	0.023	0.200	0.023	0.012	0.033	0.029
Paint Items (Container etc.)	0.311	0.000	0.000	0.000	0.000	0.000	0.025	0.015	0.000	0.007	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000
(Others)	0.383	0.000	0.002	0.013	0.011	0.008	0.020	0.025	0.015	0.030	0.000	0.000	0.000	0.034	0.028	0.000	0.006	0.008
Inorganic hazardous =	**1.823**	**0.042**	**0.002**	**0.054**	**0.039**	**0.024**	**0.045**	**0.120**	**0.153**	**0.037**	**0.015**	**0.196**	**0.072**	**0.316**	**0.061**	**0.055**	**0.085**	**0.038**
Total in-organic =	**6.120**	**0.896**	**0.516**	**0.593**	**0.907**	**0.768**	**0.613**	**0.376**	**0.535**	**0.402**	**0.525**	**0.958**	**0.992**	**1.467**	**2.672**	**0.820**	**0.464**	**1.810**
Total generated wastes =	**100.000**	**8.715**	**12.405**	**7.949**	**9.696**	**9.549**	**11.968**	**8.255**	**7.522**	**17.917**	**9.525**	**9.227**	**11.365**	**10.547**	**19.531**	**13.195**	**9.228**	**15.203**
Generation (kg/cap/day) =		**0.249**	**0.253**	**0.189**	**0.198**	**0.195**	**0.342**	**0.295**	**0.269**	**0.256**	**0.272**	**0.264**	**0.232**	**0.301**	**0.399**	**0.269**	**0.439**	**0.310**

Table A. 6 (Continued)

City corporation	Rajshahi city corporation areas									Barisal city corporation areas								
Ward No.	Ward No. 21			Ward No. 23					Average composition in percent	Ward No. 2					Ward No. 9			
Income level of family	C	D	E	A	B	C	D	E		A	B	C	D	E	A	B	C	D
No. of family member (N)	N=7	N=7	N=6	N=11	N=5	N=6	N=9	N=7		N=15	N=8	N=5	N=3	N=6	N=4	N=6	N=4	N=9
Waste type																		
Organic waste																		
Food & Vegetables Wastes	8.491	12.268	8.449	21.100	13.829	7.820	8.830	9.580	78.494	26.880	17.43	7.890	5.757	7.910	11.390	13.930	7.910	18.130
Paper & paper Products	0.580	0.016	0.204	4.349	0.320	0.385	1.470	0.382	3.907	0.294	0.427	0.147	0.156	0.098	0.434	0.173	0.133	0.236
Plastic/Polythene	0.200	0.074	0.120	0.258	0.056	0.099	1.332	0.160	1.524	0.077	0.056	0.035	0.021	0.063	0.056	0.056	0.035	0.133
Pet Bottles/Oil container	0.085	0.036	0.051	0.155	0.054	0.060	1.023	0.055	0.792	0.077	0.056	0.021	0.049	0.084	0.028	0.056	0.042	0.056
Textiles/Clothes/Rags	0.032	0.000	0.029	0.055	0.041	0.036	0.060	0.036	0.321	0.000	0.000	0.098	0.000	0.000	0.007	0.007	0.014	0.000
Rubber	0.000	0.000	0.000	0.013	0.000	0.006	0.000	0.043	0.029	0.000	0.000	0.000	0.012	0.000	0.000	0.000	0.000	0.000
Leather	0.000	0.008	0.000	0.398	0.578	0.000	2.133	0.000	1.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007
Wood	0.062	0.000	0.041	0.336	0.038	0.043	1.090	0.083	0.710	0.000	0.000	0.000	0.021	0.000	0.007	0.000	0.000	0.028
Rope/Straw/Coconut	0.043	0.032	0.043	0.043	0.019	0.008	0.063	0.011	0.247	0.000	0.014	0.000	0.000	0.000	0.000	0.007	0.231	0.007
Animal Bones	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.000	0.000	0.000	0.000	0.000
(Others)	0.072	0.028	0.028	0.049	0.028	0.028	0.049	0.034	0.961	0.000	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total organic wastes =	**9.565**	**12.462**	**8.966**	**26.756**	**14.963**	**8.485**	**16.049**	**10.383**	**87.989**	**27.328**	**18.004**	**8.191**	**6.027**	**8.155**	**11.922**	**14.229**	**8.365**	**18.597**
In-organic waste																		
Glass/Bottles	0.142	0.050	0.060	0.064	0.053	0.119	0.335	0.092	0.914	0.084	0.077	0.056	0.021	0.049	0.021	0.014	0.070	0.028
Metal/Tin Can	0.074	0.009	0.011	0.290	0.232	0.029	1.813	0.062	1.039	0.007	0.007	0.007	0.007	0.014	0.007	0.800	0.000	0.807
Ceramic/Crockery	0.029	0.000	0.000	0.000	0.000	0.000	0.059	0.000	0.150	0.084	0.105	0.000	0.035	0.056	0.000	0.049	0.056	0.070
Bricks/Concrete/Demolition	0.000	1.120	0.011	2.601	0.968	0.382	1.878	0.000	2.512	0.000	0.000	0.000	2.453	0.000	0.000	0.000	0.000	0.000
Dust/Ashes	0.557	1.775	0.579	2.285	1.475	0.496	2.902	0.526	6.067	0.000	0.000	0.000	2.191	0.000	0.000	0.000	0.000	0.000
(Others)	0.282	0.109	0.000	0.038	0.000	0.043	0.204	0.059	0.395	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
In-organic non-hazardous =	**1.084**	**3.063**	**0.661**	**5.277**	**2.727**	**1.069**	**7.191**	**0.740**	**11.078**	**0.175**	**0.189**	**0.063**	**4.708**	**0.119**	**0.028**	**0.863**	**0.126**	**0.905**
Battery	0.039	0.006	0.036	0.029	0.006	0.006	0.022	0.022	0.131	0.000	0.014	0.000	0.000	0.000	0.014	0.014	0.028	0.000
Aerosol bottles	0.050	0.000	0.000	0.295	0.000	0.040	0.084	0.032	0.187	0.035	0.021	0.000	0.014	0.000	0.000	0.000	0.000	0.021
Cleaner (Liquid/Shoe etc.)	0.000	0.000	0.000	0.089	0.056	0.000	0.089	0.000	0.101	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.014
Personal Care	0.067	0.020	0.046	0.053	0.025	0.101	0.048	0.066	0.330	0.021	0.028	0.014	0.021	0.014	0.014	0.021	0.014	0.000
Paint Items (Container etc.)	0.000	0.000	0.000	0.000	0.085	0.000	0.086	0.000	0.070	0.000	0.000	0.000	0.012	0.000	0.000	0.000	0.000	0.000
(Others)	0.028	0.006	0.023	0.013	0.006	0.028	0.029	0.032	0.113	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inorganic hazardous =	**0.183**	**0.033**	**0.104**	**0.479**	**0.178**	**0.175**	**0.358**	**0.152**	**0.933**	**0.056**	**0.063**	**0.014**	**0.047**	**0.014**	**0.028**	**0.035**	**0.042**	**0.035**
Total in-organic =	**1.266**	**3.096**	**0.765**	**5.756**	**2.905**	**1.244**	**7.549**	**0.892**	**12.011**	**0.231**	**0.252**	**0.077**	**4.755**	**0.133**	**0.056**	**0.898**	**0.168**	**0.940**
Total generated wastes =	**10.831**	**15.558**	**9.731**	**32.512**	**17.867**	**9.729**	**23.598**	**11.275**	**100.000**	**27.559**	**18.256**	**8.268**	**10.782**	**8.288**	**11.978**	**15.127**	**8.533**	**19.537**
Generation (kg/cap/day) =	**0.221**	**0.318**	**0.232**	**0.422**	**0.510**	**0.232**	**0.375**	**0.230**		**0.262**	**0.326**	**0.236**	**0.513**	**0.197**	**0.428**	**0.360**	**0.305**	**0.310**

Table A. 6 (Continued)

City corporation	Barisal city corporation areas																
Ward No.	W. 9	Ward No. 10					Ward No. 15					Ward No. 19					Average composition in percent
Income level of family	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	
No. of family member (N)	N=12	N=5	N=6	N=6	N=6	N=8	N=17	N=4	N=6	N=6	N=7	N=8	N=8	N=4	N=8	N=4	
Waste type																	
Organic waste																	
Food & Vegetables Wastes	16.380	17.360	9.870	8.610	7.910	6.930	22.890	4.112	8.400	5.390	6.370	11.410	8.890	6.350	9.380	4.400	91.163
Paper & paper Products	0.917	0.175	0.028	0.175	0.042	0.049	0.562	0.610	0.777	0.280	0.028	0.322	0.392	0.567	0.175	0.091	2.444
Plastic/Polythene	0.091	0.035	0.028	0.049	0.049	0.035	0.140	0.028	0.049	0.035	0.014	0.049	0.049	0.077	0.035	0.035	0.446
Pet Bottles/Oil container	0.084	0.035	0.021	0.035	0.000	0.014	0.105	0.014	0.056	0.042	0.021	0.049	0.042	0.049	0.021	0.014	0.359
Textiles/Clothes/Rags	0.000	0.000	0.000	0.007	0.000	0.007	0.000	0.987	0.021	0.000	0.000	0.042	0.042	0.007	0.000	0.028	0.425
Rubber	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004
Leather	0.189	0.000	0.000	0.000	0.007	0.000	0.586	0.565	0.000	0.000	0.000	0.000	0.056	0.000	0.000	0.000	0.473
Wood	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.698	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.255
Rope/Straw/Coconut	0.000	0.000	0.070	0.000	0.231	0.000	0.000	0.000	0.000	0.000	0.007	0.014	0.000	0.000	0.021	0.007	0.204
Animal Bones	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004
(Others)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007
Total organic wastes =	**17.661**	**17.612**	**10.017**	**8.876**	**8.239**	**7.035**	**24.283**	**7.014**	**9.303**	**5.747**	**6.440**	**11.886**	**9.471**	**7.050**	**9.632**	**4.575**	**95.784**
In-organic waste																	
Glass/Bottles	0.000	0.035	0.021	0.021	0.021	0.028	0.021	0.021	0.014	0.021	0.049	0.070	0.056	0.035	0.000	0.056	0.298
Metal/Tin Can	0.007	0.000	0.000	0.000	0.000	0.000	0.007	0.898	0.007	0.000	0.000	0.000	0.000	0.000	0.700	0.028	1.108
Ceramic/Crockery	0.084	0.000	0.000	0.028	0.000	0.000	0.056	0.056	0.084	0.063	0.000	0.049	0.035	0.000	0.000	0.000	0.305
Bricks/Concrete/Demolition	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.042	0.049	0.000	0.056	0.000	0.872
Dust/Ashes	0.000	0.000	0.046	0.000	0.000	0.000	0.049	0.081	0.021	0.049	1.169	0.063	0.098	0.000	0.063	0.063	1.305
(Others)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.035	0.000	0.000	0.012
In-organic non-hazardous =	**0.091**	**0.035**	**0.067**	**0.049**	**0.021**	**0.028**	**0.133**	**1.056**	**0.126**	**0.133**	**1.218**	**0.224**	**0.238**	**0.070**	**0.819**	**0.147**	**3.900**
Battery	0.014	0.000	0.000	0.014	0.000	0.014	0.014	0.007	0.014	0.007	0.007	0.000	0.021	0.014	0.014	0.000	0.070
Aerosol bottles	0.021	0.000	0.000	0.021	0.000	0.000	0.000	0.035	0.000	0.000	0.000	0.028	0.000	0.000	0.028	0.000	0.075
Cleaner (Liquid/Shoe etc.)	0.000	0.000	0.000	0.000	0.000	0.000	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009
Personal Care	0.007	0.028	0.007	0.014	0.007	0.028	0.014	0.014	0.014	0.007	0.014	0.014	0.028	0.084	0.021	0.021	0.157
Paint Items (Container etc.)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004
(Others)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inorganic hazardous =	**0.042**	**0.028**	**0.007**	**0.049**	**0.007**	**0.042**	**0.042**	**0.056**	**0.028**	**0.014**	**0.021**	**0.042**	**0.049**	**0.098**	**0.063**	**0.021**	**0.316**
Total in-organic =	**0.133**	**0.063**	**0.074**	**0.098**	**0.028**	**0.070**	**0.175**	**1.112**	**0.154**	**0.147**	**1.239**	**0.266**	**0.287**	**0.168**	**0.882**	**0.168**	**4.216**
Total generated wastes =	17.794	17.675	10.091	8.974	8.267	7.105	24.458	8.126	9.457	5.894	7.679	12.152	9.758	7.218	10.514	4.743	100.000
Generation (kg/cap/day) =	**0.212**	**0.505**	**0.240**	**0.214**	**0.197**	**0.127**	**0.206**	**0.290**	**0.225**	**0.140**	**0.157**	**0.217**	**0.174**	**0.258**	**0.188**	**0.169**	

ANNEXURE B

Table B.1 Average physical composition of MSW at wet market areas in four major cities of Bangladesh (in wet weight %)

MSW Composition	Dhaka	Khulna	Rajshahi	Barisal
Food & Vegetables	70	72	79	79
Paper & Paper Products	7	10	8	6
Polythene & Plastics	4	3	6	4
Textile & Woods	5	0.5	1	1
Rubber & Leathers	2	0.5	0.5	1
Metal & Tins	1	1	0.5	0
Glass & Ceramics	2	0	1	0.5
Brick, Concrete & Stone	2	1	1	0.5
Dust, Ash & Mud Products	4	9	1	7
Others (bone, rope etc.)	3	3	2	1
Total	**100**	**100**	**100**	**100**

Table B.2 Average physical composition of MSW at shopping complex areas in four major cities of Bangladesh (in wet weight %)

MSW Composition	Dhaka	Khulna	Rajshahi	Barisal
Food & Vegetables	28	20	31	28
Paper & Paper Products	38	38	29	35
Polythene & Plastics	10	13	7	15
Textile & Woods	2	5	9	1
Rubber & Leathers	1	1	3	0.5
Metal & Tins	2	2	2	3
Glass & Ceramics	1	1	2	0.5
Brick, Concrete & Stone	0	1	3	0
Dust, Ash & Mud Products	17	17	11	16
Others (bone, rope etc.)	1	2	3	1
Total	**100**	**100**	**100**	**100**

In Dhaka city, the daily MSW generations in commercial areas are 1177.61 tons where 36.4% from wet markets and 63.6% from shopping complex areas. Composition for commercial areas is estimated as:

$$C = w \times 0.364 + s \times 0.636$$

Similarly,

For Khulna city, $C = w \times 0.386 + s \times 0.614$
For Rajshahi city, $C = w \times 0.406 + s \times 0.594$
For Barisal city, $C = w \times 0.408 + s \times 0.592$

Where

C = Average value of particular component in commercial areas, %
w = Average value of particular component from wet market areas, %
s = Average value of particular component from shopping complex areas, %

Table B.3 Average physical composition of MSW at commercial areas in four major cities of Bangladesh (in wet weight %)

MSW Composition	Dhaka	Khulna	Rajshahi	Barisal
Food & Vegetables	43.3	40.1	50.5	48.8
Paper & Paper Products	26.7	27.2	20.5	23.2
Polythene & Plastics	7.8	9.1	6.6	10.5
Textile & Woods	3.1	3.3	5.8	1.0
Rubber & Leathers	1.4	0.8	2.0	0.7
Metal & Tins	1.6	1.6	1.4	1.8
Glass & Ceramics	1.4	0.6	1.6	0.5
Brick, Concrete & Stone	0.7	1.0	2.2	0.2
Dust, Ash & Mud Products	12.3	13.9	6.9	12.3
Others (bone, rope etc.)	1.7	2.4	2.6	1.0
Total	**100.0**	**100.0**	**100.0**	**100.0**

Table B.4 Average physical composition of MSW at hospital areas in four major cities of Bangladesh (in wet weight %)

MSW Composition	Dhaka	Khulna	Rajshahi	Barisal
Food & Vegetables	49	64	45	57
Paper & Paper Products	11	11	13	7
Saline bag & Plastics	15	8	11	10
Gauge, Bandage & Cotton	8	6	11	9
Glass & Sharp Materials	49	64	45	57
Others	11	11	13	7
Total	**100**	**100**	**100**	**100**

Table B.5 Physical composition of MSW at commercial and institutional areas in four major cities of Bangladesh (in wet weight, %)

Dhaka city corporation areas												
Area	Shokrabad wet market				Mouchak shopping complex				Monipur high school			
Date	02.08.04	03.08.04	04.08.04	Average	10.08.04	11.08.04	12.08.04	Average	07.09.04	08.09.04	09.09.04	Average
Waste Type												
Organic Waste												
Food & Vegetables Wastes	65.20	75.25	70.35	70.27	28.86	25.35	29.87	28.03	15.42	23.12	12.45	17.00
Paper & paper Products	7.68	6.68	6.87	7.08	35.12	34.25	44.98	38.12	54.14	48.50	44.41	49.02
Plastic/Polythene	1.25	1.65	0.52	1.14	6.58	5.41	5.64	5.88	7.68	7.24	7.98	7.63
Pet Bottles/Oil container	0.85	1.25	0.25	0.78	2.67	2.45	3.78	2.97	8.14	3.14	6.47	5.92
Textiles/Clothes/Rags	4.88	1.68	2.97	3.18	1.24	1.71	0.87	1.27	0.78	0.14	0.88	0.60
Rubber	0.00	1.00	2.01	1.00	0.00	0.87	0.24	0.37	0.14	0.24	0.34	0.24
Leather	1.21	0.00	1.98	1.06	0.98	0.58	0.41	0.66	0.12	0.14	0.54	0.27
Wood	2.14	1.25	2.14	1.84	0.21	1.57	0.45	0.74	0.00	0.57	0.78	0.45
Rope/Straw/Coconut	1.65	0.00	0.08	0.58	0.57	0.00	0.07	0.21	0.21	0.11	0.07	0.13
Animal Bones	1.23	0.42	0.84	0.83	0.98	0.42	0.57	0.66	0.11	0.10	0.02	0.08
(Others)	0.00	0.87	0.00	0.29	0.00	0.47	0.00	0.16	0.00	0.00	0.00	0.00
Total Organic Wastes =	**86.10**	**90.05**	**88.01**	**88.05**	**77.22**	**73.08**	**86.88**	**79.06**	**86.74**	**83.30**	**73.94**	**81.33**
In-organic Waste												
Glass/Bottles	1.47	0.54	1.61	1.21	1.10	0.47	0.15	0.57	0.25	0.24	0.39	0.29
Metal/Tin Can	1.25	0.21	1.57	1.01	0.98	0.14	4.98	2.03	4.25	0.68	7.14	4.02
Ceramic/Crockery	0.00	0.98	1.41	0.80	0.24	0.98	0.14	0.45	0.14	0.24	0.26	0.21
Bricks/Concrete/Demolition	1.54	2.98	1.68	2.07	0.00	0.00	0.00	0.00	3.58	3.54	4.98	4.03
Dust/Ashes	5.24	3.71	3.21	4.05	18.56	24.14	7.14	16.61	4.27	11.25	11.65	9.06
(Others)	0.00	0.23	0.37	0.20	0.00	0.21	0.14	0.12	0.00	0.14	0.11	0.08
In-organic Non-hazardous =	**9.50**	**8.65**	**9.85**	**9.33**	**20.88**	**25.94**	**12.55**	**19.79**	**12.49**	**16.09**	**24.53**	**17.70**
Battery	0.00	0.00	0.32	0.11	0.54	0.00	0.00	0.18	0.14	0.12	0.11	0.12
Aerosol bottles	1.14	0.68	0.38	0.73	0.00	0.24	0.24	0.16	0.11	0.14	0.05	0.10
Cleaner (Liquid/Shoe Polish/Remover etc.)	0.02	0.32	0.04	0.13	0.24	0.45	0.18	0.29	0.21	0.24	0.14	0.20
Personal Care (Shampoo/Shaving/Nail Polish etc.)	1.57	0.05	0.16	0.59	0.98	0.14	0.00	0.37	0.14	0.00	0.21	0.12
Paint Items (Container/Thinner)	1.67	0.25	1.24	1.05	0.14	0.00	0.14	0.09	0.00	0.11	0.04	0.05
(Others)	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.05	0.17	0.00	0.98	0.38
Inorganic Hazardous =	**4.40**	**1.30**	**2.14**	**2.61**	**1.90**	**0.98**	**0.56**	**1.15**	**0.77**	**0.61**	**1.53**	**0.97**
Total In-organic =	**13.90**	**9.95**	**11.99**	**11.95**	**22.78**	**26.92**	**13.11**	**20.94**	**13.26**	**16.70**	**26.06**	**18.67**
Total =	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Table B.5 (Continued)

Khulna city corporation areas												
Area	Fulbarigate wet market				Janata market				KUET			
Date	08.08.04	09.08.04	10.08.04	Average	15.08.04	16.08.04	17.08.04	Average	19.09.04	20.09.04	21.09.04	Average
Waste Type												
Organic Waste												
Food & Vegetables Wastes	71.24	76.21	68.57	72.01	22.14	25.05	12.98	20.06	16.45	17.14	14.67	16.09
Paper & paper Products	9.21	11.19	9.78	10.06	34.65	31.68	47.89	38.07	48.68	44.12	51.28	48.03
Plastic/Polythene	0.24	1.42	0.14	0.60	6.56	7.68	4.65	6.30	7.98	6.87	7.69	7.51
Pet Bottles/Oil container	2.56	1.21	1.68	1.82	4.65	5.68	7.98	6.10	5.68	3.98	6.78	5.48
Textiles/Clothes/Rags	1.10	0.14	0.00	0.41	3.45	3.54	2.24	3.08	3.14	0.65	0.98	1.59
Rubber	0.24	0.11	0.34	0.23	0.54	0.97	0.35	0.62	0.14	0.14	0.00	0.09
Leather	0.56	0.04	0.24	0.28	0.64	0.14	0.54	0.44	0.11	0.00	0.09	0.07
Wood	0.35	0.00	0.00	0.12	1.35	4.56	0.24	2.05	1.98	0.87	1.65	1.50
Rope/Straw/Coconut	0.24	0.11	0.07	0.14	0.14	0.25	0.14	0.18	0.07	0.31	0.00	0.13
Animal Bones	0.11	0.21	0.11	0.14	0.11	0.54	0.24	0.30	0.00	0.00	0.07	0.02
(Others)	0.00	0.00	0.10	0.03	0.00	0.00	0.76	0.25	0.00	1.80	0.00	0.60
Total Organic Wastes =	**85.85**	**90.64**	**81.03**	**85.84**	**74.23**	**80.09**	**78.01**	**77.44**	**84.23**	**75.88**	**83.21**	**81.11**
In-organic Waste												
Glass/Bottles	0.08	0.14	0.00	0.07	0.78	0.65	0.36	0.60	0.58	0.57	0.00	0.38
Metal/Tin Can	0.45	0.21	2.56	1.07	3.45	0.21	2.45	2.04	2.65	0.68	2.78	2.04
Ceramic/Crockery	0.00	0.08	0.03	0.04	0.41	0.78	0.14	0.44	0.65	0.00	0.09	0.25
Bricks/Concrete/Demolition	0.48	0.45	2.14	1.02	0.98	0.12	1.98	1.03	0.11	1.45	1.65	1.07
Dust/Ashes	10.98	7.98	8.12	9.03	17.98	17.06	16.24	17.09	11.17	19.24	11.66	14.02
(Others)	0.89	0.01	1.24	0.71	1.13	0.12	0.14	0.46	0.00	0.00	0.00	0.00
In-organic Non-hazardous =	**12.88**	**8.87**	**14.09**	**11.95**	**24.73**	**18.94**	**21.31**	**21.66**	**15.16**	**21.94**	**16.18**	**17.76**
Battery	0.57	0.11	2.14	0.94	0.57	0.14	0.12	0.28	0.24	0.08	0.00	0.11
Aerosol bottles	0.00	0.00	0.14	0.05	0.24	0.12	0.11	0.16	0.11	0.24	0.24	0.20
Cleaner (Liquid/Shoe Polish/Remover etc.)	0.11	0.11	0.04	0.09	0.11	0.14	0.15	0.13	0.12	0.54	0.11	0.26
Personal Care (Shampoo/Shaving/Nail Polish etc.)	0.24	0.13	0.65	0.34	0.00	0.24	0.04	0.09	0.00	0.64	0.12	0.25
Paint Items (Container/Thinner)	0.14	0.14	0.14	0.14	0.12	0.19	0.14	0.15	0.14	0.68	0.14	0.32
(Others)	0.21	0.00	1.77	0.66	0.00	0.14	0.12	0.09	0.00	0.00	0.00	0.00
Inorganic Hazardous =	**1.27**	**0.49**	**4.88**	**2.21**	**1.04**	**0.97**	**0.68**	**0.90**	**0.61**	**2.18**	**0.61**	**1.13**
Total In-organic =	**14.15**	**9.36**	**18.97**	**14.16**	**25.77**	**19.91**	**21.99**	**22.56**	**15.77**	**24.12**	**16.79**	**18.89**
Total =	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Table B.5 (Continued)

Rajshahi city corporation areas												
Area	Binudpur wet market				Rajshahi new market				Seroil high school			
Date	01.08.04	02.08.04	03.08.04	Average	09.08.04	10.08.04	11.08.04	Average	05.09.04	07.09.04	08.09.04	Average
Waste Type												
Organic Waste												
Food & Vegetables Wastes	81.69	77.01	78.35	79.02	27.24	34.65	31.24	31.04	15.62	26.87	11.58	18.02
Paper & paper Products	9.65	6.97	7.54	8.05	27.14	15.27	44.61	29.01	53.80	42.36	44.67	46.94
Plastic/Polythene	3.65	1.57	3.54	2.92	6.12	0.24	5.47	3.94	7.21	6.45	6.98	6.88
Pet Bottles/Oil container	2.16	3.11	1.01	2.09	2.15	0.32	3.47	1.98	8.21	1.24	4.32	4.59
Textiles/Clothes/Rags	0.08	1.24	0.54	0.62	4.65	8.98	0.98	4.87	0.77	0.14	2.54	1.15
Rubber	0.00	1.11	0.14	0.42	4.12	1.57	0.25	1.98	0.15	0.00	0.14	0.10
Leather	0.14	0.00	0.00	0.05	1.24	1.45	0.34	1.01	0.13	0.00	0.00	0.04
Wood	0.14	1.10	0.14	0.46	4.10	7.98	0.14	4.07	0.11	0.42	2.14	0.89
Rope/Straw/Coconut	0.12	0.00	0.08	0.07	0.57	0.10	0.08	0.25	0.31	0.12	0.07	0.17
Animal Bones	0.11	0.45	0.84	0.47	0.98	0.21	0.45	0.55	0.15	0.11	0.02	0.09
(Others)	0.00	0.84	0.00	0.28	0.00	2.35	0.00	0.79	0.00	0.00	0.47	0.16
Total Organic Wastes =	**97.75**	**93.40**	**92.18**	**94.44**	**78.31**	**73.12**	**87.03**	**79.49**	**86.46**	**77.71**	**72.93**	**79.03**
In-organic Waste												
Glass/Bottles	0.24	2.00	1.10	1.11	1.57	1.24	0.16	0.99	0.21	0.98	0.57	0.59
Metal/Tin Can	0.21	0.26	1.01	0.49	0.98	0.14	4.89	2.00	0.65	0.00	2.45	1.03
Ceramic/Crockery	0.14	0.11	1.41	0.55	0.78	1.98	0.24	1.00	0.19	0.47	0.65	0.44
Bricks/Concrete/Demolition	0.00	0.57	2.64	1.07	0.32	8.78	0.11	3.07	3.42	3.50	4.98	3.97
Dust/Ashes	0.10	2.67	0.25	1.01	16.45	9.87	6.74	11.02	8.25	16.65	14.65	13.18
(Others)	0.00	0.24	0.37	0.20	0.00	0.54	0.14	0.23	0.00	0.11	0.11	0.07
In-organic Non-hazardous =	**0.69**	**5.85**	**6.78**	**4.44**	**20.10**	**22.55**	**12.28**	**18.31**	**12.72**	**21.71**	**23.41**	**19.28**
Battery	0.00	0.08	0.21	0.10	0.24	2.86	0.11	1.07	0.15	0.21	2.14	0.83
Aerosol bottles	0.24	0.10	0.36	0.23	0.12	0.26	0.21	0.20	0.21	0.10	0.14	0.15
Cleaner (Liquid/Shoe Polish/Remover etc.)	0.54	0.21	0.08	0.28	0.21	0.65	0.17	0.34	0.16	0.00	0.16	0.11
Personal Care (Shampoo/Shaving/Nail Polish etc.)	0.57	0.12	0.24	0.31	0.78	0.24	0.00	0.34	0.19	0.14	0.24	0.19
Paint Items (Container/Thinner)	0.21	0.24	0.15	0.20	0.24	0.00	0.19	0.14	0.00	0.13	0.11	0.08
(Others)	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.11	0.11	0.00	0.87	0.33
Inorganic Hazardous =	**1.56**	**0.75**	**1.04**	**1.12**	**1.59**	**4.33**	**0.68**	**2.20**	**0.82**	**0.58**	**3.66**	**1.69**
Total In-organic =	**2.25**	**6.60**	**7.82**	**5.56**	**21.69**	**26.88**	**12.96**	**20.51**	**13.54**	**22.29**	**27.07**	**20.97**
Total =	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Table B.5 (Continued)

Barisal city corporation areas												
Area	Bangla wet market				Venus shopping complex				Barisal zilla school			
Date	01.09.04	02.09.04	03.09.04	Average	13.09.04	14.09.04	15.09.04	Average	10.08.04	11.08.04	12.08.04	Average
Waste Type												
Organic Waste												
Food & Vegetables Wastes	71.42	90.14	75.50	79.02	27.54	35.24	21.03	27.94	23.78	32.18	15.98	23.98
Paper & paper Products	9.78	3.78	4.65	6.07	36.78	29.86	38.54	35.06	45.78	35.98	40.78	40.85
Plastic/Polythene	2.10	0.54	1.24	1.29	4.87	7.63	7.98	6.83	6.78	9.76	15.24	10.59
Pet Bottles/Oil container	2.87	0.14	0.98	1.33	4.65	9.78	8.78	7.74	3.98	10.78	12.01	8.92
Textiles/Clothes/Rags	1.10	0.00	0.24	0.45	1.10	0.51	0.14	0.58	2.78	0.26	1.15	1.40
Rubber	0.14	0.24	1.16	0.51	0.00	0.88	0.14	0.34	0.11	0.00	0.00	0.04
Leather	0.64	0.07	0.78	0.50	0.10	0.57	0.00	0.22	0.00	0.13	0.11	0.08
Wood	0.88	0.14	0.87	0.63	0.25	1.10	0.10	0.48	2.89	0.87	0.98	1.58
Rope/Straw/Coconut	0.21	0.11	0.07	0.13	0.18	0.18	0.09	0.15	0.10	0.11	0.11	0.11
Animal Bones	0.15	0.14	0.94	0.41	0.13	0.06	0.08	0.09	0.11	0.00	0.10	0.07
(Others)	0.00	0.00	0.17	0.06	0.20	0.00	0.00	0.07	0.00	0.00	0.08	0.03
Total Organic Wastes =	**89.29**	**95.30**	**86.60**	**90.40**	**75.80**	**85.81**	**76.88**	**79.50**	**86.31**	**90.07**	**86.54**	**87.64**
In-organic Waste												
Glass/Bottles	0.54	0.07	0.11	0.24	0.78	0.11	0.34	0.41	0.59	0.65	0.37	0.54
Metal/Tin Can	0.11	0.21	0.10	0.14	2.98	3.25	2.78	3.00	2.22	0.66	3.11	2.00
Ceramic/Crockery	0.14	0.00	0.54	0.23	0.11	0.00	0.11	0.07	0.36	0.58	0.46	0.47
Bricks/Concrete/Demolition	0.78	0.51	0.14	0.48	0.00	0.14	0.00	0.05	1.97	0.07	0.88	0.97
Dust/Ashes	6.14	3.57	11.35	7.02	19.31	9.81	18.84	15.99	8.17	4.80	7.46	6.81
(Others)	0.00	0.00	0.14	0.05	0.11	0.00	0.11	0.07	0.00	0.00	0.00	0.00
In-organic Non-hazardous =	**7.71**	**4.36**	**12.38**	**8.15**	**23.29**	**13.31**	**22.18**	**19.59**	**13.31**	**6.76**	**12.28**	**10.78**
Battery	0.00	0.00	0.21	0.07	0.21	0.16	0.21	0.19	0.00	0.08	0.08	0.05
Aerosol bottles	0.86	0.11	0.00	0.32	0.15	0.00	0.25	0.13	0.11	0.58	0.42	0.37
Cleaner (Liquid/Shoe Polish/Remover etc.)	0.54	0.12	0.21	0.29	0.01	0.18	0.00	0.06	0.09	0.98	0.45	0.51
Personal Care (Shampoo/Shaving/Nail Polish etc.)	0.67	0.11	0.15	0.31	0.21	0.31	0.31	0.28	0.07	0.67	0.11	0.28
Paint Items (Container/Thinner)	0.79	0.00	0.31	0.37	0.19	0.12	0.00	0.10	0.11	0.78	0.12	0.34
(Others)	0.14	0.00	0.14	0.09	0.14	0.11	0.17	0.14	0.00	0.08	0.00	0.03
Inorganic Hazardous =	**3.00**	**0.34**	**1.02**	**1.45**	**0.91**	**0.88**	**0.94**	**0.91**	**0.38**	**3.17**	**1.18**	**1.58**
Total In-organic =	**10.71**	**4.70**	**13.40**	**9.60**	**24.20**	**14.19**	**23.12**	**20.50**	**13.69**	**9.93**	**13.46**	**12.36**
Total =	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

ANNEXURE C

Table C.1 Physical characteristics of MSW in four major cities of Bangladesh

SPL No.	Collection Month	MC	VS	AR	pH	BD (loose)*	BD (medium)*	BD (compact)*
		(%)	(%)	(%)	-	kg/m^3	kg/m^3	kg/m^3
Dhaka city corporation areas								
SPL 1	June, 2004	56	60	40	8.1	498	937	1089
SPL 2	July, 2004	79	79	21	8.4	553	957	1070
SPL 3	Aug, 2004	77	70	30	8.6	564	833	1463
SPL 4	Sep, 2004	69	64	36	8.5	783	971	1115
SPL 5	Oct, 2004	68	76	24	9.0	730	968	1047
SPL 6	Oct, 2004	73	69	31	9.0	664	963	1148
SPL 7	Nov, 2004	70	75	25	8.5	654	1056	1141
SPL 8	Nov, 2004	64	71	29	9.2	647	979	1125
SPL 9	Dec, 2004	68	78	22	8.7	540	901	998
SPL 10	Dec, 2004	71	68	32	8.9	581	942	1076
Average		**70**	**71**	**29**	**8.69**	**621**	**951**	**1127**
Khulna city corporation areas								
SPL 1	June, 2004	67	47	53	6.3	683	897	1036
SPL 2	July, 2004	58	39	61	8.8	606	707	750
SPL 3	Aug, 2004	66	60	40	8.6	542	734	851
SPL 4	Sep, 2004	64	46	54	7.8	530	730	811
SPL 5	Oct, 2004	71	73	27	7.4	668	902	1067
SPL 6	Oct, 2004	64	34	66	6.7	482	712	759
SPL 7	Nov, 2004	84	59	41	8.1	877	988	1051
SPL 8	Nov, 2004	78	71	29	8.3	343	683	793
SPL 9	Dec, 2004	62	56	44	7.7	498	681	813
SPL 10	Dec, 2004	68	75	25	7.9	430	605	817
Average		**68**	**56**	**44**	**7.76**	**566**	**764**	**875**
Rajshahi city corporation areas								
SPL 1	June, 2004	48	37	63	7.4	712	1190	1312
SPL 2	July, 2004	40	80	20	7.7	473	784	835
SPL 3	Aug, 2004	62	39	61	7.5	624	1023	1152
SPL 4	Sep, 2004	50	25	75	7.7	590	848	1146
SPL 5	Oct, 2004	72	59	41	7.4	592	944	1003
SPL 6	Oct, 2004	51	41	59	7.8	484	844	909
SPL 7	Nov, 2004	65	72	28	8.1	645	1003	1132
SPL 8	Nov, 2004	47	33	67	7.7	495	800	904
SPL 9	Dec, 2004	58	40	60	8.0	567	957	1126
SPL 10	Dec, 2004	64	51	49	7.9	494	816	1003
Average		**56**	**48**	**52**	**7.72**	**568**	**921**	**1052**

Table C.1 (Continued)								
Barisal city corporation areas								
SPL No.	**Collection Month**	**MC**	**VS**	**AR**	**pH**	**BD (loose)***	**BD (medium)***	**BD (compact)***
		(%)	(%)	(%)	-	kg/m^3	kg/m^3	kg/m^3
SPL 1	June, 2004	58	27	73	8.8	616	1047	1077
SPL 2	July, 2004	44	59	41	6.1	448	750	883
SPL 3	Aug, 2004	58	38	62	6.1	629	943	1121
SPL 4	Sep, 2004	48	34	66	8.8	637	1019	1177
SPL 5	Oct, 2004	63	48	52	6.3	523	856	907
SPL 6	Oct, 2004	55	46	54	6.5	490	884	1005
SPL 7	Nov, 2004	63	44	56	8.3	637	1012	1120
SPL 8	Nov, 2004	54	41	59	8.7	569	921	1093
SPL 9	Dec, 2004	65	56	44	8.8	643	867	991
SPL 10	Dec, 2004	57	39	61	8.6	582	964	1101
Average		**57**	**43**	**57**	**7.70**	**577**	**926**	**1048**

Note: SPL – Sample; MC-Moisture content, VS-Volatile solid, AR-Ash residue, BD-Bulk density, *By laboratory testing in wet weight basis.

Table C.2 Bulk densities of MSW at SDS in four major cities of Bangladesh				
SPL No.	**Bulk density (kg/m^3)**			
	Dhaka	**Khulna**	**Rajshahi**	**Barisal**
SPL 1	572	643	615	622
SPL 2	585	629	628	657
SPL 3	614	573	591	617
SPL 4	593	628	517	648
SPL 5	562	520	504	665
SPL 6	524	584	583	634
SPL 7	478	673	614	664
SPL 8	534	799	612	578
SPL 9	627	526	624	498
SPL 10	687	524	590	598
Average	**578**	**610**	**588**	**621**

Note: SPL – Sample; SDS – Secondary disposal site

Table C.3 Particle size distribution of MSW in four major cities of Bangladesh

		Percent finer								
		Sieve opening (mm)								
SPL No.	Collection Month	200	100	76.2	38.2	19.1	9.52	4.76	2.38	Pan
Dhaka city corporation areas										
SPL 1	June, 2004	100	90	84	56	35	22	15	9	0
SPL 2	July, 2004	100	86	67	30	18	8	4	2	0
SPL 3	Aug, 2004	100	84	68	47	18	9	5	1	0
SPL 4	Sep, 2004	100	80	57	32	21	17	7	3	0
SPL 5	Oct, 2004	100	62	56	42	22	9	6	2	0
SPL 6	Oct, 2004	100	75	59	46	19	7	4	1	0
SPL 7	Nov, 2004	100	67	47	38	23	11	8	4	0
SPL 8	Nov, 2004	100	75	53	30	17	9	6	2	0
SPL 9	Dec, 2004	100	81	72	53	35	20	13	6	0
SPL 10	Dec, 2004	100	81	55	41	20	8	7	3	0
Average		**100**	**78**	**62**	**42**	**23**	**12**	**8**	**3**	**0**
Khulna city corporation areas										
SPL 1	June, 2004	100	99	91	67	44	29	22	12	0
SPL 2	July, 2004	100	100	95	76	50	41	36	28	0
SPL 3	Aug, 2004	100	94	82	53	30	16	11	6	0
SPL 4	Sep, 2004	100	97	86	77	57	41	34	23	0
SPL 5	Oct, 2004	100	87	76	59	32	15	10	3	0
SPL 6	Oct, 2004	100	92	89	64	40	23	16	8	0
SPL 7	Nov, 2004	100	92	78	56	31	21	16	11	0
SPL 8	Nov, 2004	100	87	70	51	29	15	8	4	0
SPL 9	Dec, 2004	100	85	78	73	57	43	57	25	0
SPL 10	Dec, 2004	100	88	70	64	44	31	25	11	0
Average		**100**	**92**	**82**	**64**	**41**	**28**	**24**	**13**	**0**
Rajshahi city corporation areas										
SPL 1	June, 2004	100	100	97	73	53	36	27	19	0
SPL 2	July, 2004	100	98	96	89	74	64	58	47	0
SPL 3	Aug, 2004	100	92	89	69	42	28	21	12	0
SPL 4	Sep, 2004	100	81	79	63	52	41	35	25	0
SPL 5	Oct, 2004	100	76	65	50	32	17	10	5	0
SPL 6	Oct, 2004	100	74	59	49	38	29	24	13	0
SPL 7	Nov, 2004	100	71	63	57	51	44	38	33	0
SPL 8	Nov, 2004	100	69	61	43	31	22	16	10	0
SPL 9	Dec, 2004	100	90	65	57	48	40	22	15	0
SPL 10	Dec, 2004	100	97	76	62	37	27	21	8	0
Average		**100**	**85**	**75**	**61**	**46**	**35**	**27**	**19**	**0**

Table C.3 (Continued)										
Barisal city corporation areas										
SPL No.	**Collection Month**	**Percent finer**								
		Sieve opening (mm)								
		200	**100**	**76.2**	**38.2**	**19.1**	**9.52**	**4.76**	**2.38**	**Pan**
SPL 1	June, 2004	100	48	40	24	15	12	10	7	0
SPL 2	July, 2004	100	87	77	50	29	17	12	7	0
SPL 3	Aug, 2004	100	83	61	37	17	11	8	6	0
SPL 4	Sep, 2004	100	97	93	72	47	31	23	15	0
SPL 5	Oct, 2004	100	89	79	55	38	27	21	12	0
SPL 6	Oct, 2004	100	89	83	67	39	22	14	7	0
SPL 7	Nov, 2004	100	82	56	38	24	16	12	6	0
SPL 8	Nov, 2004	100	80	65	45	25	19	11	8	0
SPL 9	Dec, 2004	100	67	59	61	37	21	19	13	0
SPL 10	Dec, 2004	100	78	73	54	18	14	14	7	0
Average		**100**	**80**	**69**	**50**	**29**	**19**	**14**	**9**	**0**

Table C.4 Chemical characteristics of MSW in four major cities of Bangladesh

SPL No.	**Collection Month**	**C**	**N**	**C/N**	**K**	**P**
		(%)	(%)	-	(%)	(%)
Dhaka city corporation areas						
SPL 1	June, 2004	25.72	2.175	11.83	1.60	0.300
SPL 2	July, 2004	7.22	0.901	8.01	0.53	0.302
SPL 3	Aug, 2004	7.39	0.705	10.48	0.52	0.282
SPL 4	Sep, 2004	8.55	0.740	11.55	0.50	0.272
SPL 5	Oct, 2004	4.90	0.786	6.23	0.44	0.276
SPL 6	Oct, 2004	7.55	0.787	9.59	0.52	0.306
SPL 7	Nov, 2004	7.88	0.767	10.27	0.54	0.414
SPL 8	Nov, 2004	5.06	0.742	6.82	0.50	0.287
SPL 9	Dec, 2004	9.21	0.504	18.27	0.48	0.371
SPL 10	Dec, 2004	6.72	0.780	8.62	0.52	0.294
Average		**9.02**	**0.89**	**10.17**	**0.62**	**0.31**
Khulna city corporation areas						
SPL 1	June, 2004	24.73	1.772	13.96	1.30	0.500
SPL 2	July, 2004	22.74	1.137	12.61	1.40	0.300
SPL 3	Aug, 2004	28.05	2.200	12.75	1.40	0.408
SPL 4	Sep, 2004	20.41	1.000	20.41	1.20	0.343
SPL 5	Oct, 2004	20.74	1.634	12.69	1.40	0.387
SPL 6	Oct, 2004	29.37	1.850	15.88	1.80	0.438
SPL 7	Nov, 2004	31.37	1.845	17.00	1.40	0.293
SPL 8	Nov, 2004	21.08	1.775	11.88	1.10	0.702
SPL 9	Dec, 2004	25.72	1.808	14.23	1.40	0.405
SPL 10	Dec, 2004	25.06	1.141	21.96	1.30	0.305
Average		**24.93**	**1.620**	**16.08**	**1.37**	**0.41**

Table C.4 (Continued)

SPL No.	Collection Month	C	N	C/N	K	P
		(%)	(%)	-	(%)	(%)
Rajshahi city corporation areas						
SPL 1	June, 2004	5.00	0.502	9.96	0.30	0.281
SPL 2	July, 2004	5.67	0.783	7.24	0.40	0.261
SPL 3	Aug, 2004	5.33	0.468	11.39	0.32	0.267
SPL 4	Sep, 2004	5.00	0.663	7.54	0.41	0.404
SPL 5	Oct, 2004	10.00	0.552	18.12	0.34	0.342
SPL 6	Oct, 2004	6.33	0.545	11.61	0.38	0.343
SPL 7	Nov, 2004	6.00	0.526	7.64	0.40	0.279
SPL 8	Nov, 2004	7.33	0.397	18.46	0.34	0.322
SPL 9	Dec, 2004	7.33	0.457	16.04	0.38	0.265
SPL 10	Dec, 2004	7.33	0.751	10.89	0.50	0.373
Average		**6.53**	**0.560**	**12.15**	**0.38**	**0.31**
Barisal city corporation areas						
SPL 1	June, 2004	12.86	0.777	16.55	1.00	0.370
SPL 2	July, 2004	18.33	1.338	13.70	1.40	0.532
SPL 3	Aug, 2004	21.00	1.763	11.91	1.59	0.443
SPL 4	Sep, 2004	14.69	1.184	8.59	1.10	0.383
SPL 5	Oct, 2004	20.69	1.612	12.83	1.70	0.513
SPL 6	Oct, 2004	17.18	1.555	11.05	1.20	0.393
SPL 7	Nov, 2004	14.36	0.962	14.93	0.90	0.342
SPL 8	Nov, 2004	12.36	1.109	11.15	0.90	0.282
SPL 9	Dec, 2004	12.03	1.000	12.03	1.10	0.343
SPL 10	Dec, 2004	8.00	1.023	6.13	0.89	0.367
Average		**15.15**	**1.230**	**12.44**	**1.18**	**0.40**

Table C.5 Calorific values for major components of MSW

Component of MSW	SPL No.	Energy [a] (kJ/kg)	Average (kJ/kg)
Potato	SPL 1	7842	7574
	SPL 2	6987	
	SPL 3	7892	
Pappa	SPL 1	4126	4216
	SPL 2	3897	
	SPL 3	4625	
Pumpkin	SPL 1	8756	8113
	SPL 2	7895	
	SPL 3	7689	
Mango shell	SPL 1	6126	6673
	SPL 2	7651	
	SPL 3	6243	

Table C.5 (Continued)

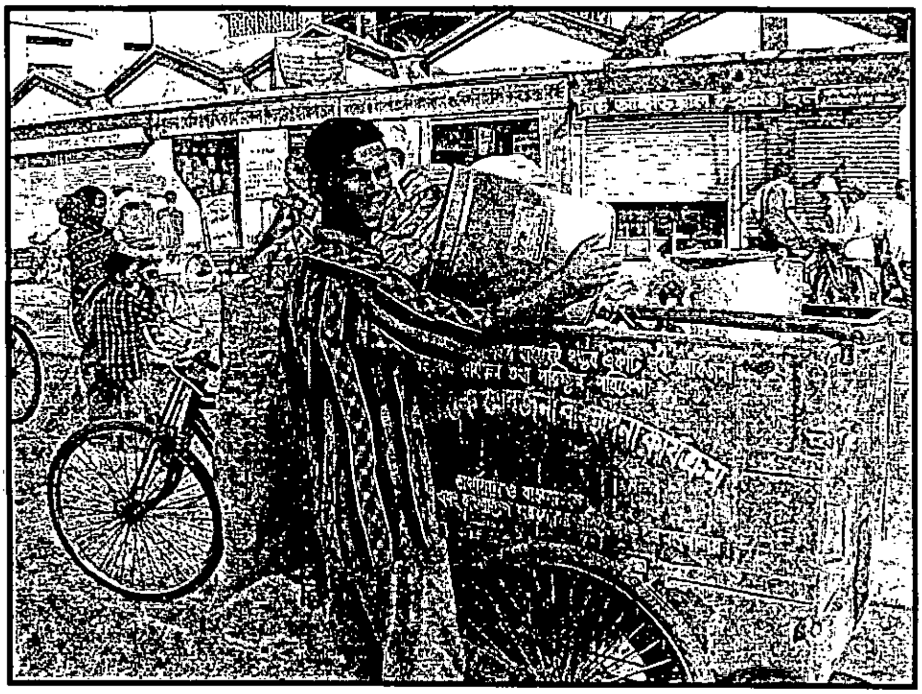
Component of MSW	SPL No.	Energy [a] (kJ/kg)	Average (kJ/kg)
Esculent root	SPL 1	7245	7920
	SPL 2	7895	
	SPL 3	8621	
Red potherb	SPL 1	3687	3429
	SPL 2	3457	
	SPL 3	3142	
Lady's finger	SPL 1	2587	3420
	SPL 2	3687	
	SPL 3	3987	
Food Waste	**Average**		**5907**
Paper	SPL 1	14,182	12,994
	SPL 2	12,816	
	SPL 3	11,984	
	SPL 4	12,136	
	SPL 5	13,973	
	SPL 6	12,876	
Plastics	SPL 1	19,050	20,077
	SPL 2	20,141	
	SPL 3	21,039	
	SPL 4	19,765	
	SPL 5	21,357	
	SPL 6	19,112	
Rubber	SPL 1	21,007	20,467
	SPL 2	19,646	
	SPL 3	20,748	
	SPL 4	19,635	
	SPL 5	20,654	
	SPL 6	21,113	
Wood	SPL 1	14,686	14,578
	SPL 2	14,182	
	SPL 3	14,865	
	SPL 4	13,981	
	SPL 5	14,781	
	SPL 6	14,972	

Note: SPL-Sample; [a] as oven dry basis

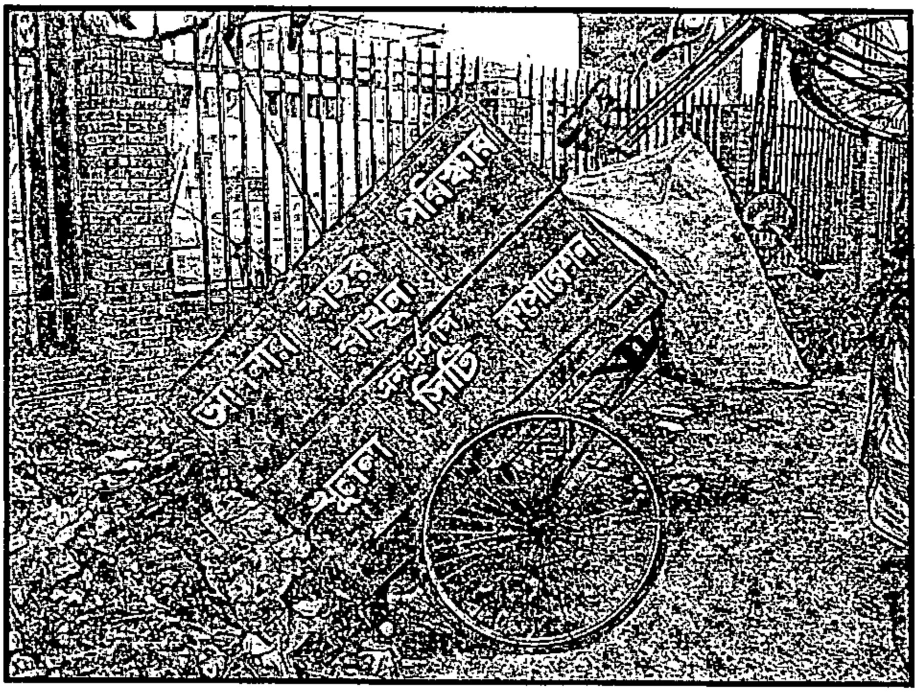
ANNEXURE D

Photograph D.1 One blue and one red bucket are supply to each family

Photograph D.2 Daily weight measurement of generated household waste

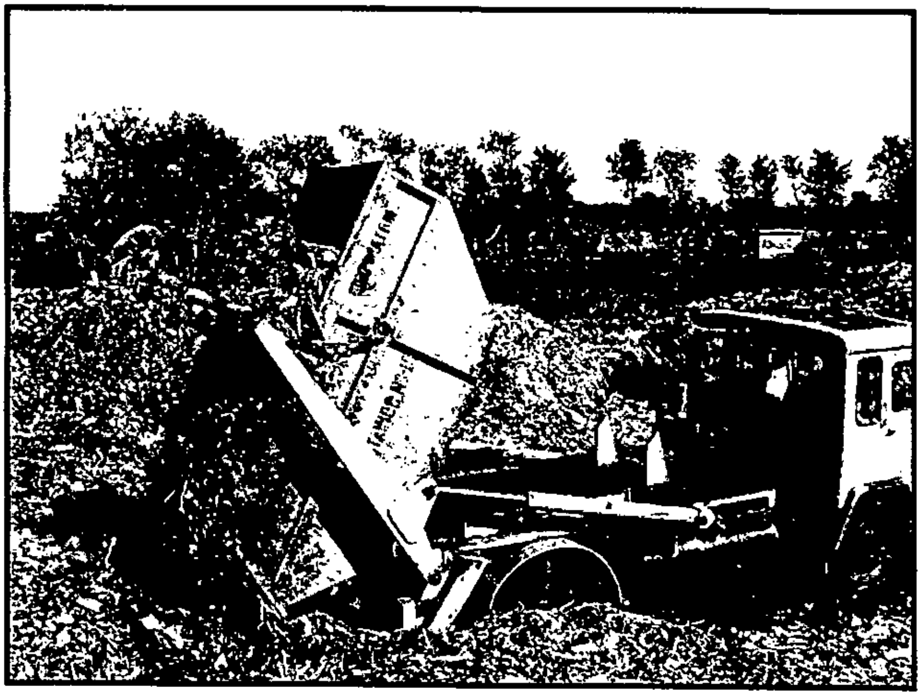


Photograph D.3 Door to door solid waste collection by NGOs in Khulna city



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

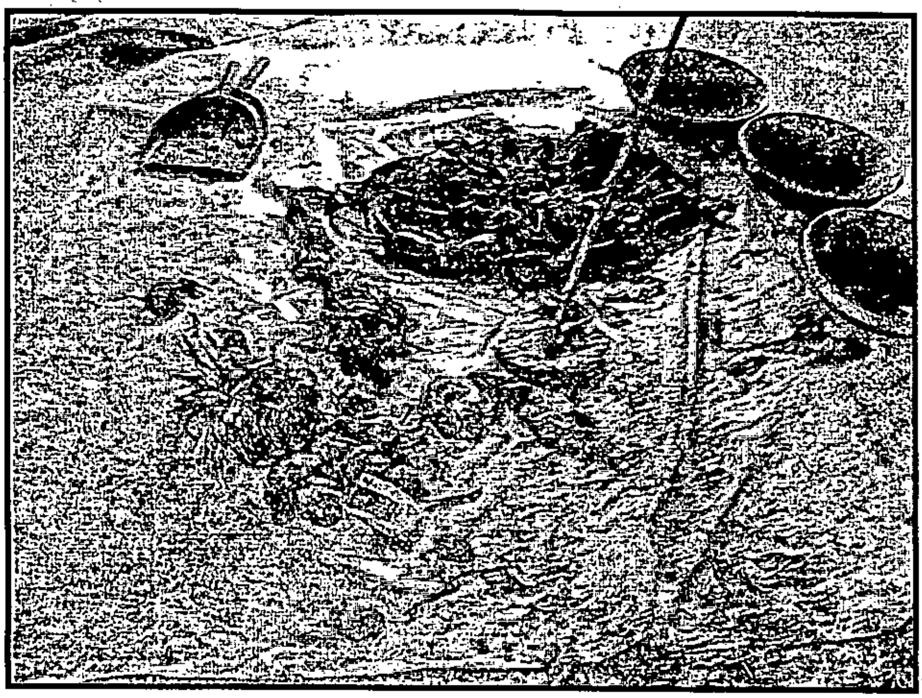
Photograph D.5 MSW transfer from secondary disposal site to final disposal site in Barisal city



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

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

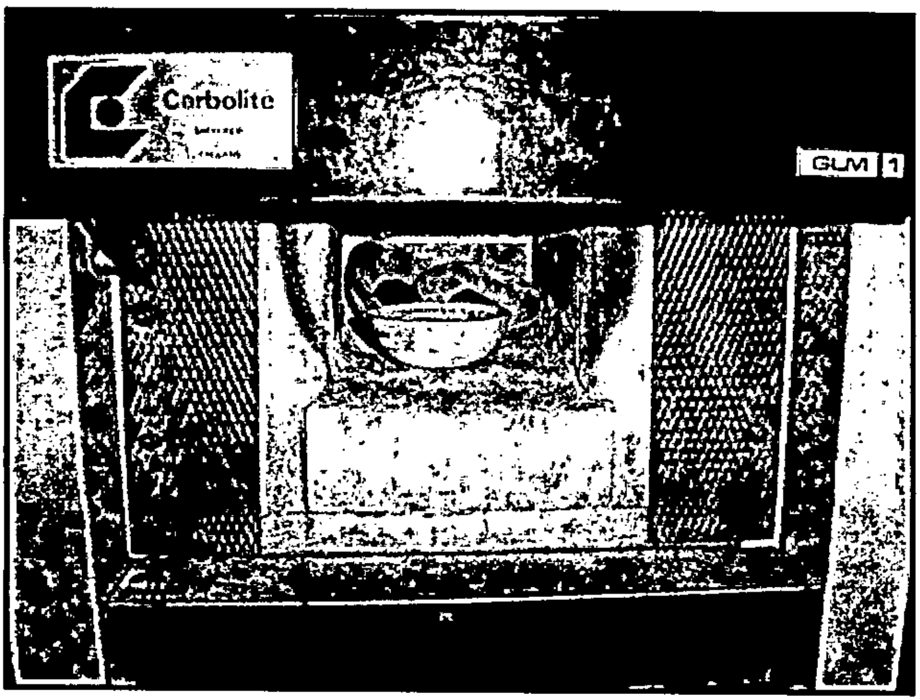
Photograph D.8 MSW collection for physical and chemical analysis



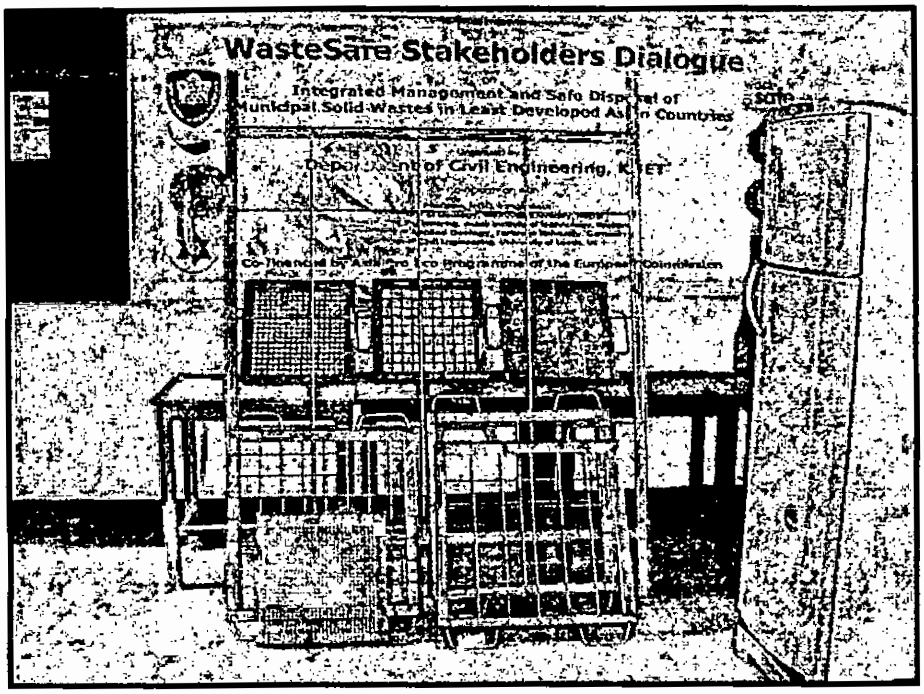
Photograph D.9 Sample preparation for physical characteristics determination in laboratory

Photograph D.10 Waste sample are grinding at laboratory for chemical analysis

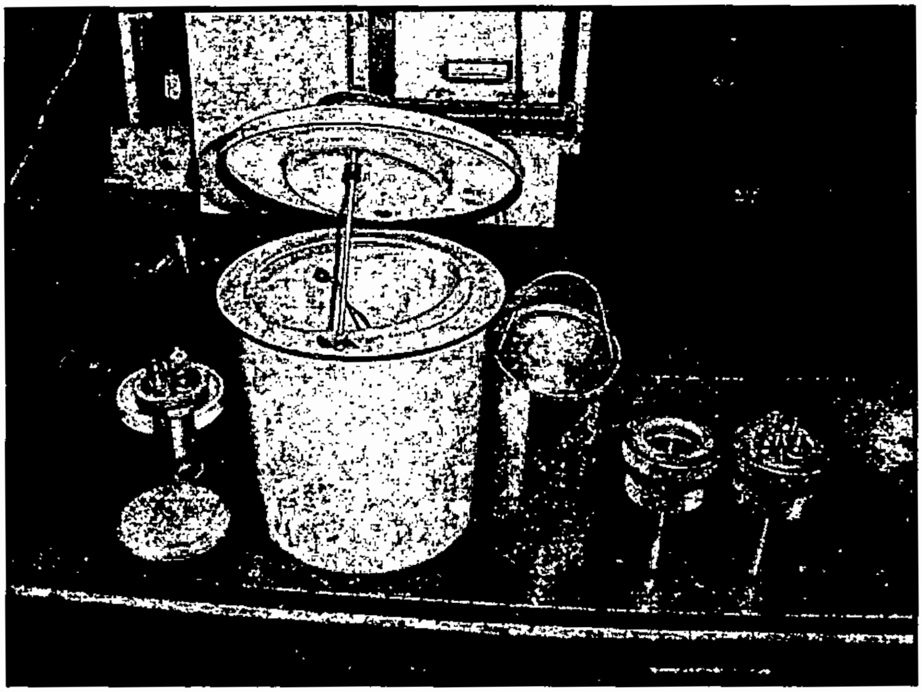
Photograph D.11 Moisture content determination at 105°C temperature in laboratory



Photograph D.12 Volatile solid content determination at 550°C temperature in laboratory



Photograph D.13 Different sizes sieves for particle size distribution



Photograph D.14 Bomb calorimeter for determination of higher calorific value of major constituents of MSW

ANNEXURE E

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 °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 °C) (B)	Dish + Oven dry (550 °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